

Modeling Cigarette Consumption

Structure of the California Board of Equalization's Nonlinear Cigarette Estimation Model

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Federation of Tax Administrators
Revenue Estimating and Tax Research Conference
September 26, 2000

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Using the structure of a nonlinear model, the annual change in apparent cigarette consumption per capita in California can be reasonably expressed as a multiplication product of ratios. Each ratio represents the multiplying effect resulting from an annual change in some economic variable from one year to the next, which either increases or decreases the annual change in cigarette consumption for that given year. The relative annual change in each variable would translate into a percentage increase/decrease in cigarette consumption per capita. Some variables are expected to increase consumption, whereas others would decrease consumption. The structure of such a model may be expressed as:

$$\begin{aligned} (\text{cig2/pop2})/(\text{cig1/pop1}) = & B_0 * (\text{catax2/catax1})^{B_1} * (\text{fedtax2/fedtax1})^{B_2} * \\ & (\text{RetailPrice2/RetailPrice1})^{B_3} * (\text{wage2/wage1})^{B_4} * \\ & (\text{CaEmployRt2/CaEmployRt1})^{B_5} * \\ & (\text{Pre-1966 indicator})^{B_6} + \text{error term} \end{aligned}$$

The B_i s (beta sub i) are the calculated coefficients determined through the nonlinear regression algorithm. The error term is defined as the difference between the historical change in cigarette consumption per capita for a given year and the replicated change in consumption as estimated using the beta coefficients in the equation. The nonlinear regression algorithm, using the Least Squares method, would attempt to estimate the betas through repetitive iterations such that the sum of squared error terms between the historical observed value and the estimated value is minimized. B_0 is the general multiplier for the overall equation. If B_0 were 1.0, then the remaining terms tend to explain much of the data variation. Otherwise, B_0 represents the overall historical trend multiplier not fully explained by the other terms.

‘Cig2/pop2’ is the annual cigarette consumption (in packs) divided by the California civilian population for a given year. ‘Cig1/pop1’ is the same ratio but for the previous year.

‘Catax2’ is the California excise tax per pack for a given year adjusted to the 1997 base year using the all urban Consumer Price Index for California. ‘Catax1’ is the previous year’s excise tax in California, also expressed in constant dollars.

‘Fedtax2’ is the U.S. excise tax per pack for a given year adjusted to the 1997 base year using the all urban Consumer Price Index for California. ‘Fedtax1’ is the previous year’s federal excise tax, also adjusted for inflation.

‘Retail Price2’ is the average retail price for a pack of cigarettes minus the federal and state excise taxes for a given year. It too has been adjusted to the 1997 base year using the all urban Consumer Price Index for California. Similarly, ‘Retail Price1’ is the average retail price for the previous year, also expressed in constant dollars.

‘Wage2’ is wage and salary portion of the personal income per capita adjusted to the 1997 base year using the all urban Consumer Price Index for California in a given year. ‘Wage1’ is the wage portion for the previous year, also adjusted for inflation.

‘Ca Employ Rt2’ is the ratio of civilian employed workers divided by the California civilian work force for a given year. ‘Ca Employ Rt1’ is the employment ratio for the previous year.

‘Pre-1966 indicator’ is an either/or binary choice variable in which the indicator equals 10 for the years before 1966 or equals 1 for the years after 1965. It is a selective trend variable used to reflect

the qualitative attractiveness of cigarette smoking, not quantitatively defined. Numerically, 10 raised to a positive B_6 power tends to magnify the annual change in cigarette consumption per capita prior to 1966. On the other hand, the value of 1 raised to the B_6 power will not affect the annual change in cigarette consumption per capita after 1965.

Calibration of the Nonlinear Statistical Model

Calibration data for dependent variables of the nonlinear regression model are shown in Table 1 (page 4).¹ Table 2 shows Calibration data for the independent variable (California per capita consumption) as well as for population, and total U.S. and California apparent consumption. In Table 3 staff listed the calibrated coefficients derived from the nonlinear regression analysis. With a statistically significant B_0 of 0.96531, staff could interpret one year's cigarette consumption per capita to be 96.531 percent of the previous year's consumption if all other conditions were kept constant. Staff could interpret this B_0 coefficient as the impact from exogenous variables on annual cigarette consumption per capita, reflecting an average annual decline of -3.5 percent each year (i.e. $1.0 - 0.965$). If the economic conditions were to remain the same from one year to the next, staff would be estimating a 3.5 percent annual decline in consumption.

Within the nonlinear model, the B_1 coefficient of -0.08946 was also statistically significant at the 95 percent confidence level. For example, a 10 percent increase in the California excise tax would generate a multiplication ratio of 0.99151, which equals $(1.1)^{-0.08946}$. This ratio converts into a -0.85 percent decline in cigarette consumption by itself. This reduction in consumption would be multiplied with the annual 3.5 percent decline from the B_0 coefficient as well.

The B_2 coefficient, -0.15505 , for the U.S. excise tax was statistically significant. For example, a 10 percent increase in the U.S. excise tax on a pack of cigarettes would generate a multiplication ratio of 0.98533, which equals $(1.1)^{-0.15505}$. This ratio converts into a -1.5 percent reduction in cigarette consumption by itself. This -1.5 percent reduction would also be multiplied by the calculated changes induced by the California excise tax changes as well as by the minus 3.5 percent trend multiplier.

The B_3 coefficient, -0.00935 , for the retail price of a pack of cigarettes without the excise taxes was not statistically significant at the 95 percent confidence level. If it were, then a 10 percent increase in the retail price would generate a multiplication ratio of 0.99911, which equals $(1.1)^{-0.00935}$. This ratio converts into a -0.1 percent decline in consumption by itself.

The B_4 coefficient, $+0.50279$, for the wage and salary portion of the personal income per capita, was statistically significant at the 95 percent confidence level. A 2 percent annual real increase in wage and salary income would generate a multiplication ratio of 1.01001, which equals $(1.02)^{0.50279}$. This ratio converts into a +1.0 percent increase in cigarette consumption per capita.

The B_5 coefficient, -1.12472 , for the civilian employment rate in California, was also statistically significant at the 95 percent confidence level. If the California Employment rate were to increase from 93.7 percent in one year to 94.2 percent in the next year, the multiplication ratio in the nonlinear equation would be 0.99403, i.e. $(0.942/0.937)^{-1.12472}$. This ratio converts into a -0.6 percent decline in consumption given a 0.5 percent rise in the employment rate.

¹ This calibration was done in August 2000, using revised historical economic data. The coefficients differ slightly from those of the original model, which were estimated in early 1999 before the revised data were available. Per capita consumption, as estimated by the revised coefficients, differs by less than 0.1 packs per capita from the estimates made using the original data. Rounded to the nearest tenth of a pack per capita, there are no differences in estimated consumption using revised and unrevised data after fiscal year 1983-84.

The B₆ coefficient, 0.00952, for the pre-1966 indicator, was also statistically significant at the 95 percent confidence level. If the annual change in cigarette consumption occurred in 1999, the indicator value would equal 1. The resulting multiplier term of $1^{0.00952}$ still equals 1. Staff designed the pre-1966 indicator to reflect arbitrarily the qualitative attractiveness of cigarette smoking before the onset of publications warning about the unhealthy aspects of cigarette smoking.

So how do these multiplication ratios help to estimate the annual change in cigarette consumption? The nonlinear regression model is a product of multiplication ratios, intended to replicate the annual change in cigarette consumption per capita. Given the above conditions in this hypothetical example, the product of these ratios would be 0.94599, or a -5.4 percent annual decline in cigarette consumption per capita.

Expressed mathematically, the computation of the nonlinear equation would be:

$$0.96531 \times 0.99151 \times 0.98533 \times 0.99911 \times 1.01001 \times 0.99403 \times 1.0 = 0.94599$$

The calibrated nonlinear model had an R squared of 63 percent. The model could explain about 63 percent of the variation in the data. The remaining 37 percent of the variation could be attributed to unknown variables, unique events, randomness, etc. The first order correlation between the year and the residuals of the annual changes in cigarette consumption per capita was a -0.36.

Results of the Analysis

The Research staff then applied the nonlinear model to estimate the apparent cigarette consumption per capita during the historical period from 1979 through 1997 as a reality check. These results are shown in Table 4 (page 7). During the fiscal year 1997-1998 (the last fiscal year prior to the passage of Proposition 10), staff estimated annual apparent cigarette consumption to be about 52.1 packs per person, compared with the historical of 50.8 packs per person, about a 2.5% error.

Selected References

1. Advisory Commission on Intergovernmental Relations, *Cigarette Bootlegging: A State and Federal Responsibility*, May 1977.
2. Advisory Commission on Intergovernmental Relations, *Cigarette Tax Evasion: A Second Look*, March 1985.
3. US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, *Reducing the Health Consequences of Smoking - 25 Years of Progress*, January 1989.
4. US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, *Reducing Tobacco Use*, August, 2000.
5. Washington State Department of Health, Community and Family Health, Non-Infectious Disease and Injury Prevention, *A Tax Study - Cigarette Consumption in Washington State*, January 1997.

Table 1: Calibration Data for Nonlinear Regression Model of California Cigarette Consumption

Beginning Fiscal Year	Calif. All Urban CPI (1982-1984 = 100)	Calif. Price (Dollars per Pack)	Calif. Excise Tax (Dollars per Pack)	U.S. Excise Tax (Dollars per Pack)	California Personal Income (Millions \$)	California Wages Income (Millions \$)	California Civilian Work Force (Thousands)	California Employed (Thousands)	Califon Excise Tax Revenue (Million)
7/1/1959	28.6	0.254	0.03	0.08	42,311	27,549	6,104	5,812	61.79
7/1/1960	29.2	0.252	0.03	0.08	44,661	29,168	6,299	5,932	66.05
7/1/1961	29.5	0.250	0.03	0.08	47,363	30,770	6,482	6,036	68.20
7/1/1962	29.9	0.253	0.03	0.08	51,062	33,260	6,650	6,261	70.82
7/1/1963	30.4	0.255	0.03	0.08	54,599	35,674	6,868	6,457	71.53
7/1/1964	31.0	0.253	0.03	0.08	59,220	38,273	7,081	6,659	74.48
7/1/1965	31.5	0.255	0.03	0.08	63,376	40,751	7,284	6,855	74.88
7/1/1966	32.2	0.260	0.03	0.08	68,933	44,914	7,592	7,217	75.65
7/1/1967	33.0	0.354	0.10	0.08	74,352	48,141	7,830	7,441	208.12
7/1/1968	34.4	0.366	0.10	0.08	81,535	52,824	8,090	7,724	238.83
7/1/1969	36.1	0.388	0.10	0.08	89,193	57,924	8,388	8,016	237.22
7/1/1970	37.9	0.397	0.10	0.08	95,743	61,251	8,167	7,575	240.37
7/1/1971	39.3	0.399	0.10	0.08	101,679	63,942	8,407	7,669	248.35
7/1/1972	40.6	0.399	0.10	0.08	111,196	69,876	8,653	7,996	253.08
7/1/1973	43.0	0.419	0.10	0.08	122,804	76,902	8,910	8,286	259.73
7/1/1974	47.4	0.450	0.10	0.08	137,198	84,420	9,317	8,638	264.18
7/1/1975	52.3	0.483	0.10	0.08	150,729	90,865	9,539	8,598	269.85
7/1/1976	55.6	0.490	0.10	0.08	169,161	100,675	9,896	8,990	270.50
7/1/1977	59.5	0.587	0.10	0.08	188,443	112,617	10,367	9,513	275.04
7/1/1978	64.4	0.601	0.10	0.08	216,040	128,866	10,911	10,137	270.65
7/1/1979	71.3	0.621	0.10	0.08	247,641	146,991	11,268	10,566	272.14
7/1/1980	82.4	0.664	0.10	0.08	281,589	164,244	11,584	10,794	280.08
7/1/1981	91.4	0.728	0.10	0.08	315,375	182,590	11,811	10,937	278.66
7/1/1982	97.3	0.849	0.10	0.16	336,098	193,358	12,177	10,967	273.74
7/1/1983	98.9	0.949	0.10	0.16	361,589	207,078	12,282	11,095	265.26
7/1/1984	103.8	0.980	0.10	0.16	402,979	230,111	12,611	11,631	265.07
7/1/1985	108.6	1.044	0.10	0.16	436,898	251,164	12,982	12,048	260.96
7/1/1986	112.0	1.039	0.10	0.16	467,657	270,508	13,333	12,443	257.33
7/1/1987	116.5	1.174	0.10	0.16	504,862	295,539	13,738	12,947	254.86
7/1/1988	121.9	1.264	0.35	0.16	548,302	320,522	14,132	13,384	499.71
7/1/1989	128.0	1.638	0.35	0.16	590,962	343,589	14,517	13,780	770.04
7/1/1990	135.0	1.868	0.35	0.20	639,298	368,413	15,193	14,319	729.61
7/1/1991	140.6	2.019	0.35	0.20	653,172	372,792	15,176	14,004	711.27
7/1/1992	145.6	2.051	0.35	0.24	684,674	383,466	15,404	13,973	667.47
7/1/1993	149.4	1.903	0.37	0.24	698,130	384,135	15,359	13,918	647.95
7/1/1994	151.5	1.951	0.37	0.24	718,321	394,356	15,450	14,122	656.92
7/1/1995	154.0	1.979	0.37	0.24	754,289	414,714	15,412	14,203	639.03
7/1/1996	157.1	2.003	0.37	0.24	798,020	440,465	15,511	14,391	629.57
7/1/1997	160.5	2.078	0.37	0.24	846,017	475,760	15,948	14,943	612.06

Table 2: 1959-1997 Apparent Cigarette Consumption in California and United States

Beginning Fiscal Year	California Annual Cigarette Packs (Millions)	California Civilian Population (Millions)	California Annual Cigarette Packs (Per Capita)	U.S. Civilian Population (Millions)	U.S. Annual Cigarette Packs (Millions)	U.S. Annual Cigarette Packs (Per Capita)
7/1/1959	2,085.000	14.964	139.334	175.277	22,685	129.424
7/1/1960	2,257.533	15.550	145.179	178.140	23,505	131.947
7/1/1961	2,319.772	16.108	144.014	181.143	24,405	134.728
7/1/1962	2,409.150	16.634	144.833	183.677	24,725	134.611
7/1/1963	2,432.961	17.197	141.476	186.493	25,480	136.627
7/1/1964	2,533.575	17.706	143.091	189.141	24,870	131.489
7/1/1965	2,546.913	18.143	140.380	191.605	25,575	133.478
7/1/1966	2,573.404	18.459	139.412	193.420	26,125	135.069
7/1/1967	2,382.985	18.796	126.781	195.264	26,390	135.150
7/1/1968	2,408.820	19.046	126.474	197.113	26,150	132.665
7/1/1969	2,392.527	19.354	123.619	199.145	25,525	128.173
7/1/1970	2,424.297	19.663	123.292	201.895	26,640	131.950
7/1/1971	2,505.251	20.002	125.250	204.866	26,445	129.084
7/1/1972	2,552.559	20.264	125.965	207.511	27,550	132.764
7/1/1973	2,619.604	20.558	127.425	209.600	29,515	140.816
7/1/1974	2,664.437	20.874	127.644	211.636	28,810	136.130
7/1/1975	2,721.612	21.249	128.082	213.788	29,415	137.589
7/1/1976	2,728.175	21.653	125.995	215.894	30,895	143.103
7/1/1977	2,773.939	22.075	125.660	218.106	29,600	135.714
7/1/1978	2,729.726	22.566	120.966	220.467	30,710	139.295
7/1/1979	2,744.459	22.991	119.371	222.969	30,700	137.687
7/1/1980	2,824.815	23.511	120.149	225.621	31,025	137.509
7/1/1981	2,810.502	24.006	117.075	227.818	31,905	140.046
7/1/1982	2,760.839	24.523	112.582	229.995	30,705	133.503
7/1/1983	2,675.321	25.058	106.765	232.097	29,875	128.718
7/1/1984	2,673.370	25.530	104.715	234.110	29,890	127.675
7/1/1985	2,631.903	26.114	100.785	236.219	29,750	125.942
7/1/1986	2,595.390	26.763	96.977	238.412	29,155	122.288
7/1/1987	2,570.489	27.427	93.721	240.550	28,860	119.975
7/1/1988	2,352.516	28.115	83.675	242.817	27,170	111.895
7/1/1989	2,218.924	28.861	76.883	245.131	26,290	107.249
7/1/1990	2,102.440	29.679	70.839	247.824	26,160	105.559
7/1/1991	2,049.605	30.266	67.720	250.542	24,855	99.205
7/1/1992	1,923.414	30.971	62.104	253.445	25,470	100.495
7/1/1993	1,823.649	31.349	58.172	256.310	23,170	90.398
7/1/1994	1,790.678	31.500	56.847	258.915	24,430	94.355
7/1/1995	1,741.889	31.827	54.730	261.452	24,515	93.765
7/1/1996	1,716.142	32.192	53.310	263.943	24,235	91.819
7/1/1997	1,668.404	32.811	50.849	266.531	23,570	88.432

Data Sources for Tables 1 and 2 (In Column Order)

1. The California all Urban Consumer Price Index is a relative measure of inflation using as its base years 1982-1984 alongside a base index of 100. The data can be found in the 1998 *California Statistical Abstract*, California Department of Finance (DOF). Source: U.S. Department of Labor, Bureau of Labor Statistics, <http://stats.bls.gov/>.
2. The average statewide prices for cigarettes include brand names and generic types. Source: The Tobacco Institute, *The Tax Burden on Tobacco*, volume 33, 1998, also found through <http://www.tobaccoinstitute.com/pop5.htm/>.
3. The data on California excise tax rates per pack can be found in *The Tax Burden on Tobacco*, The Tobacco Institute, volume 33, 1998.
4. The data on U.S. excise tax rates per pack can be found in *The Tax Burden on Tobacco*, The Tobacco Institute, volume 33, 1998.
5. The California Personal Income data can be found in the 1998 *California Statistical Abstract*, California Department of Finance (DOF). Source: U.S. Dept. Commerce, Bureau of Economic Analysis, <http://www.bea.doc.gov/>.
6. The wages and salaries portion of the California Personal Income data can be found in the 1998 *California Statistical Abstract*, California Department of Finance (DOF). Source: U.S. Dept. Commerce, Bureau of Economic Analysis, <http://www.bea.doc.gov/>.
7. The California civilian labor work force data can be found in the 1998 *California Statistical Abstract*, California Department of Finance (DOF) for years 1971-1997. Data for earlier years 1959-1971 were found in the 1973 California Statistical Abstract. Source: California Employment Development Department (EDD), Labor Market Information Division (LMID), Information Services Group, (916) 262-2345, <http://www.calmis.cahwnet.gov/>.
8. The data on California employed workers can be found in the 1998 *California Statistical Abstract*, California Department of Finance (DOF) for years 1971-1997. Data for earlier years 1959-1971 were found in the 1973 California Statistical Abstract. Source: EDD, LMID, Information Services Group, (916) 262-2345, <http://www.calmis.cahwnet.gov/>.
9. The data on the California excise tax revenue from the sale of cigarettes can be found in the 1997-98 *Annual Report – State Board of Equalization*, Table 30A.
10. The data on the California annual distributions of cigarette packages can be found in the 1997-98 *Annual Report – State Board of Equalization*, Table 30B.
11. The data on California civilian population as of July 1 of each year can be found in the 1998 *California Statistical Abstract* and in the 1997 *California Statistical Abstract*. Source: California Dept. of Finance, Demographic Research Unit, (916) 322-4651, <http://www.dof.ca.gov/>.
12. The data on U.S. taxable cigarette removals, as millions of packages, can be found at the U.S. Department of Agriculture, Economic Research Service web site: <http://www.econ.ag.gov/briefing/tobacco/Table1.htm>, updated Sept 21, 1998.
13. The data on U.S. civilian population as of July 1 of each year can be found in the *Statistical Abstract of the United States* 1996 from 1959 through 1990, available from the U.S. Department of Commerce, Bureau of the Census. Revised data from 1990 through 1998 were downloaded from the U.S. Census web site, <http://www.census.gov/population/estimates/nation/intfile1-1.txt>, updated December 28, 1998.

Table 3: Nonlinear Least Squares Model Summary Statistics					
Variable Description	Parameter	Estimate	Asymptotic Standard Error	Lower Bound 95% Confidence Interval	Upper Bound 95% Confidence Interval
Trend Multiplier	B0	0.96531	0.0044	0.9563	0.9743
CA Excise Tax	B1	-0.08946	0.0178	-0.1257	-0.0532
US Excise Tax	B2	-0.15505	0.0452	-0.2473	-0.0628
Retail Product Price	B3	-0.00935	0.0548	-0.1210	0.1023
Wages & Salaries	B4	0.50279	0.2210	0.0520	0.9536
Employment Rate	B5	-1.12472	0.5033	-2.1511	-0.0983
Pre-1966 Indicator	B6	0.00952	0.0045	0.0003	0.0188
Adjusted R squared	0.63				
Autocorrelation Coefficient	-0.36				

Table 4: Observed and Estimated Cigarette Consumption in California (Using the Nonlinear Model for Estimates, With Proposition 10 Tax)			
Fiscal Year	Observed Packs Per Person	Estimated Packs Per Person	Difference (Observed - Estimated) Packs per Person
1980-81	120.1	116.9	3.2
1981-82	117.1	118.7	-1.6
1982-83	112.6	109.6	3.0
1983-84	106.8	105.5	1.3
1984-85	104.7	103.9	0.8
1985-86	100.8	102.5	-1.7
1986-87	97.0	98.4	-1.4
1987-88	93.7	94.5	-0.8
Proposition 99 (25-cent per pack tax increase, effective 1/1/89)			
1988-89	83.7	85.1	-1.4
1989-90	76.9	78.0	-1.1
1990-91	70.8	73.9	-3.1
1991-92	67.7	67.9	-0.2
1992-93	62.1	65.3	-3.2
1993-94	58.2	58.5	-0.3
1994-95	56.8	55.9	0.9
1995-96	54.7	55.2	-0.5
1996-97	53.3	53.5	-0.2
1997-98	50.8	52.1	-1.3