Price Elasticity of the Demand for Cigarettes in the United States

HERBERT L. LYON AND JULIAN L. SIMON

The retail price elasticity of demand for cigarettes is a particularly important parameter for social decisions at this time. Results from prior cigarette elasticity studies vary widely, ranging from —0.10 to —1.48. Temporal changes may explain some of this variation, but differences in research methods are more important. The quasi-experimental approach used in this article yields an elasticity estimate (—0.511) free of many of the extraneous and irrelevant systematic influences that afflict time-series and cross-section methods. In addition, the length of run of the elasticity is known and explicit. The method provides built-in protections against bias from trends in collinear variables and produces sensible estimates with reasonably small and measurable dispersion.

THE retail price elasticity of demand for cigarettes is a particularly important parameter for social decisions at this time. It is the overwhelming consensus among scientists that cigarette smoking increases mortality.[1] And price increases are a possible sanction that the government might use to decrease cigarette use.

Several studies of this elasticity have been done previously [1, 2, 4, 5, 9, 12]. Our main reason for delving again into the matter is that the previous estimates differ rather widely, ranging from −0.10 to −1.48. Change over the course of time may explain some of the variation, but differences in method are more important, especially the difference between time series and cross sections.[2]

Study of the demand for cigarettes also provides another opportunity for trying out the "quasi-experimental" method in economics, and this study has led to further development of the method. Under this procedure, we estimated the arc elasticity of demand from the sales before and after a tax change in a state. These sales were standardized for secular changes in cigarette consumption in other states where price was unchanged. The method is therefore free of many of the extraneous and irrelevant systematic influences that afflict time series and cross sections. The method was used earlier to estimate the price elasticity of liquor [6], and cigarette consumption offers a particularly good chance to test further the usefulness and accuracy of the method.

[1] The Surgeon General's Committee *unanimously* agreed to use the term "causal" for the smoking–mortality relationship [11].

[2] The most elastic estimate was from the cross-section study [2]. This is what one would expect, assuming that the year-to-year correlation in cigarette prices among states is extremely high and that the price of cigarettes has at least some lagged effect

HERBERT L. LYON *is assistant professor of business administration at the University of Kentucky, and* JULIAN L. SIMON *is associate professor of economics and marketing at the University of Illinois.*

As with liquor, the quasi-experimental method is especially appropriate for cigarettes because retail price changes are very infrequent. Infrequency of change is helpful for this quasi-experimental method and damaging to time-series analysis. Also, the length of run of the computed elasticity is known and explicit, unlike time-series and cross-section estimates, for which the lengths of run are "short" and "long," respectively, but unspecifiable in either case. This property is useful to policy makers who contemplate price alterations. Still another relevant property of the method is that it controls for forces such as culture, religion, international tension, and other influences which might bias time-series estimates. One possible drawback of the method is that there might be "leakage" across state borders in response to price differentials, but this effect was observed not to be important in the case of liquor, and hence we think it safe to disregard it here.

For each tax-change "trial" or "experiment," we computed an arc elasticity,

$$e_p = \frac{\dfrac{Q_2 - Q_1}{Q_1} - \sum_{i=1}^{N}\left(\dfrac{Q_4 - Q_3}{Q_3}\right)\Big/ N}{\dfrac{P_2 - P_1}{P_1}},$$

where

e_p is the price elasticity,
Q_1 is the consumption for the year (January to December) ended before price change in the trial state,
Q_2 is the consumption for the year (January to December) beginning after price change in the trial state,
Q_3 is the consumption for the year (January to December) before price change in the comparison states, for example, all states in which price was unchanged during the relevant period,
Q_4 is the consumption for the year (January to December) after price change in the comparison states,
P_1 is the price for the year before change,
P_2 is the price for the year after change, and
N is the number of comparison states.

The resulting estimates of price elasticity refer to the response in a defined period of time, in this case the year from 6 to 18 months after the

on consumption; the rationale is that a simple cross-section estimate sums up much of the effect of past as well as present price influence. Short time series, such as those used in some of the studies [1, 4, 5, 9, 12], are less likely to cumulate lagged influence into the estimate because of the relatively low serial correlation; hence, they produce smaller elasticities. The logic underlying the remarks in this footnote is worked out in Simon and Aigner [8].

price change. It is implicitly assumed that no other price changes occur in the state between the price change being studied and the measurement period. If the observed elasticity is, say, −0.50, and a price change of 10 percent occurs, consumption will be 5 percent less than it would otherwise be during the 12-month period beginning six months after the price change. Estimates of state retail prices and per capita consumption in the years before and after the tax changes were taken from data published by the Tobacco Tax Council [10, pp. 61–111]. These data are obtained annually by means of a sample survey conducted in all states which impose cigarette taxes. These price terms are a weighted average retail price per pack, with both the form of sale (over the counter, single pack price, carton lot price, and vending machine price) and the types of cigarettes sold (regular size, king size, and filter tip) being taken into consideration. It seems fair to conclude that this survey produces reasonable state price estimates, since the price of cigarettes is much the same throughout a state. Substantial price differentials are normally found only by comparing states and are due primarily to the variation in state tax schedules.

The denominators in each ratio on the right-hand side of the equation are "before" quantities, despite the fact that some writers advise using the midpoint of the before and after values. Our reasoning is that when in policy discussions people ask, "What percentage change in consumption will a price change of x percent cause?" they mean, "What proportion *of the existing level* of consumption will the future level be?" Such a question calls for an answer derived from an elasticity formula with the existing level in the denominator, such as is used here. But this discussion may be moot, because the differences between estimates derived from the two formulas are quite small.

The individual estimates for each "trial" are shown in Table 1. The median estimate is −0.511. We think that the median is a more sensible central-value estimate than the mean in this case, because it is less sensitive to the kind of sampling variation that is present here. This is illustrated by the fact that the overall mean is −0.571 but the omission of only a single observation–the −7.100 observation for Maine's 1961 price change –shifts the mean to −0.477. No single observation affects the median anywhere near so much. In any case, the difference between the two estimates of central value is sufficiently small that we need not argue about which one to pitch upon as the more appropriate. Almost any policy decision would be the same no matter which estimate was used.[8]

[8] An interesting methodological sidelight comes out of an earlier time-series attempt by Lyon. Regressions were computed for each of 37 states for the years 1950–1965, using price and per capita income as independent variables, with per capita sales as the dependent variable. The estimates of price elasticity ranged from +1.497 to −1.614. This gives some idea of the accuracy of any single time-series

Table 1. Arc elasticities for changes in the price of cigarettes in individual states

State	Year of price change	Price in preceding year	Price increase (new price minus old price, divided by old price)	Computed elasticity
		cents	*percent*	
Illinois	1960	26.4	−1.8	1.725
Iowa	1959	24.8	4.8	1.139
Illinois	1961	25.9	0.3	0.957
Alabama	1955	24.0	2.9	0.863
Connecticut	1956	22.5	8.4	0.802
North Dakota	1963	27.1	5.2	0.517
Delaware	1961	24.6	10.6	0.407
Ohio	1956	20.7	8.2	0.304
Minnesota	1963	28.7	4.9	0.204
New Hampshire	1951	20.2	0.5	0.125
Mississippi	1964	30.4	3.2	0.122
Kentucky	1960	23.9	0.4	0.106
Kansas	1957	22.8	9.6	0.031
Rhode Island	1960	26.0	2.3	−0.032
Nevada	1961	25.9	11.6	−0.100
Tennessee	1963	26.1	11.1	−0.142
Michigan	1962	27.1	6.2	−0.174
Idaho	1955	22.2	7.2	−0.234
Pennsylvania	1955	23.3	5.6	−0.240
Michigan	1960	26.5	4.5	−0.251
South Dakota	1959	24.8	9.7	−0.277
Georgia	1964	29.4	1.0	−0.301
Tennessee	1951	19.4	20.1	−0.302
New Mexico	1955	22.9	7.4	−0.302
Kansas	1964	25.6	9.7	−0.307
Iowa	1963	26.4	5.7	−0.328
Maine	1955	23.0	4.8	−0.329
Pennsylvania	1963	26.8	10.8	−0.346
Arkansas	1951	20.5	18.5	−0.357
New Jersey	1956	23.1	10.3	−0.376
Georgia	1955	23.0	12.2	−0.377
Mississippi	1958	26.1	3.8	−0.383
Mississippi	1962	27.4	11.3	−0.385
South Dakota	1955	22.1	3.7	−0.393
Texas	1955	24.5	0.8	−0.444
New Jersey	1963	28.8	4.2	−0.482
Nebraska	1957	22.4	11.2	−0.511
Mississippi	1955	23.3	5.6	−0.538
Utah	1954	20.8	11.1	−0.541
Michigan	1957	22.9	13.1	−0.549
Minnesota	1959	24.8	7.7	−0.554
Utah	1963	24.9	18.1	−0.600
Kentucky	1954	20.0	16.5	−0.613
Connecticut	1961	26.6	0.8	−0.644
Rhode Island	1964	27.3	9.2	−0.692
Illinois	1959	24.5	7.8	−0.713
Iowa	1953	22.0	0.5	−0.724
Florida	1963	26.3	12.9	−0.734
New York	1959	24.0	6.7	−0.749
Alabama	1959	25.8	10.1	−0.752
New Jersey	1961	26.3	8.7	−0.753
Oklahoma	1961	26.1	9.6	−0.766
Massachusetts	1958	26.7	4.1	−0.805

Table 1. (*Continued*)

State	Year of price change	Price in preceding year	Price increase (new price minus old price, divided by old price)	Computed elasticity
Montana	1957	23.7	27.0	−0.886
South Carolina	1951	21.9	0.5	−0.926
South Carolina	1959	24.4	8.2	−0.971
Connecticut	1963	26.8	3.7	−0.972
Ohio	1959	23.8	8.9	−0.975
Texas	1959	25.6	12.1	−1.018
Minnesota	1961	26.6	7.9	−1.024
Michigan	1961	27.7	−2.1	−1.066
Pennsylvania	1959	26.2	2.3	−1.118
Idaho	1961	26.3	4.1	−1.145
Rhode Island	1958	23.6	9.3	−1.146
North Dakota	1951	22.8	0.4	−1.157
Delaware	1953	21.0	0.5	−1.282
New Mexico	1961	26.9	11.5	−1.339
Nebraska	1963	25.8	6.6	−1.420
South Dakota	1963	26.6	7.1	−1.443
Idaho	1959	25.9	1.5	−1.478
Idaho	1963	28.0	5.0	−2.041
Georgia	1951	24.8	−16.9	−2.092
Maine	1961	26.4	1.1	−7.100

One of the characteristics of this method is that it lends itself to meaningful measurement of the accuracy of the estimate. A 95-percent confidence interval around the median spans −0.346 and −0.713, the twenty-eighth and forty-sixth observations [3, p. 551], suggesting a high reliability for the estimate. The chosen central-value estimate seems quite reasonable in light of previous estimates; it is of the same general order as the time-series estimates and much lower than the cross-section estimate. This estimate can be said to be the elasticity of demand for the 12-month period centered on 6 to 18 months after the price change.[4]

Table 1 shows that in many cases there are considerable differences between the computed arc elasticities for different years for the same state; for example, the observed elasticities for Illinois were +1.725 in 1960, +0.957 in 1961, and −0.713 in 1959. Similarly for Iowa they were +1.139 in 1959, −0.328 in 1963, and −0.724 in 1953; but there are only small differences between successive observations in other states. This leads us to ask how much of a given observation's deviation from the mean

estimate for cigarettes. There is no reason to believe that an aggregate U. S. time series should be more accurate than the estimate for any single state, except that aggregate U. S. population figures are more accurate in intercensal years than are estimates for states.

[4] If monthly data had been available by states, the analysis could have been sharpened by starting the 12-month observation periods at more sensible intervals around the price changes.

is accounted for by the particular elasticity that inheres in the state and how much by chance variation. Therefore, we examined the pairs of estimates for states that appear twice or more in our list. (For states that appeared more than twice, two of the estimates were selected randomly to make a pair.) If the estimates reflect properties of the state, the members of pairs of observations should be relatively close together. We therefore counted the numbers of pairs both of whose members are on the same side of the group median. Only seven are found to be on the same side, as compared to 17 pairs that straddle the median, a result which is "more random" than the random expectation of half being straddles. We may therefore conclude that deviation of a state observation from the median is not a property of the state. This supports our procedure of lumping together all the individual observations and considering them as a sample from which to estimate the elasticity of the United States as a whole.

A useful property of this method is that one may easily examine whether price elasticities differ from place to place, among subgroups within the population, or over the course of time. We shall begin with the last.

Many changes occurred in the cigarette market over the period of this study: for example, the shift to filters, and the growing awareness of the threat to health from cigarette smoking. Therefore, it is interesting to see if there were any systematic changes in elasticity during the period, which this method allows us to examine. The estimates were grouped by years in Table 2.

Table 2. Elasticity estimates grouped by years in which change in the prices of cigarettes occurred

Year	Median elasticity	Number of observations
1951	−0.691	6
1953	−1.003	2
1954	−0.577	2
1955	−0.329	9
1956	+0.304	3
1957	−0.530	4
1958	−0.805	3
1959	−0.971	11
1960	+0.037	4
1961	−0.766	1
1962	−0.279	2
1963	−0.541	12
1964	−0.304	4

No apparent time trend in elasticity observations is found. Besides the light this throws on actual elasticities, it also suggests an absence of secu-

lar trends that might bias our central-value summary estimate. The ability to inspect for such trends seems to be an inherent advantage of the quasi-experimental method; by comparison the time-series method throws together observations from different dates, and the cross-section method yields an estimate that applies to only a single date.

Another interesting question is whether elasticity depends importantly upon income. Theory suggests that the higher per capita income is, the less elastic should demand be. We therefore examined the two median elasticity estimates for the trial states above and below the median per capita disposable income. The median for the lower-income states was −0.419 and for the higher-income states was −0.549. This does not accord with the theoretical expectation. Furthermore, a significance test[5] suggests that such a spread or an even wider one would occur frequently by chance. We may therefore conclude that there is no important relationship between income and elasticity over the range of state incomes.

Another question is whether the size of the price change influences the sharpness of response to it. The medians of the observations from price changes less than and greater than 6.7 percent (the median price change) were, respectively, —0.419 and —0.549. This enables us to conclude that elasticity is not strongly a function of size or price change (see the Nair test earlier), although the difference suggests that a bigger change tends to be associated with a higher elasticity.

A last inquiry was into regional differences in elasticity. The observed medians were —0.743 for the West, —0.360 for the North Central, —0.563 for the North East, and —0.415 for the South. A spread this great or greater would happen quite frequently just by chance even if there were no systematic difference among regions.

At the outset it was noted that price changes might be considered as a device to reduce smoking. And an elasticity of −0.50 or slightly more suggests that price is a not insignificant control variable. It is simply not true that "people will go on smoking no matter what it costs them." If the elasticity estimates can be extrapolated far beyond the range of observation, doubling price would halve sales in the first year, a very large effect by any standard. However, if there are any alternatives which would reduce consumption, and there are [7], tax increases probably should not be used for such purposes, because there may well be a vicious boomerang effect. The higher the price, the further toward the butt-end cigarettes are smoked, and the toxicity per puff increases rapidly as the cigarette grows shorter

[5] This was a randomization test using Monte Carlo drawings. We asked how often the median of a randomly drawn sample of 36 of the 73 observed values would be outside the observed bracket, —0.419 to —0.549. Of 20 trials run, only 5 were outside it.

and collects tars. The extent of this effect should be studied carefully before prices are increased to reduce consumption.

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