# MANUFACTURING INVESTMENT IN CANADA'S REGIONS*

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## Introduction

Expansion in the stock of capital goods is a major stimulus to regional economic growth. Capital investment should therefore be a central focus of regional economic analysis. However, empirical analysis of investment at sub-national levels has been retarded by the paucity of data. This paper employs time series capital data, which have recently become available at the provincial level, in a multiregional econometric analysis of manufacturing investment in Canada. The objectives are to shed light on the relationships between capital formation and a number of indicators of regional economic conditions, and to examine the dynamics of capital stock adjustment at the regional level.

For the purpose of this analysis Canada is divided into six regions: Atlantic (Newfoundland, Nova Scotia, Prince Edward Island, and New Brunswick); Quebec; Ontario; Manitoba and Saskatchewan combined; Alberta; and British Columbia.[1] For each region, a model of net investment is estimated on an annual time series from 1962 to 1981.

Most existing econometric specifications for regional investment take a "top-down" approach whereby national investment is distrib-

*I wish to thank F. L. Hall, Y. Y. Papageorgiou and two anonymous referees for comment on earlier drafts of this paper.

[1] Smaller provinces are aggregated together in order to avoid the problems of fitting the highly volatile investment patterns of small regions and to reduce the computational requirements of the seemingly unrelated regression model.

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© Canadian Journal of Regional Science/Revue canadienne des sciences régionales, X:3 (Autumn/Automne 1987), 321-319.
ISSN: 0705-4580 Printed in Canada/Imprimé au Canada

uted among regions according to demand characteristics [4;9]. By contrast, this study adopts a "bottom-up" approach whereby regional investment levels are determined individually and depend primarily on regional, rather than national, economic conditions. In order to take account of the interrelationships among the regions, the six regional models are estimated jointly *via* Zellner's seemingly unrelated regressions (SUR) method [15].

The next section provides a brief theoretical rationale for the model, followed by a discussion of relevant econometric issues. The exact specification of the model and results obtained from independent and joint estimations are then presented. The results are used to calculate elasticities, which indicate variations in the investment process across Canadian regions over the period 1962-1981.

## Theory of Investment

The investment model derives from the microeconomic theory of the firm, which states that capital goods are purchased up to that point where the net present value of the income stream they generate is equal to their cost [8]. Define **m** as a row vector of L variables that influence the cost of capital and the revenues produced by it. (The particular variables included in this vector are described below.) Assuming a linear relationship, the desired stock of capital is defined as:

$$\tilde{K}_t = \mathbf{m}_t\gamma \tag{1}$$

where $\gamma$ is a column vector of L unknown parameters and subscripts denote observations of the variable in period t.

Firms undertake investment in order to adjust the actual level of capital stock to the desired level. Net investment is defined as a change in the actual capital stock:

$$I_t^N = \mathbf{K}_t - K_{t-1}. \tag{2}$$

It is not reasonable to assume that the desired adjustment to the capital stock will be achieved over the course of one arbitrarily defined time interval. Eisner and Strotz [6] and Treadway [12] have demonstrated that net investment may involve significant adjustment costs and that, if these costs are marginally increasing, profit maximizing firms will choose to spread desired net investment over several time periods. If this is the case, the relationship between the actual investment in one period and the investment necessary to achieve the desired capital stock may be represented as follows:

$$I_t^N = \mathbf{K}_t - K_{t-1} = \lambda(\tilde{K}_t - K_{t-1}) \tag{3}$$

where $\lambda$ is a partial adjustment parameter whose value is expected to lie between zero and one.

Substituting equation 1 into equation 3 yields a model whereby capital stock in period t is a function of its own lagged value and the values of the variables included in the vector **m**:

$$K_t = (1 - \lambda)K_{t-1} + \lambda\mathbf{m}_t\gamma. \tag{4}$$

## Estimation Issues

### Serial Correlation

The parameters of equation 4 may be obtained through estimation of the parameters of the following equation:

$$K_t = \theta K_{t-1} + \mathbf{m}_t\eta + u_t \tag{5}$$

where $\theta = (1 - \lambda)$, $\eta = \lambda\gamma$ and $u_t$ is an error term with zero mean.

Ordinarily least squares (OLS) provides efficient unbiased estimates of the parameters of (5) only in the absence of serial correlation in the error term. If $\mathrm{Cov}(u_t u_{t-1}) \neq 0$, then OLS estimates are not efficient. Furthermore, since $\mathrm{Cov}(K_{t-1}u_{t-1}) \neq 0$, $\mathrm{Cov}(u_t u_{t-1}) \neq 0$ implies $\mathrm{Cov}(K_{t-1}u_t) \neq 0$. Therefore if first order serial correlation of the error term exists, OLS estimates are biased and inconsistent.

In order to eliminate any first order serial correlation, the first order autoregressive (AR1) generalized least squares estimator is used. The error term is redefined as:

$$u_t = \rho u_{t-1} + v_t\, . \tag{6}$$

where $\rho$ is estimated from the OLS error terms.[2] Equation 5 is then transformed as follows:

$$\underline{K}_t = \theta\underline{K}_{t-1} + \underline{\mathbf{m}}_t\eta + v_t \tag{7}$$

where $\underline{K}_t = \mathbf{K}_t - \rho K_{t-1}$, $\underline{K}_{t-1} = K_{t-1} - \rho K_{t-2}$, and $\underline{\mathbf{m}}_t = \mathbf{m}_t - \rho\mathbf{m}_{t-1}$. Since the $v_t$ error terms are purged of first order serial correllations, OLS estimates of the parameters of equation 7 are unbiased.

### Interregional Effects

In order to avoid the strong assumptions required for pooling regional time-series, a separate set of parameter estimaes is obtained for each of the six regions. However, it is desirable to take account of the interrelationships that naturally arise from economic linkages among

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[2] More specifically, the serial correlation parameter is estimated by the Corcorane-Orcutt iterative method, which repeatedly estimates the model until a stable value of $\rho$ is reached.

the regions. Zellner's [15] seemingly unrelated regressions (SUR) analysis is applied in order to achieve both goals.[3]

Define $\underline{\mathbf{K}}^r$ as a T X 1 vector of observations of $\underline{K}_t$ in region r (T is the length of the time series) $\underline{\mathbf{X}}^r = \{\underline{\mathbf{K}}^r_{-1} \mid \underline{\mathbf{M}}^r\}$ where $\underline{\mathbf{M}}^r$ is a T X L matrix of observations of $\underline{\mathbf{m}}^r_t$ and $\underline{\mathbf{K}}^r_{-1}$ is a T X 1 vector of observations of $\underline{K}_{t-1}$ ; $\beta^r = \{\theta^r \mid \eta^r\}$ as a vector of region specific parameters; and $\mathbf{v}^r$ as a T X 1 vector of error terms. In the SUR model the data and parameters for R regions are "stacked" as follows:

$$\underline{\mathbf{K}}^* = \begin{bmatrix} \underline{\mathbf{K}}^1 \\ \underline{\mathbf{K}}^2 \\ \cdot \\ \cdot \\ \cdot \\ \underline{\mathbf{K}}^R \end{bmatrix} \quad \underline{\mathbf{X}}^* = \begin{bmatrix} \underline{\mathbf{X}}^1 & 0 & \cdots & 0 \\ 0 & \underline{\mathbf{X}}^2 & \cdots & 0 \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ 0 & 0 & \cdots & \underline{\mathbf{X}}^R \end{bmatrix} \quad \beta^* = \begin{bmatrix} \beta^1 \\ \beta^2 \\ \cdot \\ \cdot \\ \cdot \\ \beta^R \end{bmatrix} \quad \mathbf{v}^* = \begin{bmatrix} \mathbf{v}^1 \\ \mathbf{v}^2 \\ \cdot \\ \cdot \\ \cdot \\ \mathbf{v}^R \end{bmatrix}$$

Due to interregional economic linkages and the common impact of the business cycle, one might expect to find contemporaneous correlations in the error terms across regions. Zellner demonstrated that if such correlation exists it is possible to obtain generalized least squares parameter estimates for the "stacked" model that are more efficient than parameter estimates obtained from individual time series. Define $\nabla^{ij} = E(\mathbf{v}^{i'}\mathbf{v}^j)$. The covariance matrix of the SUR model is:

$$\Omega = \begin{bmatrix} \nabla^{11} & \nabla^{12}I & \cdots & \nabla^{1R}I \\ \nabla^{21}I & \nabla^{22}I & \cdots & \nabla^{2R}I \\ \cdot & & & \\ \cdot & & & \\ \cdot & & & \\ \nabla^{R1}I & \nabla^{R2}I & \cdots & \nabla^{RR}I \end{bmatrix}$$

where I is a T X T identity matrix. The parameter estimates are obtained as follows:

$$\hat{\beta}^* = (\underline{\mathbf{X}}^{*\prime}\Omega^{-1}\underline{\mathbf{X}}^*)^{-1}\underline{\mathbf{X}}^{*\prime}\Omega^{-1}\underline{\mathbf{K}}^*. \tag{8}$$

The values of the $\nabla^{ij}$ are estimated from the residuals of the AR1 model run on the R individual time series.

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[3] Dielman [5] provides a review of estimation methods using multiple regional time series. Further discussion of the use of the SUR model in regional analysis is provided in White and Hewings [14].

## The Model

### General Specification of Independent Variables

The elements of the vector of independent variables are:

$$\mathbf{m} = [P_k, P_l, P_f, Y, R] \tag{9}$$

The first four elements of **m** are prices of productive inputs. $P_k$ is the price of capital goods, $P_l$ is the price of labour, $P_e$ is the price of electricity and $P_f$ is the price of fuels. Clearly, the price of capital is expected to have a negative effect on investment. However, it is ambiguous whether the other three prices have positive or negative effects. Since profitability is inversely related to production costs, and investment is based on expectations of profit, these input prices may have negative effects on investment. This is called the *expansion effect* [13]. On the other hand, if capital may be substituted for labour, electricity or fuel in the production technology, increasing prices for these inputs may stimulate investment. This is the *substitution effect*. Whether the parameters relating the prices of these inputs to investment are positive or negative depends upon whether the substitution effect or the expansion effect is dominant.

Y is a measure of manufacturing output that is included to represent the *accelerator effect*, by which net investment is linked to changes in the scale of production.

R is a variable intended to represent the effect of regional policy initiatives undertaken by the federal government of Canada for the purpose of stimulating investment in the Atlantic and Manitoba-Saskatchewan regions and in less developed portions of the other regions, especially eastern Quebec [11]. It is expected that this variable will show a positive influence on investment in those regions targeted by regional policy instruments.

### Data and Variable Construction

Data for the dependent and independent variables for each of the six regions in the years 1962 through 1981 are used in the analysis. All monetary measures are deflated to 1971 Canadian dollars. The sources of these data are provided in Table 1, and their values in selected years are provided in Table 2.

$K_t$ is defined as the dollar value of depreciable assets, which is estimated via the "perpetual inventory" method as:

$$K_t = (1 - \delta)K_{t-1} + I_{t-1}$$

where $I_{t-1}$ is gross investment in the previous period and $\delta$ is the rate

## Table 1
## DATA SOURCES

| Variable | Source |
|---|---|
| K | Statistics Canada, *Fixed Capital Flows and Stocks, 1955-1984.* |
| $P_k$, $P_l$, Y | Statistics Canada, *Manufacturing Industries of Canada: National and Provincial Areas* (annual series). |
| $P_e$, $P_f$ | Statistics Canada, *Consumption of Purchased Fuel and Electricity by the Manufacturing, Mining and Electric Power Industries* (annual series). The fuel price is a weighted average of the prices of gaseous, liquid and solid fuels. |
| R | Atlantic Provinces Economic Council, *An Analysis of the Reorganization for Economic Development,* Halifax, October 1982; (Table 1). |

## Table 2
## VALUES OF VARIABLES: 1962, 1972, 1981*
(all units are described in text)

| | $K_s$ | $K_m$* | $P_k$ | $P_l$ | $P_e$ | $P_f$ | Y | R |
|---|---|---|---|---|---|---|---|---|
| Atlantic Provinces | | | | | | | | |
| 1962 | 438.9 | 454.2 | .2855 | .3913 | 9.09 | 0.61 | 565.2 | 0.0 |
| 1972 | 1170.6 | 1312.2 | .1345 | .4152 | 7.55 | 0.53 | 815.9 | 134.2 |
| 1981 | 1520.0 | 1589.7 | .1729 | .3935 | 11.26 | 1.62 | 1182.0 | 79.7 |
| Quebec | | | | | | | | |
| 1962 | 1981.5 | 2750.8 | .4460 | .3394 | 6.17 | 0.65 | 4671.6 | 0.0 |
| 1972 | 2944.1 | 4152.9 | .3897 | .3533 | 6.10 | 0.57 | 6334.0 | 108.1 |
| 1981 | 3699.1 | 5754.6 | .4397 | .3241 | 6.51 | 1.48 | 8058.6 | 66.4 |
| Ontario | | | | | | | | |
| 1962 | 3584.7 | 5340.0 | .4150 | .3280 | 9.13 | 0.68 | 7911.6 | 0.0 |
| 1972 | 5417.5 | 8690.0 | .3825 | .3516 | 8.40 | 0.60 | 12163.1 | 12.4 |
| 1981 | 7471.0 | 13085.1 | .3583 | .3194 | 10.42 | 1.26 | 14686.1 | 13.7 |
| Manitoba and Saskatchewan | | | | | | | | |
| 1962 | 403.6 | 377.6 | .3340 | .3333 | 9.69 | 0.41 | 566.8 | 0.0 |
| 1972 | 542.8 | 613.0 | .3114 | .3740 | 7.00 | 0.34 | 801.4 | 34.2 |
| 1981 | 620.1 | 748.7 | .4174 | .3389 | 9.18 | 1.16 | 1136.5 | 53.3 |
| Alberta | | | | | | | | |
| 1962 | 493.8 | 450.9 | .2771 | .2976 | 9.69 | 0.41 | 506.1 | 0.0 |
| 1972 | 739.7 | 586.4 | .2982 | .3323 | 7.00 | 0.34 | 806.0 | 8.5 |
| 1981 | 1406.2 | 2005.2 | .2503 | .3036 | 8.67 | 0.40 | 1588.7 | 7.7 |
| British Columbia | | | | | | | | |
| 1962 | 1047.0 | 1155.1 | ,2925 | .3556 | 8.00 | 0.74 | 1327.6 | 0.0 |
| 1972 | 1548.2 | 2191.3 | .2428 | .4062 | 5.51 | 0.51 | 2098.8 | 10.2 |
| 1981 | 1831.2 | 2985.3 | .2269 | .4141 | 8.90 | 1.14 | 2630.9 | 15.3 |

*$K_s$ is capital in structures, $K_m$ is capital in machinery and equipment. Both are in millions of 1971 Canadian dollars.

of physical depreciation.[4] Note that physical depreciation is not equivalent to book depreciation, so the capital stock estimate is not affected by changes in depreciation policy. The available data disaggregate capital into two categories: 1) structures, and 2) machinery and equipment. In order to take advantage of this disaggregation, a separate equation is estimated for each category of capital.There is considerable regional variation in the rate of growth of both types of capital over the study period. Alberta and the Atlantic region had the fastest growth, while Quebec and Manitoba-Saskatchewan had the slowest.

$P_k$ is the price of capital services calculated by dividing payments to capital by the capital stock in place. This price is the cost of maintaining one dollar's worth of capital for one year, and is therefore some number between zero and one. Total payments to capital are calculated by subtracting all labour costs from value added. The remainder includes debt service, dividends and depreciaiton costs. Variations in $P_k$ are due to variations in interest rates, depreciation practices and the age structure of the capital stock.[5] The relatively low values for the Atlantic region probably reflect savings in capital costs due to elements of regional policy.

$P_l$ is defined as the ratio of production wages to value added in manufacturing. This "efficiency wage" is preferred over a simple hourly wage measure because it takes account of changes in productivity over the time series. There is no clear upward or downward trend in this variable; however, it is notably higher in British Columbia and the Atlantic Provinces than in the other regions.

$P_e$ and $P_f$ are measured in dollars per one thousand kilowatt hours and dollars per terajoule respectively.[6] $P_e$ generally declines from 1962 to 1972, but increases from 1972 to 1981. Note that electricity prices are lower in Quebec due to that region's large hydroelectric potential.

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[4] Statistics Canada assumes a constant value of $\delta$ across regions. Recent work by Anderson and Rigby [2] indicates that the pattern of physical depreciation may vary significantly across regions. However, since we are concerned here with variations in capital stock within regions rather than comparison across regions, the results are not expected to be very sensitive to variations in the rate of depreciation.

[5] This direct method of calculating the capital service price is chosen over the indirect method used by Lakshmanan *et al.* [10] and Anderson [1] as it does not require assumptions concerning depreciation practices and it smooths radical shifts in real interest rates. Regional differences in this price may stem from variations in the age structure of capital. Canadian law allows rapid depreciation of assets for tax purposes, so old capital may involve little or no depreciation while new capital involves very high depreciation. Since it is not possible to separate the value of payments to the two types of capital, it was assumed that the service price is equal for stuctures and machinery and equipment.

[6] Prior to 1973, separate energy data are not available for Alberta, Manitoba and Saskatchewan, so they are assumed to have the same energy prices in those years.

$P_f$ increases significantly in all regions except Alberta, where most of the oil and gas is produced. Regional variations in $P_f$ stem largely from regional differences in the mix of fuels consumed.

Value added in manufacturing is used as the measure of output (Y). This variable is a more accurate indicator of scale than the value of shipments, which may reflect the cost of materials and intermediate goods. Y increases in each region by at least 70 percent between 1962 and 1981, with the fastest growth occuring in Alberta and the slowest growth occuring in Quebec.

R represents regional policy instruments, which include regionally targeted tax breaks, capital grants, investment credits and various other subsidies, along with a variety of public infrastructure and human capital projects. These policies were coordinated by the Department of Regional Economic Expansion (DREE), which was founded in 1969. In each year up to 1969, R is set equal to zero. In each year after 1969, R is equal to the total expenditure by DREE in the region in question, measured in millions of 1971 dollars. This is a somewhat crude indicator, since it does not specifically measure expenditures directly related to manufacturing nor does it account for regional policy expenditures made by a variety of smaller agencies prior to 1969, but it is the best that can be done with the available data.

## Estimation Results

Tables 3.1 through 3.6 present the results of AR1 and SUR estimations for both categories of capital in each of the six regions.[7] Each parameter estimate is accompanied by its t-score in parentheses. As is often the case with models that include a lagged dependent variable as a regressor, the values of $R^2$ are all very close to 1. Therefore, the ratio of the standard error of the regression to the mean value of the dependent variable is presented as a more clearly discriminating goodness of fit indicator. The values of the serial correlation parameter $\rho$ that are used in both the AR1 and SUR estimations are also presented. The t-scores for these parameters indicate that $\rho$ is significantly different from zero in the majority of cases.[8]

### Table 3.1

### ESTIMATION RESULTS FOR ATLANTIC PROVINCES

| Independent Variable | Structures | | Machinery and Equipment | |
|---|---|---|---|---|
| | AR1 | SUR | AR1 | SUR |
| $P_k$ | -1238.8<br>(-4.23) | -1248.5<br>(-6.59) | -2531.1<br>(-12.5) | -2502.7<br>(-17.9) |
| $P_l$ | -1122.3<br>(-1.80) | -1067.2<br>(-2.88) | -2231.1<br>(-5.42) | -2120.6<br>(-8.10) |
| $P_e$ | -5.234<br>(-0.65) | -6.747<br>(-1.507) | 12.051<br>(2.04) | 12.091<br>(3.35) |
| $P_f$ | 116.79<br>(2.63) | 111.97<br>(3.61) | 23.51<br>(0.77) | 17.974<br>(0.85) |
| Y | 0.2209<br>(1.841) | 0.2321<br>(3.05) | 0.3345<br>(3.69) | 0.3370<br>(5.91) |
| R | 0.9528<br>(6.70) | 0.8432<br>(8.70) | 0.6730<br>(8.57) | 0.6613<br>(13.54) |
| $K_{t-1}$ | 0.5828<br>(10.0) | 0.5934<br>(14.57) | 0.4594<br>(9.47) | 0.4661<br>(15.02) |
| Constant | 844.34<br>(2.71) | 829.76<br>(4.36) | 1551.4<br>(7.64) | 2304.6<br>(11.62) |
| $\rho$ | -.1561<br>(-0.69) | | -.5389<br>(-2.79) | |
| $s/\bar{K}$ | .0143 | .0130 | .0070 | .0057 |

### Table 3.2

### ESTIMATION RESULTS FOR QUEBEC

| Independent Variable | Structures | | Machinery and Equipment | |
|---|---|---|---|---|
| | AR1 | SUR | AR1 | SUR |
| $P_k$ | -2459.2<br>(-4.64) | -2631.0<br>(-7.01) | -5815.5<br>(-4.69) | -6044.1<br>(-6.03) |
| $P_l$ | -2424.9<br>(-1.98) | -3189.1<br>(-3.85) | -5584.9<br>(-1.89) | -7333.3<br>(-3.43) |
| $P_e$ | -45.363<br>(-3.84) | -38.424<br>(-4.50) | -172.9<br>(-6.53) | -146.95<br>(-7.03) |
| $P_f$ | 88.429<br>(1.42) | 69.659<br>(1.64) | 505.95<br>(2.94) | 442.37<br>(3.42) |
| Y | 0.2077<br>(4.69) | 0.2206<br>(6.49) | 0.5099<br>(5.34) | 0.4660<br>(6.27) |
| R | 0.2599<br>(1.33) | 0.2956<br>(2.20) | -0.7983<br>(-2.20) | -0.5253<br>(-1.75) |
| $K_{t-1}$ | 0.5084<br>(4.58) | 0.5244<br>(6.85) | 0.2729<br>(1.89) | 0.3326<br>(2.90) |
| Constant | 2199.6<br>(3.92) | 2505.0<br>(6.46) | 4946.7<br>(3.71) | 5596.0<br>(5.58) |
| $\rho$ | -.0150<br>(-0.67) | | -.2229<br>(-0.99) | |
| $s/\bar{K}$ | .0052 | .0041 | .0070 | .0066 |

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[7] A linear in logarithms version of the model was also estimated, but since the results were not superior to or qualitatively different from the linear model, they are not discussed here.

[8] In those cases where the hypothesis that $\rho$=0 for $\alpha$=.1 cannot be rejected, $\rho$ is set to zero in the SUR procedure.

## Table 3.3
## ESTIMATION RESULTS FOR ONTARIO

| Independent Variable | Structures | | Machinery and Equipment | |
|---|---|---|---|---|
| | AR1 | SUR | AR1 | SUR |
| $P_k$ | -7221.1 | -6225.4 | -8131.2 | -8741.57 |
| | (-4.25) | (-5.14) | (-1.66) | (-2.58) |
| $P_l$ | -5320.6 | -4673.9 | -13523.0 | -13303.6 |
| | (-1.73) | (-2.10) | (-1.63) | (-2.31) |
| $P_e$ | 40.592 | 28.514 | 21.486 | 3.586 |
| | (1.09) | (1.08) | (0.22) | (0.05) |
| $P_f$ | 336.35 | 286.23 | 277.33 | 760.06 |
| | (1.32) | (1.55) | (0.36) | (1.46) |
| Y | 0.2687 | 0.2219 | 0.2266 | 0.2805 |
| | (3.33) | (3.73) | (1.012) | (1.89) |
| R | -0.9133 | -0.2642 | 5.488 | 9.774 |
| | (-0.26) | (-0.10) | (0.58) | (1.50) |
| $K_{t-1}$ | 0.3127 | 0.4345 | 0.6767 | 0.5763 |
| | (1.79) | (3.52) | (2.53) | (3.26) |
| Constant | 4724.7 | 1599.7 | 7859.2 | 3598.7 |
| | (3.27) | (4.07) | (2.06) | (2.98) |
| $\rho$ | .6265 | | .5508 | |
| | (3.50) | | (2.88) | |
| $s/\bar{K}$ | .0224 | .0175 | .0307 | .0242 |

## Table 3.4
## ESTIMATION RESULTS FOR MANITOBA AND SASKATCHEWAN

| Independent Variable | Structures | | Machinery and Equipment | |
|---|---|---|---|---|
| | AR1 | SUR | AR1 | SUR |
| $P_k$ | -1094.6 | -1113.8 | -1735.1 | -1784.1 |
| | (-10.66) | (-15.30) | (-12.80) | (-17.61) |
| $P_l$ | -1242.6 | -1291.5 | -1520.3 | -1651.0 |
| | (-5.24) | (-7.89) | (-4.76) | (-6.94) |
| $P_e$ | -10.446 | -11.712 | -4.411 | -4.879 |
| | (-4.706) | (-7.78) | (-1.496) | (-2.23) |
| $P_f$ | 5.743 | 10.928 | -44.460 | -42.251 |
| | (0.78) | (2.19) | (-4.49) | (-5.74) |
| Y | 0.4383 | 0.4333 | 0.8791 | 0.8779 |
| | (14.85) | (20.69) | (18.79) | (25.23) |
| R | -0.0131 | -0.0406 | 0.8316 | 0.8378 |
| | (-0.13) | (-0.56) | (5.71) | (7.71) |
| $K_{t-1}$ | 0.2662 | 0.2713 | 0.0129 | 0.0236 |
| | (4.15) | (6.24) | (0.19) | (0.48) |
| Constant | 926.40 | 1475.6 | 1028.0 | 1775.8 |
| | (7.45) | (11.09) | (6.43) | (9.14) |
| $\rho$ | -.537 | | -.631 | |
| | (-2.77) | | (-3.55) | |
| $s/\bar{K}$ | .0033 | .0026 | .0040 | .0031 |

## Table 3.5
## ESTIMATION RESULTS FOR ALBERTA

| Independent Variable | Structures | | Machinery and Equipment | |
|---|---|---|---|---|
| | AR1 | SUR | AR1 | SUR |
| $P_k$ | -3077.5 | -2569.8 | -7793.8 | -7571.7 |
| | (-7.27) | (-8.66) | (-7.54) | (-10.57) |
| $P_l$ | -1234.6 | -756.28 | -6073.8 | -5872.1 |
| | (-3.05) | (-2.72) | (-6.60) | (-8.96) |
| $P_e$ | 6.906 | 7.916 | 32.424 | 27.821 |
| | (0.96) | (1.52) | (2.25) | (2.81) |
| $P_f$ | -355.42 | -396.45 | -63.318 | -78.575 |
| | (-6.10) | (-9.10) | (-0.56) | (-1.01) |
| Y | 0.5076 | 0.5622 | 1.1388 | 1.0853 |
| | (5.65) | (9.30) | (6.725) | (9.27) |
| R | 1.138 | 1.0897 | -2.691 | -2.842 |
| | (0.97) | (1.31) | (-1.368) | (-2.15) |
| $K_{t-1}$ | 0.4961 | 0.4425 | 0.2493 | 0.2987 |
| | (3.85) | (5.01) | (1.875) | (3.24) |
| Constant | 999.74 | 752.52 | 2744.9 | 1175.5 |
| | (4.98) | (5.60) | (6.04) | (8.47) |
| $\rho$ | 0.184 | | 0.5643 | |
| | (0.818) | | (2.98) | |
| $s/\bar{K}$ | 0.0216 | 0.0155 | 0.0622 | 0.0481 |

## Table 3.6
## ESTIMATION RESULTS FOR BRITISH COLUMBIA

| Independent Variable | Structures | | Machinery and Equipment | |
|---|---|---|---|---|
| | AR1 | SUR | AR1 | SUR |
| $P_k$ | -2004.4 | -2139.5 | -7500.0 | -7194.4 |
| | (-4.99) | (-7.85) | (-8.43) | (-11.20) |
| $P_l$ | -921.93 | -1103.1 | -5903.8 | -5306.0 |
| | (-1.64) | (-2.89) | (-5.88) | (-7.36) |
| $P_e$ | 3.328 | 7.072 | 14.526 | 16.562 |
| | (0.369) | (1.22) | (0.92) | (1.67) |
| $P_f$ | -44.864 | -89.268 | -88.449 | -81.685 |
| | (-0.65) | (-1.98) | (-0.78) | (-1.14) |
| Y | 0.2810 | 0.2935 | 1.0573 | 1.0177 |
| | (4.51) | (7.11) | (8.01) | (10.86) |
| R | 0.2296 | 1.5141 | 9.7228 | 8.1409 |
| | (0.09) | (0.97) | (2.39) | (3.24) |
| $K_{t-1}$ | 0.4773 | 0.4536 | 0.0537 | 0.0889 |
| | (4.51) | (6.45) | (0.51) | (1.19) |
| Constant | 1107.7 | 1223.7 | 3973.6 | 5238.5 |
| | (3.75) | (6.11) | (7.33) | (9.37) |
| $\rho$ | 0.1209 | | -0.4291 | |
| | (0.53) | | (-2.07) | |
| $s/\bar{K}$ | .0013 | .0079 | .0092 | .0072 |

## Comparison of AR1 and SUR Results

While the results of the AR1 and SUR models are qualitatively similar, the improvement in efficiency due to SUR estimation is apparent from the reductions in the standard errors of the regressions. More important, since the t-scores of the individual coefficients are generally higher in the SUR estimates, it is possible to infer a number of significant relationships that cannot be inferred from the AR1 estimates. For example, given the AR1 results, it is not possible to reject the hypothesis that the price of labour has no influence on investment in machinery and equipment in Ontario, or that the level of output has no influence on investment in structures in the Atlantic region. However, sigificant influences are indicated in the SUR results. In light of their clear superiority, only SUR parameter estimates are discussed in the remainder of this paper.

## Interregional Effects

The interregional covariances employed by the SUR model provide some insights into the linkages among Canada's regional economies. In order to ease interpretaion, these covariances have been transformed to correlation coeficients in Table 4. A positive correlation for two regions implies that in any given year their residuals tend to have the same sign. One would expect this to occur when the economies of the two regions have similar structures or are highly interconnected. A negative correlation implies that the residuals of the two regions tend to have opposite signs. This might occur when there is a migration of capital between the two, so that a greater than expected investment in one region occurs at the cost of a less than expected investment in the other.

For structures, all of the correlations among the three eastern regions and among the three western regions are positive, but generally small. There are some large negative correlations between the Atlantic region and both Alberta and Manitoba-Saskatchewan and between Quebec and Manitoba-Saskatchewan. The high correlation between the Atlantic region and British Columbia may be due to the importance of wood-based manufacturing in both regions.

For machinery and equipment, the correlations are generally positive and higher. Quebec, however, is negatively correlated with both Alberta and British Columbia. The high positive correlation between the Atlantic region and Manitoba-Saskatchewan may be due to the fact that both of these regions are major beneficiaries of regional investment incentives.

Table 4

CROSS CORRELATION OF RESIDUALS ESTIMATED IN THE SUR MODEL

| | Atlantic | Quebec | Ontario | Manitoba & Saskatchewan | Alberta | British Columbia |
|---|---|---|---|---|---|---|
| | | | | **Structures** | | |
| Atlantic | 1.000 | | | | | |
| Quebec | 0.197 | 1.000 | | | | |
| Ontario | 0.214 | 0.291 | 1.000 | | | |
| Manitoba & Saskatchewan | -0.455 | -0.442 | 0.167 | 1.000 | | |
| Alberta | -0.555 | 0.367 | 0.387 | 0.165 | 1.000 | |
| British Columbia | 0.544 | 0.190 | 0.435 | 0.071 | 0.030 | 1.000 |
| | | | | **Machinery & Equipment** | | |
| Atlantic | 1.000 | | | | | |
| Quebec | 0.173 | 1.000 | | | | |
| Ontario | 0.327 | 0.257 | 1.000 | | | |
| Manitoba & Saskatchewan | 0.308 | 0.163 | 0.420 | 1.000 | | |
| Alberta | 0.263 | -0.019 | -0.532 | -0.160 | 1.000 | |
| British Columbia | 0.660 | -0.450 | 0.414 | 0.063 | 0.058 | 1.000 |

Since our estimated residuals probably reflect the effects of a broad range of missing variables, it would be imprudent to try to infer too much directly from the correlations among them. However, some of them raise interesting questions. In general, one might expect contiguous regions to be highly interconnected, and therefore to have residuals that are relatively highly correlated. However, the correlations between the Atlantic region and Quebec are very close to zero. The same is true for the correlations between Alberta and the other western regions. These results, along with the negative correlations between Quebec and some western regions, do not support a simple contagious pattern of spatial economic relationships in Canada.

## The Partial Adjustment Parameter

As equation 5 indicated, the estimate of the value of the partial adjustment parameter $\lambda$ is obtained by subtracting the coefficient on the lagged capital stock from 1. These values are presented in Table 5.

Table 5
VALUES OF THE PARTIAL ADJUSTMENT PARAMETER λ

| | Structures | Machinery & Equipment |
|---|---|---|
| Atlantic | .4066 | .5389 |
| Quebec | .4756 | .0674 |
| Ontario | .5655 | .4237 |
| Manitoba & Saskatchewan | .7287 | .9764* |
| Alberta | .5575 | .7013 |
| British Columbia | .5464 | .9111* |

* Not significantly different from 1 at the .05 level.

Since $\lambda = 1$ indicates that any desired adjustment to capital stock is completed within one period, relatively high values of λ indicate relatively rapid capital adjustment. Those regions that have low values of λ are therefore more likely to be in a state of disequilibrium, during which the difference between the desired and the actual capital stock is large.

In general, the values are lower for structures than for machinery and equipment. This may reflect the fact that investments in structures are more time-consuming and impose higher adjustment costs. The only region in which λ is higher for structures is Ontario.

For structures, the Atlantic region has the lowest value of λ, followed by Quebec. There is more regional variation in the estimates of λ for machinery and equipment. Two regions, Manitoba-Saskatchewan and British Columbia, have values close to one, indicating that nearly all desired capital stock adjustments take place within a year. By contrast, the estimates for Ontario and the Atlantic region suggest that less than half of the desired adjustments are completed within a year.[9]

## Response to Independent Variables

In order to assess the responsiveness of capital stocks to changes in the independent variables, elasticities are calculated as:

$$\epsilon_x = (\partial K/\partial x) \cdot (\overline{x}/\overline{K}) = \eta_x \cdot (\overline{x}/\overline{K})$$

where x is the value of the independent variable in question and $\eta_x$ is the value of the coefficient it takes in the regression. This is actually a

partial adjustment elasticity, because it represents the response occuring over one year. A full adjustment elasticity, which represents the effect of a change in the value of the independent variable on the *desired* capital stock is also calculated. From equation 5, this is defined as $\epsilon_x^f = \epsilon_x/\lambda$.

Table 6 presents the partial adjustment and full adjustment elasticities of the stock of capital in structures and in machinery and equipment with respect to the prices of capital, labour, electricity and fuels, the level of output, and the regional policy variable. As expected, the elasticities with respect to the price of capital are all negative. While the magnitudes of the partial adjustment elasticities vary considerably, most of the full adjustment elasticities are close to one. One notable exception is Alberta, for which an extremely high capital price elasticity was estimated for machinery and equipment.

The elasticities of both types of capital with respect to the price of labour are generally negative and significant, indicating that the expansion effect outweighs the substitution effect. In this case there is considerable spatial variation in the full adjustment elasticities. Once again, an extremely high elasticity was estimated for machinery and equipment in Alberta.

Many of the elasticities associated with electricity and fuel prices are not calculated, due to the instability of the parameter estimates. A mixture of expansion and substitution effects are observed for both forms of energy. For fuels, a relatively large substitution effect is indicated for structures in the Atlantic region, and a relatively large expansion effect is indicated for structures in Alberta. For electricity, relatively high expansion effects are indicated for structures in Manitoba-Saskatchewan and for machinery and equipment in Quebec, while a significant substitution effect is indicated for machinery and equipment in Alberta. In general, the absolute values of these elasticities are quite low.

The elasticities of capital stock with respect to output should be interpreted with some caution. One might expect values of one or greater, indicating that capital intensity remains constant or increases as output expands. However, period to period variations in output may be due to short-term business cycle effects rather than long-term growth trends. The capital stock measure is not adjusted for capacity utilization, and is therefore not very sensitive to these short-term variations. As a result, business cycle effects should tend to reduce the elasticity. This is probably why this elasticity is so low in the Atlantic region, where output has been shown to be more sensitive to the business cycle than in the other regions [3]. The output elasticities for the remaining regions are all fairly close to one, with the exception of

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[9] Guccione and Gillen [7] used a similar partial adjustment mechanism in an earlier study of regional investment in Canada. However, since they used investment rather than capital stock as their independent variable, the results are not directly comparable.

Alberta, where a much higher elasticity is indicated for machinery and equipment.

Table 6
**PARTIAL ADJUSTMENT ELASTICITIES OF CAPITAL STOCK WITH RESPECT TO INDEPENDENT VARIABLES***
**(Full adjustment elasticities in parentheses)**

| | Atlantic | Quebec | Ontario | Manitoba & Saskatchewan | Alberta | British Columbia |
|---|---|---|---|---|---|---|
| | | | **Structures** | | | |
| $P_k$ | -.239<br>(-.587) | -.376<br>(-.790) | -.444<br>(-.785) | -.731<br>(-1.003) | -.610<br>(-1.094) | -.410<br>(-.750) |
| $P_l$ | -.411<br>(-1.011) | -.380<br>(-.798) | -.287<br>(-.507) | -.860<br>(-1.180) | -.297<br>(-.532) | -.289<br>(-.530) |
| $P_e$ | ** | -.081<br>(-.170) | ** | -.179<br>(-.245) | ** | ** |
| $P_f$ | .085<br>(.209) | ** | ** | .011<br>(.015) | -.202<br>(-.362) | -.043<br>(-.079) |
| Y | .196<br>(.482) | .482<br>(1.0134) | .474<br>(.838) | .676<br>(.928) | .490<br>(.878) | .424<br>(.775) |
| R† | .098<br>(.241) | .008<br>(.017) | ** | ** | ** | ** |
| | | | **Machinery & Equipment** | | | |
| $P_k$ | -.435<br>(-.807) | -.583<br>(-.873) | -.380<br>(-.896) | -1.062<br>(-1.0874) | -1.695<br>(-2.42) | -.985<br>(-1.0811) |
| $P_l$ | -.741<br>(-1.375) | -.590<br>(-.884) | -.498<br>(-1.175) | -.996<br>(-1.0201) | -2.177<br>(-3.10) | -.997<br>(-1.094) |
| $P_e$ | -.097<br>(-.179) | -.210<br>(-.314) | ** | -.068<br>(-.070) | .279<br>(.397) | ** |
| $P_f$ | ** | .082<br>(.122) | ** | -.040<br>.041 | ** | ** |
| Y | .258<br>(.478) | .690<br>(1.034) | .366<br>(.863) | 1.240<br>(1.27) | 1.173<br>(1.67) | 1.053<br>(1.15) |
| R† | .067<br>(.130) | ** | ** | .054<br>(.055) | -.038<br>(-.053) | .029<br>(.032) |

*Elasticities are calculated at the mean values of the data.

**Since we cannot reject the hypothesis that the coefficient is equal to zero ($\alpha = .1$), no elasticity is inferred.

†The elasticity is calculated at the mean values of the data for those years in which $R \neq 0$.

From the estimated elasticities, the regional policy variable appears to be much more important in the Atlantic region than in many of the other regions. Significant effects are indicated for structures in Quebec and for machinery and equipment in Manitoba-Saskatchewan and British Columbia, but their elasticities are much smaller. A perverse negative effect is indicated for machinery and equipment in Alberta, but again the elasticity is very small. Due to the problems in the specifications of this variable described above, it would be imprudent to infer too much from the magnitudes of these elasticities. Still, the stable relationship estimated for both types of capital in the Atlantic region at least indicates that regional policy expenditures have had some positive effect on investment there.[10]

The regional variations in individual elasticities are subject to a broad range of interpretations, so further research will be required before specific explanations are obtained. For example, the extremely high elasticities of machinery and equipment capital with respect to the price of capital, the price of labour, and the level of output indicate a hypersensitivity of investment to the economic environment in Alberta. Further work is required to discover what structural characteristics of the Alberta economy lead to these results. Also, more detailed study is required to explain why changes in energy prices induce substitution effects in some regions and expansion effects in others.

## Conclusion and Research Directions

The results provide some useful guidance concering econometric methodology in regional analysis. Comparison of the independent AR1 estimates and the joint SUR estimates shows that the benefits of the latter approach are sufficient to justify the extra computational effort involved. This is true not only because of the improvement in efficiency but also because the estimation of interregional covariances can provide information concerning the relationships among the regions under study. In the context of this study, these covariances suggest that the strength of economic interdependency among the regions does not follow a simple spatial pattern, as evidenced by the lack of correlation between Quebec and the Atlantic region.

At a more substantive level, the results indicate significant sensitivities of investment in all regions to both capital and labour costs but do not indicate many strong relationships between investment and energy prices. The relationship between capital and output is generally stable, but its magnitude varies significantly across regions. Although

[10] Anderson [1] shows the effect of regional policy on investment in Canada by adjusting the price of capital to reflect various policy instruments. However, that study employs pooled data over a shorter time series, and is therefore not directly comparable to this one.

the regional policy variable employed in this study is somewhat crude, it does indicate that federal government expenditures for regional development have had a significant effect on capital formation in the Atlantic region.

The results point the way for further research in a number of areas. The high volatility of investment in machinery and equipment in Alberta, as indicated by the very high estimated elasticities, deserves further analysis. Also, further work is required to provide structural explanations for regional variations in the partial adjustment parameter and in the relationship between output and capital stock.

Finally, although the results of this analysis provide much useful information, we cannot expect to untangle all the interrelationships among investment, labour markets, and economic growth through a single equation model. Research effort should therefore be directed towards developing comprehensive multi-equation regional econometric models for Canada.

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