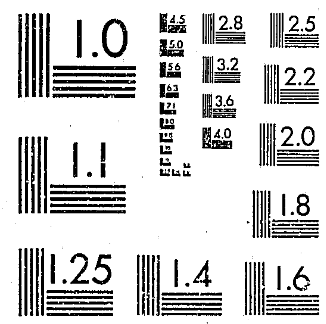

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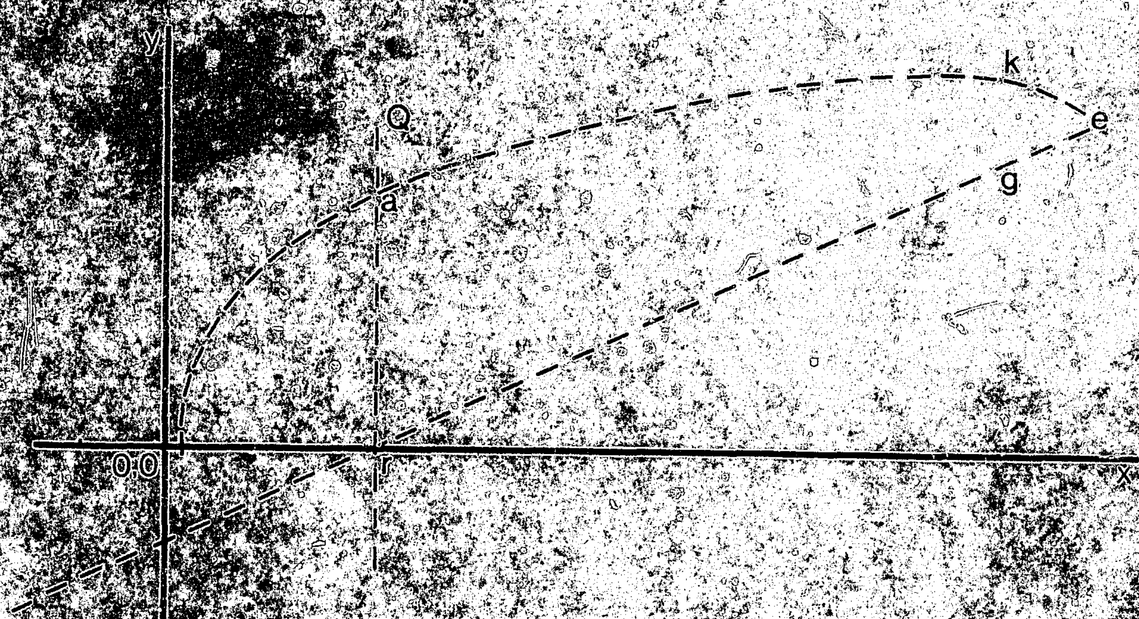
Criminal Justice Statistics Association Incorporated



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AN ECONOMETRIC MODEL OF CIGARETTE SMUGGLING DETERRENCE

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ABSTRACT

This paper examines four full-time investigators' impact on cigarette smuggling deterrence in Minnesota by estimation of an economic market model over the preinvestigator period. The simultaneous equation model estimated by two-stage least squares technique is composed of a supply equation and a demand equation where the levels of cigarette supply and demand are measured by cigarette taxes collected. It is found that cigarette prices have a significant effect on cigarette supply but not upon cigarette demand. Neither the personal income level, population level, nor legislative attempts to alter smoking habits have had a significant effect on cigarette taxes collected prior to July, 1976. Using this model, cigarette tax revenues are projected beyond July, 1976, and are compared to actual tax revenues collected over the same period. Unfortunately, the statistical error found around the predicted revenue levels is too large to gauge whether or not the investigators have met their goal of raising cigarette tax revenues by $500,000 per year.

I. INTRODUCTION

Minnesota loses an estimated $12.2 million per year in foregone cigarette taxes [1][2] due to the activities of cigarette smugglers. For this reason, the Minnesota Department of Revenue hired two full-time investigators who began their antismuggling operations in July, 1976, and who were subsequently joined in July, 1977, by another two full-time investigators funded by an LEAA grant awarded by the Minnesota Crime Control

[1]This research was supported by LEAA grant #77 AF AX 0027 awarded to the Evaluation Unit by the Minnesota Crime Control Planning Board. Points of view and opinions stated are those of the author and do not necessarily represent the official positions or policies of the Minnesota Crime Control Planning Board.

[2]Numbers in brackets denote references listed at the end of the paper.

Planning Board. All investigators try also to reduce liquor smuggling; however, only the effect of cigarette smuggling deterrence will be examined in this paper. Over the first project year, a goal of raising liquor and cigarette tax revenues by $500,000 has been set. For this paper, an optimistic increase in cigarette tax revenues alone by $500,000 has been assumed as the project goal. This revenue increase is expected to occur as the activities of the investigators force a decrease in untaxed liquor and cigarettes thereby forcing more purchasers into the legitimate (taxed) market for such products. The model that follows describes the components of the market for cigarettes.

II. THE SUPPLY AND DEMAND FOR CIGARETTES

According to economic theory, the interaction of the supply and demand for cigarettes in the legitimate market determines cigarette sales. Cigarette supply (V_s) depends on production cost (*COST*) and cigarette price net of taxes (*PRICE*) while cigarette demand (V_d) is determined by cigarette price net of taxes (*PRICE*), consumer income (*INC*), the cigarette tax rate (*TAX*), personal tastes (*TASTE*), and population (*POP*). These relationships[1] are described below.

(1) $V_s = f(\mathit{PRICE}, \mathit{COST})$

(2) $V_d = g(\mathit{PRICE}, \mathit{INC}, \mathit{TAX}, \mathit{TASTE}, \mathit{POP})$

(3) $V_s = V_d$

Equation (1) describes the cigarette volume supplied; equation (2) describes the cigarette volume demanded; and equation (3) denotes the condition for market clearance; namely, that the amount of the product supplied is equal to the quantity of the product purchased by consumers.

In the demand equation, the incidence of the cigarette tax is expected to fall solely on consumers given that the cigarette tax industry has been found by others to be a constant cost industry with the ability to pass such taxes along to consumers [2] [3]. A binary variable (*TASTES*) is used to denote implementation of the Minnesota Clean Air Act which restricts smoking in public areas. The population variable is used to capture growth in the number of smokers over time.

The economic theory of markets provides some information concerning the expected signs of each equation's variable coefficients [4] [5]. In the supply equation, economic theory predicts that the price coefficient should be positive (a higher price encourages suppliers to produce more goods) while the cost coefficient should be negative (higher production costs reduce production efficiency and cause suppliers to produce less at each price level). In the estimated demand equation, economic theory indicates that the price coefficient should be negative (higher prices cause consumers to buy less) and that the income coefficient should be

[1]This model is based upon a preliminary model developed by Charles M. Gray, Ph.D., (Evaluation Unit, Minnesota Crime Control Planning Board).

positive (higher income levels increase product purchases).

These equations, estimated using preprogram data, will be used to forecast cigarette volume. If the program under consideration is the only major influence absent in the model, then the predicted volume is that volume which would be expected *in the absence* of an antismuggling program. Actual cigarette sales volumes will be compared to predicted sales volumes. Program success is gauged by the difference between actual and predicted sales after taking into account the statistical error bound around the predicted values. The technique used to estimate these equations follows.

III. ECONOMETRIC TECHNIQUE

To estimate equations (1) and (2) over the preprogram period, these equations are expressed in linear form as follows:

(4) $V_s = a_0 + a_1 PRICE + a_2 COST$

(5) $V_d = b_0 + b_1 PRICE + b_2 INC + b_3 TAX + b_4 TASTES + b_5 POP$

where $V_s = V_d = V$.

These equations form a simultaneous equation model because of the jointly determined (or endogenous) variables, *V* and *PRICE*. To estimate the coefficients for each equation's variables using ordinary least squares techniques would lead to inconsistent estimators for the coefficients since such estimators would be correlated with the residuals of the estimated equations. Thus, since not all variables on the right-hand side of each equation are independent, an alternative estimation technique must be used to solve this equation system.

The technique used to avoid the above identification problem is two-stage least squares [6]. This statistical method first estimates a price vector as a function of all independent variables and then estimates equations (4) and (5) using this price vector. In this manner, consistent estimates for all coefficients are derived.

Using these estimated equations, predicted values for cigarette sales over the program period can be calculated by inserting the observed values for the right-hand side variables during the program period into the estimated equations.

IV. STATISTICAL RESULTS

Equations (4) and (5) were estimated using quarterly data over the period, first quarter, 1968 to second quarter, 1976. In particular, the following quarterly data were used:

1. *V*--Minnesota cigarette tax revenue in thousands of dollars [7],

2. *PRICE*--Minimum retail price for one carton of regular cigarettes [8],
3. *COST*--Quarterly interpolations of hourly wages in wholesale and retail trade [9] [10] [11] [12],
4. *INC*--Minnesota total personal income [13],
5. *TAX*--Minnesota cigarette tax rate [14],
6. *TASTES*--Binary variable for implementation of the Minnesota Clean Air Act:
   TASTES = 0 before 3rd quarter, 1975
   TASTES = 1 after 3rd quarter, 1975, and
7. *POP*--Estimates of Minnesota population (aged 16 and over) derived from applying national quarterly trends in population to Minnesota's adjusted annual population figures. Annual Minnesota population data were available for the age groups 15+ and 15-19 years. These figures were adjusted by examining each year's 15-year-old age cohort's impact on past census figures. In each year, the 15-year-old age group is found by assuming it is the same proportion of the 15-19 year-old group as the proportion formed by these two age groups' cohorts in the past census, and it is then subtracted from the group aged 15+ to form the group aged 16+ (see [15] [16] [17] [18] and [19]).

The personal income variable was available only in seasonally adjusted form. All other figures were not seasonally adjusted (see [20] for the reason).

During initial estimation of the demand function, the *TASTES* and *POP* variables had positive coefficients but were not statistically significant. It was found that by dropping these two variables, the explanatory value of the subsequently estimated equation as measured by the coefficient of determination corrected for degrees of freedom ($\bar{R}^2$) was virtually unaffected. Hence, the revised demand equation for which results are presented is:

(6) $V = c_0 + c_1 INC + c_2 PRICE + c_3 TAX.$

The results for the estimated supply and demand equations follow. Gross tax revenue as the dependent variable resulted in a higher $\bar{R}^2$ than using cigarette packs taxed. Hence, gross tax revenue is used as the dependent variable.

Table IV.1 presents results of the model's statistical estimation. Even though a majority of the coefficients (except the coefficient for *TAX*) have the correct sign according to economic theory, only two coefficients in the supply equation (for *PRICE* and the constant) and only one coefficient in the demand equation (for *TAX*) are statistically significant. When all coefficients in each equation are examined together under an *F* test, it is found that the test statistics are significant at the

1 percent level. Thus, the separate contribution of each variable to explaining variation in tax revenue may be weak but their joint contribution is quite strong. The Durbin-Watson statistic indicates the absence of autoregression in the disturbance term of each equation [21], i.e., there appears to be no unexplained influences acting upon the dependent variable. The total contribution of each equation's variables toward explaining variation in the tax collected is found by examining the $\bar{R}^2$. In the demand equation, $\bar{R}^2$ is 0.91 while in the supply equation, it is 0.88. Hence, the demand equation does a better job in explaining variations in the dependent variable than the supply equation. The Standard Error of Estimate (S.E.E.) indicates the statistical error inherent in each estimated equation. Cigarette tax forecasts based upon the estimated demand equation are presented since this equation has a higher $\bar{R}^2$ and a lower S.E.E. than the estimated supply equation.

TABLE IV.1

STATISTICAL RESULTS OF THE SUPPLY-DEMAND MODEL[a,b]

A. ESTIMATED SUPPLY EQUATION

$$V_s = -1276337\ COST + 7466440\ PRICE - 9257188$$
$$(-0.886) \quad (5.906)^c \quad (-5.247)^c$$

$\bar{R}^2 = 0.88$
$F = 121$
Durbin-Watson statistic = 1.87
$S.E.E.$ = 1,569,657

B. ESTIMATED (revised) DEMAND EQUATION[d]

$$V_d = 380\ INC - 296910\ PRICE + 84937371\ TAX - 2431900$$
$$(1.566) \quad (-0.096) \quad (2.348)^c \quad (-0.681)$$

$\bar{R}^2 = 0.91$
$F = 117$
Durbin-Watson statistic = 2.06
$S.E.E.$ = 1,330,109

[a]Each equation was estimated using quarterly data over the period 1/68-2/76. The numbers in parentheses are t statistics.

[b]The levels of cigarette supply and demand volumes (V_s, V_d) are measured by cigarette taxes collected. Hence, the dependent variable is cigarette taxes.

[c]Significant at the 5 percent level using a 2-tailed t test.

[d]The *TASTES* and *POP* variables were dropped from the demand equation due to their estimated coefficients' low t statistics and their minor contribution to $\bar{R}^2$.

The predicted tax revenue figures in Table IV.2 result when values for the variables *INC*, *PRICE*, and *TAX* are inserted into the estimated demand equation for each quarter of program operation.

TABLE IV.2

ACTUAL CIGARETTE TAX COLLECTIONS, DEMAND EQUATION CIGARETTE TAX PREDICTIONS, AND TAX PREDICTION ERROR TERMS
(millions of dollars)

QUARTER/YEAR	ACTUAL CIGARETTE TAX REVENUES[a]	PREDICTED CIGARETTE TAX REVENUES[a]	PREDICTION ERROR
3rd/76	22.153	20.762	1.468
4th/76	20.435	20.920	1.563
1st/77	19.823	21.229	1.542
2nd/77	21.273	21.498	1.677
3rd/77	22.595	21.635	1.658
4th/77	20.965	22.045	1.705

[a]Direct comparisons should *not* be made between actual and projected cigarette revenues due to the absence of a seasonal adjustment to the dependent variable in the estimated equation (see text).

Since any estimated equation has some statistical error associated with it and such errors become larger as one projects the dependent variable farther into the future, a prediction error term [22] was calculated for each quarter over which cigarette tax revenues were projected. Conclusions drawn by comparing actual and predicted tax revenues together with the prediction error size are presented in the next section.

V. CONCLUSIONS

The following conclusions may be drawn from Table IV.1:

1. The model tends to underpredict revenues in the third quarter and overpredict revenues in all other quarters. Hence, the decision not to correct the dependent variable (cigarette tax revenues) for seasonal changes was unwise. Such seasonal variation in the dependent variable also causes problems with the prediction error term calculations. Such error terms should become larger the farther the prediction period from the period over which the equation was estimated. This is not true in Table IV.2.

2. Even though the $\bar{R}^2$ for the demand equation is quite high (0.91), the sheer magnitude of the quarterly prediction error terms (between \$1 million and \$2 million), while at most only 8 percent of predicted tax revenues, is large compared to the project's goal of raising cigarette tax revenue by \$500,000 *per year*. Assuming the project raises cigarette tax revenues by \$125,000 per quarter, this amounts to only 0.5 percent of quarterly cigarette tax revenue. Hence, the model estimated would have to possess a statistical error term much lower than 0.5 percent of

total revenue predicted in order to aid in the evaluation of the project.

In summary, in view of the prediction error terms' magnitude compared to the project's goal, the tax forecast model formulated must be reassessed. Subsequent attempted models will take into account seasonal variation in tax revenues and/or the use of dummy variables for investigator impact. Also, since the cigarette tax revenue lost by Minnesota each year is estimated at $12.5 million, is reducing this loss by 4 percent each year or $500,000 a realistic goal for the project (which can be evaluated)? Therefore, the model presented here, like many research undertakings, raises more questions than it answers.

REFERENCES

[1]. Advisory Commission in Intergovernmental Relations, *Cigarette Bootlegging: A State and Federal Responsibility* (Washington, D.C.: Advisory Commission on Intergovernmental Relations, 1977), Table 19.

[2]. Paul B. Manchester, "An Econometric Analysis of State Cigarette Taxes, Prices, and Demand with Estimates of Tax-Induced Interstate Bootlegging." Unpublished Ph.D. dissertation, University of Minnesota, 1973, pp. 8-9.

[3]. Richard A. Musgrave, *The Theory of Public Finance* (New York: McGraw-Hill, 1959), pp. 290-291.

[4]. George J. Stigler, *The Theory of Price* (3rd Edition) (New York: Macmillan, 1966), pp. 21-29.

[5]. Jack Hirshleifer, *Price Theory and Applications* (Englewood Cliffs, N.J.: Prentice-Hall, 1976), pp. 22-38.

[6]. G. S. Maddala, *Econometrics* (New York: McGraw-Hill, 1977), pp. 220-233.

[7]. Tobacco Tax Council, *State Cigarette Taxes and Tax-Paid Volume* (Richmond, Va.: Tobacco Tax Council), monthly reports--January, 1968, to December, 1977.

[8]. Minnesota Department of Revenue--Alcohol, Tobacco, and Special Taxes Division, *Minimum Retail Cigarette Prices (1968-1978)*. (Typewritten.)

[9]. Paul B. Manchester, "An Econometric Analysis of State Cigarette Taxes, Prices, and Demand with Estimates of Tax-Induced Interstate Bootlegging." Unpublished Ph.D. dissertation, University of Minnesota, 1973, pp. 21-22.

[10]. U.S. Department of Labor, *Employment and Earnings*, XXIV(5), 1977, p. 81.

[11]. U.S. Bureau of the Census, *Census of Population: 1960*, I (25D), 1965, Table 130.

[12]. U.S. Bureau of the Census, *Census of Population: 1970*, I (25D), 1973, Table 188 and Table 189.

[13]. U.S. Department of Commerce, *Survey of Current Business*, LI(10), 1971, p. 18. Also, subsequent issues: LII(7), 1972, p. 6; LV(10), 1975, p. 28; LVII(7), 1977, p. 14; LVIII(4), 1978, p. 19.

[14]. Minnesota Department of Revenue--Alcohol, Tobacco, and Special Taxes Division, *Cigarette Tax Rate (1968-1978)*. (Typewritten.)

[15]. Minnesota State Board of Health, *Vital Statistics, 1968*. Also subsequent annual reports for 1969, 1970, and 1971.

[16]. Minnesota Health Department, *Minnesota Health Statistics, 1972*. Also, subsequent annual reports for 1973, 1974, and 1975 (data beyond 1975--unpublished form).

[17]. U.S. Bureau of the Census, *Current Population Reports*, P-25 (706), 1977, p. 11. Also, subsequent issue: P-25(724), 1978, p. 2.

[18]. U.S. Bureau of the Census, *Census of Population: 1960*, I (25B), 1963, Table 16.

[19]. U.S. Bureau of the Census, *Census of Population: 1970*, I (25B), 1973, Table 19.

[20]. Paul G. Hoel, *Elementary Statistics* (2nd Edition) (New York: John Wiley & Sons, 1966), pp. 291-294.

[21]. Jan Kmenta, *Elements of Econometrics* (New York: Macmillan, 1971), pp. 295-297.

[22]. Ibid., pp. 374-376.

END