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State Support for Ethanol Use and State Demand for Ethanol Produced in the Midwest

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Contact author for FAPRI–MU Report #11-08 is Wyatt Thompson (thompsonw@missouri.edu).

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Prepared by the Food and Agricultural Policy Research Institute
The University of Missouri
101 Park DeVille Drive, Suite E
Columbia, Missouri 65203
www.fapri.missouri.edu
573-882-3576

Food and Agricultural Policy Research Institute
FAPRI

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I. Executive summary

This study examines US demand for ethanol produced in the Midwest and assesses how state policies that target ethanol demand affect biofuel and agricultural commodity markets. The focus of this report is on the representation of state-level demand for ethanol produced in the Midwest. The results are used in simulations of national market effects using the FAPRI–MU agricultural and biofuel market models. This representation of state-level ethanol demand leads to some conclusions. While not all of the conclusions are new, the results put numbers to several of these outcomes, as discussed in the text.

State policies to encourage ethanol consumption affect a minority of total US motor fuel demand now. Before taking into account the price effects of policy changes:

- Existing support causes no more than a 10 percent shift in the US ethanol demand curve in any of the price combinations examined here. Effects are closer to 10 percent if the ethanol price is high and the petroleum price is low and if mandates are not relaxed.
- If a supportive policy of the type used in some Midwestern states were applied in all 50 states and the District of Columbia, then the quantity of ethanol demand could nearly double at high ethanol prices, but effects would be small at lower ethanol prices.

Broader effects on national biofuel and crop market of existing state policies may not be very large given the small share of the affected motor fuel markets in total demand.

- Corn price is increased a small amount by existing policies and US total corn area planted may be 0.2 million acres greater.
- The hypothetical case of support to ethanol demand in all states would lead to larger effects on all markets, raising corn area by 1.6 million acres if the petroleum price is high.
- Spill-over into other commodity markets is apparent in generally higher prices and reallocation of area to corn, in particular from soybeans. The effects are larger in the hypothetical case of widespread support to ethanol use.
- Ethanol imports are also price sensitive and are likely to respond as quickly as domestic production to rising prices.

Results could be substantially different under alternative assumptions. For example, federal biofuel policies, the petroleum price, corn yields and trade are critically important. These simulations result from a particular representation that ignores certain important characteristics of markets. The representation can be improved as new information becomes available.

II. State policies to support ethanol demand

State policies to support ethanol demand include differential tax treatment and mandates requiring a minimum level of use or inclusion. Here, these policies are summarized. Other possible forms of support are not considered. Federal incentives are not addressed here, but are included in the representation of US markets used to simulate wider effects of these policies.

Taxes

State excise taxes for gasoline and gasohol are not always the same. According to one source, the rates paid on gasohol, or E10, are lower in several states (Table 1). This has implications for consumers, based on the underlying assumption is that excise taxes are passed on to consumers.

Table 1. Gasoline taxes and gasohol tax exemptions, FTA

	Tax on Gasoline	Gasohol exemption		Tax on Gasoline	Gasohol exemption
	(cents per gallon)			(cents per gallon)	
Alabama	18	0	Montana	27	4
Alaska	8	0	Nebraska	23	0
Arizona	18	0	Nevada	24	0
Arkansas	21.5	0	New Hampshire	18	0
California	18	0	New Jersey	10.5	0
Colorado	22	0	New Mexico	17	0
Connecticut	25	0	New York	24.45	0
Delaware	23	0	North Carolina	30.15	0
District of Columbia	20	0	North Dakota	23	0
Florida	15.6	0	Ohio	28	0
Georgia	7.5	0	Oklahoma	16	0
Hawaii	17	1	Oregon	24	0
Idaho	25	3	Pennsylvania	30	0
Illinois	19	0	Rhode Island	30	0
Indiana	18	0	South Carolina	16	0
Iowa	20.7	2	South Dakota	22	2
Kansas	24	0	Tennessee	20	0
Kentucky	21	0	Texas	20	0
Louisiana	20	0	Utah	24.5	0
Maine	27.6	5	Vermont	19	0
Maryland	23.5	0	Virginia	17.5	0
Massachusetts	21	0	Washington	36	0
Michigan	19	0	West Virginia	32.2	0
Minnesota	20	0	Wisconsin	30.9	0
Mississippi	18.4	0	Wyoming	14	0
Missouri	17	0			

Source: Federation of Tax Administrators (www.taxadmin.org/FTA/rate/motor_fl.html), 2008.

The data above are supplemented by information from other sources that suggest more incentives are given to support ethanol demand. State sales tax exemptions and other tax reductions that target the retail price are drawn from the Energy Efficiency and Renewable Energy (EERE) office of the Department of Energy (DOE) and from an annual report of the

American Coalition for Ethanol (ACE).[1] Special treatment may take the form of an absolute or relative reduction in tax rates (Table 2). Arkansas, Pennsylvania and Wisconsin reportedly assign taxes based on the energy or gasoline equivalent, leading to an assumption that there is a percent reduction in the tax on ethanol blends that reflects the lower energy of ethanol.

These sources do not always agree. In combining these sources, preference is given to the exact exemption given by FTA. The reduction given to gasohol is applied to E10 and E85. However, if the ACE or EERE indicate that there is a demand or more of a demand incentive relative to FTA data, then the tax is reduced according to these alternative sources. Based on the interpretation of material in these sources, the end result is a reduction in the tax on E10 in eleven states (Alaska, Arkansas, Hawaii, Idaho, Iowa, Maine, Montana, Oklahoma, Pennsylvania, South Dakota and Wisconsin). The tax on E85 is lower than the gasoline tax in twenty states (those with tax reductions for E10 plus Illinois, Kansas, Michigan, Minnesota, New Mexico, New York, North Carolina, North Dakota and South Carolina).

Table 2. Preferential tax treatment for ethanol blends, ACE and EERE

	Relative reduction		Absolute reduction			Relative reduction		Absolute reduction	
	E10	E85	E10	E85		E10	E85	E10	E85
	(percent)		(cents per gallon)			(percent)		(cents per gallon)	
Alabama	0	0	0	0	Montana	15	15	0	0
Alaska	0	0	6	6	Nebraska	0	0	0	0
Arizona	0	0	0	0	Nevada	0	0	0	0
Arkansas	3.45	25.53	0	0	New Hampshire	0	0	0	0
California	0	0	0	0	New Jersey	0	0	0	0
Colorado	0	0	0	0	New Mexico	0	0	0	6.9
Connecticut	0	0	0	0	New York	0	4.25	0	0
Delaware	0	0	0	0	North Carolina	0	4.5	0	0
District of Columbia	0	0	0	0	North Dakota	0	0	0	22
Florida	0	0	0	0	Ohio	0	0	0	0
Georgia	0	0	0	0	Oklahoma	0	0	1.6	1.6
Hawaii	4	4	0	0	Oregon	0	0	0	0
Idaho	0	0	2.5	2.5	Pennsylvania	3.45	25.53	0	0
Illinois	0	6.25	0	0	Rhode Island	0	0	0	0
Indiana	0	0	0	0	South Carolina	0	0	0	5
Iowa	0	0	2	2	South Dakota	0	0	2	12
Kansas	0	0	0	7	Tennessee	0	0	0	0
Kentucky	0	0	0	0	Texas	0	0	0	0
Louisiana	0	0	0	0	Utah	0	0	0	0
Maine	0	0	2.4	2.4	Vermont	0	0	0	0
Maryland	0	0	0	0	Virginia	0	0	0	0
Massachusetts	0	0	0	0	Washington	0	0	0	0
Michigan	0	0	0	7	West Virginia	0	0	0	0
Minnesota	0	0	0	5.8	Wisconsin	3.45	25.53	0	0
Mississippi	0	0	0	0	Wyoming	0	0	0	0
Missouri	0	0	0	0					

Note: See Appendix 2 for sources.

State mandates

State policies introduce another partly involuntary form of ethanol consumption, namely mandates (Table 3). Mandate information is drawn primarily from some of the same sources as information about relative tax treatment. Some mandates are only effective under certain conditions, often relating to in-state production of ethanol, and are ignored in this study. However, at least some of the state mandates included here are also contingent on conditions in some way, such as the price of ethanol relative to gasoline. Nevertheless, the mandates listed here

[1] Exact references are available in an appendix.

are included in subsequent analysis without any flexibility. In some cases, a local mandate might lead to some assumed state-level mandate such as in the case of the treatment of the mandate in Portland, Oregon.

Table 3. State mandates to use ethanol, by volume, for 2009

State	Volume share
Iowa	10.0%
Minnesota	10.0%
Missouri	10.0%
Hawaii	8.5%
Oregon	2.5%
Washington	2.0%

Source: EERE and ACE, as described in text.

Overall importance of state support for ethanol

State level support is summarized briefly before introducing the effects of state support to ethanol demand on total demand and subsequently on broader markets. In particular, the number of states that give some form of incentive to ethanol use and their share in US motor fuel use merits attention before considering how these policies affect markets (Table 4). Interpreting source material with a view that identifies the upper bound of support, 19 states provide some form of preferential tax treatment and some mandate is present in six states (or a city in one state). Removing duplicates, 22 states provide some form of incentive to ethanol use. Said differently, the upper bound is that more than two-in-five states provide some incentive for ethanol consumption.

These states accounted for one-third of US motor fuel use in historical data. Consumers in the 19 states providing tax incentives used about 28 percent of motor fuel bought in the US, and the 6 states with mandates used 9 percent. The share of motor fuel use in states offering a discount in total US motor fuel use falls to 8 percent if the states that provide a tax incentive for E85 use only, like New York, Illinois, New Mexico, and North Carolina, are excluded. If expansion of E85 use is limited in the short run, then the tax incentives and mandates for ethanol use currently in place are applicable to only a small portion of motor fuel use.

Table 4. Summary of which states have policy incentives and their share in motor fuel use

	State policy		Fuel use (2004)			State policy		Fuel use (2004)	
	pref. tax	mandate	Total	Share		pref. tax	mandate	Total	Share
			(bil. gal.)	(percent)				(bil. gal.)	(percent)
Alabama	N	N	2.55	1.9%	Montana	Y	N	0.47	0.3%
Alaska	Y	N	0.28	0.2%	Nebraska	N	N	0.81	0.6%
Arizona	N	N	2.69	2.0%	Nevada	N	N	1.07	0.8%
Arkansas	Y	N	1.39	1.0%	New Hampshire	N	N	0.70	0.5%
California	N	N	15.58	11.4%	New Jersey	N	N	4.30	3.1%
Colorado	N	N	2.08	1.5%	New Mexico	Y	N	0.94	0.7%
Connecticut	N	N	1.80	1.3%	New York	Y	N	5.65	4.1%
Delaware	N	N	0.41	0.3%	North Carolina	Y	N	4.28	3.1%
District of Columbia	N	N	0.14	0.1%	North Dakota	Y	N	0.33	0.2%
Florida	N	N	8.26	6.0%	Ohio	N	N	5.12	3.8%
Georgia	N	N	4.96	3.6%	Oklahoma	Y	N	1.82	1.3%
Hawaii	Y	Y	0.44	0.3%	Oregon	N	Y	1.50	1.1%
Idaho	Y	N	0.60	0.4%	Pennsylvania	Y	N	5.16	3.8%
Illinois	Y	N	5.17	3.8%	Rhode Island	N	N	0.38	0.3%
Indiana	N	N	3.17	2.3%	South Carolina	Y	N	2.53	1.9%
Iowa	Y	Y	1.54	1.1%	South Dakota	Y	N	0.40	0.3%
Kansas	Y	N	1.28	0.9%	Tennessee	N	N	3.01	2.2%
Kentucky	N	N	2.23	1.6%	Texas	N	N	11.35	8.3%
Louisiana	N	N	2.20	1.6%	Utah	N	N	1.01	0.7%
Maine	Y	N	0.70	0.5%	Vermont	N	N	0.34	0.3%
Maryland	N	N	2.62	1.9%	Virginia	N	N	3.90	2.9%
Massachusetts	N	N	2.82	2.1%	Washington	N	Y	2.64	1.9%
Michigan	Y	N	4.86	3.6%	West Virginia	N	N	0.84	0.6%
Minnesota	Y	Y	2.64	1.9%	Wisconsin	Y	N	2.48	1.8%
Mississippi	N	N	1.58	1.2%	Wyoming	N	N	0.30	0.2%
Missouri	N	Y	3.13	2.3%					

Source: Summary of previously described policy data drawn from sources given in Appendix 2; data source for motor fuel use, and for other model variables, is given in Appendix 1.

III. State fuel price calculations and ethanol demand model structure

Overview

The demand curves for ethanol produced in the Midwest trace out the relationship between quantities of ethanol consumed in each state (and DC) and a benchmark price. As such, there are two steps to this representation.

1. Link benchmark ethanol and petroleum prices to retail prices. These links take into account any differentials in fuel taxes between ethanol and gasoline, as well as transportation and infrastructure costs.
2. Simulate how demand responds to variations in relative price. The demand response is based on a comparison of retail prices in energy equivalent terms. Consumers are assumed to substitute one fuel type for another over a range of relative prices.

The model of state ethanol demand is recursive on the basis of benchmark prices. The results are stylized but intended to represent the nature of US demand for ethanol produced in the Midwest for the next few years.

Limits of the study

Given the focus on demand, the model is not a market-clearing type. Prices are exogenous and ethanol supply is not relevant. The focus is not on whether or not the Midwest would supply a particular amount of ethanol at a particular price. Moreover, imported supplies are ignored, even though imports may be an important supply source that competes with ethanol produced in the Midwest.

The model represents short- and medium-run future ethanol demand. Results do not extend to the longer horizon. For example, the capability of consumers to adopt E85 is subject to limits associated with the size of the fleet of flex fuel vehicles and the pace at which E85 retail infrastructure can expand. Extrapolations beyond the next few years may be unwarranted as the center of ethanol locations may change, distribution of ethanol and ethanol-blend fuels may evolve, and the underlying policy structure may change.

Representation of prices

Benchmark price variables are:

- PB_E for the ethanol rack price for ethanol in Omaha and
- PB_O for the refiners' acquisition cost of crude oil in dollars per barrel.

These benchmark prices are linked to retail consumer prices for different fuels as

(1) $PR_{i,s} = [S_{O,i,s}(\alpha_{g0,s} + \alpha_{g1,s} * PB_O) + S_{E,i,s}(PB_E + TC_{W,PADD} - C) + T_i + T_{i,s}] * \gamma_{i,s} + TC_{ER}$.

The retail price of each retail fuel *i* in state *s* (of which the District of Columbia is an element) is a function of the benchmark prices. Fuels are gasoline without ethanol, fuel in which ethanol is an additive, E10 in which ethanol constitutes 10 percent of the fuel by volume, and E85 with up to 85 percent ethanol by volume.

Each fuel is derived from the weighted sum of its ingredient fuels, with weights equal to the shares of gasoline and ethanol in volume terms, $S_{O,i,s}$ and $S_{E,i,s}$.[2]

The link from benchmark petroleum price to price of gasoline before taxes is estimated from historical data to estimate parameters that govern that link, $\alpha_{go,s}$ and $\alpha_{g1,s}$. This regression is based on the benchmark petroleum price and on gasoline price data from 1985 to 2007, extended one year based on the first 6 months of 2008.[3] The partial data for 2008 are used in the regression with a view to facilitate extrapolation outside the price ranges observed over the preceding years.[4] The petroleum price is expressed on a per gallon basis by dividing by 42. Estimated values have intuitive meaning: the intercept is a constant margin between petroleum price and before-tax retail gasoline prices; and the slope indicates the increase in pre-tax gasoline prices for each increase in the petroleum price, both expressed in cents per gallon (Table 5). The average constant is $0.32 per gallon and the slope parameter implies that a $1.00 increase in the petroleum price causes an average increase of $1.13 in the retail gasoline prices before taxes. Incidentally, estimated links from the West Texas Intermediate (WTI) crude oil price to these before-tax gasoline prices over a shorter time period for which data are available give similar results, with average intercept 0.35 and slope of 1.12.

A similar relationship between the benchmark ethanol price and retail ethanol prices before taxes cannot be estimated because data are too few. Instead, 2002 data relating to the costs of ethanol shipments between regions, $TC_{W,PADD}$, are used, but updated by one-tenth of the

[2] It is assumed that the average inclusion rate of ethanol in E85 is 74 percent based on the "Annual Energy Outlook" of 2007 by EIA (www.eia.doe.gov/oiaf/aeo/pdf/appa.pdf).

[3] EIA data are available at tonto.eia.doe.gov/dnav/pet/pet_pri_allmg_a_EPMR_PTA_cpgal_a.htm.

[4] Several alternative regressions were explored with an additional term besides the petroleum price, but were discarded because of problems of endogeneity or implausible results for certain ranges of petroleum prices.

percent change in petroleum price in intervening years.[5] A constant markup in ethanol price to reflect factors other than taxes and transportation costs is imposed, and is assumed to be \$0.12 per gallon.[6]

Table 5. Intercept and slope parameters linking gasoline prices to benchmark petroleum price

	Intercept	Slope		Intercept	Slope		Intercept	Slope
Alabama	0.29	1.12	Louisiana	0.26	1.14	Ohio	0.29	1.13
Alaska	0.55	1.19	Maine	0.35	1.15	Oklahoma	0.25	1.15
Arizona	0.40	1.07	Maryland	0.29	1.14	Oregon	0.38	1.12
Arkansas	0.26	1.14	Massachusetts	0.32	1.14	Pennsylvania	0.28	1.13
California	0.35	1.16	Michigan	0.28	1.15	Rhode Island	0.32	1.11
Colorado	0.35	1.11	Minnesota	0.36	1.11	South Carolina	0.25	1.14
Connecticut	0.33	1.14	Mississippi	0.30	1.12	South Dakota	0.35	1.14
Delaware	0.29	1.13	Missouri	0.28	1.11	Tennessee	0.26	1.13
Florida	0.22	1.19	Montana	0.37	1.11	Texas	0.27	1.13
Georgia	0.28	1.13	Nebraska	0.31	1.12	Utah	0.33	1.10
Hawaii	0.24	1.16	Nevada	0.41	1.09	Vermont	0.36	1.16
Idaho	0.46	1.19	New Hampshire	0.35	1.13	Virginia	0.28	1.13
Illinois	0.35	1.12	New Jersey	0.34	1.10	Washington	0.36	1.12
Indiana	0.31	1.14	New Mexico	0.35	1.15	West Virginia	0.30	1.15
Iowa	0.29	1.12	New York	0.30	1.14	Wisconsin	0.31	1.14
Kansas	0.30	1.13	North Carolina	0.26	1.13	Wyoming	0.37	1.13
Kentucky	0.29	1.12	North Dakota	0.37	1.15	Average	0.32	1.13

Source: Estimated parameters, as described in text.

Taxes and tax credits are assumed to be passed on to final consumers. This is a critical assumption for this analysis. In theory, blenders could capture the tax reductions intended to support ethanol demand. If blenders operate in an uncompetitive environment, then they may opt to pocket the tax incentives rather than lower consumer prices. In that case, these taxes intended to increase consumer willingness to buy ethanol would instead lead be to increase in blender profits without affecting consumer prices or quantities. If blenders compete, however, then they will be forced through competition to use the taxes to lower consumer prices. This representation is apparently consistent with other researchers who assume that the federal tax credit is not captured by fuel blenders. Other circumstantial evidence includes the fact that equations linking gasoline prices to petroleum prices indicate strong pass-through of prices and the fact that policy makers opt to encourage demand by support given initially to blenders.

The federal tax credit provided to fuel blenders per unit of ethanol used, C, is subtracted from the benchmark ethanol price. The value of this tax credit is 51 cents per gallon through 2008, and is then set at 45 cents per gallon as set out in the new US farm bill, the Food, Conservation, and Energy Act of 2008. The retail price for each fuel blend includes federal and state fuel taxes for the fuel type, T_i and $T_{i,s}$.

[5] Raw data are from Technical and Management Services, Inc., and were generated for Downstream Alternatives, Inc., but are taken here from the reproduction available in the EIA's "Review of Transportation Issues and Comparison of Costs for a Renewable Fuels Standard," September, 2002. These data report the transportation costs of shipping ethanol from the Petroleum Administration for Defense District (PADD) 2, which corresponds to the Midwest, to other PADDs. The PADD-to-PADD data are coarse relative to the 50 states, plus DC, representation used here. (PADDs composition is reproduced in an appendix.) The values used here are the average of all modes reported, namely truck, barge and rail.
[6] National Biodiesel Education Program.

For purposes of simulating consumer demand, the retail fuel prices are compared in fuel efficiency terms. Each fuel price is converted into a gasoline equivalent. The conversion factor, $\gamma_{i,s}$, is fuel specific, and reflects the amount of ethanol in the fuel. A common element of the parameter for all fuels is the equivalence between ethanol and gasoline. Here, 65.5 percent is used as the energy content of ethanol as compared to that of gasoline.

Retailing E85 leads to additional costs relative to the retailing costs of other fuels. An additional cost is added to reflect these infrastructure costs, TC_{ER}. Here, this potential for infrastructure costs is based on three casual observations or simple assumptions: the cost of installing an E85 pump is $50,000 according to industry experts; the average volume of sales per E85 pump is 7557 gallons[7]; and a three-year period in which to recover costs. This estimate is relevant if all E85 sold uses new E85 pumps. However, a better estimate for incremental costs would be zero. There seems little potential for such increases in retail distribution costs for relatively small changes in E85 distribution patterns from year to year. Thus, the additional retail costs are imposed gradually as E85 sales expand within a state and the full cost is applied only for very large increases in E85.[8]

Base data reflect the case of 2004. More recent data are not consistently available at the time of model development. Data sources are summarized in an appendix.

Results of mapping from benchmark price to retail price

This representation of the link from benchmark prices to retail prices is by no means certain and may not be stable. The lack of historical data for estimation and the changing distribution network may undermine these calculations at least to some extent. Nevertheless, the links can be used to distinguish between price comparisons at benchmark prices and retail prices. In the representation of demand that will follow, consumers are assumed to make their judgments based on relative retail prices, including taxes, in fuel equivalent terms.

These links are further illuminated by showing these comparisons in the case of both $140 per barrel petroleum and $70 petroleum (Table 6). First, the average prices of fuels based on the equations used here are shown. For example, a benchmark ethanol price of $2.00 per gallon and a $70 petroleum price imply that average retail prices of fuels, including taxes, transportation and E85 infrastructure costs, and relative energy content for gasoline, E10, and E85 are $2.61, $2.64, and $3.00 per gallon. At double the petroleum price, these average retail prices are $4.50 for gasoline, $4.41 for E10, and $3.82 for E85.[9]

Increased prices for ethanol blended fuels follows from three factors. First, the higher cost of the gasoline component of these fuels which, for E10, comprises 93 percent in energy equivalent terms. Second, ethanol transportation costs are assumed to move proportionally with petroleum price, so a doubled petroleum price leads to double the costs of moving ethanol from the Midwest to other regions.[10] Third, for E85 only, increasing use associated with changing prices leads to higher infrastructure costs.

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[7] Waterman, T. "There Are Several Ways to Increase Ethanol Demand, None of Which Is Easy." *Ethanol Monitor*, vol. 3, no. 36: (Sept 17, 2007): p. 7.

[8] The determination of quantities demanded is described in the next section.

[9] While these estimates of gasoline prices are consistent with historical data, more recent events hint that they may be too high. Recent petroleum prices have been as high as the levels investigated here for a brief period of time, but the gasoline price has not risen as much as the estimated equations imply.

[10] The assumption that the evolution of costs is entirely proportional to the petroleum price almost certainly overstates the effects, and understates the potential for other cost factors that are invariant with respect to petroleum prices. Better and up-to-date data about ethanol transportation costs would be valuable.

If the combination of benchmark prices is $2.00 per gallon of ethanol and $70 per barrel of petroleum, then the average retail prices of both E10 and E85 are higher than the average gasoline price, taking into account taxes, margins, and energy content. On the other hand, if the petroleum price were $140 per barrel, then the E10 and E85 prices would be, on average, less than the gasoline price if the ethanol price were still $2.00. Looking at other calculations, the expected results hold in that a higher ethanol benchmark price will tend to decrease competitivity of ethanol blended fuels relative to pure gasoline. At the same time, a higher petroleum price tends to increase competitivity of ethanol blended fuels.

Table 6. Calculated fuel price for varying conditions

Ethanol price	Petro. Price	Average retail price			Ratio of retail prices	
		Gasoline	E10	E85	E10/Gas	E85/Gas
(per gallon)	(per barrel)	(per gallon, energy basis)				
$1.50	$70	$2.61	$2.59	$2.54	99%	97%
	$140	$4.50	$4.36	$3.40	97%	76%
$2.00	$70	$2.61	$2.64	$3.00	101%	115%
	$140	$4.50	$4.41	$3.82	98%	85%
$2.50	$70	$2.61	$2.70	$3.50	103%	134%
	$140	$4.50	$4.46	$4.23	99%	94%

Source: Calculations based on data and model described in text.

A common question is at what price is ethanol competitive with gasoline. Here, this question can be addressed is explored by calculating the benchmark prices of ethanol and petroleum at which are retail prices the same (Table 7). The two benchmark prices cannot be compared directly to judge their value to consumers because (1) ethanol has less energy than petroleum and (2) consumers do not buy crude petroleum or, typically, ethanol at the plant gate. Supposing, for example, that the benchmark petroleum price is $140 per barrel, or about $3.33 on a per gallon basis, there are several comparisons that can be made. These comparisons are listed below on the basis of national average prices, culminating in the most appropriate one for assessing the situation of consumers. The question this addresses is a common one, namely at what benchmark or indicator price of ethanol are the prices of this fuel source equal to the price of petroleum based fuel.

1) The ratio of benchmark prices is one if the ethanol is $3.33 per gallon.
2) The ratio of prices in fuel equivalent terms is one if the benchmark price of ethanol is 34.5 percent less than the benchmark petroleum price, or $2.22 per gallon.
3) Retail prices:
    a. The ratio of E10 and gasoline in fuel equivalent terms and after taxes is one if the benchmark ethanol price is $2.61 per gallon.
    b. The ratio of E85 and gasoline in fuel equivalent terms and after taxes is one if the benchmark ethanol price is $2.84 per gallon.

In short, for consumers to opt to buy ethanol in the form of blended fuels, the benchmark price of ethanol must be lower than the $3.33 per gallon petroleum price. For the price of E10 to be competitive with gasoline, on average, requires that the Omaha rack price of ethanol is 15 percent lower than the price per gallon of petroleum.

Price comparisons vary by level, wholesale or retail. The reasons include the averaging of prices among states. More substantive explanations are the combination of constant and relative mark-ups, including the effect higher petroleum price is assumed to have on ethanol transportation costs. Also, there is a relative shift caused by the lower energy content of ethanol versus the largely constant tax differentials. The end result is that, based on this treatment of margins and taxes, the benchmark ethanol price at which ethanol can compete in retail markets can be higher or lower than the benchmark ethanol price that implies direct equivalence with the benchmark petroleum price.

A common back-of-the-envelope calculation is to go from a particular petroleum price and estimate an equivalent ethanol price without going through retail prices (Table 7). This is reproduced as follows. First, the given petroleum price is used to calculate the wholesale gasoline price before taxes based on historical relationships.[11] Taking this price, times 65.5 percent, gives the price at which ethanol would need to be priced to offer the same energy content per dollar. The next adjustment is to add the blender tax credit, 45 cents per gallon, to see the price that a fuel blender would be willing to pay for ethanol. The result is an estimate of the Omaha rack price of ethanol that corresponds to the petroleum price, which is $1.81 in the case of $70 per barrel petroleum and $3.08 in the case of $140 per barrel petroleum.

Table 7. Fuel price comparisons and equivalent price calculations

Equivalent prices based on retail prices simulated here		
Petroleum price	(per barrel)	
Benchmark price, in dollars per barrel	$70	$140
	(per gallon)	
Benchmark price, in dollars per gallon	$1.67	$3.33
--> *Equivalent benchmark ethanol price*	*$1.67*	*$3.33*
Retail, with transportation and taxes, common energy content		
Average gasoline price	$2.61	$4.50
--> *Equivalent benchmark ethanol price*		
Equivalence of gasoline and E10 price	*$1.62*	*$2.84*
Equivalence of gasoline and E85 price	*$1.58*	*$2.80*
Back of the envelope: direct from petroleum to wholesale ethanol, without retail		
	(per barrel)	
Given petroleum price	$70	$140
	(per gallon)	
Estimated rack gasoline price in Omaha	$2.08	$4.01
Multiply by energy content (65.5%)		
Equals energy equivalent retail price	$1.36	$2.63
Add tax credit for blenders (45 cents per gallon)		
Equals rack equivalent	$1.81	$3.08
Difference: back-of-the-envelope versus E10 above		
Absolute	$0.19	$0.24
Percent	12%	8%

Source: Calculations based on data and model described in text.

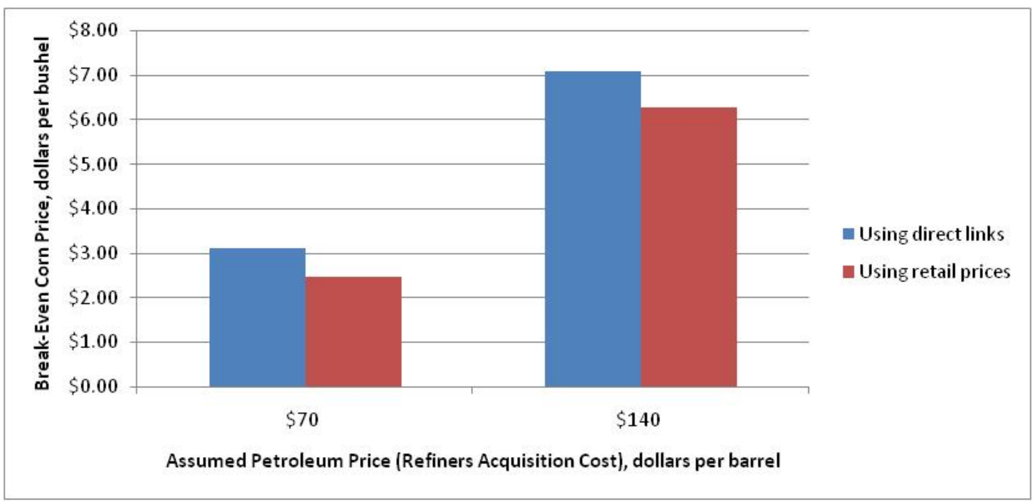
These back-of-the-envelope calculations overstate the benchmark ethanol price that is competitive with the petroleum price by $0.19 or $0.24 per gallon, which is 8 or 12 percent, as

[11] The rack price of unleaded gasoline in Nebraska (www.neo.ne.gov/statshtml/66.html) is estimated as a function of the refiner's acquisition price of petroleum.

compared to calculations based on the retail prices of fuels. One important difference between these two approaches is in the treatment of taxes: the back-of-the-envelope calculation presumes that taxes are proportional (expressed in percent terms), whereas most tax data found for purposes of this study are specific (expressed in cents per gallon).

Based on such calculations, an analyst might infer a break-even corn price. This is the corn price for a given petroleum price at which ethanol processors are willing to buy corn and will make neither losses nor profits, taking into account costs of capital. This is a further extension of back-of-the-envelope calculations that are conducted here in these steps. First, the ethanol price calculated above is taken for each case, with petroleum price at $70 or $140 and the results based on either retail price comparison of direct links at wholesale level. Second, costs of ethanol production are subtracted. These costs are assumed to be 90 cents per gallon if the petroleum price is $70 per barrel (30 cents for energy-related costs, 30 cents for other operating costs, and 30 cents for capital costs) and $1.00 per gallon if the petroleum price is $140 (40 cents for energy-related costs, 30 cents for other operating costs, and 30 cents for capital costs). This gives the net return per gallon, apart from feedstock costs. As a third step, the net returns are put on the basis of bushels of corn by multiplying by ethanol yield per bushel, which is assumed to be 2.75. This would be the break-even price except for the coproduct of ethanol production, distillers grains and solubles, whose price has historically been linked to the corn price. Fourth, the value of distillers grains is computed. This is taken to be a price, which is assumed to be 80 percent of the break-even price before distillers grains and solubles, times a quantity per bushel of corn used to make ethanol, which is assumed to be 17 pounds per 56 pound bushel used.

Figure 1. Implications for Break-Even Corn Price Calculations



In this way, the petroleum price implies a competitive ethanol price which implies in turn a competitive corn price. The break-even corn prices calculated using retail prices simulated here are lower than the break-even corn prices calculated using the direct, back-of-the-envelope calculation described above (Figure 1). The difference is $0.65 per bushel, or 26 percent, if the petroleum price is $70 per barrel and $0.82 per bushel, or 13 percent if the petroleum price is $140.

Apart from establishing the link from benchmark to retail prices necessary to assess consumer demand, this section results in one conclusion. In applied research, relative prices have been gauged using relative wholesale prices times some correction for energy equivalence. But adding in taxes and transportation costs that have fixed components do not support this method because the ratio of benchmark prices at wholesale may not reflect the ratio of retail prices. Moreover, if correct then a comparison of relative benchmark prices cannot be rendered accurate simply by choosing a coefficient that represents adjustments for margins, taxes, and energy content. A single coefficient could only be used to correct the comparison at one point, and would consequently not be useful in the context of changing prices, if this representation of the links from benchmark to equivalent retail prices is structurally correct.

Representation of consumer demand

The representation of consumer demand for motor fuel takes into account five potential outcomes.

1. Consumers may have the choice to buy gasoline without any ethanol, and may choose this option.
2. In some areas, local regulatory requirements may lead consumers to buy fuel in which ethanol serves the role of additive to change certain properties.
3. Consumers may be able to choose to buy fuel in which ethanol is blended at a 10 percent inclusion rate.
4. Consumers with flex fuel vehicles may have the option to buy E85, fuel in which ethanol inclusion can be as high as 85 percent, and might choose to do so.
5. Consumers may opt to buy more or less motor fuel overall.

This model is intended to represent, in a stylized way, all of these possible outcomes, with consumer decisions motivated by relative prices within a regulatory context that may preclude some options.

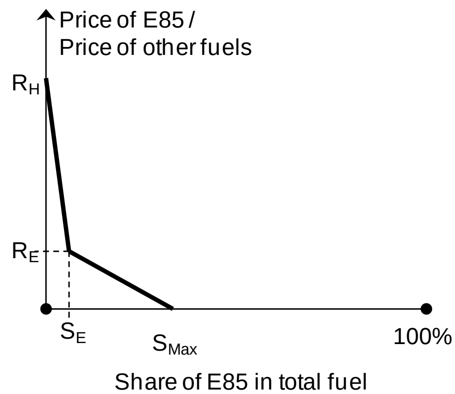
The representation proceeds in stages. First, total motor fuel demand is a function of the average fuel price. The own-price elasticity for every state is -0.05 by assumption on the basis of literature review and comparison to structural model elasticity reported by the EIA. This elasticity implies a very small consumer response to motor fuel prices overall: a 1 percent increase in the average motor fuel price will lead consumers to buy 0.05 percent less motor fuels.

Total motor fuel is disaggregated in stages, first between E85 and other fuels, second, the non-E85 fuels are disaggregated between E10 and other fuels, and, third, other fuels are divided into gasoline and fuels with ethanol as an additive. This stylized representation is intended to reflect consumer choice in broader fuel types that are subject to greater limits, namely the option to buy E85 if the consumer owns a flex fuel vehicle, before the lower-stage decision with greater flexibility.

The E85 or non-E85 choice depends on relative prices. The assumed relationship in aggregate for any given state is one of smooth transition from non-E85 fuels to E85 fuels as the relative price of E85 falls (Figure 2). Historical data do not provide a basis for understanding broader acceptance, nor for putting precise numbers to this transition. It is assumed that widespread adoption would begin if the relative retail prices were equal, after taking into account energy content and taxes, and the consumer willingness to substitute E85 for other motor fuel would rise in the theoretical case that the price fell towards zero. This expansion is subject to a sharp limit in this representation based on the E85 fleet in existence at the time of writing and an assumed expansion path. The maximum E85 potential rises to 10 percent of total motor fuel use in 2009.[12]

[12] The level is applied on a state-by-state basis. Useful exercises to explore sensitivity with respect to this parameter might include not only varying this parameter, but also changing the allocation among states to

Figure 2. Consumer choice between E85 or non-E85

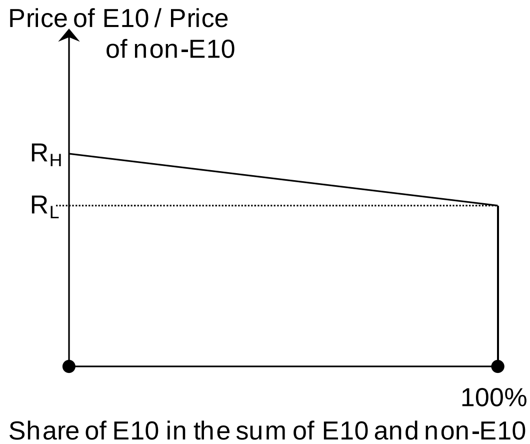


Historical data reveal that E85 was used in all states in 2004 even though relative retail prices averaged at the state level would not favor this motor fuel over its competitors, at least by these calculations. However, the comparison of relative retail prices in equivalent terms is fully appropriate for all consumers only if the chief and perhaps only criterion when buying fuel is the cheapest way to move a car a mile. A broader array of consumer preferences may be manifested in their motor fuel purchases. Consumers may opt to buy ethanol-blend fuels based on any of a longer list of perceived outcomes of their fuel purchases that relate to farm income, fuel imports, environment quality, rural economic health, or driving performance. To capture the role of consumers who tend to buy E85 even when its cost of providing motor fuel services is higher than for competing fuels, a small share of the E85 demand is assumed to be much less price-sensitive. At most, these consumers are assumed to account for one percent of motor fuel use ($S_E=1$). That level only occurs if retail prices are equal ($R_E=1$). The upper limit these consumers are willing to pay for E85 relative to other fuels (R_H) is calibrated to observed 2004 data.

Non-E85 fuels are disaggregated in a second stage (Figure 3). The basis of consumer choice is assumed to be the ratio of E10 to non-E10 prices. It is assumed, moreover, that consumers will opt entirely for one or the other of these two fuels. The ratio at which E10 use is adopted is 0.85 for states that require that ethanol be labeled if used in such fuels and 0.925, otherwise ($R_L=0.85$ *or* $R_L=0.925$). The upper limit (R_H) is calibrated to 2004 data. Unlike the case of E85, E10 use is not reported in all states in the base period, so the upper limit is calibrated based only very loosely on calculated relative prices in other states. Mandates at the state level are imposed here by adjusting the E10 share to make sure total ethanol use achieves the share of overall motor fuel use required.

allow for greater use in some states relative to others to mimic the possibility that E85 expansion is extremely centralized.

Figure 3. Consumer choice between E10 or non-E10



The final disaggregation of fuel that is neither E85 nor E10 is not a matter of consumer choice, in a certain sense. Fuel sold in certain areas or at certain times was required to be oxygenated or reformulated in 2004 as required by the Clean Air Act, 1990 As Amended. In contrast to conventional fuel, these fuels have additives included to change certain properties. Two subsequent changes to the legal and regulatory environment are critical to assessing the evolution of the role of ethanol. First, MTBE was a common additive until 2006, from which point it has fallen into disuse as regulations no longer shield MTBE users from litigation brought about by its cancerous nature. Additive requirements are now met almost exclusively by ethanol. The second change is that the national requirement for additive use is no longer in effect, although local requirements typically remain.

To extrapolate beyond the 2004 base period, the share of fuel with additives in that year is assumed to remain constant into subsequent years. This may overstate the additive market. The share of ethanol in additive fuels is assumed to be 10 percent in all markets except California at least through 2009.[13] This use of ethanol might be considered involuntary, because motor fuel consumers in some areas or at some times may face a smaller array of choices, all of which include ethanol. Technically, of course, consumption is voluntary as consumers could opt not to buy motor fuel at all, although the small overall elasticity of motor fuel demand suggests that this is not a common consumer choice.

IV. State ethanol demand model results

The recursive model is simulated for ranges of ethanol prices to generate the demand for ethanol at a given petroleum price. For each case, however, the model is extrapolated forward to 2009 as a first step based on observed prices until 2008, expected prices in 2008, and the prices of the experiment in 2009.

[13] EPA data indicate that 10 percent is commonplace (www.epa.gov/otaq/regs/fuels/rfg/properf/rfgperf.htm) so this inclusion rate is applied almost universally. The sole exception is California, where legal provisions suggest that the appropriate assumption is 5.7 percent ethanol in additive fuels (Western Farm Press, "California Moves to Increase Ethanol Use", www.westernfarmpress.com/news/082907-ethanol-increase/index.html, August 29, 2007).

Ethanol demand

The cases of $70 and $140 per barrel petroleum in 2009 are used as examples to highlight some structural elements (Figure 4 and Figure 5). Given each of these prices in turn, the ethanol price is varied over a wide range to simulate possible levels of use given the stylized representation described above. These results highlight certain characteristics of fuel use and ethanol demand which, while not new, are put to numbers using this stylized approach.

- The inelastic portion of the demand curve at near or over five billion gallons of ethanol use reflects the sum of additive use and state-level mandates.
- The growth of additive use decreases overall elasticity of demand for ethanol because most additive fuel also has 10 percent ethanol so there is little cause for consumers to substitute between additive fuel and E10.
- The range of ethanol prices over which E10 and E85 use expand is very sensitive to the petroleum price.
- The "blend wall" is caused by the natural limit of ethanol penetration in the form of E10 to 10 percent of total motor fuel use, and the imposed limit to the E85 share.
- A reduction in the benchmark petroleum price from $140 to $70 leads to about 10 percent less ethanol demand at extremely high or low ethanol prices, but can lead to a decrease in ethanol demand of just under 30 percent for mid-range ethanol prices.

Figure 4. Ethanol demand, petroleum price $140/barrel

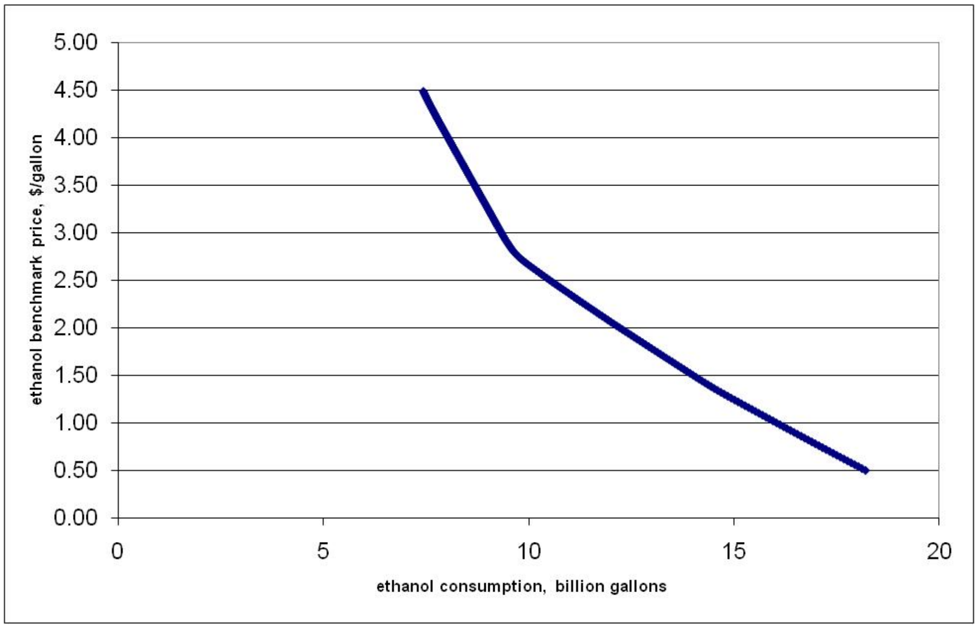
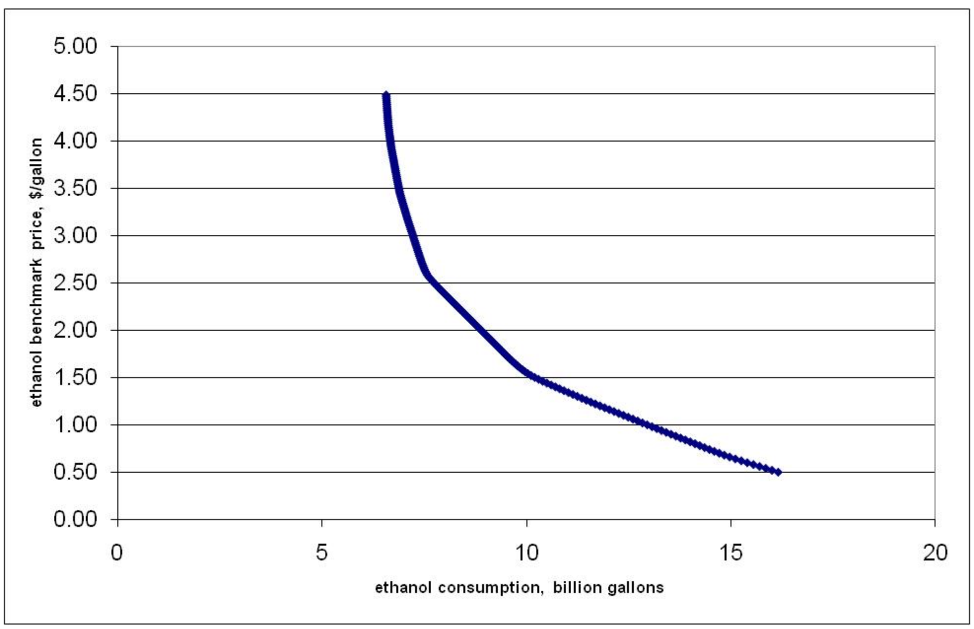


Figure 5. Ethanol demand, petroleum price $70/barrel



State ethanol demand policy scenarios

The effects of state policies are explored in various scenarios for the two different prices.[14] First, the existing policies are removed for all states, such that there is no differential taxation in any state and there are no mandates. Second, a certain set of policies is extended to all states. The preferential tax treatment of the scenario is at least $0.10 for E10 and E85. The scenario mandate

[14] The effects of national policies are not changed. The federal mandates are ignored at this point, but added later in the context of a complete US ethanol market representation.

is at least 5 percent in energy equivalent terms, or almost 8 percent in volume terms. In cases with greater mandates or discounts in ethanol-blended fuel taxes, the base levels are not changed. The results are summarized as follows (Figure 6 and Figure 7).

Eliminating state support

If the petroleum price is $140 per barrel, then the results of eliminating state-level support have their greatest impact at higher ethanol prices, but in any case the relative impact is small. The case of no policy support, which amounts to the case that state-level differential tax treatment is discontinued and there are no state mandates, results in a reduction in the quantity of ethanol used at any given price that ranges from -1 to -5 percent relative to the base case of existing policies. The states that currently apply policies that encourage ethanol use do not account for a large share of the aggregate US motor fuel demand, as shown above, so their ability to induce greater total US ethanol use is limited.

The effects are particularly small when the ethanol price is low. In that case, much of the potential ethanol use in these states is exhausted and mandates are less likely to be binding, so there is very little effect on consumer behavior from either mandate or tax. In contrast, at higher ethanol prices the mandates tend to cause greater consumption than would occur otherwise. Simulations not shown here indicate that state mandates explain a less than half of the effect of overall state support to demand at a low ethanol price, but these mandates explain almost the entire effect of state support at higher ethanol prices.

The results of eliminating state support for ethanol use reflect the lower willingness of consumers to buy ethanol-blended fuels if the petroleum price is $70 per barrel, but are only somewhat larger in scale. Removing state support for ethanol demand lowers the quantity of demand by -1 percent at a low ethanol price and -7 percent at a higher ethanol price. The mandate effects are, again, most pronounced at a high benchmark ethanol price. Given the lower petroleum price in this case, however, a rising ethanol price would look high to consumers much more quickly than if petroleum costs $140 per barrel.

Widespread state support

The implications of the alternative case in which all states offer at least a certain absolute reduction in the excise tax per gallon and required that ethanol comprise at least 5 percent of motor fuel use also has little effect at low ethanol prices and more substantial effects at higher prices. If prices are low, then consumers in many states might already use 5 percent ethanol or more in their motor fuel consumption. However, at higher ethanol prices, the mandate is more likely to matter. In the event of extremely high prices, the outward shift in ethanol demand can amount to more substantial shift relative to the base case of existing policies. At $140 per barrel petroleum price, the shift ranges from as low as two percent at a low ethanol price to an increase of about two-thirds at a high ethanol price. If, instead, the petroleum price is assumed to be $70, then the increase in the quantity demanded at a given ethanol price ranges from six percent to over 90 percent. At high ethanol prices, ethanol demand is sustained in this case by a combination of additive and mandated uses which are both very insensitive to further price increases.

Figure 6. Ethanol demand without state-level support policies and with broader support policies, $140 per barrel petroleum price

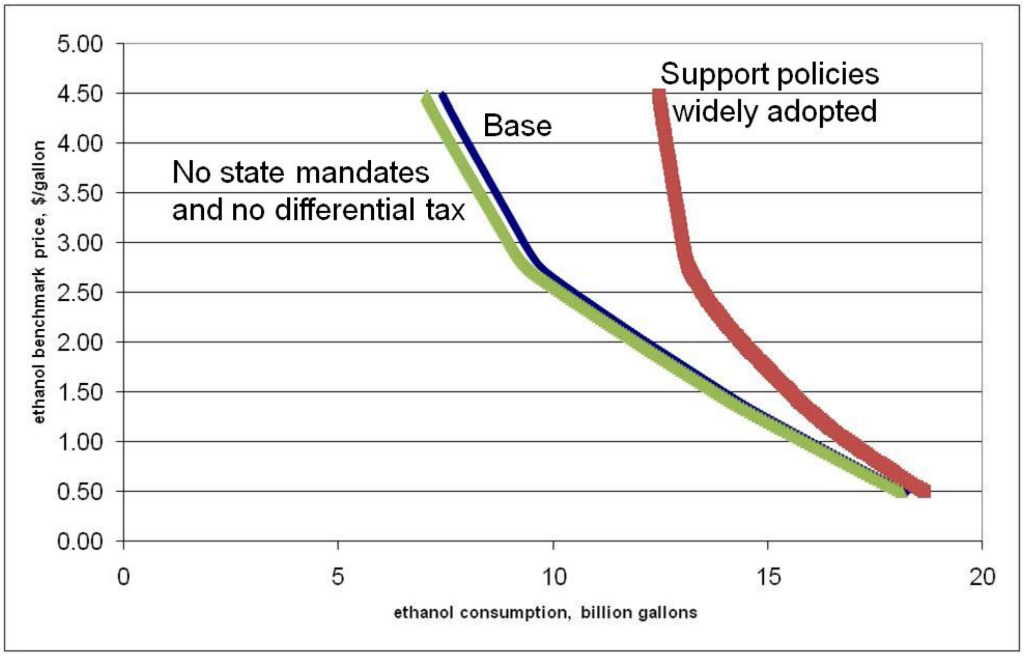
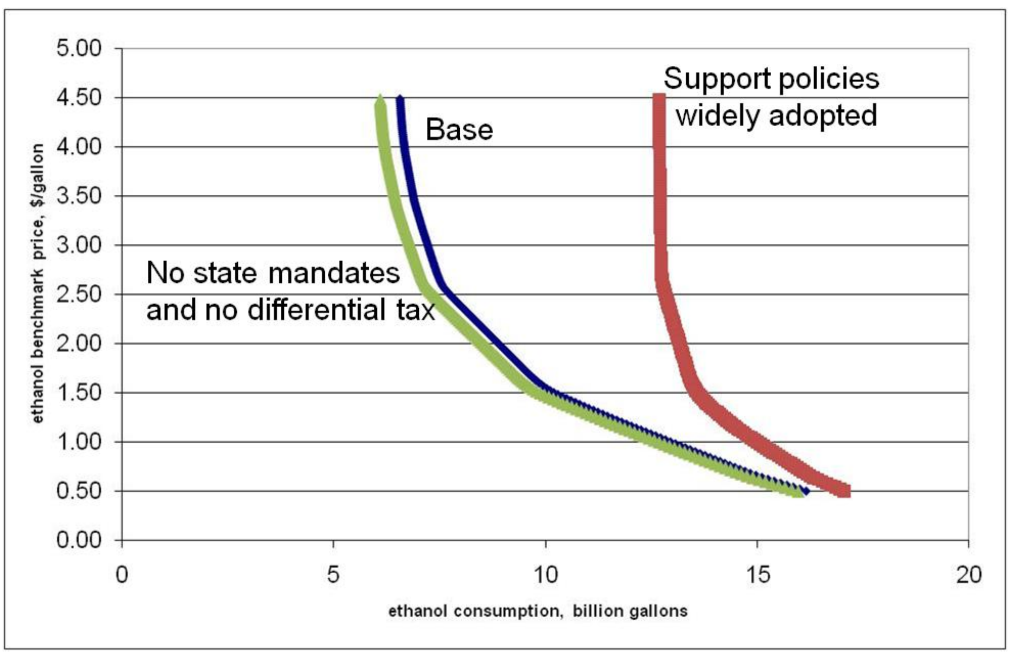


Figure 7. Ethanol demand without state-level support policies and with broader support policies, $70 per barrel petroleum price



These results can be assessed in terms of the vertical distance, too. In this fashion, the results answer the question, at what benchmark ethanol price (Omaha rack rate price) would the given quantity sell under different sets of state policies to support ethanol demand? The answer depends on the petroleum price as well. For example, if the petroleum price is $140 per barrel, then to sell 13 billion gallons of ethanol, the benchmark price would have to be no higher than

$1.78 per gallon in the base case (Table 8). In the case of less support, the price would have to be lower, at $1.72, in order for consumers to buy the same volume. On the other hand, with broader state support for ethanol use, the benchmark price could be as high as $3.04 per gallon and 13 billion gallons would still be used. At $70 per barrel petroleum, the ethanol price would have to be lower to sell the same quantity. Thus, to sell 13 billion gallons of ethanol when petroleum is less expensive would require a benchmark price of $1.00 in the base case, $0.94 without any state support to demand, and $2.26 if there were widespread state support for ethanol in the form of tax discounts and mandates. Smaller quantities would be purchased at higher prices, even rising beyond the levels explored here in some cases. In order for greater and greater volumes of ethanol to be sold, these prices must be lower. The differences become smaller as the volumes increase, much as the quantity differences outlined above largely evaporated at low prices.

Table 8. Ethanol prices at which given volumes of ethanol can be sold

Ethanol demand in billion gallons	**Ethanol benchmark price required to sell given quantity** Petroleum price $70 per barrel			Petroleum price $140 per barrel		
	Base	No policy	All policy	Base	No policy	All policy
7	$3.28	$2.76	*	*	*	*
9	$1.94	$1.80	*	$3.26	$3.00	*
11	$1.34	$1.28	*	$2.36	$2.28	*
13	$1.00	$0.94	$2.26	$1.78	$1.72	$3.04
15	$0.66	$0.62	$1.00	$1.24	$1.20	$1.72

Note: Asterisk (*) indicates a combination of price and quantity not calculated here.
Source: calculations based on model results as described in text.

A key assumption about state mandates in the results above is that they are not relaxed under any condition. The results for high ethanol price conditions presented above, and the results following section as well to a certain extent, depend on this assumption. If states relax their mandates at some point as the price of ethanol rises relative to the gasoline price, then the mandates would not shift demand outward as much in these conditions.

V. National ethanol and commodity market implications

National model and state policy scenarios

The stylized state ethanol demand representation is useful for exploring the structure of demand and how state policies to support ethanol demand may shift that relationship. However, this model does not extend far enough to study the broader implications in terms of the impact of these policies on ethanol markets taking into account the ethanol processing sector and, through that sector, the effects on agricultural commodity markets. To assess these effects, the vertical shifts in ethanol demand that are described above are introduced into a broader model system that is simulated to estimate the effects.

The model of ethanol markets is documented elsewhere.[15] This US commodity and biofuel model includes equations that represent ethanol supply, demand, imports, and price-

[15] FAPRI–MU "Model of the US Ethanol Market". FAPRI–MU Report #07-08. July 2008 (http://www.fapri.missouri.edu/outreach/publications/2008/FAPRI_MU_Report_07_08.pdf).

clearing; ethanol processor returns, ethanol capacity, and capacity utilization; corn market supply and demand, including uses for ethanol, feed, and exports; and supply, demand, and market clearing for distillers grains and solubles. Other major field crops are also included, as is biodiesel. National level policies are represented, including the multi-level mandates to use biofuels as delineated in the Energy Independence and Security Act.[16]

The outcomes are sensitive to the wider context, particularly the petroleum price but also with respect to federal policies. The base data are from the FAPRI–MU 2008 baseline update.[17] These numbers were developed at a time when petroleum prices were projected by Global Insight to be near $115 per barrel for the next few years. The ethanol price was projected to be about $2.45 per gallon.

The results of the scenarios conducted with the representation of ethanol demand described in preceding sections of this paper are introduced into the model of US ethanol demand as follows. At these prices, the effect of an elimination of state support for demand is about a -3.4 percent reduction in the quantity of demand or, $0.06 change in the average price if expressed in terms of a vertical shift. Most of this change is associated with the elimination of mandates and a less part is caused by the elimination of preferential tax treatment. Thus, the effect is introduced as a -3.1 percent shift in the quantity of demand and an increase of $0.01 in the consumer price.

The scenario of widespread state support for ethanol demand is similarly introduced. E10 and E85 tax reductions of $0.10 and a 5 percent mandate by energy, or almost 8 percent in volume terms, are imposed in those states that offer less support. At $115 per barrel petroleum and $2.45 per gallon ethanol, the effect is almost 40 percent higher quantity demand or, if expressed as a vertical shift, about $1.30. Assuming the same allocation between mandate and tax effects leads to a shift in demand of 34 percent and a reduction in consumer ethanol price of $0.13 per gallon.

The structure of demand in the national model is exploited for this purpose in that the price change associated with a scenario is applied universally for all demand categories and the quantity shift is added to the part of demand that represents less elastic uses.[18]

The scenario starts in marketing year 2009/2010.

Ethanol and agricultural commodity market effects

These shifts are an initial effect. The final effect depends on the extent to which demand changes affect the wider market. Stronger demand triggered by greater state support for ethanol use will tend to bid ethanol prices higher, neutralizing some part of the initial effect. Likewise, reduced state support for ethanol would lead to lower ethanol demand and, consequently, lower ethanol price, with this price decrease offsetting in part the initial reduction in support. Moreover, through ethanol processors, the effects on ethanol prices will have further effects on agricultural commodity markets.

Market effects are shown for averages of 2009/10 to 2012/13 (Table 9). These averages overstate the initial price effects and understate the area effects of the first year if the policy changes were anticipated. After more years of adjustment, there would be somewhat more supply

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[16] Analysis of federal biofuel policies using this model is available in "Biofuels Impact of Selected Farm Bill Provisions and other Biofuel Policy Options", FAPRI–MU Report #06-08.

[17] FAPRI–MU "Baseline Update for US Agricultural Markets". FAPRI–MU Report #10-08. September, 2008. (http://www.fapri.missouri.edu/outreach/publications/2008/FAPRI_MU_Report_10_08.pdf)

[18] In fact, state level mandates are already reflected in the model based on rough calculations. The implementation of scenarios in this paper uses this value as a starting point, but apply the shift calculated from the demand representation defined here.

response and, consequently, slightly smaller price effects. Nevertheless, these averages usefully represent medium-term market effects.

The implications of removing all existing state mandates and differential tax treatment in support of ethanol use are modest. A slightly lower ethanol producer price leads to less ethanol processing, with output down by half a percent, on average, or -0.13 billion gallons. This change is manifested in corn markets as lower demand. Thus, the average farm corn price is lower, by -$0.01 per bushel, and the amount of area planted to corn is also reduced, by -0.16 million acres in aggregate, on average. Of this, the reduction of Corn Belt area planted to corn is -0.06 million acres following a similar decrease in the corn price in this region.

Table 9. National market effects of state ethanol demand policies, average 2009/10-2012/13

		Base	No state support for demand			Widespread state support		
			Level	Difference form base		Level	Difference form base	
				absolute	relative		absolute	relative
Ethanol								
Disappearance	(billion gallons)	15.01	14.85	-0.16	-1.0%	17.30	2.29	15.3%
Production	(billion gallons)	14.60	14.49	-0.12	-0.8%	15.87	1.26	8.7%
of which, corn-based ethanol	(billion gallons)	14.25	14.13	-0.12	-0.8%	15.48	1.23	8.6%
Imports	(billion gallons)	0.46	0.42	-0.04	-8.3%	1.51	1.05	227.1%
Price to consumers	(dollars/gallon)	2.63	2.62	-0.01	-0.3%	2.51	-0.11	-4.3%
Price to corn-based ethanol processors	(dollars/gallon)	2.43	2.41	-0.02	-0.7%	2.65	0.22	9.1%
Corn								
National area planted	(million acres)	93.07	92.91	-0.16	-0.2%	94.68	1.61	1.7%
of which, Corn Belt area planted	(million acres)	40.49	40.43	-0.06	-0.2%	41.16	0.67	1.6%
Production	(billion bushels)	13.63	13.61	-0.02	-0.2%	13.87	0.25	1.8%
of which, Corn Belt production	(billion bushels)	6.83	6.82	-0.01	-0.2%	6.94	0.12	1.7%
Domestic disappearance	(billion bushels)	11.69	11.66	-0.03	-0.3%	12.03	0.34	2.9%
of which, used for fuel alcohol	(billion bushels)	5.12	5.08	-0.04	-0.8%	5.56	0.44	8.6%
Exports	(billion bushels)	1.94	1.95	0.01	0.5%	1.84	-0.09	-4.9%
Farm price	(dollars/bushel)	5.26	5.25	-0.01	-0.2%	5.40	0.14	2.7%
Corn Belt farm price		5.32	5.31	-0.01	-0.2%	5.46	0.14	2.7%
Selected other crops								
US area planted								
Soybeans	(million acres)	72.06	72.14	0.08	0.1%	71.21	-0.85	-1.2%
Wheat	(million acres)	58.54	58.56	0.02	0.0%	58.34	-0.20	-0.3%
Sorghum	(million acres)	6.92	6.91	0.00	-0.1%	6.97	0.06	0.8%
Barley	(million acres)	4.34	4.34	0.00	-0.1%	4.38	0.03	0.8%
Corn Belt area planted								
Soybeans	(billion bushels)	32.04	32.10	0.05	0.2%	31.50	-0.55	-1.7%
Wheat	(billion bushels)	3.42	3.42	0.00	0.1%	3.38	-0.04	-1.1%
Sorghum	(billion bushels)	0.15	0.15	0.00	0.1%	0.15	0.00	-0.6%
Barley	(billion bushels)	0.01	0.01	0.00	0.0%	0.01	0.00	0.0%
US farm price								
Soybeans	(dollars/bushel)	11.60	11.60	-0.01	-0.1%	11.68	0.08	0.7%
Wheat	(dollars/bushel)	6.69	6.68	-0.01	-0.1%	6.78	0.08	1.2%
Sorghum	(dollars/bushel)	4.95	4.94	-0.01	-0.2%	5.04	0.09	1.9%
Barley	(dollars/bushel)	5.18	5.17	-0.01	-0.2%	5.29	0.11	2.1%

The net effect on ethanol price to consumers requires some explanation. The demand effect is implemented in two initial effects, one for the quantity impact associated with the mandate elimination and one for the price effect of eliminating differential taxes. Of these, the quantity shift is more important. The net effect is that the reduced quantity of demand at any given price associated with no mandated uses in these states causes price to fall. This reduction in price more than offsets the slight increase in average price associated with the removal of tax reductions. Thus, the net effect on the prices ethanol consumers pay is small, and even somewhat negative.

If all states and the District of Columbia chose to provide at least a certain level of tax reduction for ethanol-blend fuels and to mandate some use, then the ethanol price to consumers could be reduced by -$0.11 per gallon, on average, and the price to corn-based ethanol producers could be increased by $0.22 per gallon. While this increase gives a signal to increase domestic production capacity, half of the 2.3 billion gallon increase in ethanol use would be met by greater imports at least during the medium-term. Ethanol production would account for about 1.3 billion gallons of the increase in use, implying greater demand for corn, so the average farm price of corn rises by $0.14 per bushel. Average corn area planted is simulated to rise by about 1.6 million acres in this case, including 0.7 million acres in the Corn Belt given the $0.14 higher corn price there.

The effects of ethanol policies spill over not only into the corn market, but also into other agricultural commodity markets. The changing price of corn leads affects land use mostly through reallocation among competing land uses, rather than by drawing new land into crop production in the US. Nationally, more than half of the additional land planted to corn is reallocated from soybean use, and another 12-13 percent is from wheat. In the Corn Belt, over 80 percent of the additional land used for corn in either scenario was previously used to grow soybeans, and 6 percent was used for wheat. Substitution in demand uses, for example among grains used in feed and also in food uses, also causes other market prices to move as corn markets adjust to the changing demand on the part of ethanol processors. The relative effects reflect not only the area shifts, but also the degree of substitution in demand and also the overall responsiveness of various agents, including foreign buyers, to price changes. If state support to ethanol demand is eliminated, there are broad decreases in farm prices but of no greater magnitude than the effects on corn price. With widespread state support for ethanol use, farm prices of other crops rise by $0.08 to $0.11 cents per bushel. At each step, however, the results are moderated in part by limits to substitutability, of land among its various uses or of commodities in demand, so effects tend to be more and more muted in each market.[19]

VI. Limitations of the study

The representation of ethanol demand is stylized. While the data may be too sparse for an estimated model at this point, further research should illuminate better the price links and the fundamental nature of consumer behavior to allow more exact representation.

The results are also context-specific. The assumption about petroleum price is particularly important, and exogenous to these models. A higher petroleum price leads to greater demand for ethanol and decreasing likelihood that a mandate requiring at least a certain level of use will prove binding. Conversely, a lower petroleum price increases the probability that mandates will affect market outcomes.

[19] Livestock, meat, milk, and milk product markets are not considered. There would be effects, but they are judged to be modest based on the magnitude of crop market changes, and not simulated here. On the other hand, effects on world crop and crop product markets through trade are represented using reduced form equations that reflect how total demand for US crop exports and supplies to US crop importers responds to changes in US markets.

Appendix 1: Data sources

Table 10. Base period data sources

Category	Variable	SOURCE	DATE OF SOURCE	DATE OF DATA
2007 base tax rates				
	Gasoline excise tax rates	Federation of Tax Administrators (http://www.taxadmin.org/FTA/rate/motor_fl.html).	January, 2006	January, 2006
	Gasohol excise tax rates	Federation of Tax Administrators (http://www.taxadmin.org/FTA/rate/motor_fl.html).	January, 2006	January, 2006
2004 policy: preferential tax treatment				
	E10 tax rate benefit rel to gas	Infer from http://www.eere.energy.gov/afdc/progs/ddown_matrx2.cgi	March, 2007	Varies by state
	E85 tax rate benefit rel to gas	Infer from http://www.eere.energy.gov/afdc/progs/ddown_matrx2.cgi	March, 2007	Varies by state
	E10 tax abs benefit rel to gas	Infer from http://www.eere.energy.gov/afdc/progs/ddown_matrx2.cgi	March, 2007	Varies by state
	E85 tax abs benefit rel to gas	Infer from http://www.eere.energy.gov/afdc/progs/ddown_matrx2.cgi	March, 2007	Varies by state
2004 data on ethanol use				
	Share of ethanol in blends of E10L	Calculated from http://www.fhwa.dot.gov/policy/ohim/hs04/xls/mf21.xls.	October, 2005	2004
	Share of equiv E10L in sum of E10L + E0			
2004 policy: mandates				
	Mandate E10 or E85 use in 2004 Binary 1=YES	American Coalition for Ethanol, "StatUS: 2006; ACE State by State Ethanol Handbook", 2006.	Early 2006	See mandate date
	Minimum share by volume	American Coalition for Ethanol, "StatUS: 2006; ACE State by State Ethanol Handbook", 2006.	Early 2006	See mandate date
	Minimum share in equiv	Calc	na	2004
2004 policy: label requirements				
	Label Req as minimum content for label	American Coalition for Ethanol, "StatUS: 2006; ACE State by State Ethanol Handbook", 2006.	Not known, other data labeled 2004.	Not known, other data labeled 2004.
Extrapolation				
	2004 to 2007 FINAL growth factor			
2007 policy: mandates				
	Mandate use in 2007 Binary 1=YES	American Coalition for Ethanol, "StatUS: 2006; ACE State by State Ethanol Handbook", 2006.	Early 2006	See mandate date
	Minimum share by volume	American Coalition for Ethanol, "StatUS: 2006; ACE State by State Ethanol Handbook", 2006.	Early 2006	See mandate date
	Minimum share in equiv	Calc	na	2004
For extrapolating to 2007, MTBE replacement				
	Retail deliveries Conventional	EIA (EIA, pet_cons_refmg_a_EPM0U_VTR_mgalpd_m.xls).	2006	2004
	Retail deliveries Oxygenated	EIA (EIA, pet_cons_refmg_a_EPM0X_VTR_mgalpd_m.xls).	2006	2004
	Retail deliveries Reformulated	EIA (EIA, pet_cons_refmg_a_EPM0R_VTR_mgalpd_m.xls).	2006	2004
	Assumed ethanol content in conventional	Unknown		
	oxygenated	EIA	2006	2006
	reformulated	EIA; Gallagher, Otto, Dikeman, 2000	2006; 2000	2006; ?
	Implied avg eth content	Calc	2004	
	Share of ethanol in blends of E10L	Calc	Assume 2007	
	Share of equiv E10L in sum of E10L + E0	Calc	Assume 2007	
2004 Base data for prices and quantities				
	Price Reg Gas no tax	Calculated	na	2004
	Price Ethanol Whlsle no tax	na	na	na
	Price Ethanol Retail no tax	na	na	na
	Quantity Fuel Use Highway, not specialty	http://www.fhwa.dot.gov/policy/ohim/hs04/xls/mf21.xls	October, 2005	2004
	Quantity E10 fuel	http://www.fhwa.dot.gov/policy/ohim/hs04/htm/mf33e.htm	April, 2006	2004
	Quantity E10L fuel	http://www.fhwa.dot.gov/policy/ohim/hs04/htm/mf33e.htm	April, 2006	2004
	Quantity E85 fuel	Calc	na	2008
	Quantity E0 fuel	Calc	na	2004
	Q gas equivalent E10 fuel	Calc	na	2004
	Q gas equivalent E10L fuel	Calc	na	2004
	Q gas equivalent E85 fuel	http://www.eia.doe.gov/cneaf/alternate/page/atftables/afv_hist_data.html	Feb, 2008	2008
	Q gas equivalent E10L+E0 fuel	Calc	na	2004
	Q gas equivalent All fuel	Calc	na	2004

Appendix 2: Sources for state-level tax treatment for ethanol blended fuels

Sources of state taxes incentives for ethanol use are not consistent. For the purposes of this study, three sources are used. The Federal Tax Administration gives a relatively clear list of relative tax rates that is not reproduced here. Supplemental information from the American Coalition for Ethanol and the Energy Efficiency and Renewable Energy office of the US DOE are combined with a view to estimate the upper bound of state support. Thus, a tax reduction listed in either source is applied, even if it is not listed in both or all sources.

Table 11. Sources of tax reduction information

State	Source	Quote or passage	Note
Arkansas	EERE	"Excise taxes on alternative fuels are imposed on a gasoline gallon equivalent basis."	
Hawaii	ACE	"Fuel blends containing at least 10 percent ethanol are exempt from the 4 percent state excise tax on retail sales of gasoline."	May have expired by time of writing.
Idaho	ACE	"E10 receives a 2.5 cent per gallon exemption from the state's excise tax on gasoline."	EERE also notes tax reduction.
Illinois	ACE	"No tax applies to sales of E85."	Sales tax from www.state.il.us.
Iowa	ACE and EERE	Stated reductions vary by source.	
Kansas	EERE	States minimum $0.17 tax rate for E85.	Compared to $0.24 for gasoline reported by FTA.
Maine	ACE	"E10 receives a tax exemption of approximately 2 cents per gallon … . E85 receives a tax exemption of approximately 6.4 cents …."	
Michigan	EERE	"A tax of $0.12 per gallon is imposed on gasoline containing at least 70% ethanol …"	Compared to $0.19 for gasoline reported by FTA.
Minnesota	ACE	"E85 receives a 5.8 cent per gallon exemption…"	
Montana	EERE	"A state road tax reduction of 15%, as compared to the tax on gasoline, is available to consumers for using gasohol. Gasohol is defined as a gasoline fuel that is blended with denatured ethanol."	Assumed to apply to E85 at same rate.
New Mexico	EERE	"The excise tax imposed on alternative fuel distributed in New Mexico is $0.12 per gallon."	Compared to $0.186 for gasoline reported by FTA. Assumed to apply to E85.
New York	EERE	"E85, compressed natural gas, and hydrogen used exclusively to operate the engine of a motor vehicle is exempt from state sales and use taxes."	Sales tax from www.tax.state.ny.us.
North Carolina	EERE	"The retail sale, use, storage or consumption of alternative fuels is exempt from the state retail sales and use tax..."	Sales tax from www.taxfoundation.org.
North Dakota	EERE	"Sale of ethanol blended gasoline fuel containing 85% ethanol (E85) is exempt from the $0.23 per gallon tax, and is instead subject to a reduced tax of $0.01 per gallon on all E85 fuel sold or used in the state, up to 1.2 million gallons."	Upper limit is ignored.
Oklahoma	ACE	"1.6 cent per gallon tax credit for each gallon of ethanol blended gasoline sold at the retail level."	
Pennsylvania	EERE	"The rate of tax is determined on a gasoline gallon equivalent basis."	
South Dakota	EERE	"E85 and M85 are taxed at a rate of $0.10 per gallon, and other ethanol blends are taxed at a rate of $0.20 per gallon. "	Compared to $0.22 for gasoline reported by FTA.
Wisconsin	EERE	"A state excise tax, based on the standard number of British thermal units per gallon generated by each alternative fuel, is imposed on the use of alternative fuels."	Use gasoline equivalence as defined in paper.

Sources

ACE = American Coalition for Ethanol. "ACE Ethanol Handbook." 2006.

EERE = Energy Efficiency and Renewable Energy office of the US Department of Energy. Accessed via www.eere.energy.gov/afdc/ethanol/incentives_laws.html.

FTA = Federation of Tax Administrators. Accessed via www.taxadmin.org/FTA/rate/motor_fl.html.

Appendix 3: Petroleum Administration for Defense District (PADD) composition

The states in each of the five PADDs are reproduced here for convenience. In the text, PADD 2 is referred to as the Midwest.

Table 12. PADD composition

	PADD		PADD		PADD
Connecticut	1	Illinois	2	Alabama	3
Delaware	1	Indiana	2	Arkansas	3
District of Columbia	1	Iowa	2	Louisiana	3
Florida	1	Kansas	2	Mississippi	3
Georgia	1	Kentucky	2	New Mexico	3
Maine	1	Michigan	2	Texas	3
Maryland	1	Minnesota	2		
Massachusetts	1	Missouri	2	Colorado	4
New Hampshire	1	Nebraska	2	Idaho	4
New Jersey	1	North Dakota	2	Montana	4
New York	1	Ohio	2	Utah	4
North Carolina	1	Oklahoma	2	Wyoming	4
Pennsylvania	1	South Dakota	2		
Rhode Island	1	Tennessee	2	Alaska	5
South Carolina	1	Wisconsin	2	Arizona	5
Vermont	1			California	5
Virginia	1			Hawaii	5
West Virginia	1			Nevada	5
				Oregon	5
				Washington	5

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