Toward an Optimal U.S. Ethanol Fuel Subsidy

Dmitry Vedenov

and

Michael Wetzstein

Corresponding author:

Michael Wetzstein
Dept. of Agr. and Applied Economics
University of Georgia
Athens, GA 30602
(706) 542-0758
(706) 542-0739 Fax
Mwetzstein@agecon.uga.edu

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Dmitry Vedenov and Michael E. Wetzstein are an Assistant Professor and Professor, respectively, in the Department of Agricultural and Applied Economics, University of Georgia.

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Abstract

Enhanced environmental quality, fuel security, and economic development along with reduced prices of ethanol-gasoline blends are often used as justifications for the U.S. federal excise tax exemption on ethanol fuels. However, the possible effect of increased overall consumption of fuel in response to lower total price, mitigating the environmental and fuel security benefits, are generally not considered. Taking this price response into account, the optimal U.S. ethanol subsidy is derived. Estimated values of the optimal subsidy reveal the subsidy's environmental and security benefits are questionable. However, positive environmental and security benefits from the ethanol tax-exemption subsidy may be obtained if the subsidy is combined with an increase in the excise tax on gasoline.

Key words: economic development, energy security, environmental quality, ethanol, excise tax, renewable fuels, tax exemption.

varied with *s*.

The F.O.C.s for (7) are

$$\partial\mathcal{L}/\partial X = u_X - \lambda = 0,\ \ \partial\mathcal{L}/\partial F = u_M M_F - \lambda(p - s\alpha_R) = 0,\ \ \partial\mathcal{L}/\partial H = u_M M_H - \lambda = 0,$$

where the subscripts denote first partial derivatives of the respective functions. From these

$$\frac{M_F}{p - s\alpha_R} = \frac{\lambda}{u_M} = M_H\,. \tag{8}$$

With the vehicle travel function (2) specified as linearly homogeneous, the Euler theorem states

$$M = M_F F + M_H H. \tag{9}$$

Substituting (8) into (9) and solving for the agent's monetary benefit of driving per mile, u_M/λ, yields

$$\frac{u_M}{\lambda} = \frac{(p - s\alpha_R)F}{M} + \frac{H}{M} = p_M\,. \tag{10}$$

Equation (10) can be interpreted in the sense that agents equate their monetary marginal benefit of driving per mile, u_M/λ, with the total per mile cost of driving, p_M. This total cost is the sum of the fuel cost per mile, $(p - s\alpha_R)F/M$ and non-fuel costs per mile, H/M. The determination of the agent's cost per mile (10) is based on the assumption that agents ignore the effect of their own driving on aggregate mileage, $\bar{M}$, aggregate fuel consumption, $\bar{F}$, and aggregate fuel efficiency, $\bar{H}$, and treat those as constant. Thus, agents ignore their own impact on fuel security, environmental quality, and government spending. However, these impacts should be taken into account in determining the social welfare effects of the ethanol subsidy.

Welfare Effects

As noted by Parry and Small (2005), due to the homogeneity property of $M(F, H)$, the ratios of variables become the functions of the subsidy only, holding the fuel price constant, i.e. $\alpha_{FM} = F/M = \alpha_{FM}(s)$ and $\alpha_{HM} = H/M = \alpha_{HM}(s)$. Then from (10)

$$p_M = p_M(s),\ M = M(p_M, s),\ F = F(s) = \alpha_{FM}(s)M(p_M, s),\ \text{and}\ H = H(s) = \alpha_{HM}(s)M(p_M, s).$$

The welfare effects of an incremental change in the ethanol subsidy may then be determined by totally differentiating the indirect utility function (7) with respect to the subsidy level s. Noting that $\partial V/\partial s = \lambda[dI/ds + \alpha_R F + (d\alpha_R/ds)sF]$ (by the envelope theorem), and $\partial V/\partial G = \gamma' > 0$, $\partial V/\partial P = -\delta' < 0$, $\partial V/\partial A = \rho' > 0$, yields

$$dV/ds = \gamma' dG/ds - \delta' dP/ds + \rho' dA/ds + \lambda[dI/ds + \alpha_R F + (d\alpha_R/ds)sF]. \quad (11)$$

Next, from the definitions of G, P, and A in (5), (4), and (3), respectively,

$$dG/ds = -F\alpha_R + (dF/ds)(t - s\alpha_R) - (d\alpha_R/ds)sF, \quad (12a)$$

$$dP/ds = (dP_F/dF)[(dF/ds)(1 - \alpha_R\alpha_q) - (d\alpha_R/ds)\alpha_q F] + (dP_M/dM)(\partial M/\partial s), \quad (12b)$$

$$dA/ds = (\partial A/\partial F)[(dF/ds)(1 - \alpha_R) - (d\alpha_R/ds)F] + (\partial A/\partial H)(dH/ds). \quad (12c)$$

In determining (12), the social welfare effects, aggregate mileage, $\bar{M}$, fuel consumption, $\bar{F}$, and fuel efficiency, $\bar{H}$ are no longer constant, so their partials with respect to s are the partials of M, F, and H. Since higher levels of subsidy result in lower overall prices and thus higher consumption of fuel, $dF/ds > 0$ (cf. 10), and hence $\partial M/\partial s > 0$ and $dH/ds < 0$ (cf. 9).

Substituting (12a)–(12c) into (11) and dividing by λ results in the marginal monetary welfare effect of the ethanol subsidy s:

$$(dV/ds)/\lambda = (\gamma'/\lambda)\{-F\alpha_R + (dF/ds)(t - s\alpha_R) - (d\alpha_R/ds)sF\}$$

where the parameters β, ζ, ξ, α_{FM}, α_{FH}, and $\alpha_{F\alpha}$ are defined as

$$\beta = \frac{(\partial M/\partial s)F}{(dF/ds)M} = \frac{\epsilon_{Ms}}{\epsilon_{Fs}} > 0,$$

$$\zeta = \frac{(dH/ds)F}{(dF/ds)H} = \frac{\epsilon_{Hs}}{\epsilon_{Fs}} < 0,$$

$$\xi = \frac{(d\alpha_R/ds)F}{(dF/ds)\alpha_R} = \frac{\epsilon_{\alpha s}}{\epsilon_{Fs}} > 0,$$

$$\alpha_{FM} = F/M, \;\; \alpha_{FH} = F/H, \;\; \alpha_{F\alpha} = F/\alpha_R,$$

and ϵ_{Ms}, ϵ_{Fs}, ϵ_{Hs}, and $\epsilon_{\alpha s}$ denote the elasticities of mileage, fuel, fuel efficiency, and renewable fuel share with respect to the subsidy, respectively.

MEB is composed of the direct benefits of fuel use, $-E^{PFF} + E^{AF}$, and indirect net external marginal benefits from a per unit change in fuel consumption. The direct marginal benefits are the effects of fuel use on greenhouse gas emission $-E^{PFF}$ and fuel security E^{AF}. The indirect marginal benefits are changes in air quality, $E^{PM}\beta/\alpha_{FM}$, fuel efficiency, $E^{AH}\zeta/\alpha_{FH}$, and renewable fuel share, $(E^{PF\alpha} - E^{A\alpha})\xi/\alpha_{F\alpha}$, per unit change in fuel consumption.

An increase in the subsidy will stimulate additional fuel consumption $(dF/ds > 0)$, which, in turn, will add to the greenhouse gas effect $(-E^{PFF} < 0)$ and decrease fuel security $(E^{AF} < 0)$ resulting in lower *MEB*. The subsidy will also provide a positive incentive to increase miles traveled $(\partial M/\partial s > 0)$ thus reducing air quality $(-E^{PM}\beta/\alpha_{FM} < 0)$, creating a disincentive to invest in fuel efficiency $(E^{AH}\zeta/\alpha_{FH} < 0)$, and again negatively affecting *MEB*.

In contrast, *MEB* can be positively augmented if the subsidy increases the share of renewable fuel share in the total fuel consumption. From (14) an increase in renewable fuel share will retard greenhouse gases emission and enhance fuel security, $(E^{PF\alpha} - E^{A\alpha})\xi/\alpha_{F\alpha} > 0$, if

an incremental annual addition to GDP of approximately $0.8 billion from ethanol plants. This includes using a 2.77 multiplier for food manufacturing, but does not consider the impact on corn production. With an increase in corn production and price enhancement, the personal income, wages, and salaries component of GDP is estimated to rise by $6.0 billion. Considering a regional multiplier used by the Department of Commerce, GDP would be $10.5 billion lower if ethanol demand and production were zero. For analysis a benchmark of $7.5 billion in income is used with a range of zero to $10.0 billion. With the benchmark level of income and given the production of ethanol in 1997 was 1.3 billion gallons, this gives an estimate of the increase in income, dI/ds, of $5.77 per gallon of ethanol. The amount of ethanol produced in 2004 was 3.4 billion gallons (Renewable Fuel Association, 2005a), and the level of disposable personal income for the first quarter of 2004 was 8.5 trillion (US. Department of Commerce, 2005). Combining these estimates yields $\epsilon_{Ie} = 2.308\times10^{-3}$ and $\epsilon_{Is} = 1.869\times10^{-3}$ using the estimate of ϵ_{es} obtained earlier.

In estimating the contribution of highway capital to productivity, Nadiri and Mamuneas (1998) determine the current net social rate of return on highway expenditures to be 10% but in the 1950s and 1960s it was as high as 35%. With these estimates, the net marginal welfare effect from highway expenditure, γ'/λ, is set at 1.10 with a range of 1.00 to 1.35.

As noted by Parry and Small (2005), current estimates of greenhouse gases cost, $(\delta'/\lambda)(dP_F/dF)$, are very speculative due to unknown long-run consequences, the limited science of atmospheric dynamics, and possible technology advancements. In reviewing the literature on these cost estimates, they suggest a wide range of costs from $0.02 to $0.24 per gallon with a central value of $0.06. Using these estimates results in

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Table 1. Parameter Values

Parameter	Benchmark Value	Range
Proportion of Renewable Fuel, α_R	0.02	0.02 to 0.10
Proportion of Greenhouse Gases, α_q	0.2	0.2 to 1
Excise Tax, t (dollars/gallon)	0.184	
Ethanol Subsidy, s (dollars/gallon)	0.51	
Fuel, F (gallons/vehicle)	550	
Fuel Efficiency, $1/\alpha_{FM}$ (miles/gallon)	22	15 to 30
Elasticities		
Gasoline price, ϵ_{Fs}	0.55	0.3 to 0.9
Ethanol price, ϵ_{es}	0.81	0.37 to 2.82
Income Response to Subsidy, ϵ_{Is}	1.87×10^{-3}	0 to 8.68×10^{-3}
Mileage/Fuel, β	0.4	0.2 to 0.6
Fuel Efficiency/Fuel, ζ	−0.18	−0.7 to −0.09
Renewable Fuel Share /Fuel, ξ	0.473	−0.59 to 8.40
Government Welfare Effect, γ'/λ	1.10	1 to 1.35
Externality Effects		
Fuel Consumption		
Greenhouse Gases, E^{PFF} (dollars/gallon)	0.059	0.018 to 0.239
Fuel security, E^{AF} (dollars/gallon)	−0.169	−0.202 to −0.126
Air quality, E^{PM} (dollars/mile)	0.02	0.004 to 0.1
Engine efficiency, E^{AH}	0.303	0.250 to 0.361
Renewable Fuel Proportion		
Greenhouse Gases, $E^{PF\alpha}$ (dollars)	6.60	2.20 to 132.00
Fuel security, $E^{A\alpha}$ (dollars)	− 95.20	−114.0 to −78.0
Ratios		
Fuel/Engine Efficiency, α_{FH}	4.870	
Fuel/Proportion of Renewable, $\alpha_{F\alpha}$	27,500	
Fuel/Income, α_{FI}	0.0158	

Table 2. Benchmark Calculations of the Optimal Ethanol Tax Exemption (Subsidy)

Elements	Estimates		
	Components		Total
Marginal Benefits			\$0.00327
Pigovian Subsidy, $MEB\epsilon_{Fs}$		\$−0.2265	
Fuel Use			
Greenhouse Gases, $-E^{PFF}\epsilon_{Fs}$	\$−0.0387		
Fuel Security, $E^{AF}\epsilon_{Fs}$	−0.0932		
Air Quality, $-(E^{PM}\beta/\alpha_{FM})\epsilon_{Fs}$	−0.0968		
Fuel Efficiency, $(E^{AH}\zeta/\alpha_{FH})\epsilon_{Fs}$	−0.0046		
Renewable Fuel Share			
Greenhouse Gases, $(E^{PF\alpha}\xi/\alpha_{F\alpha})\epsilon_{Fs}$	6.0×10^{-5}		
Fuel Security, $-(E^{A\alpha})\xi/\alpha_{F\alpha})\epsilon_{Fs}$	0.0009		
Ramsey Subsidy, $\epsilon_{Is}/\alpha_{FI}$		0.1185	
Governmental Marginal Benefits, $(\gamma'/\lambda)t\epsilon_{Fs}$		0.1113	
Marginal Costs			
Per Dollar Change in Welfare, $[(\gamma'/\lambda)(\epsilon_{Fs}+1)-1-\epsilon_{\alpha s}+(\gamma'/\lambda)\epsilon_{\alpha s}]\alpha_R$			0.01462
Marginal Benefits/Marginal Costs			
Optimal Ethanol Subsidy, s^*			0.22345

Table 3. Monte Carlo Results for Optimal Ethanol Subsidy

Level, x (dollars/gallon)	Probability $s^* < x$
−2.00	0.42
−1.00	0.56
−0.50	0.64
−0.25	0.68
0.0	0.72
0.25	0.75
0.50	0.78
1.00	0.84
2.00	0.92