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The market and consumer welfare effects of mid-level ethanol blends in the US fuel market

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HIGHLIGHTS

- Competiveness of 20% ethanol blends replacing gasoline is examined.
- Households can reduce costs by $1000 over vehicle life with ethanol blend.
- Blended fuel could gain a 60% share in a voluntary US gasoline market.
- US ethanol supply in a voluntary market would match current mandated output.

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ABSTRACT

This study examines the prospect that a consumer-driven market could eventually replace the myriad regulations and demand quotas in the US ethanol and gasoline fuel market. Given efficient households that minimize the cost of operating automobiles, recent vehicle technology that improves blended fuel substitution, and typical market conditions of the last five years, blended fuels with 20% ethanol concentration could occupy a volume of 82.2 billion gallons in a 138.3 billion gallon gasoline market. The consumer welfare gain associated with blended fuel is $15.9 billion annually for US consumers, or about $1000 over the life of a vehicle.

The ethanol demand associated with a voluntary blended fuel market is 16.4 BGY, slightly more than the conventional component of the Renewable Fuels Standard. It is time to replace the corn RFS with a free market. But an active competition policy in the fuel marketing system may also be required. Intervention for the impending Biomass Ethanol Industry, such as a subsidy or an exemption a carbon tax, may also be in order.

1. Introduction

Global warming is a serious environmental problem, and complete international participation in a well-designed policy will be required for a solution. Ethanol's contribution to the mitigation of global warming may be limited according to some estimates, because carbon emissions are only reduced by 10–20% when ethanol fuel replaces pure gasoline fuel (Sinn, 2012, p. 98; Congressional Record, 2007, p. 121). However, ethanol assessments are typically based on fuels like E85, which has a concentration of 70% ethanol and 30% gasoline – some consider ethanol an inferior fuel due to the 25% reduction in fuel economy when E85 substitutes for gasoline (US EPA and US DOE Staff, 2015). Indeed, E85 has struggled in the US marketplace. Economic incentives for E85 adoption are limited (Consumer Reports Staff, 2011. p. 4). Further, demand has not grown-only about 12.0 million US cars and light trucks (6.8%)

Abbreviations: RFS, Renewable Fuel Standard; BGY, Billion Gallons per Year; EIA, Energy Information Agency; FFV, Flexible-Fuel Vehicle; EPA, U.S. Environmental Protection Agency; DOE, U.S. Department of Energy; FSR or $f\alpha_i$, Fuel Substitution Rate; BMEP, Break Mean Effective Pressure; E10, ten percent ethanol in gasoline blended fuel; E20, twenty percent ethanol in gasoline blended fuel; HWEET, EPA highway drive cycle; E0, zero percent ethanol in gasoline fuel; GLS, Generalized least squares; OLS, Ordinary least squares; GEEG, Gasoline Energy Equivalent Gallons; DOT, U.S. Department of Transportation; IDALS, Iowa Department of Agriculture and Land Stewardship; AMS, U.S. Dept. of Agriculture, Agricultural Marketing Service; BAR, A unit of pressure in multiples of standard atmospheric pressure; CRC, Coordinating Research Council; OPIS, Oil Price Information Service; NACS, fifteen percent ethanol in gasoline blended fuel E15, thirty percent ethanol in gasoline blended fuel E30, National Association of Convenience Stores

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are flex-fuel vehicles(FFVs) equipped for E85 (EIA Staff, 2015b, Table 46).

Mid-level blends with ethanol concentrations from 15% to 40% may be more effective at competing in the marketplace and improving the carbon balance for biofuels. Indeed, blender pumps offering 15%, 20%, 30%, or 50% ethanol concentrations of FFVs are available in the central US (Elesland, 2015). And the EPA has authorized sales of E15 (15% ethanol) for some vehicles manufactured since 2001 U.S. Environmental Protection Agency, 2015). The adoption of intermediate blends will also depend on relative fuel economy of intermediate blends and gasoline, and economic incentives.

This paper examines the consumer market for fuel with intermediate ethanol concentrations and evaluates the consumer welfare gain associated with adoption. We show that intermediate blends could effectively substitute for gasoline, occupy a substantial segment of the fuel market, and also yield a moderate welfare gain for US consumers. First, we introduce the economic model. Second, estimates of the technical fuel substitution rate for gasoline to ethanol blend are presented. Next, we report demand and welfare estimates. Finally, we review current US ethanol policy in light of mid-level blend potential, generally suggesting more market reliance and less government intervention.

2. Methodology

2.1. Consumer equilibrium, demand, and price relationships

Household models of consumer behavior distinguish between household goods, whose quantities are arguments in the utility function, and household inputs, whose quantities are arguments of the household production function. In the short run, inputs include the household's capital stock of appliances, such as clothes washers, automobiles, and housing (Bryant and Zick, 2006, p. 133). Then the household spends time and money operating its capital stock in the production of household goods, in this case transportation services and housing services. The takeaway is that transport services and housing services are the inputs in the consumers' utility function. In contrast, the automobile capital stock and the fuel used to maintain and operate the automobile are inputs to the household production function. Transport services and housing services are also outputs of the household production function.

We consider a simplified case of two substitute operation-input fuels for an appliance. That is, a blended fuel with ethanol concentration, α, substitutes for straight gasoline, which is indicated by the subscript g. The competiveness of blended fuel can be determined in this fashion. Also, a range of blended fuel concentrations is possible under this approach.[1]

The equilibrium requires that the input price ratio equals the technical rate of substitution between the two operation-inputs (Appendix A). The same equilibrium condition holds for a constant-output firm minimizing the cost of inputs (Perloff, 2011, p. 221). For the case of the automobile where a blended fuel with ethanol concentration, α, and retail price $P\alpha^r$ (in \$/gal α) substitutes for gasoline with retail price Pg^r (in \$/gal g), equilibrium requires that

$$-\frac{\Delta Q_{gi}}{\Delta Q_{\alpha i}} = \frac{P_\alpha^r}{P_g^r}, \tag{1}$$

where $\Delta Q_{gi}/\Delta Q_{\alpha i}$ is the technical substitution rate of gasoline for blended fuel (in gal g/gal α). In words, the equilibrium condition defines the cost minimizing combination of fuels for a given level of transportation service output.

Previous empirical studies of household models are incomplete for our purposes. Transportation service expenditures were measured as the rental rate for transport capital plus purchased transport services (taxis and subways) plus fuel for appliances and vehicles (Huffman, 2011, p. 469). But the input allocation of time and money associated with alternative transport methods and fuels was not included. So consider the short run-a household's transport technology (automobile), housing stock and location, and employment location are all given. Then the allocation of purchased (public) and owned (automobile) transport services is determined by relative money, time, and congestion costs.

Thus, our short-run analysis of fuel substitution technology and costs can start with a given distance traveled using an automobile. This does not mean that miles traveled is fixed in the intermediate or long run – consumer preferences could indicate another consumption and household production level for transportation services. Then the allocation of inputs to public and private transport services would change, and miles driven would change.

In the short run with a given vehicle, household i maintains a given distance traveled, M, using gas (Q_{gi}), and blended fuel ($Q_{\alpha i}$) purchases: $M = e_\alpha Q_{\alpha i} + e_g Q_{gi}$, where e_j is fuel economy with fuel type j. The cost of maintaining the given level of transport services is $C = P_\alpha^r Q_{\alpha i} + P_g^r Q_{gi}$. Fig. 1 shows the technically based fuel-substitution constraint and a set of iso-cost curves. The fuel-substitution constraint is , $Q_{gi} = M/e_g - f_{\alpha i} Q_{\alpha i}$, where $f\alpha_i$ is the technical substitution rate of gasoline for blended fuel (in gal g/gal α). Each iso-cost curve, $Q_g = (C/P_g^r) - (P_\alpha^r/P_g^r)\, Q_\alpha$, is defined by a given level of cost, C. Household i chooses the minimum-cost solution with all blended fuel in Fig. 1, because the slope of the iso-cost line, $(P_\alpha^r/\ P_g^r)$, is less than the slope of the fuel-substitution constraint, $f_{\alpha i}$.

The consumer is indifferent between inputs when the ethanol blend and blend-equivalent gasoline price are equal because variable travel costs are the same with either fuel:

$$P\alpha^r = Pg^r * f\alpha_i. \tag{2}$$

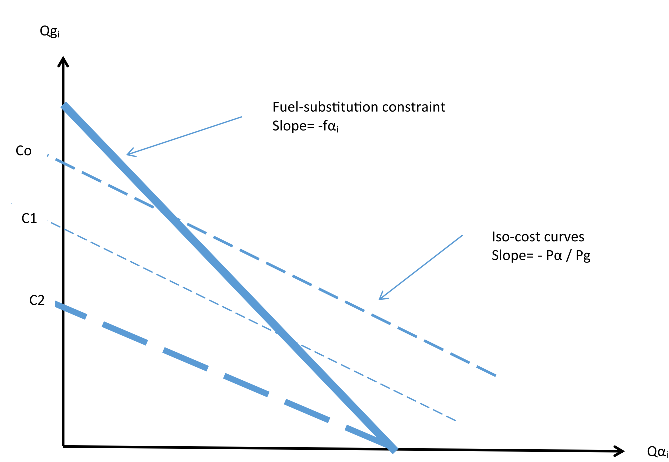

Fig. 1. Household fuel choice in short run.

[1] Most gasoline stations actually offer about six products, and restaurant menus have about 50 items. The replacement of retail products is an interesting economic problem concerning new customer attraction versus existing customers' losses and substitutions. Such an analysis would go beyond our more modest concern with the competitiveness of blended products.