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Technical Notes

On the Estimation of Smuggling in a "Gray Market" Commodity

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This note develops a method for estimating the amount of cigarette smuggling occurring among the various states. This particular organized crime is termed a "gray market" activity because the commodity is not illegal but is differentially taxed by the states, thus leading to illegal importing from low-tax states to high-tax states. Sales tax, demographic, and geographic data are combined in a mathematical model of the smuggling operation, which is used to estimate the amount of smuggling into a state and its impact on the state's revenue. It should be useful in determining the effectiveness of programs aimed at reducing cigarette smuggling.

ONE OF THE major problems in studying crime is the lack of knowledge of the total universe, of how much total crime of a certain type has occurred. Only about half of the crimes with an identifiable victim are reported to the police (see references 2 and 4). For "victimless" crimes such as prostitution, drug peddling, or black marketeering, the reporting rate is very low since both parties want to keep the transaction secret.

This is also true for transactions in some legal commodities, such as cigarettes and liquor. They are termed "gray market" commodities because they are neither illegal nor rationed (as in a black market) but are differentially taxed by the states. The tax differences are sufficiently great to create a market for smuggled cigarettes—one truckload of cigarettes of 3000 cubic feet bought legally in North Carolina (tax, 2¢/pack) and sold in Connecticut (tax, 21¢/pack) will bring a gross profit of over $100,000 from the tax difference alone (see Note 1).

Federal funds are being spent on programs to reduce cigarette smuggling. Evaluations of these programs usually rely on official statistics of seizures of bootleg cigarettes or arrests of the smugglers. However, our experiences

during Prohibition and, more recently, in the war on narcotics have shown us that these statistics have no relation to the extent of the problem being attacked.

This note develops a model for estimating the extent of cigarette smuggling in the United States. It is based on determining the difference between tax-paid sales and estimated consumption for each state (see Note 2). The variation in sales is considerable, and varies approximately inversely with state tax (see Table I). Since the aggregate demand for cigarettes has been increasing along with the price of cigarettes (Table II), I assume that the elasticity is in *sales*, not *consumption* (see Note 3). The difference, then, is attributed to smuggling.

I consider two modes of smuggling: "casual" smuggling, by smokers or small-time smugglers, across the borders of contiguous states; and "organized" smuggling, by major smugglers, between any two pairs of states for which the trade is favorable.

The model is based on the following set of linear regression equations:

$$S_i = C_1 p_i + C_2 \sum_{j \in \mathrm{K}_i} f_\kappa(t_i, t_j) p_j + C_3 \sum_{j \in \Omega_i} f_\omega(t_i, t_j) p_j + C_4, \qquad i = 1, 2, \cdots, N,$$

where S_i is the tax-paid cigarette sales in state i; C_1 through C_4 are the regression constants; p_i is the population in state i (see Note 4); t_i is the tax imposed by state i; N is the number of jurisdictions, in this case 49 (see Note 2); f_κ and f_ω are the weighting functions for casual and organized smuggling, respectively, from state i to state j; K_i consists of those states that are contiguous to state i; and Ω_i consists of those states that might import from state i, depending on the relative distances and tax differentials, as described below.

The cost of transporting the cigarettes is assumed to play an indirect part in the organized smuggling term. The transportation cost is very small compared to the tax differences, but the interstate distances should still dictate which states are potential exporters and which are not. The distances are calculated from border to border, assuming that each state is a "cookie-cutter," a circle whose radius is $(\text{area}/\pi)^{1/2}$ centered on the state's geographic midpoint. A state i is a possible exporter to state j if (1) its tax is lower than state j's, and (2) there are no states closer to state j with taxes equal to or lower than state i (see Note 5).

The functions f_κ and f_ω in the regression equation can be of many forms. We assume first that the amount of smuggling is proportional only to the tax difference rather than to the actual levels of tax in each state. We further assume that there is a threshold effect; i.e., below a certain tax difference little smuggling goes on. The functional form is the delayed ramp function, which is used for both f_κ and f_ω: $f_\kappa(t_i, t_j) = f(t_j - t_i, \theta_\kappa)$ and $f_\omega(t_i, t_j) = f(t_j - t_i, \theta_\omega)$, where $f(t, \theta) = 0$ for $t \leqq \theta$ and $f(t, \theta) = t - \theta, t > \theta$.

Our results were obtained with the delayed ramp function, with the threshold set at the value that reduces the residual (in the regression equation) to the smallest value. We obtained population data from reference 7, cigarette sales and tax data from reference 6, and geographic data

TABLE I

1973 Cigarette Taxes and Sales, and Estimates of States Present Cigarette Revenue and Amount Lost (or Gained) Because of Smuggling

State	State tax (¢/pack)*	Per capita sales (packs)*	Tax-paid sales (billions of packs)*	Present tax revenue ($millions)*	Revenue from smuggling ($millions)	Revenue with no smuggling ($millions)	Percentage of present revenue gained or lost (−) because of smuggling
NC	0.02	226.5	1.1812	23.62	10.01	13.61	42.37
VA	0.025	143.1	0.6817	17.04	6.61	10.43	38.79
KY	0.03	201.9	0.6661	19.98	8.24	11.73	41.27
DC†	0.05	209.4	0.1566	7.83	−0.03	7.86	−0.46
CO	0.05	137.9	0.3251	16.25	2.54	13.70	15.67
SC	0.06	125.5	0.3344	20.06	0.73	19.32	3.66
MD	0.06	137.3	0.5570	33.42	7.07	26.34	21.16
IN	0.06	156.0	0.8256	49.53	8.05	41.47	16.26
WY	0.08	141.2	0.0487	3.89	0.43	3.45	11.26
UT	0.08	72.7	0.0819	6.55	0.04	6.50	0.74
OR	0.09	155.3	0.3388	30.49	1.33	29.15	4.36
MO	0.09	132.1	0.6278	56.50	1.13	55.37	2.00
ID	0.091	121.8	0.0921	8.38	1.31	7.06	15.69
NV	0.10	201.5	0.1062	10.61	−0.10	10.72	−1.02
CA	0.10	124.4	2.5463	254.62	−3.50	258.13	−1.37
AZ	0.10	128.3	0.2496	24.95	−0.81	25.77	−3.24
ND	0.11	108.7	0.0687	7.55	1.48	6.06	19.70
NH	0.11	279.0	0.2151	23.66	−0.22	23.89	−0.96
MS	0.11	115.0	0.2603	28.63	0.68	27.95	2.38
MI	0.11	133.7	1.2146	133.60	−4.39	138.00	−3.29
LA	0.11	126.7	0.4715	51.86	6.53	45.33	12.59
KS	0.11	115.2	0.2601	28.61	−1.27	29.88	−4.45
WV	0.12	116.6	0.2077	24.92	1.68	23.23	6.76
VT	0.12	146.8	0.0678	8.13	2.03	6.09	25.05
SD	0.12	103.5	0.0703	8.43	1.37	7.05	16.35
NM	0.12	98.9	0.1053	12.63	4.53	8.10	35.89
MT	0.12	119.9	0.0862	10.34	−0.35	10.69	−3.42
IL	0.12	124.4	1.3991	167.89	−16.06	183.95	−9.56
GA	0.12	119.8	0.5655	67.85	−3.77	71.63	−5.56
AL	0.12	102.9	0.3611	43.33	1.44	41.88	3.33

TABLE I—*Continued*

State	State tax (¢/pack)*	Per capita sales (packs)*	Tax-paid sales (billions of packs)*	Present tax revenue ($millions)*	Revenue from smuggling ($millions)	Revenue with no smuggling ($millions)	Percentage of present revenue gained or lost(−) because of smuggling
TN	0.13	109.7	0.4423	57.49	−13.13	70.62	−22.83
RI	0.13	142.0	0.1375	17.87	2.06	15.80	11.56
OK	0.13	124.1	0.3268	42.48	1.70	40.77	4.02
NB	0.13	106.6	0.1625	21.12	−2.42	23.55	−11.48
IA	0.13	110.6	0.3188	41.44	0.07	41.36	0.18
ME	0.14	138.0	0.1420	19.87	−0.75	20.63	−3.81
DE	0.14	154.7	0.0874	12.23	4.42	7.81	36.12
OH	0.15	120.5	1.2992	194.87	−36.38	231.26	−18.67
NY	0.15	118.7	2.1792	326.87	−11.62	338.50	−3.55
WI	0.16	109.5	0.4950	79.19	−8.97	88.17	−11.32
WA	0.16	91.0	0.3132	50.11	−6.52	56.63	−13.01
MA	0.16	121.2	0.7011	112.17	−6.02	118.20	−5.37
FL	0.17	132.6	0.9625	163.62	−10.36	173.98	−6.33
AR	0.1775	108.0	0.2136	37.91	−7.84	45.75	−20.69
PA	0.18	110.7	1.3200	237.59	−48.17	285.77	−20.27
MN	0.18	106.8	0.4159	74.86	−17.58	92.44	−23.48
TX	0.185	110.4	1.2863	237.96	−32.78	270.75	−13.77
NJ	0.19	120.2	0.8856	168.26	−15.55	183.82	−9.24
CT	0.21	109.3	0.3368	70.72	−12.56	83.29	−17.76
Nat'l avg.		135.1					

* Source: reference 6.

† The DC tax rate went from 4¢/pack to 6¢/pack on December 1, 1972. We used a 5¢ tax rate in our computations.

from reference 8. The computer program for the regression was taken from reference 1.

If a least-squares fit of state cigarette sales data is made only to state population ($C_2 = C_3 = 0$), we obtain an excellent fit ($t = 34.8, p < 0.001$), with a correlation coefficient of 0.981. Thus, all but about 4 percent of the variation in the sales data is explained by population differences. However, further inspection of the data showed that the residuals were far from randomly distributed—a random distribution would tend to approach a straight line in Fig. 1, on the "probability paper" coordinates used. The states with the three highest residuals are North Carolina, Kentucky, and Indiana, all of which have relatively low taxes and are considered the

sources of cigarettes smuggled illegally into New York, Ohio, and Illinois, respectively.

By including the second and third terms in the regression equation, we obtain a major improvement in the fit (all but 1 percent of the variation in sales data can now be explained), and the cumulative distribution of the

TABLE II

NATIONAL PER CAPITA CIGARETTE SALES, 1900–1974*

Year	Sales
1900	1.7
1910	4.0
1920	23.8
1930	48.8
1940	67.4
1950	119.5
1955	116.1
1960	132.3
1961	133.2
1962	133.4
1963	135.4
1964†	131.3
1965	135.1
1966	133.1
1967	134.0
1968	132.0
1969	130.2
1970	126.7
1971	132.4
1972	131.6
1973	135.1
1974	141.7

* Source: reference 6.

† Year of publication of *Smoking and Health* by the U. S. Surgeon General.

residuals now suggests that the unexplained variation is of a random nature (Fig. 2).

The coefficients of the regression equation were found to be: $C_1 = 0.1596$, $C_2 = 0.1049$, $C_3 = 0.0283$, and $C_4 = -0.00867$. When these are substituted into the equation, we can solve for the net estimated imports to or exports from each state. These are listed in Table I. I should emphasize the fact that these figures are only estimates based on an admittedly crude model that neglects some important factors and assumes away others. However, they should be useful as first approximations and can be quite useful in deter-

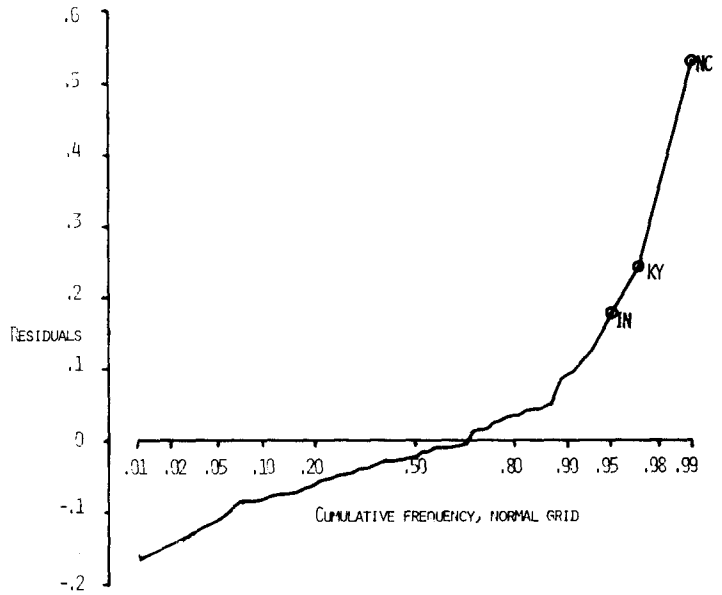

Fig. 1. Cumulative distribution of residuals, fitting sales data to population data.

mining how alternative taxing policies affect both total state revenue and the prevalence of smuggling.

Some areas for further research are suggested by this study. First, the model should be tested against data for other years. Second, the model

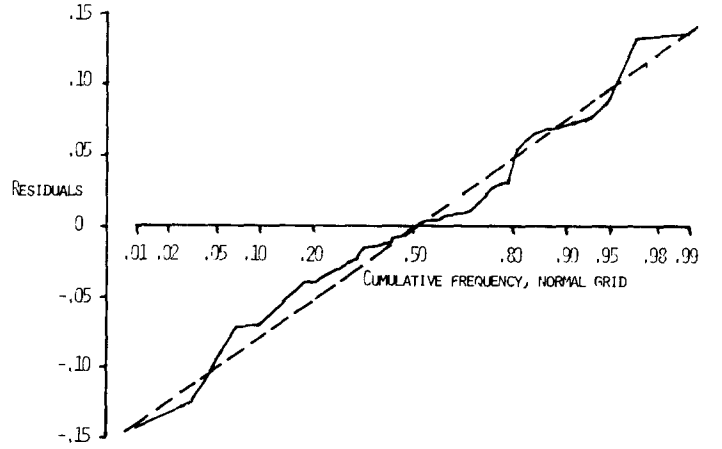

Fig. 2. Cumulative distribution of residuals, fitting sales data to population data and using smuggling terms.

could be modified to include the effects of state enforcement activity on cigarette smuggling. Third, other "gray market" areas might also be investigated by the same approach; in particular, the market for liquor or for illegally purchased ethical drugs could be examined to estimate the extent of smuggling in these commodities. Evaluations based on models such as this may become more prevalent as greater emphasis is placed on combatting economic crimes.

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NOTES

1. Actually, there are even greater tax differentials, since many cities and counties impose additional taxes on cigarettes [5]. Among these are New York City and Chicago, which impose taxes of 8¢ and 5¢ per pack, respectively. (Until early 1976, New York City's tax was 4¢ and up to an additional 4¢, depending on a brand's nicotine and "tar" content; the additional tax is now imposed uniformly.)
2. This study does not include Alaska and Hawaii but does include the District of Columbia. Excluded also are cigarettes sold through military PX's, Indian reservations, and international ports of entry.
3. Figure 2 shows the relative inelasticity in aggregate demand for cigarettes, which Sullivan [5] has also pointed out. The Tobacco Tax Council feels that the demand is quite elastic. However, as their explanation makes clear, they are referring to *state-specific* demand, not to *aggregate* demand:

   > "Contrary to the thinking of economists of the past, the demand for cigarets is quite elastic. Simply stated the demand for cigarets in a given community is directly influenced by the market price of cigarets. Consumers have already demonstrated their unwillingness to buy cigarets in a community in which tax rates on cigarets are high. They have several alternative choices. They can cut down or abandon their use of cigarets, they can cross political boundaries where cigaret taxes are lower, or they can acquire their cigarets from sources which by one means or another avoid the heavy burden of the tax in their own communities" (reference 6, page iv).

   It does not appear that many people are taking the first alternative. Cigarette consumption has increased steadily over the years despite frequent and major tax increases.

4. The population figures used in the model are the over-15 populations of each state. It would be more accurate to obtain a breakdown of smokers by age, race, religion, and other such factors and weight the population in each state according to the specific characteristics. For example, Utah and Hawaii have the two lowest per capita cigarette sales. In neither case would it be reasonable to attribute it to smuggling since the religious and ethnic character of these states are so unlike that of the other states. Since it has been impossible thus far to obtain the socioeconomic characteristics of smokers, eliminating the population under 16 is the only concession made to nonsmokers. Since Hawaii is not included in this study and Utah has a small population, the results should not be greatly affected.
5. We estimated the distance between states by converting the latitude and longitude of state midpoints into miles (assuming that the states are on a cartesian plane), calculating the distance between midpoints, and subtracting the effective radii of the two states from the distance. This approximation of border-to-border distance should be adequate for the intended purpose, ordering the states by distance. To compensate for any inaccuracies in this approximation, if two distances to be compared are calculated to be within 150 mi of each other, they are considered equally likely as smuggling routes.

REFERENCES

1. C. Daniel and F. S. Wood, *Fitting Equations to Data*, John Wiley & Sons, New York, 1971.
2. P. H. Ennis, *Criminal Victimization in the United States: A Report of a National Survey*, U. S. Government Printing Office, Washington, D.C., 1967.
3. M. D. Maltz, H. Edelhertz, and H. H. Chamberlain, *Law Enforcement Guide: Combatting Cigarette Smuggling*, Law Enforcement Assistance Administration, U. S. Department of Justice, Washington, D. C., January 1976.
4. National Criminal Justice Information and Statistics Service, *Criminal Victimization in the United States, January–June 1973*, Volume I, Law Enforcement Assistance Administration, U. S. Department of Justice, Washington, D.C., November 1974.
5. R. F. Sullivan, "The Economic Organization of the Nicotine, Heroin and Other Drug Industries," *Drug Issues*, **3**, 231–239 (Summer 1973).
6. *The Tax Burden on Tobacco*, Tobacco Tax Council, Richmond, Va., 1974.
7. U. S. Bureau of the Census, *Statistical Abstract of the United States: 1973*, U. S. Government Printing Office, Washington, D.C., 1973.
8. U.S. Department of the Interior, Geological Survey, *The National Atlas of the United States of America*, U. S. Government Printing Office, Washington, D.C., 1970.