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THE 55 m.p.h SPEED LIMIT AND GASOLINE CONSUMPTION*

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Within the context of driver trip production this paper examines the effects of the 55 m.p.h. speed limit on gasoline consumption in private cars. The focus is on the noticeable short-run reductions in speed and gasoline consumption immediately following the imposition of the national speed limit. Analysis of highway speeds indicates that indeed speeds were substantially lower than otherwise expected after the energy conservation measure took effect. When technical information on the speed–gasoline consumption relationship is considered, however, the effect on gasoline consumption is found to be surprisingly small. This finding is corroborated by direct analysis of gasoline demand.

1. Introduction

1.1. Background

Against a background of several decades of growth in energy consumption, the sudden widespread concern for energy conservation during the energy crunch of 1973 and 1974 was strikingly noticeable. One program, the Emergency Highway Energy Conservation Act of January 1974, which emerged as a temporary measure to save motor fuel, set a national maximum speed limit of 55 m.p.h. Some states voluntarily reduced speed limits as early as November 1973 and all states officially complied by April 1974. The national limit remains today as a permanent policy incorporated into Federal-Aid Highway Amendments.

The energy rationale for the 55 m.p.h. speed limit is clear: (a) gasoline consumption depends directly on the rate of consumption per mile, (b) the rate of consumption per mile depends directly on highway speed, (c) if highway speed is reduced, then the rate of consumption and total consumption will be reduced. The U.S. Federal Highway Administration [U.S. FHWA (1975, pp. 72 and 85)] reports that observed average speeds on main rural highways decreased 9.4 percent from 1972 and 1973 to 1974 and attributes all of the slowdown to the 55 m.p.h. speed limit. Other reports

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[U.S. GAO (1977, pp. 8–9)] estimate that lower speeds due to the national speed limit reduced fuel consumption by 1 to 3 percent from pre-limit consumption.

The purpose of this paper is to systematically analyze the short-run effect of the 55 m.p.h. speed limit on one component of energy use, the private use of gasoline for highway travel. Recent public reevaluation by several states and the Reagan Administration suggests that closer examination of the merits of the national speed limit including its initial energy benefits is warranted. The speed limit issue is comprehensive and includes benefits such as increased safety and the choice of the socially optimal speed limit, e.g., see Clotfelter and Hahn (1978), and Jondrow, Bowes and Levy (1983), but such considerations are beyond the scope of this paper.

1.2. Approach

With the energy crunch came extraordinary adjustments in the amount of travel, mode of travel and the manner in which particular modes were used. A framework for analyzing these adjustments is a model of driver behavior in which the individual maximizes utility consumption of travel and a vector of other goods subject to limited endowments of money, time and health, and a vector of prices. Accordingly a person will divide consumption between travel and other goods so that the marginal utility per dollar spent on each is equal. When the price of travel increases the quantity demanded of travel will decrease. Moreover, a traveller will choose cycle, car, bus, train, plane or whatever is the least costly mode of transportation by comparing the minimum cost at which travel on each mode can be produced. Costs considered are: money costs, time costs, safety costs, and comfort costs. For a particular mode, such as private automobile, an individual seeks to minimize costs by using inputs in such a way that the value of marginal product is the same for each. The individual wants to obtain the same contribution to trip production for each of the car characteristics (such as average mile per gallon, mile per tune up, size, weight, and accessories) as from the speed of travel and effort expended while driving. Within the framework sketched here optimal short-run driver response to an increase in the price of gasoline is to reduce speed and increase driving effort saving on relatively more expensive gasoline and using more of relatively cheaper time. In fig. 1 this change is shown as an increase from T_1 to T_2 and a decrease from G_1 to G_2. Given more time to respond, drivers will choose cars which give better gas mileage and further change the input mix, see Dahl (1979) and Fishelson (1982). While a more complete analysis would consider all three types of adjustment, this paper will concentrate on short-run adjustment within automobile highway travel.

This study of the 55 m.p.h. speed limit differs from the government reports

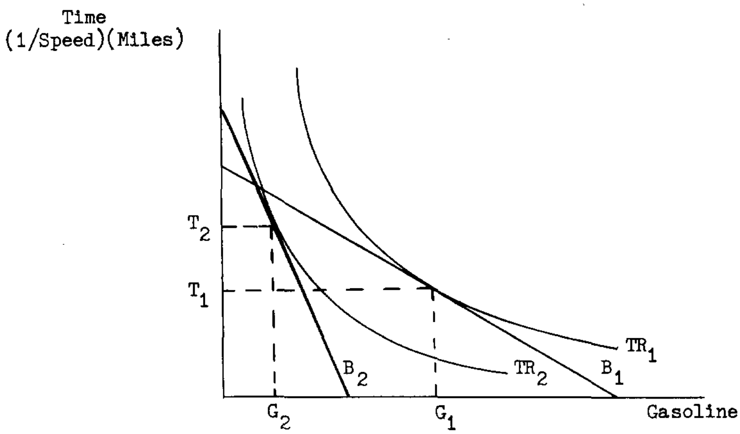

Fig. 1. Driver use of inputs under different circumstances.

cited above by explicitly considering driver response to factors other than the speed limit. Reductions in highway speed and gasoline consumption are decomposed into that part attributable to the national speed limit and that part attributable to other factors particularly the price of gasoline. In section 2 highway speeds are analyzed within the context of driver minimization of trip cost. The effects of the 55 m.p.h. speed limit on average highway speed and a hybrid variable measuring fast driving are estimated. In section 3 the well-known engineering relationship between gasoline consumption per mile and highway speed, and data on driving patterns are used to estimate the energy savings implied by the estimated reduction in highway speed. Direct analysis of gasoline consumption is carried out in section 4 as an alternative method of estimating the effect of the 55 m.p.h. speed limit on gasoline consumption. A summary and conclusions are contained in section 5.

2. Changes in highway speeds

2.1. Before the 55 m.p.h. speed limit

The FHWA reports speeds on main rural highways and interstates across the nation where drivers are observed under ideal driving conditions, i.e., flat, dry, sunlit roads. Using the framework just outlined and expanding Peltzman's (1975) model average, passenger car, highway speeds are analyzed for the period 1945–1972. The specification is

$$MPHA_t = \beta_1 + \beta_2 PG_t + \beta_3 Y_t + \beta_4 HD_t + \beta_5 NF_t + \beta_6 IM_t + \beta_7 IS_t + \beta_8 AG_t + e_t, \quad (1)$$

where *MPHA* is observed average speed of autos, *PG* is the real retail price of regular gas, *Y* is real per capita personal income, *HD* is rural highway traffic density, *NF* is real enforcement expenditures per highway mile, *IM* is the percentage of the stock of autos which is either imports or subcompacts, *IS* is the percentage of existing paved rural highway miles which are divided highway miles, and *AG* is the average age of autos in use. Data sources and means of the variables can be found in table 1. The regression results are given in table 2 where the absolute *t* value and the absolute value of the elasticity evaluated at the means are given below each coefficient. All regressions shown, including those for *ASE* to which we will return later, are OLS results. All DurbinWatson values imply the tests are inconclusive or that there is no first order serial correlation.

For the speed (*MPHA*) regression, column (1), the elasticity of speed with respect to the price of gas, -0.23, is the largest of any of explanatory values.[1] The coefficient of income is positive indicating that at the margin saving time is more important than the increased risk of injury, but the coefficient is insignificant at any reasonable level. The weak effect of income is due to the increased safety costs of an accident for drivers with higher incomes which partially offsets the incentive to save more valuable time by driving faster. The weak effect of income is due to correlation as shown by the size and significance of *Y* in the equation without *AG*, column (2). Interstates and divided highways increase highway speeds because they are built for high speed travel and are inherently safer; *IS* is positive, has an elasticity of $+0.11$ which in size is second only to that for the price of gas. Since 1945 technical change and design innovation such as larger engines could well be contributing factors to speed. To the extent that these are correlated with the growth of interstate highways some of the effect of interstates on speed may well be due to design factors as engine size. Imports and subcompacts are known to have engines which are smaller than average and to some extent the slowing influence of *IM* on average speed may well be due to this effect.

2.2. The national speed limit and average highway speed

The speed regression [column (1)] permits investigation of the effect of the 55 m.p.h. speed limit on rural highway speeds. One test is to check for a shift in the speed relationship in 1974–1975, the years immediately after the

[1]Using a similar data set Peltzman (1975) analyzes U.S. average highway speed from 1947–65 and finds the elasticities of speed with respect to the price of gasoline and income to be -0.2 and 0.1, respectively. The elasticities reported in column 2 (Peltzman's specification) of table 2 of this paper are -0.17 and 0.12, respectively.

Table 1
Variables for the estimation of highway speed, 1945–75.

		Mean value			
Variable	Definition	1945–72	1945–75	Units	Source[a]
PG	Real retail price of regular gas	34.29	34.20	1967 cents per gallon	1
Y	Real personal income	2615	2743	1967 dollars per person	2
HD	Highway traffic density	1.195	1.213	Million vehicle miles per highway mile	2, 3
NF	Real enforcement expenditures	2766	2956	1967 dollars per highway mile	2, 3
IM	Imported and subcompact autos	2.190	2.992	Percent of stock which is imported or subcompact	4, 5
IS	Interstate	4.676	5.286	Percent of rural highway miles which are divided	2, 3
AG	Average age of autos	6.439	6.377	Years	5
D55	55 limit dummy	—	0.065	1974 and 1975 = 1, all other years = 0	—
MPHA	Average speed of passenger cars	53.93	54.31	Miles per hour	2, 3
ASE	$\sum_{i=55}^{75} f_i s_i$ where f_i is the fraction of drivers observed travelling in interval i and s_i is the average speed of the interval	23.80	24.91	Drivers times miles per hour	2, 3

[a]*Sources*: 1 — *Petroleum Facts and Figures* and *Basic Petroleum Data Book*, 2 — *Historical Statistics, Colonial Times to 1970* and *U.S. Statistical Abstract 1977*, 3 — *Highway Statistics*, 4 — *Automative News*, 5 — *Motor Vehicle Facts and Figures.*

Table 2
Rural highway speed regressions, 1945–75.[a]

	MPHA				*ASE*			
	1945–72		1945–75		1945–72		1945–75	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PG	−0.3539	−0.2593	−0.3473	−0.6401	−0.0764	−0.2735	−0.0275	−1.0538
	(3.09)	(2.14)	(3.25)	(8.81)	(0.35)	(0.14)	(0.14)	(5.51)
	0.23	0.17	0.22	0.40	0.05	0.04	0.04	1.45
Y	+0.0005	+0.0026	+0.0006	+0.0001	+0.0053	+0.0063	+0.0057	+0.0075
	(0.39)	(2.35)	(0.49)	(0.00)	(2.18)	(3.47)	(3.33)	(2.70)
	0.02	0.12	0.03	0.01	0.26	0.70	0.63	0.82
HD	+5.0238	+4.1606	+5.0132	+5.0257	+10.3674	+9.9196	+9.8201	+7.9398
	(3.63)	(2.77)	(3.79)	(3.17)	(3.95)	(3.95)	(3.94)	(1.98)
	0.11	0.09	0.11	0.11	0.23	0.50	0.48	0.39
NF	−0.0004	−0.0016	−0.0004	−0.0001	−0.0002	−0.0008	−0.0009	−0.0012
	(0.69)	(5.23)	(0.82)	(0.19)	(0.17)	(1.59)	(1.68)	(1.40)
	0.02	0.08	0.02	0.01	0.01	0.10	0.10	0.14

IM	−0.4079	−0.4043	−0.3990	−0.6268	−1.0646	−1.0627	−1.1230	−2.1375
	(2.82	(2.50)	(3.30)	(5.25)	(3.88)	(3.92)	(4.80)	(7.69)
	0.02	0.02	0.02	0.03	0.04	0.10	0.14	0.26
IS	+1.2411	+1.4713	+1.2482	+1.0726	+3.0258	+3.1452	+3.2871	+3.1204
	(6.49)	(7.82)	(7.44)	(5.62)	(8.35)	(10.01)	(12.42)	(7.30)
	0.11	0.13	0.12	0.10	0.26	0.62	0.70	0.66
AG	−0.7344		−0.7094	+1.0746	−0.3809			
	(2.52)		(2.65)	(3.68)	(0.69)			
	0.09		0.08	0.13	0.05			
D55			−3.3226				−11.2877	
			(3.33)				(6.35)	
β_1	+59.6273	+49.5943	+59.1817	+72.8080	−8.6045	−13.8090	−12.5473	+24.1305
	(9.56)	(9.22)	(10.56)	(15.87)	(0.73)	(1.54)	(1.44)	(2.29)
R^2	0.993	0.990	0.993	0.990	0.995	0.995	0.995	0.987
F	379	352	397	315	585	700	675	296
SEE	0.499	0.559	0.477	0.572	0.945	0.933	0.931	1.512
DW	2.57	2.66	2.36	2.36	2.13	2.21	2.21	2.11
n	28	28	31	31	28	28	31	31
Method	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS

[a]Absolute t values are given in parentheses beneath the coefficients. Absolute values of elasticities computed at the means are given below the t values.

implementation of the speed limit for which comparable data is available.[2] Results for the variable, *D55* which is 0 from 1945–73 and 1 from 1974–75, are shown in column (3) for the 1945–75 regression. The speed limit variable is negative and significant at the 1 percent level supporting the hypothesis that the 55 m.p.h. speed limit reduced highway speed. The estimated coefficient indicates that the speed limit reduced average speed by 3.3 m.p.h. or 5.4 per cent. [It should be noted that the price of gasoline is markedly higher in the same year the limit was imposed and that since the coefficient on *PG* is halved when *D55* is included *D55* could represent the extraordinary price effect. See columns (3) and (4) of table 2. Since the calculations below are based on the coefficient of *D55* and the coefficient of *PG* when *D55* is included the results may attribute too much of the observed slowing to the speed limit.]

Another way of looking at the effectiveness of the 55 m.p.h. limit is to predict speeds for the years covered by the regulation assuming that the regulation had no effect, and then test whether or not predicted speeds differ significantly from actual speeds. The test can be explained in terms of driver trip production and is illustrated in fig. 1 where time is the reciprocal of speed (multiplied by miles). The question is whether a decrease in observed speed like that from T_1 to T_2 was due to the 55 m.p.h. limit or other factors such as an increase in the price of gasoline (B_1 to B_2) and/or a decrease in the number of miles of travel produced (TR_1 to TR_2). One answer can be obtained by using the 1974 and 1975 values of the explanatory variables in the 1945–72 equation [column (1)] to predict speeds for 1974 and 1975 and comparing the predicted with observed speeds. Table 3 shows the actual and predicted speeds for 1972 through 1975. Actual speed, *MPHA*, was 3.3 m.p.h. less than predicted speed for 1974 and 3.1 m.p.h. less than predicted speed for 1975. The difference for 1974 is significantly different from 0 at the 10 percent level, and the difference for 1975 is significant at the 2.5 percent level. This analysis of highway speeds shows that the 55 m.p.h. limit was quite effective in causing speeds to be substantially lower than they otherwise would have been. For both periods non-speed limit factors which influence driver behavior account for only 43 percent ($4.06/9.42=0.431$ and $3.73/8.77=0.425$) of the reductions in observed speeds leaving up to 57 percent of the reduction to be attributed to the national speed limit.

2.3. The national speed limit and fast driving

One would expect the 55 m.p.h. speed limit to affect fast driving more than

[2]The way in which the speed data is collected and reported unfortunately was changed in 1976 preventing analysis of more recent years. See U.S. FHWA (1975, p. 33). As a consequence, this paper focuses on the short-run response to the 55 m.p.h. speed limit. If the sample period could be extended through the second energy crunch in 1979, then the coincidence between the energy crunch and the introduction of the national speed limit could be eliminated and a better test of the effect of the speed limit could be made.

Table 3
Actual and predicted highway speeds for 1972–1975 based on U.S. average speeds from 1945–1972.

Year	Actual m.p.h.	Change from 1973 %	Predicted m.p.h.	Change from actual 1973 %	Difference m.p.h.	S_e^f	T^a
	MPHA, miles per hour						
1972	61.6	—	61.9	—	−0.3	—	—
1973	61.6	—	61.8	—	−0.2	0.74	−0.28
1974	55.8	−9.42	59.1	−4.06	−3.3	2.47	−1.34
1975	56.2	−8.77	59.3	−3.73	−3.1	1.34	−2.28
	ASE, driver-miles per hour						
1972	42.75	—	43.23	—	−0.48	—	—
1973	42.75	—	37.32	—	+5.43	1.39	+3.92
1974	30.38	−28.94	34.19	−20.02	−3.81	2.09	−1.83
1975	32.68	−23.56	34.92	−18.32	−2.24	2.20	−1.02

[a] T is the difference between actual and predicted consumption divided by the standard error of forecast, S_e^f.

average speed, *MPHA*, since some drivers were travelling less than 55 m.p.h. before the new law. Hence it makes sense to investigate the upper tail of the speed distribution of drivers. The same two tests for the effect of the 55 m.p.h. limit on speeds are made for a hybrid variable which measures fast driving, *ASE*. *ASE* is approximately a weighted average speed of drivers who exceed 55 m.p.h. Precisely, *ASE* is the percentage of drivers travelling between 55 and 60 m.p.h. times 57.5, plus the percentage of drivers travelling between 60 m.p.h. and 65 m.p.h. times 62.5 m.p.h. and so on up to the percentage of drivers travelling over 75 times 77.5 m.p.h. *ASE* is larger the larger the percentage of drivers exceeding 55 m.p.h. and the faster those exceeding 55 m.p.h. drive.

The *ASE* regressions shown in table 2 to the right of those for *MPHA* display highly significant, reasonable results similar to those for *MPHA*, average speed. The exceptions are the insignificance of *AG* and *PG* and the increased importance of income for the regression in column (5) for *ASE* compared to that in column (1) for *MPHA*. When *AG* is dropped from the regression, column (6), we find that the elasticity for income, +0.070, is even larger than that for *IS*. The coefficient of *D55* is negative and significant at the 1 percent level indicating that fast driving indeed was usually low in the years immediately after implementation of the 55 m.p.h. limit. Fast driving is more sensitive to the national speed limit in that the t value for *D55* for *ASE* is almost twice that for *MPHA* and when evaluated at the 1972 values *D55* causes a 26 percent drop in *ASE* and only a 5 percent drop in *MPHA*.

Table 3 shows the actual and predicted *ASE* for 1972 through 1975 below those values for *MPHA*. Fast driving was 11.1 percent lower than predicted in 1974 and 6.4 percent lower than predicted in 1975 with the difference for 1974 being significant at the 5 percent level. The difference for 1975 is not significantly different from 0 at any reasonable level (perhaps due to increased usage of citizens-band radios.) These results for fast driving (*ASE*) reinforce those for average speeds *MPHA* and provide strong evidence that the 55 m.p.h. speed limit did reduce highway speeds.[3]

3. Implied reductions in gasoline consumption

3.1. Accounting for consumption changes

The analysis of highway speed clearly indicates that the 55 m.p.h. speed limit reduced speeds. The analysis also shows that part of the reduction was driver response to changes in other factors such as the price of gasoline income. These non-speed limit factors account for 2.5 m.p.h. of the actual 5.8 m.p.h. decrease in *MPHA* from 1973 to 1974 (43 percent of the 9.4 percent reduction). These non-speed limit factors account for 2.3 m.p.h. of the actual 5.4 m.p.h. decrease in *MPHA* from 1973 to 1975 (43 percent of the 8.8 percent reduction). This decomposition means that reductions in gasoline consumption due to the 55m.p.h. speed limit are less than reductions implied by the entire drop in observed highway speeds.

To determine the implied reductions in gasoline consumption we view gasoline consumption as the product of miles travelled and the usage rate of gasoline per mile: $G/P=(M/P)g$ where G is gasoline consumed in private autos on streets and highways, P is population over 16 years old in the labor force, M is vehicle miles and g is the usage rate of gasoline per mile (1/miles per gallon). The change in per capita gasoline consumption can be expressed as the sum of changes in M, P and g:

$$\dot{\overline{G/P}}=\dot{M}-\dot{P}+\dot{g}, \qquad (2)$$

where the dot indicates percentage change.

Total per capita gasoline consumption is the sum of consumption on each of various types of roads, or $G/P=(\sum G_i)/P$ where, following *FHWA*

[3]A cross-section analysis of speed in states in 1972, the last full year unaffected by the 55 m.p.h. speed limit, was made with much the same variables as in the national time-series analysis. The major difference is that the estimated elasticity of *MPHA* with respect to *PG* is −0.47, which is twice the time-series estimate. Mostly due to the greater response to changes in the price of gasoline, the speeds predicted using the state-by-state equation are lower than those predicted using the time equation with people driving faster than predicted for 1974 and 1975 conditions, (but the differences between the actual and predicted speeds are not significant at any reasonable level). While this could be taken as evidence that the national speed limit had no effect, the relative size of the standard errors of forecast do not allow rejection of the hypothesis that it did have some effect.

definitions, i runs over 7 types of road. Substituting into eq. (2), $\dot{G/P} = -\dot{P} + \sum_i G_i/G(\dot{M}_i + \dot{g}_i)$. Assuming population growth (P) and vehicle miles (M) are unaffected by the national speed limit and recalling $G = Mg$, the change in gasoline consumption is[4]

$$\dot{G/P} = \sum_i (M_i g_i/G)\dot{g}_i, \tag{3}$$

where the right-hand side is the sum for various types of road of the shares of gasoline consumed on each road type and the percentage change in the gasoline usage rate on each respective road type.

Even on roadways where average speeds are high some drivers will not exceed 55 m.p.h. The 55 m.p.h. limit only affects driving on roads where the speed limit was previously greater than 55 and drivers who chose to drive faster than 55, e.g., most drivers on interstate highways. The average gasoline usage rate will depend on speeds of slow and fast drivers with the 55 m.p.h. limit affecting only the latter. Consequently, the reduction in g will be less than the reduction of g for the fast drivers. If we assume that the fraction of drivers travelling less than 55 m.p.h. on each road type is constant then substituting into eq. (3) for the effect of the 55 m.p.h. limit gives

$$\dot{G/P} = \sum_i (M_i g_i/G)(f_i \hat{g}_i/g_i)\hat{g}_i, \tag{4}$$

where f_i is the fraction of drivers exceeding 55 m.p.h. on road type i, g_i is the (average) gasoline usage rate per mile for those drivers exceeding 55 m.p.h. on road type i. In eq. (4) the first term in parentheses is the share of road type i consumption in total consumption, and the second term in parentheses is the share of fast driver's gasoline usage rate in the average gasoline usage rate on road type i.

3.2. Estimates of energy savings

Data for vehicle miles, speed, fraction of drivers exceeding certain speeds, and gasoline consumption are given by the Federal Highway Administration (1973–75) for completed rural interstate highways, rural interstate travelled ways, primary rural highways, rural secondary roads, urban interstates, primary urban highways and urban secondary roads. Data on the speed–gasoline usage rate is given by the U.S. Environmental Protection Agency (1973, p. 26) for the existing stock of autos. Using the data and the predicted reductions in speed ($MPHA$) shown in table 3 the effect of the 55 m.p.h.

[4]To the extent that vehicle miles decrease as a result of the 55 m.p.h. speed limit, the effect in reducing gasoline consumption is underestimated. However, typical specifications for estimation of vehicle miles, e.g., Dahl (1979), include the price of gas, fuel efficiency, income and the stock of autos, but not highway speed.

speed limit on gasoline consumption can be estimated. For example, if there had been complete compliance with the speed limit, gasoline consumption would have been reduced by 2.72 percent — a change compatible with the 1 percent to 3 percent reduction anticipated by policy planners.[5] In fact from 1973 to 1974 the reduction in gasoline consumption due to the reduction in the gasoline usage rate from all changes in driving is a bit smaller, 2.24 percent.[6] From eq. (4) and the speeds observed in 1974, the calculated effect of speed alone was a 1.64 percent reduction.

Based on the analysis of highway speed in section 2 the gasoline savings due to slower highway driving can be decomposed into a reduction due to the 55 m.p.h. speed limit and a reduction due to factors others than the speed limit. Some of the gasoline savings attributable to slower highway driving would have occurred in the absence of the speed limit because of driver response to factors such as the higher price of gasoline. Using eq. (4) and based on the speeds predicted for 1974 from regression 1 in table 2, the predicted reduction in gasoline consumption without the 55 m.p.h. speed limit is 1.40 percent. Notice that this predicted savings is 85 percent of the reduction calculated to be due to reductions in observed speed (1.64 percent). For 1975, using eq. (4) and the speeds predicted for 1975 from regression 1 in table 2, the predicted reduction in gasoline consumption from 1973 is 1.31 percent. This predicted savings is 97 percent of the reduction calculated to be due to reductions in observed speed (1.35 percent). In other words, partly because the slowing by drivers was voluntary (43 percent), partly because some drivers still drove faster than 55 m.p.h. and partly because over

[5]The reduction in gasoline consumption is found by substituting the appropriate data into eq. (4). For each of the road types we have:

$$(5853/77619)[(0.93)(0.0559)/0.0552][(0.0488-0.0559)/0.0559)]=-0.90\% \tag{4a}$$

for completed rural interstate highways;

$$(930/77619)[(0.65)(0.0540)/0.0508][(0.0488-0.0540/0.0540]=-0.08\% \tag{4b}$$

for rural interstate travelled ways;

$$(10717/77619)[(0.63)(0.0534)/0.0503][(0.0488-0.0530)/0.0534]=-0.80\% \tag{4c}$$

for rural primary highways;

$$(6456/77619)[(0.62)(0.0530)0.0530][(0.0488-0.0530)/0.0530]=-0.43\% \tag{4d}$$

for urban interstate highways;

$$(12608/77619)[(0.41)(0.0525)/0.0478][(0.0488-0.0525)/0.0525]=-0.51\% \tag{4e}$$

for rural secondary highways.

The sum of these changes is −2.72 percent with most of the change due to reductions on rural interstates and highways. The change on urban primary and secondary roads is assumed to be negligible because the average speeds are well below 55 m.p.h. on these roads (42.2 and 36.8) and few drivers exceed 55 m.p.h. (14 percent and 1 percent). Approximately 53 percent of gasoline is consumed on these urban roads. Predicted reductions are made assuming that average speed on each road type changes by the same percentage as the average speed on main rural highways and interstates.

[6]Using the actual values for G/P, $\dot{M}$ and $\dot{P}$ eq. (2) can be solved for $\dot{g}$. For 1973 to 1974: $-7.20=-2.54-2.42+\dot{g}$; $\dot{g}=-2.24$. For 1973 to 1975: $-5.95=+1.06-4.12+\dot{g}$; $\dot{g}=-2.89$.

half of gasoline consumption takes place under conditions unaffected by the speed limit, the effect of the speed limit on total gasoline consumption was quite small — a reduction of only 0.24 percent for 1973–74 and 0.04 percent for 1973–75.

4. Direct analysis of gasoline consumption

4.1. Demand for gasoline

To analyze gasoline consumption directly, the derived demand for gasoline used in personal passenger cars for street, road and highway travel can be viewed in terms of standard demand analysis. Using the framework outlined in the introduction above a simple stock model of gasoline demand is estimated where gasoline consumption depends upon the real price of gasoline, real income, the stock of autos and import share. The specification is similar to Dahl's (1978) stock model, but in contrast to Dahl (1983) and Tishler (1983) the price of gasoline is taken as exogenous. An alternative is a flow model such as that used by Fishelson (1982) or Mehta, Narasimham and Swamy (1978) where current gasoline consumption depends on lagged values of gasoline consumption. Simplicity is not costly in this case as it turns out that the estimated coefficients are similar to those of the above and other studies and within two standard deviations of the average values of their coefficients, see Dahl (1983, pp. 31–32).

U.S. per capita demand for gasoline is estimated for the years 1936–41 and 1947–72 using ordinary least squares. The basic equation estimated is

$$QG_t = \alpha_1 + \alpha_2 PG_t + \alpha_3 Y_t + \alpha_4 SA_t + \alpha_5 IM_t + u_t, \tag{5}$$

where QG is the quantity of gasoline consumed by privately-owned automobiles on highways (non-farm use) divided by the U.S. population 16 years of age and older (in the labor force); PG is the average real retail price of regular gasoline; Y is real personal income divided by U.S. population 16 years of age and older; SA is the stock of autos divided by the U.S. population 16 years of age and older; IM is the summation of the last five years of retail sales of new imported and domestic subcompact autos divided by the U.S. population 16 years of age and older (average age of cars in use is typically about 5 years), and u is the error term. Data sources and mean values for these variables can be found in table 4. Regression results are given in table 5 where the coefficients (elasticities) and absolute t values are reported. For the period before the energy crunch the price elasticity for gasoline is -0.26 and the income elasticity is $+0.22$.

Table 4
Variables for the estimation of gasoline demand.

Variable	Definition	Mean value[a] 1936–41 and 1947–72	Mean value[a] 1936–41 and 1947–75	Units	Source[b]
PG	Real retail price of gasoline	36.26	36.01	1967 cents per gallon	1
Y	Real personal income	5219	5416	1967 dollars per person	2
SA	Stock of autos	0.764	0.794	Autos per person	3
IM	Imports and subcompacts	1.918	2.651	Percent of auto stock	3,4,5
D55	55 limit dummy	—	0.057	1936–73 = 0, 1974–75 = 1	—
QG	Gasoline consumption	510.4	536.5	Gallons per person	5

[a]The means are for the levels, not logarithms.
[b]*Sources*: 1 — *Petroleum Facts and Figures* and *Basic Petroleum Data Book*, 2 — *Economic Report of the President*, 3 — *Auto Facts and Figures* and *Motor Vehicle Facts*, 4 — *Highway Statistics*, 5 – *Automotive News*.

Table 5
U.S. demand for gasoline for highway use.[a]

Variable	1936–41 and 1947–72 (1)	1936–41 and 1947–75 (2)	(3)
PG	−0.2593 (2.81)	−0.2298 (2.48)	−0.3292 (5.94)
Y	+0.2174 (2.42)	+0.2219 (2.54)	+0.2228 (2.47)
SA	+0.6464 (4.58)	+0.6140 (4.42)	+0.6466 (4.60)
IM	+0.0036 (0.52)	+0.0032 (0.47)	+0.0042 (0.61)
D55		−0.0276 (1.31)	
α_1	+5.6073 (6.08)	+5.5248 (6.11)	+5.8067 (6.56)
R^2	0.999	0.999	0.999
F	6099	6013	7156
SEE	0.0117	0.0116	0.0118
n	30	33	33
ρ	0.944	0.954	0.943
Method	OLS-CORC	OLS-CORC	OLS-CORC

[a]The dependent variable is *QG*. All variables except *D55* are in natural logarithms. Absolute *t* values are given in parentheses below each coefficient.

4.2. The 55 m.p.h. speed limit

The gasoline demand equation permits estimation of the 55 m.p.h. speed limit on gasoline consumption. One test is to check for a shift in gasoline demand in 1974–75, the years immediately after implementation of the speed limit. The variable *D55*, which is 0 from 1936–73 and 1 from 1974–75, is shown in column (2) for the demand equation for the 1936–41 and 1947–75 period. The coefficient is negative, which is what we expect if the law reduces gasoline consumption, but it is not significant at any reasonable level. The change in consumption is not large enough to be detected in this way.[7]

[7]A case can be made that the price of gasoline is endogenous, e.g., see Ramsey, Rasche and Allen (1975). Accordingly following Dahl (1978) demand was estimated using 2SLS where the prices of kerosene, distillate and residual and gasoline tax are used as instrumental variables on *PG* to avoid simultaneity bias. The resulting equation is quite similar to those of OLS with the elasticities for *PG*, *Y* and *SA* a bit larger numerically; 0.37, 0.29, and 0.81, respectively. *D55* is not significant at any reasonable level and has a *positive* sign. Predicted consumption is less than actual consumption for 1974 and 1975, but the difference is not significant. Another potential problem is that since the price increase was large in the year the 55 m.p.h. limit was imposed, it might well be that we underpredict consumption because of the constant elasticity, static specification of gasoline demand. However, with the imprecise (relative to anticipated effects of the national speed limit) forecasts likely to result from any gasoline demand specification it seems unlikely that the conclusions would change materially.

Another way to look at the effectiveness of the 55 limit is to predict gasoline consumption for the years covered by the regulation assuming that the regulation had no effect, and then test whether or not the predicted consumption differs significantly from actual consumption. The test can be explained in terms of driver production of trips and is illustrated in fig. 1.

The question is whether a decrease in actual consumption like that from G_1 to G_2 was due to the 55 m.p.h. limit or due to other changes, such as a decrease in the number of trips produced, (TR_1 to TR_2) and/or an increase in the price of gasoline (B_1 to B_2). One answer can be obtained by using the 1974 and 1975 values of the explanatory variable in the 1936–41 and 1947–72 equation [column (1)] to predict gasoline consumption to 1974 and 1975.

Table 6 shows the actual and predicted per capita gasoline consumption for 1972 which is the last year before the national speed limit, 1973 in which we saw several states adopt the 55 limit. If the law was effective, actual consumption should be less than predicted consumption. Gasoline consumption was indeed 8 gallons per person less than predicted for 1974. It was, however, 5 gallons per person greater than predicted for 1975. When the differences between actual and predicted consumption are divided by the estimated standard error of forecast neither difference is significant.[8]

Table 6
Actual and predicted gasoline consumption, 1972–1975.

	Gallons per person				
Year	Actual	Predicted	Difference	S_e^f	T[a]
1972	822	820	+2	—	—
1973	853	843	+10	43	+0.23
1974	791	799	−8	40	−0.20
1975	802	797	+5	38	+0.13

[a] T is the difference between actual and predicted consumption divided by the standard error of forecast. For 1974 and 1975, T is actually smaller than that shown since the calculated standard error of forecast uses predicted values of 1973 and/or 1974 consumption. See footnote 5.

The demand analysis indicates what changes in gasoline consumption can be accounted for by changes in demand factors, excluding the speed limit. Consider first the 3.8 percent average decline in gasoline consumption from

[8] The variance of forecast error is

$$\sigma^2+\sigma^2/n+\sum_{k=1}^{4}(X_{ik}-\bar{X}_k)^2\operatorname{var}(\hat{\alpha}_k)+2\sum_{j<k}(X_{ij}-\bar{X}_j)(\bar{X}_{ik}-\bar{X}_k)\operatorname{cov}(\hat{\alpha}_j,\hat{\alpha}_k).$$

The correct variance is larger for 1974$\widehat{QG}$ and 1975$\widehat{QG}$ since with the lagged dependent variables implicit in the Cochrane–Orcutt procedure, predicted values for 1973 and 1974 are used to get 1974$\widehat{QG}$ and 1975$\widehat{QG}$. Since the calculated T values are small anyway, the actual forecast errors were not determined.

1972 to 1974. Using the elasticities (not the predicted values shown in table 6) from the 1936–41 and 1947–72 equation a 3.0 percent average decline in gas consumption from 1972 to 1974 is estimated. This is the 3.0 percent decline net effect of: a 5.4 percent decline due to the 20.7 percent average increase in the price of gas ($20.68 \times 0.2593 = 5.36$), a 0.2 percent decline due to the 1.0 percent average decrease in income ($1.03 \times 0.2174 = 0.22$), a 2.5 percent rise due to the 3.8 percent average increase in the stock of autos ($3.81 \times 0.6464 = 2.46$), and a 0.1 percent rise due to the 23.0 percent increase in imports ($22.95 \times 0.0036 = 0.08$). Consider next the 2.4 percent average decrease in gas consumption from 1972 to 1975. Using the same elasticities a 3.3 percent average decline from 1972 to 1975 is estimated. This 3.3 percent decline, is the net effect of: a 5.4 percent decline due to a 20.7 percent increase in the price of gas ($20.74 \times 0.2593 = 5.38$), a 0.2 percent decline due to a 1.1 percent average decrease in income ($1.10 \times 0.2174 = 0.24$), a 2.1 percent rise due to a 3.3 percent increase in the stock of autos ($3.31 \times 0.6464 = 2.14$), and a 0.1 percent rise due to a 20.3 percent increase in imports ($28.31 \times 0.0036 = 0.10$).

The results from direct estimation of gasoline consumption are similar to those for speed in that again most of the reduction in gasoline consumption is predicted implying the 55 m.p.h. speed limit had a small effect on gasoline consumption. According to the predictions in table 6, for 1973 to 1974, 87 percent of the actual reduction can be attributed to factors other than the national speed limit and for 1973 to 1975 all of the reduction can be accounted for by other factors. The difficulty in detecting any direct effect of the national speed limit on gasoline consumption is due primarily, to the large fraction of driving which is unaffected by the regulation and would not be affected even with complete compliance, i.e., over half of the gasoline consumed is used for driving on non-interstate urban driving.

5. Summary and conclusions

To systematically analyze the impact of the national 55 m.p.h. speed limit on energy consumption, highway speed and gasoline consumption were viewed within the context of driver trip production where the tradeoff between inputs of time and gasoline are emphasized. Speeds of passenger cars on primary rural highways under ideal driving conditions were studied to determine the effect of the 55 m.p.h. limit on speeds. For U.S. average speeds ($MPHA$) analysis showed that the price of gasoline and availability of interstates are the most important factors having elasticities of -0.2 and 0.1 respectively. For fast driving (ASE) income and availability of interstates were found to be the most important variables. When speed was predicted for 1974, actual speed (which was about 10 percent less than 1972 speed) did indeed turn out to be less than predicted. This was the case for 1975 also. Actual fast driving was less than that predicted for 1974 and 1975 as well.

While the results indicate that the 55 m.p.h. speed limit considerably reduced speeds below what they would have been without it when technical information on the relationship between speed and the rate of gasoline consumption is applied to convert the impact on speeds to an implied effect on total gasoline consumption used in private cars the effect of the national speed limit turned out to be surprisingly small. It was found that of the 1.64 percent reduction in gasoline consumption from 1973 to 1974 which was due to slower travel 1.40 percent (or 85 percent of the reduction) was predicted leaving only a 0.24 percent reduction to be attributed to the speed limit. The savings is a mere 3.3 percent of the total reduction in per capita gasoline consumption in 1974. For the 1973–1975 period of the 1.35 percent reduction due to lower consumption rates per mile, 1.31 percent (or 97 percent of the reduction) was predicted leaving only a 0.04 percent reduction to be attributed to the national speed limit. This savings is a mere 0.7 percent of the total reduction in per capita gasoline consumption in 1974 and 1975.

To measure the direct effect of the regulation on gasoline consumption, U.S. per capita gasoline demand for highway use in privately-owned automobiles was estimated. The price of gasoline, per capita personal income and stock of autos were found to have elasticities of −0.3, +0.2 and +0.6, respectively. When gasoline consumption is predicted for 1974, the first year covered by the 55 m.p.h. speed limit, actual consumption (which was about 3.8 percent less than the 1972 level) does indeed turn out to be less than predicted. Unlike that for 1974, actual gasoline consumption turns out to be greater than predicted for 1975, but neither difference is significant at any reasonable level. The insignificance is taken to be a consequence of the large portion (over 50 percent) of driving which is virtually unaffected by the speed limit, namely city driving, and of the other ways drivers can improve gas mileage besides slower travel. Direct analysis of gasoline demand corroborates the finding implied by analysis of highway speed that the national speed limit had little short-run effect on private gasoline consumption.

If one can draw a general conclusion about the short-run impact of the 55 m.p.h. speed limit on highway travel, it is that highway speeds were reduced substantially, but the energy savings were quite small and difficult to detect. Without question there were noticeable drops in the upward trends of both speed of travel and gasoline consumption — changes often attributed to the national speed limit. The changes, however, are explained primarily by a 21 percent increase in the relative price of gasoline from 1972 to 1974 and the consequent adjustments in the mix of gasoline and time and other inputs made by drivers to minimize the cost of highway trips. It appears that the case for the 55 m.p.h. speed limit must be based on long-run energy savings or benefits from safer travel.

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