

AN ECONOMETRIC MODEL OF THE PRINCE EDWARD ISLAND TAX SECTOR

P. Nagarajan*
University of Prince Edward Island

Introduction

The purpose of this investigation is to develop an econometric model of the Prince Edward Island (P.E.I.) tax sector that may be used to forecast the general tax revenues of the province. The model is designed to estimate the impact on certain P.E.I. economic variables as the result of the changes in selected exogenous variables. The specification of a 14-equation tax model and its schematic diagram are presented in the following section. The third section contains the estimation of the structural equations of the model, and in the fourth the reduced form equations of the tax model are presented. The fifth section contains simulation of the model and model validation test statistics. Finally, the impact analysis and projections of tax revenues are presented.

Specification of the Model

A simultaneous equation model is specified to describe the tax sector of the P.E.I. economy. A schematic diagram showing the behavioral relationships among the variables is presented in Figure 1. The model presented here involves 14 equations (13 behavioral and 1 identity type); 5 are used as supporting equations for the remaining 9, which are used to estimate the total tax revenue and its components. The general structure of the model is as follows:

$$(1) \quad RS = f(PY, T_1)$$

$$(2) \quad N = f(POP, RS, \Delta GNP)$$

$$(3) \quad VR = f(PY, VR_{t-1})$$

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- (4) $PY = f(N, AVW, PY_{t-1})$
 (5) $PRT = f(PRT_{t-1}, Dum1)$
 (6) $ERPYT = f(PY, PYTR)$
 (7) $PYT = f(ERPYT, PYT_{t-1})$
 (8) $ST = f(\Delta VR, RS, STR)$
 (9) $ABUT = f(N)$
 (10) $TOBT = f(PY, Dum2)$
 (11) $GAST = f(VR, Dum3)$
 (12) $ABT = f(PY, T_2)$
 (13) $AOT = f(PY, Dum4)$
 (14) $GTR = ST + PYT + PRT + GAST +$
 $ABUT + TOBT + ABT + AOT$

The endogenous variables of the model are:

- ABT alcoholic beverages tax revenue
 ABUT all business tax revenue
 AOT all other tax revenue
 ERPYT effective rate of personal income tax
 GAST gasoline tax revenue
 GRT general tax revenue
 N employment
 PRT property tax revenue
 PY personal income
 PYT personal income tax revenue (provincial)
 RS retail sales
 ST sales tax revenue
 TOBT tobacco tax revenue
 VR vehicles registered

The exogenous and lagged variables of the model are:

- AVW average weekly wages
 ΔGNP change in gross national product
 (GNP-GNP_{t-1})
 POP population
 PRT_{t-1} property tax revenue in the previous year
 PY_{t-1} personal income in the previous year
 PYT_{t-1} personal income tax revenue in the previous
 year
 PYTR personal income tax rate (provincial)
 STR sales tax rate
 ΔVR change in vehicles registered (VR-VR_{t-1})
 VR_{t-1} vehicles registered in the previous year
 T time (linear trend element)
 Dum1 a dummy variable to observe the effect of
 changes in the property tax rate
 Dum2 a dummy variable to observe the effect of
 changes in the tobacco tax rate
 Dum3 a dummy variable to observe the effect of
 changes in the gasoline tax rate
 Dum4 a dummy variable to observe the effect of
 changes in the tax-base (introduction of new
 tax)

(The values used for four dummy variables in course of estimating the model for the 1959-1973 period are: Dum=1 for the years when there was a change in the tax rate; and Dum=0 for the years when there was no change in the tax rate.)

As can be seen from the specification of the model, employment is taken to depend on population, retail sales, and the change in gross national product. These explanatory variables were chosen to account for the potential number of employable persons in the province and the actual demand placed on this potential. The variable retail sales (a proxy for "economic activity") represents this demand from P.E.I., while ΔGNP represents the demand from outside the economy. The personal income is explained by relating it to employment, previous year's personal income, and average weekly wages. Personal income, directly or indirectly, is linked to several equations

of the model. For example, retail sales is expressed as a function of personal income and a trend variable. The number of vehicles registered is taken to depend on personal income and the previous year's stock of registered vehicles. Personal income is also used as one of the explanatory variables to explain the variations in tobacco tax revenue, alcoholic beverages tax revenue, and all other tax revenues, consisting of amusement tax, insurance premium tax, and so forth.

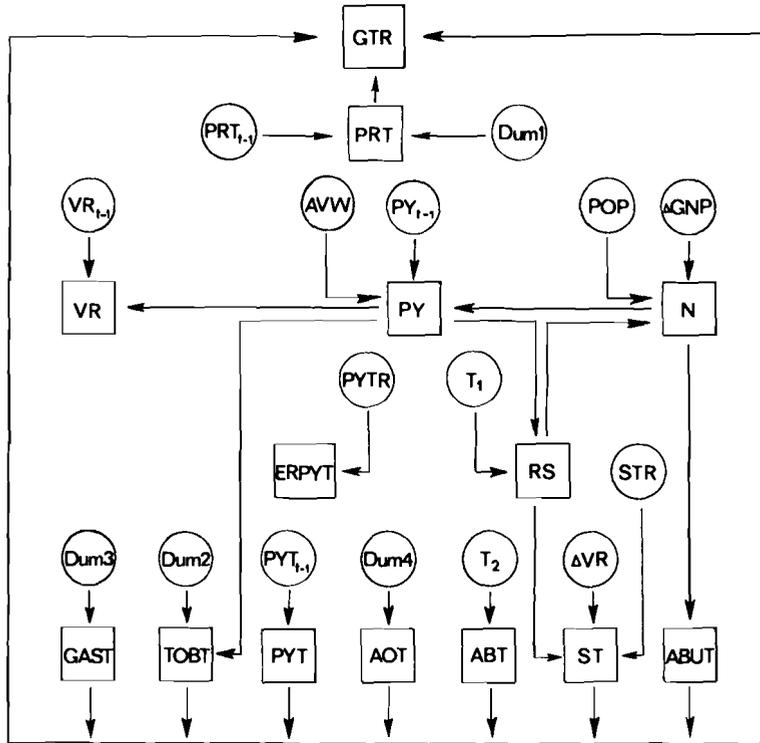


Figure 1
SCHEMATIC PRESENTATION—P.E.I. TAX MODEL

Estimation of the Model

The model is estimated by two-stage least squares method with annual data from the period 1959 - 1973. The tax revenues, personal income, and retail sales are expressed in millions of dollars; employment, population, and vehicles registered in thousands; and GNP in billions. The fitted equations with their t-ratios (numbers beneath the regression coefficients), the adjusted coefficient of multiple

determination, \bar{R}^2 , the Durbin-Watson statistic (D.W.), F, statistics, and standard error of the estimate (SEE) are given below:

- 1) $RS = 45 + 0.337PY + 1.26OT$
(6.5) (1.5)
 $\bar{R}^2 = 0.9854$ F = 405.0242 SEE = 3.9221 D.W. = 1.5428
- 2) $N = 11.36 + 0.169POP + 0.017RS + 0.353AGNP$
(1.50) (0.88) (2.38)
 $\bar{R}^2 = 0.9407$ F = 58.1696 SEE = 0.6621 D.W. = 2.6690
- 3) $VR = 4.08 + 0.0153PY + 0.836VR_{t-1}$
(2.57) (12.03)
 $\bar{R}^2 = 0.9935$ F = 928.9801 SEE = 0.5401 D.W. = 2.2030
- 4) $PY = -179.70 + 3.89N + 2.38AVW + 0.33PY_{t-1}$
(1.37) (2.59) (1.26)
 $\bar{R}^2 = 0.9929$ F = 515.6270 SEE = 6.8803 D.W. = 2.4181
- 5) $PRT = 0.28 + 1.02PRT_{t-1} - 4.09DUM1$
(9.95) (5.87)
 $\bar{R}^2 = 0.8933$ F = 50.2465 SEE = 0.5895 D.W. = 2.0947
- 6) $ERPVT = -1.12 + 0.00409PY + 0.062PYTR$
(2.01) (2.54)
 $\bar{R}^2 = 0.9679$ F = 136.0408 SEE = 0.1269 D.W. = 0.7053
- 7) $PYT = -0.646 + 1.086ERPVT + 0.920PYT_{t-1}$
(1.46) (3.60)
 $\bar{R}^2 = 0.9830$ F = 231.7229 SEE = 0.3406 D.W. = 1.3408
- 8) $ST = -12.04 + 0.505VR + 0.0987RS + 0.958STR$
(1.68) (6.42) (2.58)
 $\bar{R}^2 = 0.9791$ F = 156.5269 SEE = -0.6818 D.W. = 2.2111
- 9) $ABUT = -3.43 + 0.138N$
(2.92)
 $\bar{R}^2 = 0.4861$ F = 8.5132 SEE = 0.2926 D.W. = 1.8024

$$10) \quad \text{TOBT} = -0.2019 + 0.00467\text{PY} + 0.2046\text{DUM2}$$

(19.00) (2.97)

$$\bar{R}^2 = 0.9689 \quad F = 187.0054 \quad \text{SEE} = 0.0664 \quad \text{D.W.} = 1.0215$$

$$11) \quad \text{GAST} = -3.745 + 0.245\text{VR} + 0.110\text{DUM3}$$

(12.27) (0.30)

$$\bar{R}^2 = 0.9337 \quad F = 84.5058 \quad \text{SEE} = 0.4415 \quad \text{D.W.} = 0.4268$$

$$12) \quad \text{ABT} = 0.1386 + 0.0022\text{PY} + 0.0231\text{T}$$

(5.81) (3.77)

$$\bar{R}^2 = 0.9895 \quad F = 569.6655 \quad \text{SEE} = 0.0287 \quad \text{D.W.} = 1.6344$$

$$13) \quad \text{AOT} = -0.0445 + 0.00103\text{PY} + 0.8954\text{DUM4}$$

(1.72) (10.65)

$$\bar{R}^2 = 0.9151 \quad F = 64.6968 \quad \text{SEE} = 0.15897 \quad \text{D.W.} = 1.2250$$

$$14) \quad \text{GTR} = \text{PRT} + \text{ST} + \text{ABUT} + \text{TOBT} + \text{GAST} + \text{ABT} + \text{AOT} + \text{PYT}$$

By substituting appropriate values into equation 14, we get:

$$\begin{aligned} \text{GTR} = & -19.60 + 0.00791\text{PY} + 0.0987\text{RS} + 0.138\text{N} \\ & + 0.245\text{VR} + 1.086\text{ERPYT} + 1.022\text{PRT}_{t-1} \\ & + 0.920\text{PYT}_{t-1} + 0.505\Delta\text{VR} + 0.958\text{STR} \\ & -4.093\text{DUM1} + 0.2046\text{DUM2} + 0.110\text{DUM3} \\ & + 0.8954\text{DUM4} + 1.283\text{T} \end{aligned}$$

Given the relatively unsophisticated specification of the theoretical or hypothetical relationships contained in the structural form of the model, it can be seen from the empirical results that the degree of fit is remarkably good in most cases.

Reduced Form Equations

The reduced form equations of the tax model are derived from the set of structural equations of the model. A matrix formulation of the structural form is as follows:

$$Y'A + X'\beta + \mu' = 0$$

Where A, the endogenous matrix, is an m by m matrix of coefficients of the dependent variables, and β , the exogenous matrix, is an n by m matrix of coefficients of the independent variables. The

reduced form equations of the model are obtained by rearranging structural equations into the form:

$$-Y'A - X'\beta = \mu'$$

The inverse of the endogenous matrix A is then found by conventional inversion method and the inverted matrix multiplied by the exogenous matrix β . The newly formed n by m matrix is again multiplied by the constant -1 to form matrix C. Matrix C contains the coefficients of the reduced form equation with the basic form:

$$Y' = X'C + \mu'$$

The reduced form coefficients reflect both direct and indirect effects of the exogenous variables on the endogenous variables. For example, ΔGNP does not appear in the structural equation determining retail sales (equation 1). However, ΔGNP does affect total employment in the province (equation 2), which, in turn, affects personal income (equation 4). Personal income, in turn, affects retail sales. Therefore, ΔGNP has an indirect effect on retail sales.

The estimates of the reduced form parameters are also called impact multipliers since they measure the direct and indirect impacts of changes in the exogenous variables. The reduced form equations of the tax model are presented below. In this form, the effect of a change in any one, or all, of the exogenous variables can be easily measured on any one, or all, of the endogenous variables in the model.

$$(R-1) \quad \text{RS} = -1.7084 + 0.2264\text{POP} + 0.4729 \Delta\text{GNP} + 0.8211\text{AVW} + 0.1138\text{PY}_{t-1} + 1.2630\text{T}$$

$$(R-2) \quad \text{N} = 11.0927 + 0.1690\text{POP} + 0.3530\Delta\text{GNP} + 0.01396\text{AVW} + 0.00193\text{PY}_{t-1} + 0.02196\text{T}$$

$$(R-3) \quad \text{VR} = 2.0033 + 0.0103\text{POP} + 0.0215\Delta\text{GNP} + 0.8360\text{VR}_{t-1} + 0.0373\text{AVW} + 0.00516\text{PY}_{t-1} + 0.0013\text{T}$$

$$(R-4) \quad \text{PY} = -131.4830 + 0.6719\text{POP} + 1.4034\Delta\text{GNP} + 2.3820\text{AVW} + 0.3300\text{PY}_{t-1} + 0.08537\text{T}$$

$$(R-5) \quad \text{PRT} = 0.2800 + 1.0220\text{PRT}_{t-1} - 4.09\text{Dum1}$$

$$(R-6) \quad \text{ERPYT} = -1.6760 + 0.00275\text{POP} + 0.00575\Delta\text{GNP} + 0.0014\text{PY}_{t-1} + 0.0004\text{T}_1 + 0.0626\text{PYTR} + 0.0010\text{AVW}$$

$$(R-7) \quad \text{PYT} = -2.4754 + 0.00299\text{POP} + 0.00624\Delta\text{GNP} + 0.01095\text{AVW} + 0.00151\text{PY}_{t-1} + 0.920\text{PYT}_{t-1} + 0.0004\text{T} + 0.068\text{PYTR}$$

$$\begin{aligned}
 \text{(R-8)} \quad ST &= -12.1074 + 0.02234\text{POP} + 0.0467\Delta\text{GNP} + \\
 &\quad 0.081\text{AVW} + 0.01122\text{PY}_{t-1} + 0.505\Delta\text{VR} \\
 &\quad + 0.1275\text{T}_1 + 0.958\text{STR} \\
 \text{(R-9)} \quad \text{ABT} &= -1.8588 + 0.02385\text{POP} + 0.0498\Delta\text{GNP} + \\
 &\quad 0.0019\text{AVW} + 0.0003\text{PY}_{t-1} + 0.00303\text{T} \\
 \text{(R-10)} \quad \text{TOBT} &= -0.8714 + 0.0032\text{POP} + 0.0066\Delta\text{GNP} + \\
 &\quad 0.0115\text{AVW} + 0.0016\text{PY}_{t-1} + 0.0004\text{T} + \\
 &\quad 0.2046\text{Dum2} \\
 \text{(R-11)} \quad \text{GAST} &= 4.2418 + 0.00251\text{POP} + 0.00525\Delta\text{GNP} + \\
 &\quad 0.2048\text{VR}_{t-1} + 0.0091\text{AVW} + 0.0013\text{PY}_{t-1} \\
 &\quad + 0.0003\text{T} + 0.110\text{Dum3} \\
 \text{(R-12)} \quad \text{ABT} &= -0.1596 + 0.0015\text{POP} + 0.0031\Delta\text{GNP} + \\
 &\quad 0.0054\text{AVW} + 0.0007\text{PY}_{t-1} + 0.0232\text{T} \\
 \text{(R-13)} \quad \text{AOT} &= -0.0891 + 0.0007\text{POP} + 0.0014\Delta\text{GNP} + \\
 &\quad 0.0024\text{AVW} + 0.00033\text{PY}_{t-1} + 0.00012\text{T} \\
 &\quad + 0.8954\text{Dum4} \\
 \text{(R-14)} \quad \text{GTR} &= -20.5038 + 0.0570\text{POP} + 0.1191\Delta\text{GNP} + \\
 &\quad 0.02048\text{VR}_{t-1} + 0.1222\text{AVW} + \\
 &\quad 0.0169\text{PY}_{t-1} + 1.0220\text{PRT}_{t-1} + \\
 &\quad 0.9200\text{PYT}_{t-1} + 0.5050\Delta\text{VR} + 0.1549\text{T} \\
 &\quad 0.068\text{PYTR} + 0.958\text{STR} - 4.093\text{Dum1} + \\
 &\quad 0.2046\text{Dum2} + 0.110\text{Dum3} + 0.8954\text{Dum4}
 \end{aligned}$$

As can be seen from the above reduced form equations, population, ΔGNP , average weekly wages, and lagged personal income affect all taxes. As expected, all the exogenous variables of the model exert some influence on the general tax revenue of the province (reduced form equation 14).

Model Validation

Given that the tax model has been estimated by conventional methods and transformed into its reduced form, an important question arises concerning how one can validate the model. Despite the simplicity of the tax model, its simulation of performance is surprisingly good. To see this, we can examine an *ex post* (historical) simulation over the estimation period 1959 - 1973. The results are shown graphically (Figure 2), where the actual and simulated values of the endogenous variables, including the general tax revenues (Figure 3), are plotted on the same set of axes. It can be seen that over the period 1959 - 1973 the general tax revenue is apparently simulated with a fairly high degree of accuracy.

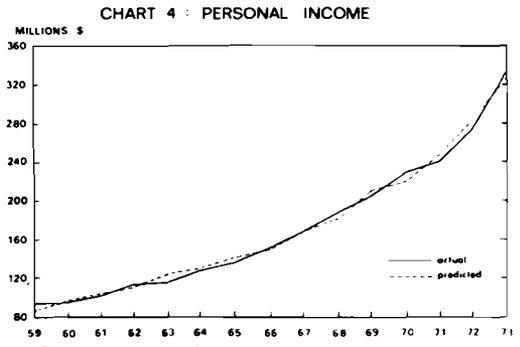
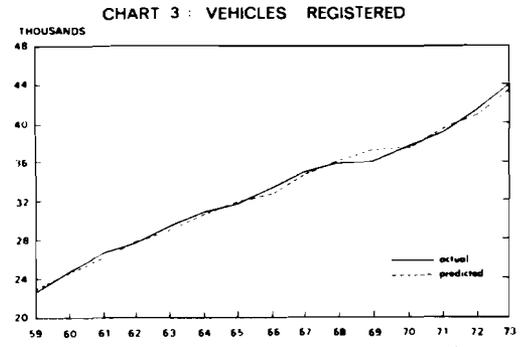
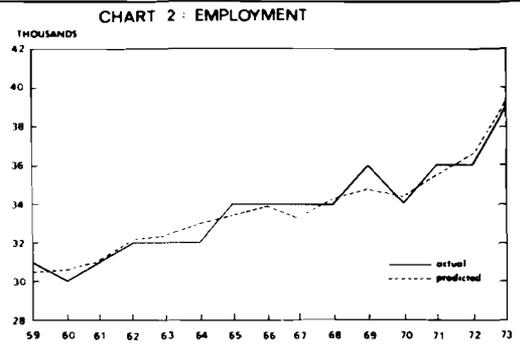
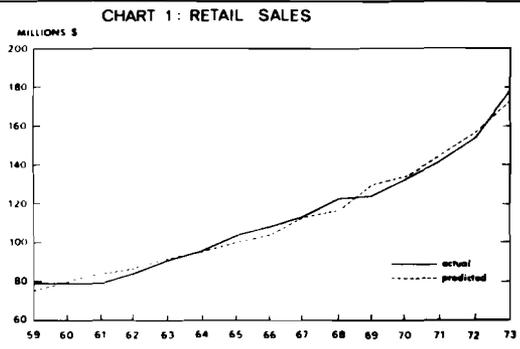


Figure 2 PERFORMANCE OF EQUATIONS

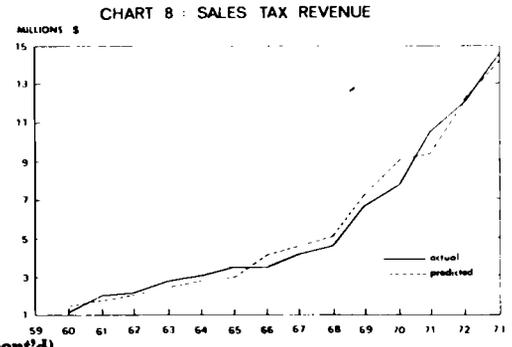
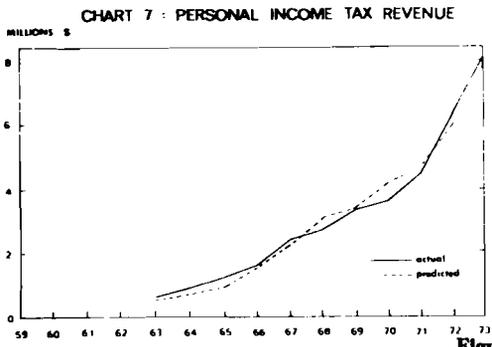
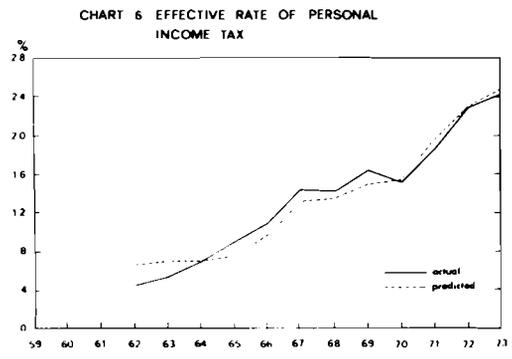
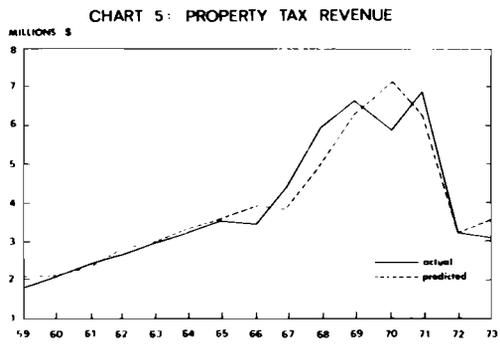


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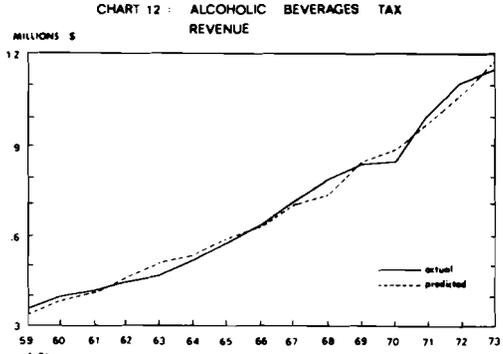
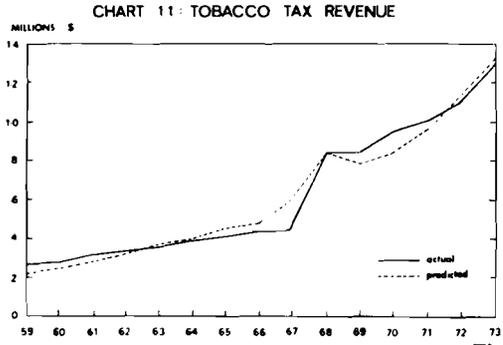
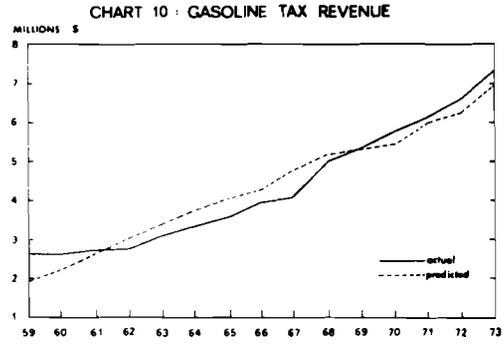
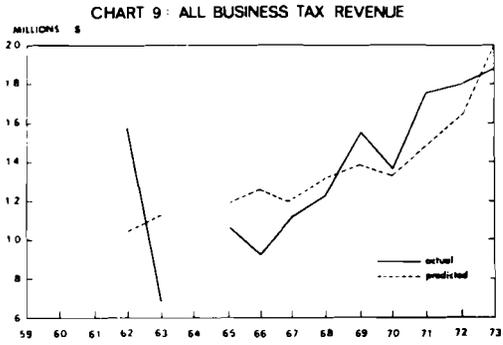


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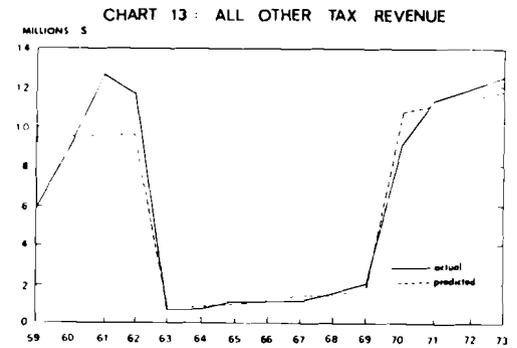


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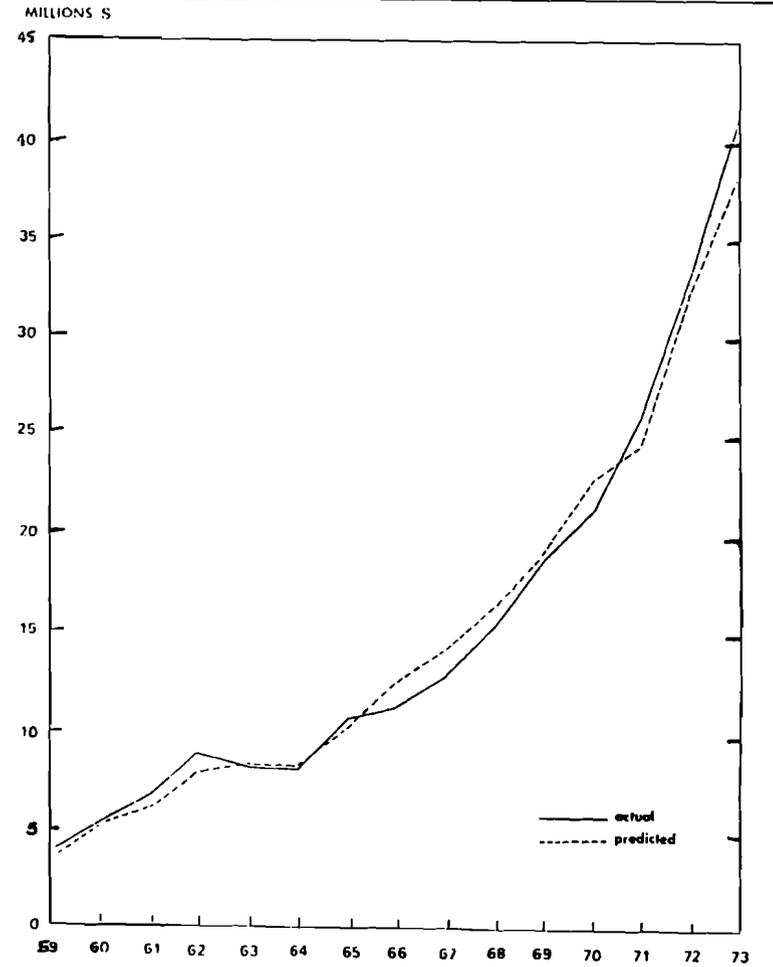


Figure 3 SIMULATION OF GENERAL TAX REVENUES

The RMS (root-mean-square) per cent error was computed to measure the deviation of the simulated variables from their actual time path. A low RMS simulation error is only one desirable measure of the simulation fit. Another test of the model's performance is to examine its capacity to signal turning points. For the purpose of evaluating how well the tax model simulates turning points in the historical data, the Theil's inequality coefficient (U-statistic) was computed for all the endogenous variables of the model. The U-statistic and RMS per cent error are shown in Table 1. It should be observed that in general the root-mean-square per cent errors are rather small, and only one variable (all business tax revenue) shows root-mean-square error larger than 5 per cent. The RMS error is just less than 2 per cent for the general tax revenue. This provides a considerable insight into the accuracy of the tax model.

Inspection of Table 1 also shows that thirteen out of fourteen Theil's inequality coefficients are rather low. The coefficient for general tax revenue is just 0.18. This general smallness of the inequality coefficient tends to confirm that the tax model signals turning points fairly well.

By inserting appropriate values into equation 14 we obtained a predicted general tax revenue of \$43.15 million for the year 1974 (outside the sample period), and the actual figure turned out to be \$44.60 million. This means that the percentage error was only -2.80.

Impact Analysis and Projection

One of the important analytic results of any econometric model is its impact results. A summary of the impact of changes in some autonomous forces on selected P.E.I. economic variables is presented in Table 2. The change in gross national product is one of the exogenous variables in the model. It is estimated that a change in GNP of \$1.0 billion would lead to an increase in employment by 353 jobs in the province, \$1.4 million in personal income, and \$119,000 in general tax revenues of the province. This reflects the degree of interaction between the national and provincial economy. Given the structure of the economy, it is estimated from the model that an increase in population of 1,000 would affect personal income by \$672,000, retail sales of \$226,000, general tax revenues of \$57,000, and total employment of 170. A decline in employment would have negative impact on all the endogenous variables. The impact of other exogenous stimuli on P.E.I. economic variables can be seen from Table 2.

Table 3 shows the projected general tax revenues, 1975 - 1983, on the basis of certain assumed growth rates in three exogenous variables—GNP, average weekly wages in P.E.I., and population. An interesting observation that can be made from the projected

Table 1
MODEL VALIDATION TEST STATISTICS—ROOT-MEAN-SQUARE
SIMULATION ERRORS¹ AND THEIL'S COEFFICIENTS²

Endogenous variable	RMS per cent error	U-coefficient
RS	2.62	0.26
N	0.42	0.40
VR	0.35	0.23
PY	0.95	0.22
PRT	2.78	0.36
ERPYT	4.90	0.22
PYT	3.73	0.19
ST	3.28	0.33
ABUT	7.70	0.74
TOBT	3.18	0.26
GAST	3.04	0.33
ABT	1.01	0.25
AOT	5.00	0.23
GTR	1.87	0.18

$${}^1\text{RMS Simulation Error} = \frac{1}{n} \sqrt{\sum_{i=1}^n \left(\frac{Y_t^s - Y_t^a}{Y_t^a} \right)^2}$$

This is a measure of the deviation of the simulated variable from its actual time path expressed in percentage terms.

²Theil's inequality coefficient is defined as:

$$u = \frac{\sqrt{\frac{1}{n} \sum_{i=1}^n \left[\left(S_t - S_{t-1} \right) - \left(A_t - A_{t-1} \right) \right]^2}}{\sqrt{\frac{1}{n} \sum_{i=1}^n \left(S_t - S_{t-1} \right)^2 + \frac{1}{n} \sum_{i=1}^n \left(A_t - A_{t-1} \right)^2}}$$

Where $(S_t - S_{t-1})$ = change in simulated value

$(A_t - A_{t-1})$ = change in actual value

n = number of observations.

Like the correlation coefficient, u -coefficient is confined to the zero one interval. When u is zero there is the case of perfect prediction. Also u will be one in the case of worst possible forecasts. The smaller the value of u , the more accurate the forecast.

Table 2

**IMPACT OF CHANGES IN AUTONOMOUS FORCES
ON THE PROVINCIAL ECONOMY**

Autonomous Changes	Selected Variables Affected										
	ΔRetail Sales (\$)	ΔEmployment (No. of Jobs)	ΔPersonal Income (\$)	ΔPersonal Income Tax Revenue (\$)	ΔSales Tax Revenue (\$)	ΔAll Business Tax Revenue (\$)	ΔGasoline Tax Revenue (\$)	ΔAlcoholic Beverages Tax Revenue (\$)	ΔTobacco Tax Revenue (\$)	ΔAll Other Tax Revenue (\$)	ΔTotal General Tax Revenue (\$)
ΔGNP by \$1.0 Billion	472,000	353	1,403,400	6,240	46,700	49,800	5,250	3,000	6,600	1,400	119,000
ΔPopulation by 1000	226,000	170	672,000	3,000	23,340	23,850	2,510	1,500	3,200	700	57,000
ΔAverage Weekly Wages by one dollar	820,000	14	2,382,000	10,950	81,000	1,900	9,100	5,400	11,500	2,400	122,250
ΔPersonal income by \$1.0 million (Exogenous Stimuli)	337,000	6	—	4,450	33,000	800	3,748	2,200	4,680	1,030	49,908
ΔEmployment by 100 (Exogenous Stimuli)	131,000	—	388,700	1,710	12,900	13,800	1,500	900	1,800	400	33,040
ΔRetail Sales by \$1.0 million (Exogenous Stimuli)	—	17	66,000	294	98,000	2,300	245	145	3,080	100	104,164

values is that the general tax revenues of the province would be increasing at a decreasing rate, regardless of the assumption about the annual growth rates in three exogenous variables.

In summary, given the relatively unsophisticated specification of the individual equations, the degree of fit is remarkably good in most cases. The overall performance of the simple, tentative model presented in this paper is also very good, judged from the simulation results. The model has tracked the historical data with a high degree of accuracy, and captured the so-called turning points quite satisfactorily.

Sources of Data

ABT	Alcoholic Beverages Tax Revenue. Millions of Dollars.
ABUT	All Business Tax Revenue. Millions of Dollars.
AOT	All Other Tax Revenue. Millions of Dollars.
ST	Sales Tax Revenue. Millions of Dollars.
PYT	Personal Income Tax Revenue. Millions of Dollars.
TOBT	Tobacco Tax Revenue. Millions of Dollars.
GAST	Gasoline Tax Revenue. Millions of Dollars.
PRT	Property Tax Revenue. Millions of Dollars.

Source:

- (1) *Historical Review: Financial Statements of Governments in Canada, 1952-1962.* Statistics Canada, Catalogue No. 68-503.
- (2) *Provincial Government Finance: Revenue and Expenditure.* Statistics Canada, 68-205, 68-207.
- (3) *Consolidated Government Finance: Revenue, Expenditure and Debts, 1961-1971.* Statistics Canada, 68-202.

STR	Sales Tax Rate
PYRT	Personal Income Tax Rate (Provincial)

Source:

- (4) *Principal Taxes and Rates.* Statistics Canada, Catalogue No. 68-20.

VR	Vehicles Registered. Thousands.
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Source:

- (5) *Public Accounts.* Department of Finance, P.E.I.

AVW	Average Weekly Wages. Dollars.
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Source:

- (6) *Canadian Statistical Review*. Statistics Canada, Catalogue No. 11-003.

RS	Retail Sales. Millions of Dollars.
POP	Population. Thousands.
PY	Personal Income. Millions of Dollars.
N	Employment. Thousands.

Source:

- (7) *Atlantic Provinces Statistical Review*. Atlantic Provinces Economic Council.

ΔGNP Change in Gross National Product ($GNP_t - GNP_{t-1}$).
Billions of Dollars.

Source:

- (8) *Economic Review*, 1975. Department of Finance, Canada. Catalogue No. F1-21/1975.

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