

The Pricing of Gasoline Grades and the Third Law of Demand

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Abstract:

Alchian and Allen's "third law of demand" states that as a fixed cost increases by the same amount for low- and high-quality goods, the ratio of the prices of high- to low-quality goods will fall and the quantity demanded of high quality goods relative to low quality goods will increase. We examine the more general hypothesis by estimating the ratio of the quantities of sales of premium to regular grade gasoline using the ratio of premium to regular prices, controlling for supply and demand factors. We find moderate evidence for the more general hypothesis.

JEL Codes: D120 - Consumer Economics: Empirical Analysis

Keywords: *Third Law of Demand, Price Ratios, Gasoline Grades*

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1. Introduction

Alchian and Allen's (1967, pp. 62-64) famous "third law of demand" suggested that a cost change that adds the same amount to the price of both low- and high-quality goods will lower the price of the higher quality (and higher price) good relative to the lower quality good. A decrease in the price ratio increases the quantity demanded of the higher quality good relative to that of the lower quality good. Of course, perverse income effects could wipe out any substitution effects, leaving the total effect ambiguous; but we will present evidence that the income effect in the relative demand for premium is likely weak.

Earlier studies of Alchian and Allen's "third law" of demand have depended upon adding a fixed per unit shipping cost to both high-quality and low-quality substitute products. The results have produced some confusion. Gould and Segall (1969) show that Alchian and Allen's theorem only holds in a two-good world, and may not hold in a world of more than two goods. Borcharding and Silberberg (1978) show that if two goods are close substitutes, the Alchian and Allen result still holds. Some ambiguities arose over the interpretation of "fixed charge." Cowen and Tabarrok (1995) pointed out that the "fixed charge" must be applied on a per unit basis. Consequently, it mattered whether the goods were shipped to the consumers or the consumers shipped to the goods.

Other articles have used the "third law" to examine the effects of quantity-based excise taxes upon the quality consumed (James and Alston, 2002). Barzel (1976) applied the "third law" to the per unit excise taxation of cigarettes, gasoline and alcoholic beverages. In the case of cigarettes, he found that such taxes could be more than fully passed forward to consumers because a tax increase lowered the ratio of prices of high-quality to low-quality cigarettes, so that

the higher quality and more expensive cigarettes would be substituted for the cheaper smokes. With regard to gasoline and alcoholic beverages, Barzel found nothing of significance.

Razzolini, Shughart and Tollison (2003) have argued that the “third law” could not be properly tested without considering the supply side. They argued that adding a fixed per unit cost (i.e. transportation or taxes) to goods will affect the relative prices of high and low quality goods depending upon whether or not the different qualities are produced in competitive or monopoly markets and also upon the nature of long-run cost for each of the qualities (increasing, decreasing or constant cost industries). While it is certainly true that these supply considerations affect the relative prices of the two qualities, their interpretation of the “third law” recasts it from a demand theorem to a hypothesis about markets.

We also believe that supply conditions should be taken into account, but only as controls. In this paper, we examine the basic premise of the “third law” by analyzing the effect of relative prices of premium to regular grades of gasoline upon the relative consumption of the grades after controlling for other demand and supply influences. As the prices of both grades increase by the same amount, the relative price of premium falls. To non-economists, focused only upon the income effect, higher prices would induce people to switch towards the cheaper grades. On the other hand, the “third law” (or substitution effect) suggests that people would switch towards the higher quality premium grades. Our method of testing for the “third law” also avoids the pitfalls of including transportation cost mentioned above. We put the “third law” to the test, not by considering some common incremental change to prices (as in Nesbit, 2005), but by looking at the more general case of changes in price ratios of high- and low-quality goods and the effect of such changes on consumption ratios of high- to low-quality goods.

2. Basic Theory

Gasoline is one item out of many that people buy. Of course, in the short run, people are stuck living a certain distance from work, schools, shopping areas and friends, and they can do little to change those distances. They are also stuck with their current means of transportation and will have difficulty switching between alternative fuels. To some degree, a household may switch between alternative grades of gasoline, and it can make these substitutions more easily with certain vehicles than with others and more easily if it owns more than one vehicle.

The choice between gasoline (in general) and all other goods involves only a little substitutability, as we observe long-run estimates of price elasticity of demand around -0.86 and short-run estimates around -0.26 (Dahl and Sterner 1991, pp. 210).

While gasoline and all other goods are not close substitutes, one grade of gasoline should be a relatively close substitute for another grade, if people are at least able to substitute gasoline grades across the vehicles they drive. Substitution across grades is more likely to occur when there is a change in price ratios across grades, as is the case when the price spread between two grades of gasoline stays the same, yet the prices of both rise, cutting the ratio of high- to low-priced grades. With such price ratio changes, the ratio of purchases of high- to low-priced grades should increase.

3. Empirical tests

3.1 Data

The dependent variable, *prgas*, is the ratio of the number of gallons of premium gasoline sold to the number of gallons of regular gasoline sold in a given month and in a given state in the United States. The first difference of this variable is *prgasdiff*.

The current price variable is *prprice*, the ratio of the price of a gallon of premium gasoline to the price of a gallon of regular gasoline in a given month and state. The prices include local, state and federal fuel taxes. An *n*-month lag of a variable is denoted with the prefix *Ln*. For example, the one-month lag of the dependent variable is *L1.prgas*. The differenced variable is *prpdiff*.

Data on sales and prices excluding taxes come from the Web page of the U.S. Energy Information Administration (http://tonto.eia.doe.gov/STEO_Query/app/papage.htm). Data on state fuel taxes were collected from the *Highway Statistics* (<http://www.fhwa.dot.gov/policy/ohpi/hss/hsspubs.htm>) and *Monthly Motor Fuel Reported by States* (<http://www.fhwa.dot.gov/ohim/mmfr/mmfrpage.htm>) series of the Federal Highway Administration; corrections were provided by e-mail or by phone by the transportation or finance departments of the state governments. The state governments also provided data on local fuel taxes, which we weighted by population when adding them to fuel prices. The state taxes include sales taxes, environmental taxes (such as fees for a Leaking Underground Storage Tank fund), and inspection fees based on gallons used. The local and federal taxes are excise taxes that are quantity-based or (for many local taxes) sales-based.

A control for cost factors is *Crude*, which measures the real acquisition cost of crude oil per barrel to the U.S. refineries each month, based on a composite of foreign and imported oil, and deflated by the producer price index for oil refineries (in 1982 dollars). The cost data were collected from various issues of the *Monthly energy review* of the U.S. Energy Information Administration (<http://tonto.eia.doe.gov/FTPROOT/monthlyhistory.htm>). The deflator is from the U.S. Bureau of Labor Statistics (<http://data.bls.gov/cgi-bin/surveymost>). The differenced variable is *crudediff*.

Income represents disposable personal income per capita in a given month and state, expressed in the number of gallons of regular gasoline that the income could purchase. It was constructed from quarterly income and tax data as well as from annual population data, and it was deflated by the monthly price of regular gasoline from the U.S. Energy Information Administration.^a Population data were from the Census Bureau's *Statistical abstract of the United States* (<http://www.census.gov/prod/www/statistical-abstract-04.html>). Income data were from *State quarterly personal income* of the Bureau of Economic Analysis (<http://www.bea.gov/region/sqpi/>). Tax data were from the Census Bureau's *Quarterly summary of state and local tax revenues* (<http://www.census.gov/govs/www/qtax.html>) and from its *Federal tax collections by state*, based on the *Internal Revenue Service data book* for various years (<http://www.irs.gov/taxstats/article/0,,id=102174,00.html>). Differenced income is *incomediff*.

Time series of 75 months – from January 1998 through March 2004 – were collected for each of the 50 states.

Summary statistics are presented in Table 1. The price of premium gasoline exceeds the price of regular gasoline by only 13 percent, but Americans buy only a sixth as much of premium as of regular. The relative price of premium varies from 1.3 (Georgia, February 1999) to 1 (North Dakota, October 2001). Relative purchases of premium vary from .51 (New Jersey, February 1999) to .035 (North Dakota, March 2000). Annual per capita disposable income

^a This method of estimating monthly income has the advantage of using all available information; but, because we lack direct data for monthly income, we have likely introduced a measurement error. Let our measure of monthly income be *Income*; and let actual monthly income be *Income**. Then it is likely that $Income = Income^* + e$, where e is a measurement error. Because income tends to rise over time, our measure of income likely underestimates actual income. This implies that the measurement error has a negative mean and is correlated negatively with actual income. OLS estimators are thus biased and inconsistent. However, as we see it, the main problem with the measurement error is that it biases the *Income* coefficient toward zero; this coefficient is not the main concern of our analysis.

averages 16,283 gallons of regular gasoline, ranging from 9,928 gallons in Georgia (January 2001) to 29,600 gallons in Florida (February 1999).

[Table 1 here]

3.2 Empirical Results

We estimated the model by three-stage least squares in order to disentangle the effects of supply and demand. The model is in first differences, rather than levels, in part because our variables for the relative consumption of premium gasoline and for its relative price, *prgas* and *prprice*, may follow random walks and thus induce a spurious correlation^b; and in part because we wished to remove the effects of unobservable variables that were fixed over time and that may correlate with explanatory variables, since this could render the coefficient estimators biased and inconsistent. We calculated robust standard errors (White, 1980; Wooldridge, 2003) because tests indicated heteroskedasticity in the 3SLS equations. Serial correlation is also present, but it is not significant in magnitude.^c

We first discuss the demand model. Generally, the evidence for the third law of demand is moderate. In differences, the relative sales of premium gasoline respond negatively and highly significantly to an increase in the relative price of premium gasoline (*prprice*) with a two-month lag; the negative coefficient on the three-month lag is significant at the 10% level for a one-tailed test but not at the 5% level. (The current relative price, and its one-month lag, were dropped from the model for statistical insignificance.) The price elasticity of demand for premium gasoline, relative to regular gasoline, is $-.097$ with a two-month lag and $-.05$ with a three-month lag.^d

^b A regression of each variable on its lag produces a coefficient over .93.

^c A regression of the residual of each equation on its lag turned up a coefficient of about $-.1$.

^d Elasticities were estimated from a 3SLS model of the first differences of natural logs.

The relative demand for premium may be falling over time. Large vehicles today may be more likely to use regular gasoline than they were before 1998. Figures 1 and 2 suggest a fall in the relative demand for premium gasoline: Relative sales of premium gasoline have fallen along with its relative price.

The fall in the relative price of premium gasoline is not due to the reduction, through inflation, in the effective tax rate on gasoline, which is indicated by Figure 3. The bulk of the gasoline tax consists of per-gallon taxes that are the same for premium and regular gasoline (as opposed to ad valorem taxes). Since 1998, the per-gallon taxes, relative to the untaxed price of gasoline, have dropped fairly steadily (Figure 3): While few states have lowered their nominal taxes, few have raised them as rapidly as the rise in gasoline prices. The relative reduction in the effective tax rate has been greater for regular gasoline than for premium gasoline, since the price of regular has risen relative to the price of premium. Instead, the fall in the relative price of premium gasoline seems due either to the fall in relative demand for premium or to the rise in the cost of crude oil. If the cost of crude is about the same to manufacture a gallon of regular gasoline as for a gallon of premium gasoline, then a rise in oil costs will raise the relative price of regular gas – that is, lower the relative price of premium gas.

[Figure 1 here]

[Figure 2 here]

[Figure 3 here]

The coefficient on per capita personal disposable income, *Incomediff*, expressed in gallons of regular gasoline, is positive but not significant. The income elasticity of relative demand for premium gasoline is .668.

We turn now to the supply model. The coefficients on price and its one-month lag are positive and highly significant: Measured in differences, the relative supply of premium gasoline rises with the relative price. Producers are quite sensitive to price: The price elasticity of relative supply for premium gasoline is 7.85 in the current month and .615 with a one-month lag. The coefficient on *Crude* is negative but insignificant. The elasticity of relative supply of premium gasoline with respect to crude costs is small, as expected: -.03.

The results of the basic model are shown in Table 2.^e The constants, *Cons*, indicate that the relative quantity of premium gasoline may have fallen over time, holding prices, income and crude costs constant.

[Table 2 here]

Since 3SLS estimates coefficients by using instrumental variables, it may introduce noise. For comparison, we provide in Table 3 an OLS model of the relative demand for premium gasoline.^f Lags of the dependent variable are highly significant, and the price coefficients are positive. We suspect that this model reflects supply factors.

[Table 3 here]

^e One can show that the linear demand function used here derives from an indirect money metric utility function that is quasi-linear and quasi-exponential, in which “income” denotes the budget allocation to purchases of premium and regular gasoline. We use personal disposable income per capita as a proxy for the budget allocation.

Conclusions and discussion

Overall, we find moderate support for the third law of demand in the market for premium gasoline, in a simultaneous-equations model of demand and supply. We thus avoid conflating demand and supply factors.

We cannot claim to have isolated the substitution effect, since in theory the income effect may also increase the relative quantity demanded of premium gasoline. For example, if premium and regular gasoline are both normal goods, and the absolute price of premium gasoline drops, then the consumer may spend relatively more of the resulting increase in real income on premium than on regular gasoline. But we believe that the income effect in the relative demand for premium gasoline is likely weak: The estimated income elasticity of relative demand is .66, and the income coefficient in the demand function is statistically insignificant. Also, the usual \$0.20 per gallon price spread between regular and premium is unlikely to have much effect on most Americans' buying power. We believe that we are observing primarily the substitution effect.

^f A regression of the residual upon its lag did not indicate serial correlation in this model. The dependent lags have probably controlled for much of the innate serial correlation.

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Table 1. Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
prprice	3727	1.129	.0353	1.002	1.299
prgas	3705	.176	.082	.036	.508
crude	3750	23.31	2.24	18.63	27.77
income	3750	16283.0	2896.0	9297.7	29600.2
prgdifff	3644	-.0012	.0129	-.0974	.294
prpdifff	3655	-.00029	.0218	-.0675	1.135
incomedif	3700	-34.8	972.8	-4065.4	4937.8
crudedifff	3700	.044	1.26	-3.03	3.45

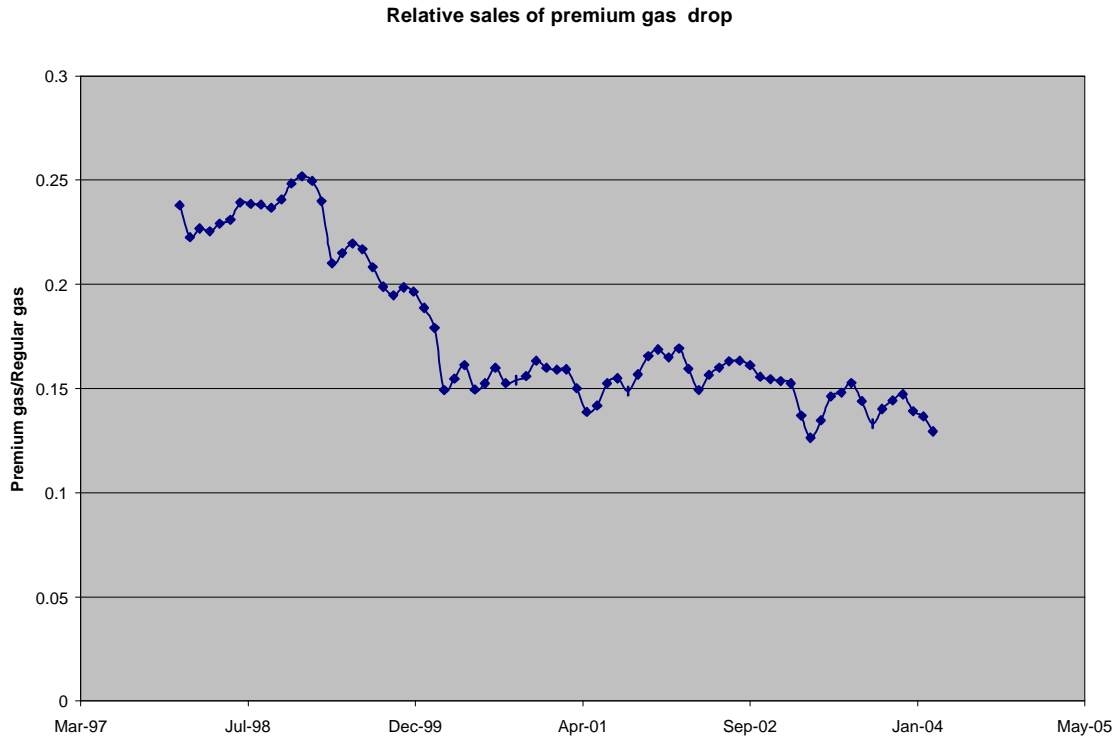


Figure 1

Relative price of premium gas falls

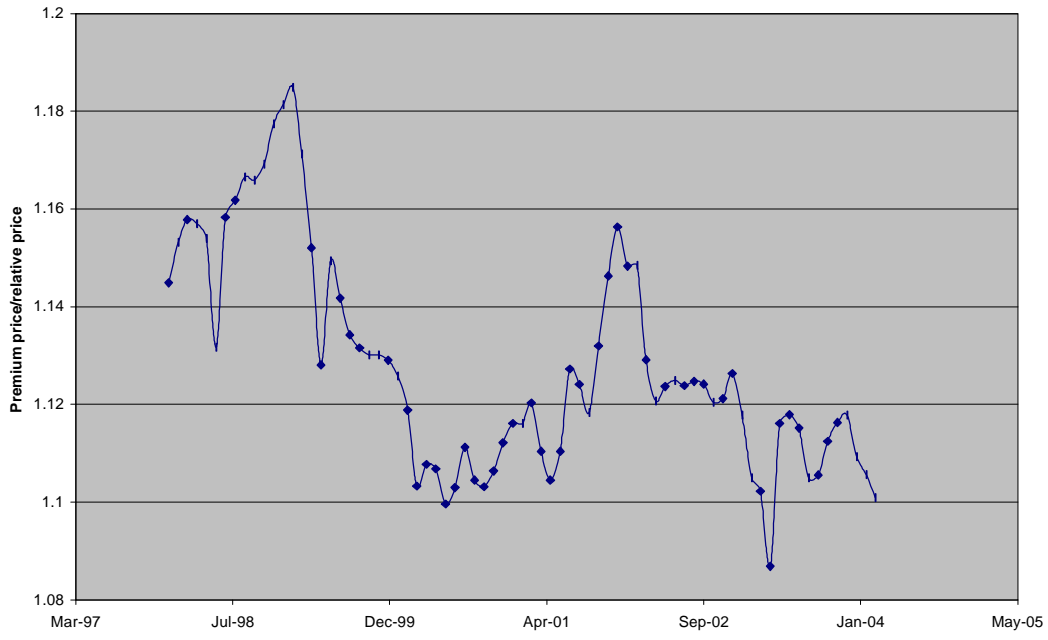


Figure 2

Gas tax rates fall

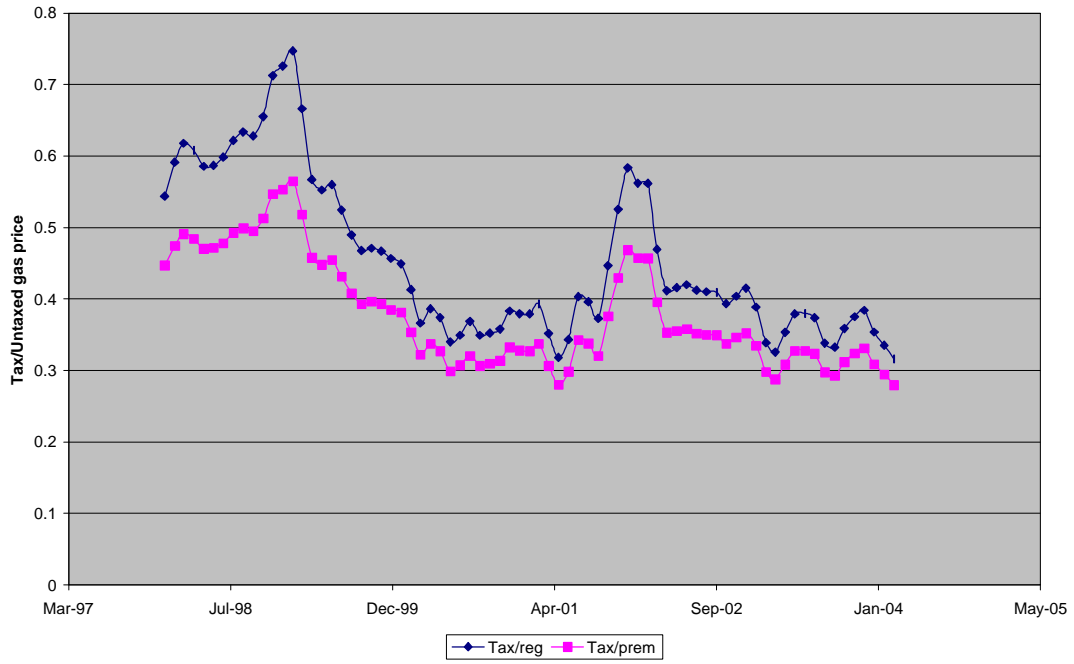


Figure 3

Table 2. Estimates of the 3SLS model

Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
qDemand	3409	3	.009826	0.2824	1341.000	0.0000
qSupply	3409	3	.011652	-0.0091	1028.583	0.0000

	Coef.	Std. Err.	Rob. Std. Err.
<i>qDemand</i>			
prpdiff			
L2	-.1049	.0111	.0101
L3	-.0151	.0053	.0107
incomedf	5.99e-06	1.67e-07	.0114
_cons	-.0011	.0002	
<i>qSupply</i>			
prpdiff			
--	.9641	.0317	.0250
L1	.0845	.0126	.0141
crudedff	-.0003	.0001	.0109
_cons	-.0005	.0002	

Table 3. Estimates of an OLS model

Number of obs = 3325
 F(9, 3315) = 167.61
 Prob > F = 0.0000
 R-squared = 0.3682
 Root MSE = .00909

	Coef.	Robust Std. Err.	t	P> t	[95% Conf. Interval]	
prgdiff						
L1	-.1161	.025	-4.65	0.000	-.165	-.0671
L2	-.1215	.021	-5.76	0.000	-.1629	-.0801
L3	-.0717	.0189	-3.80	0.000	-.1087	-.0348
L4	-.0482	.0186	-2.59	0.010	-.0847	-.0117
prpdiff						
--	.2657	.0237	11.22	0.000	.2192	.3121
L1	.1661	.0235	7.08	0.000	.1201	.2121
L2	.0005	.0198	0.03	0.979	-.0383	.0394
L3	.0206	.0167	1.24	0.217	-.0121	.0534
Income	4.12e-06	2.34e-07	17.61	0.000	3.66e-06	4.58e-06
Constant	-.0012308	.000165	-7.46	0.000	-.0016	-.0009