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PRICE-COST MARGINS, EXPORTS AND PRODUCTIVITY GROWTH: WITH AN APPLICATION TO CANADIAN INDUSTRIES

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ABSTRACT

A model is estimated for oligopolistic industries producing multiple outputs in short-run equilibrium. Outputs are sold domestically and exported, while capital is treated as a quasi-fixed factor. The model is applied to the Canadian nonelectrical machinery, electrical products and chemical products industries.

The results show that there is significant oligopoly power in each of the industries, and that the degree of this power differs between the domestic and export markets.

Total factor productivity is decomposed. Price-cost margins exert little influence but the rate of technological change, returns to scale and the rate of capital adjustment determine productivity growth.

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1. INTRODUCTION*

An important element relating to the conduct and performance of Canadian industries is the degree by which price exceeds marginal cost. It is often claimed that there is a direct relationship between industrial concentration and price-cost margins (see Scherer [1980] and Domovitz et.al. [1986a]). Indeed, Canadian industries are often relatively more concentrated than their counterparts in other industrialized countries (see Green [1985]). However, Canadian industries are subjected to international competition. In domestic markets Canadian producers compete against foreign exports, while in foreign markets Canadian exports compete against foreign producers. International competition can serve to mitigate Canadian industrial price-cost differentials.

The first purpose of this paper is to develop and estimate a model of production and pricing of outputs sold on domestic and foreign markets. A novel feature of the model is that exported products and products sold on domestic markets are not assumed to have identical demand characteristics. The products are not assumed to be perfect substitutes. As a consequence, it is possible to test whether domestic markets are relatively more or less competitive that foreign markets. Tests are conducted to see whether price-cost margins in the two markets are different from zero and different from each other. Due to the importance of exports out of total sales, the nonelectrical machinery, electrical products and chemical products industries were selected for analysis. In 1983 the ratio of exports to sales for each of the industries was respectively; 58%, 25% and 21%.

Diewert [1974] and Appelbaum [1979], within the context of production theory, have shown how to model the simultaneous decisions on outputs and inputs for monopolistic industries in long-run equilibrium. This class of model has been empirically implemented by Appelbaum [1979] for the U.S. crude petroleum and natural gas industry and by Appelbaum and Kohli [1979] for Canadian manufacturing. More recently research has been extended to production decisions in oligopolistic industries. Appelbaum [1982], using a long-run equilibrium framework and Roberts [1984] applying a short-run equilibrium model, where capital is treated as a fixed factor, have estimated price-cost margins for U.S. industries.[1] The importance of the production theory approach is that both output and input decisions are modelled. Price-cost margins in output markets affect both output and input choices.

Price-cost margins in oligopolistic industries depend on product demand through the price elasticity and on firm interdependence through the conjectural elasticity. In this paper the two sources of price-cost differentials are estimated for both the domestic and foreign markets supplied by Canadian firms. Tests are conducted to see whether price and conjectural elasticities differ between domestic and foreign markets. This is the first time that oligopoly power is tested for Canadian industries.

Unlike previous research in this area, one type of equilibrium is not adopted as a maintained hypothesis. The second purpose of this paper is to estimate the model for both short and long-run equilibria in order to determine the appropriate specification for the Canadian industries. Following Schankerman and Nadiri [1986] tests are performed with respect to the equilibrium specification. Specifically capital is tested as to whether or not it is a source of short-run fixed costs so that the expected marginal benefit of capital does not equal its rental rate.

During the seventies and into the eighties Canadian industries (like their U.S. counterparts) have suffered from a slowdown in total factor productivity (TFP) growth. Numerous explanations have been put forward for the productivity slowdown (for example see Jorgensen, Gollop and Fraumeni [1988]); a declining rate of technological change, an increasing rate of factor price inflation (notably energy price increases), decreases in the degree of returns to scale, and increases in adjustment costs associated with capital expansion. Recently, Hall [1986] and Domovitz et.al. [1986b] have found that price-cost margins have led to a decline in U.S. industrial productivity growth. Their work was carried out in the context of constant returns to scale and the absence of capital adjustment costs. Much earlier in the Canadian context, Denny, Fuss and Waverman [1981] have shown how price-cost differentials affect productivity growth for telecommunications carriers in long-run equilibrium. The third objective of this paper is to trace the sources of the decline in productivity growth for the Canadian industries. TFP growth is decomposed into four components; the traditional technological and scale parts and components relating to price-cost margins and capital adjustment costs.

The paper is organized into a number of sections. In the next section the model of oligopolistic pricing and production is developed. Section 3 contains a description of the data, and the estimation results and hypothesis tests on price-cost margins and equilibrium specification. In section 4 TFP growth is measured and decomposed into its four sources. Lastly there is a summary of the paper.

2. THE MODEL

The variable cost function for each of the F firms can be written as

$$(1) \qquad c^{vj} = c^{vj}(y^j, w, K^j) \qquad j = 1, \ldots, F$$

where c^v is variable cost, y is a vector of ℓ output quantities, $w > 0$ is a vector of n exogenous variable factor prices, K is a vector of m quasi-fixed factor quantities and the superscript j denotes the firm.[2] The variable cost function C^v is twice continuously differentiable, nonnegative for positive variable factor prices, and for nonnegative outputs, the function is nondecreasing in variable factor prices and output, homogenous of degree one and concave in the variable factor prices.[3] All firms in the industry face the same variable factor prices.

By Shephard's Lemma (see Diewert [1974]) the firm equilibrium conditions for the variable factors can be obtained from the firm's variable cost function,

$$(2) \qquad s^j = \frac{\partial \ln C^{vj}}{\partial \ln w} \qquad\qquad j = 1,\ldots,F$$

where $s_i^j = w_i v_i^j / c^{vj}$ is the ith variable factor cost share, $s^j = (s_1^j,\ldots,s_n^j)$, v_i is the ith variable factor demand and the right side of (2) is the vector of variable factor price elasticities of variable cost. Equation set (2) shows that in equilibrium variable cost shares are equated to price elasticities of variable cost.

Product market equilibrium is determined from

$$(3) \qquad \max_{(y^j)} \; \Sigma_i D_i(\Sigma_j y_i^j, z_i) y_i^j - C^{vj}(y^j, w, K^j) \qquad\qquad j = 1,\ldots,F$$

where $p_i = D_i(y_i, z_i)$, p_i is the ith product price, $y_i = \Sigma_j y_i^j$ is the industry ith output quantity, z_i is a vector of exogenous variables which affect the ith product demand, D_i is the ith product inverse product demand function which is twice continuously differentiable, nonnegative for positive output quantity and nonincreasing in output quantity. Each of the ℓ products are homogenous across firms. Thus, each product price depends on the industry's output.

The product market equilibrium conditions are given by

$$(4) \qquad s_y^j(I_\ell + \Phi^j) = \frac{\partial \ln C^{vj}}{\partial \ln y^j} \qquad j = 1,\ldots,F$$

where $s_{yi}^j = p_i y_i^j / c^{vj}$ is the ith revenue to cost ratio, $s_y^j = (s_{y1}^j,\ldots,s_{y\ell}^j)$. I_ℓ is the ℓ dimensional identity matrix, Φ^j is an ℓ dimensional diagonal matrix and the ith element is θ_i^j/ϵ_i where $\theta_i^j = \partial \ln y_i / \partial \ln y_i^j$ is the jth firm's ith conjectural elasticity, $\epsilon_i = [(\partial D_i/\partial y_i)(y_i/p_i)]^{-1}$ is the price elasticity of the ith product demand. The right side of (4) is the vector of output elasticities of variable cost or the vector of variable cost flexibilities (see Jorgenson [1986]). In product market equilibrium revenue cost ratios are proportional to cost flexibilities.

The jth firm's degree of oligopoly power is given by the negative of the parameter matrix Φ^j in equation set (4). Clearly there are ℓ different degrees of oligopoly power for each firm in the industry, since there are ℓ different product markets. If the industry is purely competitive in the ith product market then $\theta_i^j=0$ for all $j=1,\ldots,F$. There is no oligopoly power pertaining to product i and in equilibrium the revenue cost ratio equals the variable cost flexibility. If the industry is purely monopolistic in producing i then $j=1$, $\theta_i^j=1$ and the degree of oligopoly (or rather monopoly) power is given by the negative of the inverse of the price elasticity for product i. Moreover by the nonnegativity of marginal costs, the positive product prices and since product prices exceed their respective marginal revenues then from (4), $0 \leq -\theta_i^j/\epsilon_i \leq 1$ for all i=1,...,n and j=1,...,F. For each firm and product, the degree of oligopoly power lies between zero and one.

Following Cowling and Waterson [1976] Appelbaum [1982] and Roberts [1984] from the single product case, the industry's degree of oligopoly power for product i is

$$(5) \qquad L_i^p = \Sigma_j S_i^j(-\theta_i^j/\epsilon_i) \qquad i=1,\ldots,\ell.$$

where $S_i^j = y_i^j/\Sigma_j y_i^j$. The industry's degree of oligopoly power for product i is a weighted average of the firms' oligopoly power, where the weights are the ratio of firm to industry output for the ith product.[4] Notice if the conjectural elasticity for product i is the same for all firms so that $\theta_i^j = \theta_i$ j=1,..., F then $L_i^p = -\theta_i/\epsilon_i$ since $\Sigma_j S_i^j = 1$.

The equilibrium conditions given by equation set (2) and (4) for each firm define a short-run equilibrium. Variable factor cost shares and revenue cost ratios are conditioned on the m quasi-fixed factors. In order for each firm and thereby the industry to be in long-run equilibrium, the quasi-fixed factor demands must be chosen by each firm. The conditions governing these decisions are (see Bernstein [1989] and Schankerman and Nadiri [1986]).

$$(6) \qquad s_k^j = -\frac{\partial \ln C^{vj}}{\partial \ln K^j} \qquad j = 1,\ldots, F$$

where $s_{ki}^j = w_{ki}K_i^j/C^{vj}$ i=1,...,m, $s_k^j = (s_{k1}^j,\ldots,s_{km}^j)$ and w_{ki} is the ith quasi-fixed factor price. Equation set (6) states that the percentage reduction in variable cost due to the expansion of the ith quasi-fixed factor equals the ratio of capital cost to variable cost. The long-run equilibrium conditions are given by equation set (2), (4) and (6). Thus long-run equilibrium is a special case or is nested by the short-run equilibrium. In this paper the model will be estimated for both equilibrium conditions and tests carried out to see whether each industry is in short or long-run equilibrium.

In principle it is possible to estimate the short-run equilibrium equation set (2) and (4) or long-run equilibrium equation set (2), (4) and (6) for each firm in an industry. If firm level time series data existed for variable factor, quasi-fixed factor and output quantities and a variable cost functional form assumed for each firm then the models could be estimated. It is often very difficult to obtain a relatively long time series data set at the firm level. As an alternative the model can be implemented at the industry level. In order to undertake this task, the aggregation problem must be confronted. There are two approaches to the aggregation problem. In the first approach a functional form for the variable cost function is assumed for each firm such that an industry variable cost function can be derived which only depends on industry variables (see Blackorby, Primont and Russell [1978]). In this approach the admissible firm variable cost functions must be separable in outputs and capital. From the estimation results, separability is rejected for the three industries. Hence an alternative approach is used in this paper.

The second approach to the aggregation problem and the one adopted in this paper is to fix the distribution within the industry of firm specific variables. This assumption permits the construction of an industry variable cost function which only depends on industry variables (see Diewert [1977]). Thus it is assumed that $y_i^j = \mu_i^j y_i$, $\mu_i^j \geqq 0$ for

$i=1,\ldots,\ell$ and $\Sigma_j\mu_i^j = 1$; $K_k^j = \phi_k^j K_k$, $\phi_k^j \geqq 0$ for $k=1,\ldots,m$ and $\Sigma_j\phi_k^j = 1$. Notice that the proportionality between firm and industry variables can vary across firms.

The industry variable cost function is assumed to be translog (see Jorgenson [1986] for the details underlying the translog function used in production analysis) and it is written as

$$
\begin{aligned}
(7)\qquad \ln(c_t^v/w_{mt}) = {} & B_o + \Sigma_{i=1}^2 B_i \ln y_{it} + B_v \ln\omega_t + B_k \ln K_t + B_t t \\
& + .5\,[\Sigma_{i=1}^2 B_{ii}\,(\ln y_{it})^2 + B_{vv}(\ln\omega_t)^2 + B_{kk}(\ln K_t)^2 \\
& + B_{tt}t^2] + B_{12}\ln y_{1t}\ln y_{2t} + \Sigma_{i=1}^2 B_{iv}\,\ln y_{it}\ln\omega_t \\
& + \Sigma_{i=1}^2 B_{ik}\ln y_{it}\ln K_t + \Sigma_{i=1}^2 B_{it}\ln y_{it}t + B_{vk}\ln\omega_t\ln K_t \\
& + B_{vt}\ln\omega_t t + B_{kt}\ln K_t t + u_{ct}
\end{aligned}
$$

where the parameters are $B_o = \Sigma_j\beta_i^j$, $B_i = \Sigma_j(\beta_i^j + \Sigma_\ell\beta_{i\ell}^j\ln\mu_\ell^j + \beta_{ik}^j\ln\phi^j)$, $i=1,2$, $B_v = \Sigma_j(\beta_v^j + \Sigma_i\beta_{iv}^j\ln\mu_i^j + \beta_{vk}^j\ln\phi^j)$, $B_k = \Sigma_j(\beta_k^j + \Sigma_i\beta_{ik}^j\ln\mu_i^j + \beta_{kk}^j\ln\phi^j)$, $B_t = \Sigma_j(\beta_t^j + \Sigma_i\beta_{it}^j\ln\mu_i^j + \beta_{kt}^j\ln\phi^j)$, $B_{i\ell} = \Sigma_j\beta_{i\ell}^j$ $i,\ell=1,2,v,k,t$, where β^j represent firm specific parameters. In specifying the industry variable cost function, it is assumed that there are $t=1,\ldots,$ T time periods, two variable factors, labour and materials, where w_ℓ and w_m are the respective prices with $\omega = w_\ell/w_m$; there are two outputs, one sold on domestic markets (y_1) and one sold on foreign markets (y_2), there is a single quasi-fixed factor which is capital (K), a time trend representing the industry indicator of technology (t), and u_c is the random error term.[5] Notice that each of the two outputs can enter into the cost function because, even if they are physically alike, variable cost includes non-advertising marketing costs (e.g. cost of sales personnel) which can differ among the outputs. Tests will be conducted to see if the outputs do in fact generate distinct effects on variable cost.[6]

The random error term (u_{ct}) appears in the cost function because at any point in time the industry variable cost is defined as the sum of all firm variable costs in the industry. However, industry data is not obtained by summing over all firm data. Observations for the industry variables are constructed from a random sample of firms from data on the production of commodities. Thus the error corresponds to unobservable errors of measurement in the observations that underlay industry variable cost.

The inverse product demand functions are

$$(8) \qquad \ln p_{it} = \alpha_i + \xi_i \ln y_{it} + \psi_i^T \ln z_{it} + u_{pit} \qquad i=1,2$$

where α, ξ and the vector ψ define the parameters and $u_{pt} = (u_{p1t}, u_{p2t})$ are the random disturbances arising from price measurement errors for each of the products.[7] The parameter $\xi_i = 1/\epsilon_i$ is the inverse price elasticity of the ith product demand.

The industry equilibrium conditions (given by the aggregation of (2), (4) and (6)) can be written using the industry variable cost function and the inverse product demand functions. For the labour input,

$$(9) \qquad s_{vt} = B_v + B_{vv} \ln \omega_t + \Sigma_{i=1}^{2} B_{iv} \ln y_{it} + B_{vk} \ln K_t + B_{vt} t + u_{vt}$$

where s_{vt} is the aggregate share of labour cost to variable cost and u_{vt} is the measurement error arising from the fact that the aggregate cost share is not the sum of all the firm labour cost shares. The aggregate material cost share is not independent of the aggregate labour share since the sum of the two variable factor cost shares equals unity. Thus the aggregate material share can be treated as a residual in specifying the equilibrium conditions.

Next for the two products

$$(10) \qquad s_{yit}(1 + \theta_i\xi_i) = B_i + \Sigma_{\ell=1}^{2} B_{i\ell}\ln y_{\ell t} + B_{iv}\ln\omega_t + B_{ik}\ln K_t + B_{it}t + u_{yit} \qquad i=1,2$$

where $s_{yt} = (s_{y1t}, s_{y2t})$ is the vector of aggregate revenue to variable cost ratios for both products, and $u_{yt} = (u_{y1t}, u_{y2t})$ is the vector of disturbances due to the measurement errors arising from the aggregate revenue to variable cost ratios. In deriving equation set (10), it was assumed that each firm had the same conjectural elasticity for the same product in equilibrium. Thus in aggregating the equilibrium conditions given by (4), $\theta_i^j = \theta_i^k = \theta_i$ for $j \neq k$, $j, k = 1,\ldots,F$ and $i = 1,2$. The conjectural elasticities are parameters to be estimated, in equilibrium they do not vary across firms but they do vary across products.[8]

Lastly, for the capital input

$$(11) \qquad s_{kt} = -[B_k + B_{kk}\ln K_t + \Sigma_{i=1}^{2} B_{ik}\ln y_{it} + B_{vk}\ln\omega_t + B_{kt}t] + u_{kt}$$

where s_{kt} is the aggregate capital cost to variable cost ratio and u_{kt} is the disturbance due to the measurement error associated with aggregate capital cost to variable cost.

There are two models to be estimated. The first model consists of the aggregate or industry short-run equilibrium conditions, variable cost function and inverse product demand functions. The equations are (7), (8),

(9) and (10) and the endogenous variables are variable cost, two product prices, two output quantities and the labour cost share.[9] The second model to be estimated relates to the long-run equilibrium. This model contains the equations and endogenous variables of the previous model along with equation (11) and the capital input as an additional endogenous variable.[10]

3. ESTIMATION RESULTS

The data used in the paper consist of time series of industry variables relating to the nonelectrical machinery (SIC 31), electrical product (SIC 33) and chemical products (SIC 37) industries. The variables were obtained from public domain sources for the period 1962 to 1983.

Gross output and intermediate input (or material input) were obtained from the input-output tables at the M-level of aggregation for the Canadian economy (Statistics Canada 15-201, 15-202, 15-508 and 15-509). Gross output at current and constant (1971) dollars producers' value is measured as value added at factor cost plus materials. Material input at current and constant dollars purchase value is defined as total production minus value added at market price minus non-competing and unallocated inputs. The prices of gross output and material input are implicit and the quantities are taken as 1971 dollar magnitudes.

Gross output quantity is divided into two components; one sold domestically and one sold in foreign markets. Exports in current and constant dollars were taken from the input-output tables (re-exports are excluded). Exports are valued at the producers' value and hence do not include trade and transportation costs. The export quantities are 1971 dollar magnitudes and the prices are implicit. In order to arrive at outputs sold in the domestic market, export quantities are subtracted from gross output quantities. In order to obtain the price of output sold domestically the current dollar value of exports was subtracted from the current dollar value of gross output and this difference was divided by the domestically sold output quantity.

The data for labour input quantity and price were obtained from data on the number of employees, number of hours paid and wages and salaries (Statistics Canada 31-203). Total employees include production and related workers and nonmanufacturing employees. Total number of hours worked is obtained from total number of hours paid multiplied by 50/52. Hours paid represent hours worked and paid vacations. It is assumed that the work year is 50 weeks and not 52 weeks. In addition, hours paid only refer to production and related workers. In order to get hours worked for nonproduction employees, hours worked per production employee is calculated and assumed to be the same for nonproduction workers. Next the hour worked per employee is multiplied by the number of nonproduction employees. The number of hours worked for production and nonproduction workers is summed to obtain the labour input quantity.

The labour cost is taken to be the wages and salaries multiplied by one plus the ratio of supplementary labour income from the input-output tables to the wages and salaries from the input-output tables. Thus wages and salaries are supplemented by labour expenses which pertain to employers' contribution to pension funds, employee welfare funds, unemployment insurance and workmen's compensation. The labour input price is defined as the labour cost divided by the total number of hours worked.[11]

Data on the capital input are taken from capital stock figures (Statistics Canada 13-568). The capital input quantity is taken as the

1971 dollar net of depreciation capital stock. This stock is constructed by the perpetual inventory method. The rental rate on capital is defined by the formula

$$w_{kt} = p_{kt}(\rho + \delta)\ (1 - \nu_t - u_{ct}z_t)/(1 - u_{ct})$$

where p_k is the implicit price index on capital stock, ρ is the nominal rate of return on capital measured as the average interest rate on long term government bonds, δ is the depreciation rate which was obtained by dividing the capital cost allowance of the current year by the real net capital stock at the end of the previous year and then the ratio was averaged over the sample, ν is the effective investment tax credit which was computed as the tax credits claimed in the current year divided by investment expenditures in the same year, u_c is the effective corporate income tax rate which was measured as federal and provincial income taxes payable divided by corporate taxable income, z is the present value of capital cost allowances associated with a dollar's worth of capital.[12]

The exogenous variables which enter the inverse product demand function for domestically sold output are the gross national product (taken from Statistics Canada 13-201) and the industrial product price index for all manufacturing industries (Statistics Canada 62-543 and 62-011). Since over 65% of the exports from chemical products and electrical products and over 75% from nonelectrical machinery are sold to the U.S., it is assumed that U.S. demand governs the demand for Canadian exports.[13] The exogenous variables entering the inverse product demand function for exports are the U.S. gross national product and the total producer price index for industrial commodities (from the U.S. Department of Commerce publication).

In addition, to convert the Canadian price of exports to the U.S. price the average annual market exchange rate between the U.S. and Canadian dollar (from the International Monetary Fund publication) was used in the inverse demand function. Table 1 shows the data for some years in the sample.

The error terms in equation set (7), (8), (9) and (10) were assumed to have zero expected values, positive definite, constant, contemporaneous covariance matrix and be normally distributed. The equation set was estimated as a complete system using the full information maximum likelihood estimator.[14] The equation system was nonlinear in the parameters and nonlinear in the endogenous variables. The nonlinearity in the parameters occurred because of the integration of the inverse product demand functions (equation set (8)) and the profit maximizing conditions for the products (equation set (10)). These two sets of equations were also the source of the nonlinearity in the endogenous variables. The system of equations was estimated as an implicit system because of the nonlinearity in the endogenous variables.

First the short-run equilibrium conditions along with the variable cost and inverse product demand equations ((7), (8), (9) and (10)) were estimated. The estimated system of equations must satisfy five integrability conditions (see Jorgenson[1986]). Output supply and variable factor cost share equations must be homogenous of degree zero in variable factor prices. This condition has been imposed since only the relative variable factor price enters the equations. Next the variable cost share equations must sum to unity. This condition has been imposed since the material cost share equation was treated as one minus the estimated labour cost share (the material share equation is not estimated). Third the matrix of variable factor price elasticities of the variable factor cost

TABLE 1: **Data for Selective Years**

INDUSTRY	YEAR	SERIES									
		Y_1	P_1	Y_2	P_2	V_ℓ	W_ℓ	V_m	W_m	K	W_k
Non-Electrical Machinery (31)	1969	2570	0.948	907	0.942	169	3.714	1330	0.942	532	0.256
	1976	3218	1.565	2036	1.432	174	6.999	2040	1.510	767	0.295
	1983	2685	2.204	3657	2.097	158	13.323	2544	2.057	1065	0.517
Electrical Products (33)	1969	3194	0.967	485	0.937	290	3.349	2148	0.995	760	0.210
	1976	4270	1.439	661	1.392	277	6.531	2705	1.382	1023	0.253
	1983	3943	2.673	1338	2.129	260	12.754	2591	2.317	1185	0.458
Chemical Products (37)	1969	3366	0.944	699	0.977	162	3.697	2055	0.987	2474	0.224
	1976	4655	2.212	876	1.812	177	7.172	2787	1.725	3607	0.286
	1983	4642	6.520	1213	4.118	196	14.163	3523	3.356	6326	0.539

shares must be symmetric. Since the cost shares are homogenous of degree zero in variable factor prices and there are only two variable factors, then this third condition has been imposed on the estimating system. Fourth, variable cost, variable factor cost share, product prices, product quantities and variable profit must be nonnegative. This condition was satisfied at each point in the sample by the estimation results.

The last integrability condition is that the variable cost function must be concave in the variable factor prices and variable profit must be concave in the output quantities. Initial estimates showed that the concavity conditions were not satisfied. Two reasons accounted for this failure; some parameters had the wrong sign and a structural shift or break in the industry outputs and capital input data occurred in the mid 1970's. In order to overcome these problems, certain parameters were restricted to be zero and dummy variables were introduced. The structural shift in industry outputs and capital stock could arise from a change in the distribution of firm outputs and capital within the industry. Recall that the industry variable cost function was consistent with the proportionality between firm and industry outputs and capital input. The proportions could differ between firms and between variables but were constant over time. To model the structural shift associated with the change in the firm distribution, dummy variables were introduced such that $y_i^j = \mu_i^j(1+d)y_i$ $i = 1, 2$ and $K^j = \phi^j(1+d)K$ where d is the dummy variable which is zero before 1977 and unity from 1977 onwards. With the dummy variable, the industry output and capital input variables were redefined in the estimating equations as $y_i(1+d)$ and $K(1+d)$.[15] The estimates found in Table 2 resulting from the parameter and variable transformations were consistent with all of the integrability conditions.[16]

The equation set was tested for autocorrelation. It was found that for each industry there was first order autocorrelation for the two inverse product demand functions. These equations were corrected for autocorrelation within the estimation of the system of equations. The parameter estimates presented in Table 2 generated equations whose residuals did not have any significant autocorrelation.

The results found in Table 2 show that the conjectural elasticities for the nonelectrical machinery industry operating in the domestic and foreign product markets were 0.63 and 0.91 respectively. The standard errors of these two parameters point out that each conjectural elasticity was different from zero. In addition, a test was conducted to see if these two elasticities were equal. The model was estimated with $\theta_1 = \theta_2$, the chi-square statistic between the two estimation results was 145.318 which was greater than $\chi^2_{005,1} = 7.879$. Thus the equality of the two conjectural elasticities for the nonelectrical machinery was rejected.

The inverse product demand elasticities for the domestic and foreign markets faced by the nonelectrical machinery industry found in Table 2 was -0.73 and -0.44 respectively Thus the degree of oligopoly power for the nonelectrical industry in the domestic market was 0.47 ($-\theta_i/\epsilon_i = -\theta_i\xi_i$) and in the foreign market the degree was 0.39. There was about a 20% differential in the degree of oligopoly power or in other words in the markups between the domestic and foreign markets. To see if the markups were equal the model was reestimated with $-\theta\xi_1 = -\theta_2\xi_2$. The chi-square statistic between the two estimation results was 12.194. Thus the equality of the two markups for the nonelectrical machinery industry was rejected.

From Table 2, the conjectural elasticities in the domestic and

TABLE 2: Estimation Results

Parameter	Nonelectrical Machinery Estimate	Nonelectrical Machinery Std.Error	Electrical Products Estimate	Electrical Products Std.Error	Chemical Products Estimate	Chemical Products Std.Error
B_0	7.5894	2.4394	12.7035	1.8302	50.3232	13.7741
B_1	-0.6822	0.1859	- 0.9407	0.3624	-19.1051	5.2623
B_2	0.6932	0.1922	0.2299	0.1219	12.1850	3.2805
B_v	0.9520	0.1744	0.2870	0.1401E-01	0.1528	0.3531E-01
B_k	-1.3350	0.4089	-1.3418	0.1744	- 1.1806	0.6167
B_t	-0.1784E-01	0.2615E-01	0.3842E-04	0.3842E-02	- 0.5417E-02	0.6878E-01
B_{11}	0.3151	0.5249E-01	0.1533	0.6082E-01	5.4185	1.3903
B_{22}	0.2909	0.2606E-01	0.9435E-01	0.2625E-01	2.8804	0.9839
B_{vv}	0.6779E-02	0.2624E-01	0.2237E-01	0.6984E-02	0.9883	0.1685E-01
B_{12}	-0.3046	0.3743E-01	-0.8684E-01	0.3274E-01	-3.7346	1.1084
B_{1k}	0.1734	0.1496E-01	0.1409	0.1303E-01		
B_{vk}	-0.1027	0.2566E-01				
B_{vt}					-0.8621E-02	0.2596E-02
θ_1	0.6322	0.9656E-01	0.2303	0.1007	0.2139	0.1044
θ_2	0.9132	0.2112	0.1531	0.6695E-01	0.0000*	0.0000
ξ_1	-0.7321	0.2626	-1.3852	0.1923	-0.7929	0.2954
ξ_2	-0.4376	0.2787	-2.0833	0.8313	-0.5318	0.2254
α_1	-0.1891	2.1497	2.6303	0.9518	0.9612	0.5221
α_2	0.4023	0.6859	6.1843	2.7560	0.4139	0.4614

Equation	Nonelectrical Machinery Standard Error	Electrical Products Standard Error	Chemical Products Standard Error
Variable Cost	0.3304 E-01	0.7128 E-01	0.2925
Labour Share	0.2022 E-01	0.1107 E-01	0.1855 E-01
Domestic Output	0.2663 E-01	0.7121 E-01	0.4851
Foreign Output	0.3081 E-01	0.1871 E-01	0.3006
Domestic Demand	0.1527	0.1627	0.2531
Foreign Demand	0.7533 E-01	0.2832	0.1319

* $\theta 2 = 0$

foreign markets for the electrical products industry was 0.23 and 0.15 respectively. The test to see whether or not $\theta_1 = \theta_2$ resulted in a chi-square statistic of 8.574 which was slightly greater than the $\chi^2_{005,1}$ = 7.879. Thus the conjectural elasticities for the electrical products industry were different from each other and each was different from zero.

The degree of oligopoly power or the price-cost differential in both the domestic and foreign markets for the electrical products industry was 0.32. In the estimation results presented in Table 2 the markups were constrained to be equal ($-\theta_1\xi_1 = -\theta_2\xi_2$). The chi-square statistic which resulted from the model being estimated with and without the equality of the markups was 1.334. Thus it was not possible to reject that price-cost differentials in the domestic and foreign markets were equal for the electrical products industry.

Turning to the chemical products industry, it was found that the conjectural elasticity relating to the foreign market was not different from zero. Thus Canadian producers in the chemical products industry were price-takers in the foreign market. However, the conjectural elasticity in the domestic market was 0.21. Combining this elasticity with the inverse product demand elasticity of -0.79 for the domestic market generates a markup of 0.17 for the chemical products industry.

Appelbaum [1982] found that for the U.S. electrical products industry the conjectural elasticity was on average about 0.20 and the degree of oligopoly power was also about 0.20. These results are similar to those obtained for the Canadian electrical products industry operating in both domestic and foreign markets. Hall [1986] and Domovitz, Hubbard and Peterson [1986b] not using an oligopolistic production approach found for the U.S. chemical products industry that the price-cost differential was more than twice the estimate found in this paper for the domestic market supplied by Canadian producers. For the U.S. nonelectrical machinery and electrical products, Domovitz, Hubbard and Peterson [1986b] found markups which were twice the magnitudes estimated in this paper for Canadian producers in both domestic and foreign markets, while Hall's [1986] U.S. estimates were two-thirds of the estimates for Canadian firms. Lastly, Appelbaum and Kohli [1979] estimated the price-cost differential for Canadian manufacturing exports. They estimated that the markup was 130% at the mean of the sample. Thus they concluded that Canadian firms were not price-takers in export markets. The estimates in this paper show that there was industry variation as to whether or not firms in export markets were price-takers. Indeed, producers in the nonelectrical machinery and electrical products industries did exert oligopoly power in their foreign markets.

The estimation results in this paper were obtained within a short-run equilibrium framework. However, most of the models used to determine price-cost differentials postulate that producers are in long-run equilibrium. In this paper the equilibrium specification of production is tested. The test follows the one outlined in Schankerman and Nadiri [1986].[17] Let B_s be the parameter vector for the equation set (7) - (10). Let B_k be the parameter vector from equation (11). Now partition the parameter vector B_s so that $B_s = (B_s^1, B_s^2)$, B_s^1 consists of parameters that appear in equations (7) - (10) but not in (11) and B_s^2 consists of the remaining parameters. Thus estimating the long-run equilibrium specification of the model (that is equations (7) - (11)) imposes the restriction that $B_s^2 = B_k$, while the short-run equilibrium specification does not impose any restrictions on B_s^2.

The test statistic is $M = (\tilde{B}_s - \hat{B}_s)^T \hat{V}^{-1}(\tilde{B}_s - \hat{B}_s) \approx \chi^2_q$, where $\tilde{B}_s$ is the consistent estimator of B_s from equations (7) - (10) and $\hat{B}_s$ is the consistent estimator of B_s from equations (7) - (11) (with the restriction $B_s^2 = B_k$), $\hat{V}$ is the consistent estimator of $V = V_s - V_\ell$ where V_s is the asymptotic covariance matrix of $(\tilde{B}_s - B_s)$ and V_ℓ is the asymptotic covariance matrix of $(\hat{B} - B_s)$. The M statistic is asymptotically distributed as a chi-square distribution with q degrees of freedom, where q is the number of parameters in B_k (that is in equation (11)), and represents the number of parameter restrictions in the test. The value of M for nonelectrical machinery was 161.173 and $\chi^2_{005,3} = 12.838$; for electrical products M was 213.474 and $\chi^2_{005,2} = 10.597$; and lastly the value of M for chemical products was 814.288 and $\chi^2_{005,1} = 7.879$. Thus the long-run equilibrium specification was rejected for each of the three industries. Capital was a quasi-fixed factor so that its expected marginal benefit was not equated to its factor price. This result implies that producers in Canadian industries did not determine their capital decisions in the same manner as those for labour and materials.

4. TOTAL FACTOR PRODUCTIVITY GROWTH

An important measure of industrial growth and thereby of dynamic or innovative efficiency is the rate that output growth exceeds input growth. The differential in these growth rates defines the rate of total factor productivity (TFP) growth. In general TFP growth arises from technological change and from increasing returns to scale. However, if product prices are not equal to marginal costs and if marginal cost reduction due to capital expansion is not equal to its rental rate then two additional sources of profitability and thereby of TFP growth can occur.

Denny, Fuss and Waverman [1981] have shown how TFP grc th is related to the gap between price and marginal cost under long-run equilibrium conditions. In the present short-run equilibrium framework applicable to the industries considered in this paper, TFP growth is decomposed into technology, scale, margin and capital adjustment components.

The definition of TFP growth is

$$(12) \qquad TFPG = \Sigma_j \frac{p_j y_j}{R} \frac{dlny_j}{dt} - \Sigma_i \frac{w_i v_i}{c} \frac{dlnv_i}{dt} - \Sigma_k \frac{w_k K_k}{c} \frac{dlnK}{dt}$$

where total revenue is $R = \Sigma_j p_j y_j$ and total cost is $c = c^V + \Sigma_k w_k K_k$. Recall that in the estimation model there are two outputs, two variable factors and one quasi-fixed factor.[18]

In general with the variable cost function defined by the right side of equation (1) and with the definition of variable cost as $c^V = \Sigma_i w_i v_i$ then

$$(13) \qquad 0 = [-\Sigma_j \frac{\partial lnc^V}{\partial lny_j} \frac{dlny_j}{dt} + \Sigma_i \frac{w_i v_i}{c^V} \frac{dlnv_i}{dt}$$

$$- \Sigma_k \frac{\partial lnc^V}{\partial lnK_k} \frac{dlnK_k}{dt} - \frac{\partial lnc^V}{\partial t}]/(1-\Sigma_k \frac{\partial lnc^V}{\partial lnK_k}) \; .$$

By adding (13) to (12) and with further manipulation

$$(14) \qquad TFPG = - \frac{\partial lnc^V}{dt}/(1-\Sigma_k \frac{\partial lnc^V}{\partial lnK_k})$$

$$+ ((1-\rho_y{}^{-1}) \; \Sigma_j \frac{\partial lnc^V}{\partial lny_j} \frac{dlny_j}{dt}/\Sigma_j \frac{\partial lnc^V}{\partial lny_j})$$

$$+ \Sigma_j \left(\frac{p_j y_j}{R} - \frac{\partial \ln c^V/\partial \ln y_j}{\Sigma_j \partial \ln c^V/\partial \ln y_j}\right)\frac{d\ln y_j}{dt}$$

$$+ \rho_y^{-1} \left[\left[\Sigma_k \left(\frac{w_k K_k}{c^V} + \frac{\partial \ln c^V}{\partial \ln K_k}\right)\left(\Sigma_h \frac{w_h K_h}{c} \frac{d\ln K_h}{dt} - \frac{d\ln K_k}{dt}\right)/\Sigma_j \frac{\partial \ln c^V}{\partial \ln y_j}\right]\right.$$

$$\left. + \left(\Sigma_k \left(\frac{w_k K_k}{c^V} + \frac{\partial \ln c^V}{\partial \ln K_k}\right)/\Sigma_j \frac{\partial \ln c^V}{\partial \ln y_j}\right) \Sigma_i \frac{w_i v_i}{c} \frac{d\ln v_i}{dt}\right],$$

where $\rho_y = (1 - \Sigma_k \partial \ln c^V/\partial \ln K_k)/(\Sigma_j \partial \ln c^V/\partial \ln y_j)$ (See Caves et al [1981] and Bernstein [1989]).

There are five terms on the right side of equation (14). These terms point out the decomposition of TFP growth. The terms relate to; technological change $(-\partial \ln c^V/\partial t)/(1-\Sigma_k \partial \ln c^V/\partial \ln K_k)$, returns to scale (ρ_y), price-cost margins $(p_j y_j/R - \partial \ln c^V/\partial \ln y_j)/(\Sigma_q \partial \ln c^V/\partial \ln y_q))$, and capital adjustment $(w_k K_k/c^V + \partial \ln c^V/\partial \ln K_k)$. If output growth is positive, then, for either a positive rate of technological change, increasing returns to scale or product prices greater than marginal costs (with revenue equalling total cost) there is a positive rate of TFP growth. However, there are two terms associated with the capital adjustment component. From the fourth term on the right side of (14), for the kth capital input, if the cost reduction exceeds the rental rate, with a positive growth rate of capital that exeeds the weighted average of capital growth rates, then the rate of growth of TFP is positive. There is also a capital adjustment term associated with the variable factors. If the variable factor growth rates are positive while the capital growth rates are held constant then a cost reduction exceeding the rental rate implies that there is insufficient capital relative to the variable input quantities. In this case TFP growth becomes negative. Thus the capital adjustment component generates effects on TFP growth through capital growth and variable factor growth.

In order to determine industrial TFP growth and its components, the rate of technological change, the degree of returns to scale, the price-cost margins and the capital adjustment term must be computed for each industry. The degree of returns to scale in short-run equilibrium is measured as $\rho_y = (1-\partial \ln c^v/\partial \ln K)/(\Sigma_{i=1}^{2} \partial \ln c^v/\partial \ln y_i)$. Table 3 shows the degree of returns to scale and its components for each industry. There are three components to returns to scale; the effect of capital on variable cost and the effect of each output on variable cost.

In each industry, capital increases caused variable cost to decline. From Table 3, in the nonelectrical machinery industry a 1% increase in capital led to a 0.15% decrease in variable cost in 1983. The effect was 50% greater in the electrical products industry compared to nonelectrical machinery. In the chemical products industry the only parameter associated with capital was $B_k = -1.1806$, which defined the capital elasticity of variable cost.

The output elasticities of variable cost in Table 3 showed that at the margin it was relatively more costly to produce output for domestic markets than for export. Indeed, the export elasticity of variable cost was only about 10% to 70% of the variable cost effect of domestic output. This is an important result as the magnitudes of the cost flexibilities showed that it paid for the industries to diversify to export markets. This finding is further highlighted by considering the effect of increasing one output on the cost flexibility of the other output. The effect is denoted by the value of the parameter B_{12} which was negative and significant for each of the industries (see Table 2). Thus the percentage increase in variable cost due to one output, declined as the other output grew. In terms of cost flexibility, there were variable cost

TABLE 3: **VARIABLE Cost and Scale Elasticities**

Industry	Year	Capital	Domestic Output	Export Output	Scale
Nonelectrical	1969	-0.1310	0.7826	0.3049	1.0400
Machinery	1976	-0.0637	0.0825	0.3200	0.9262
	1983	-0.1486	0.7548	0.5250	0.9735
Electrical	1969	-0.2130	0.7324	0.0662	1.5189
Products	1976	-0.1533	0.7395	0.1379	1.3145
	1983	-0.2172	0.7258	0.1942	1.3230
Chemical	1969	-1.1806	1.1981	0.2654	1.4987
Products	1976	-1.1806	1.5006	0.3417	1.1905
	1983	-1.1806	1.6822	0.3168	1.0972

complementarities between domestic and export markets. A test was conducted for each industry to see if the cost flexibilities for domestic and foreign sold outputs were equal. This test involved three parameter restrictions ($B_1 = B_2$, $B_{11} = B_{22}$, $B_{12} = 0$) and the model was reestimated with the restrictions. The chi-square statistic between the unrestricted and restricted estimation was 95.174 for nonelectrical machinery, 201.744 for electrical products and 85.544 for chemical products. Since $\chi^2_{005,3}$ = 12.838, the hypothesis that the cost flexibilities were equal was rejected. Domestic and foreign sold outputs exerted differential effects on variable cost and were complementary.

The degree of returns to scale is given in the last column of Table 3. The estimation results showed that there were increasing returns to scale for the electrical and chemical products industries, and constant returns to scale for the nonelectrical machinery industry. In 1983 returns to scale was 0.97 for nonelectrical machinery, 1.32 for electrical products and 1.10 for chemical products. A test for constant returns to scale was conducted. The test involved the restrictions $B_1 + B_2 + B_k = 1$, $\Sigma_{i=1}^{2} B_{ji} + B_{jk} + B_{jv} = 0$ j=1,2 and $\Sigma_{i=1}^{2} B_{ik} + B_{kk} + B_{vk} = 0$. Thus for the chemical products industry there were three restrictions and for the other two industries there were four restrictions (see Table 2). The chi-square statistic arising from the estimation with and without the restrictions was 9.564 for nonelectrical machinery, 193.152 for electrical products and 40.144 for chemical products. Since $\chi^2_{005,4}$ = 14.860 and $\chi^2_{005,3}$ = 12.838 then constant returns to scale was rejected for electrical and chemical products and could not be rejected for nonelectrical machinery.

The rate of technological change is defined by $-(\partial \ln c^V/\partial t)/(1-\partial \ln c^V/\partial \ln K)$. The rates for each industry are shown in

Table 4. There was virtually no technological change for the electrical products industry, while the rate was around 1.6% for nonelectrical machinery and 0.08% for chemical products. In addition, the positive rates of technological change were quite constant over the sample period. In the chemical products industry technological change was also labour reducing and material using as the B_{vt} parameter (see Table 2) in the labour share equation was negative and significantly different from zero.

The last component of TFP growth relates to capital adjustment.[19] Capital adjustment is defined by $(w_k K/c^v + \partial \ln c^v/\partial \ln K)$. Clearly if producers are in long-run equilibrium then the capital adjustment component is zero, as the percentage reduction in variable cost equals the ratio of capital to variable cost. However, as shown in the previous section, long-run equilibrium was rejected, and thus the capital adjustment terms were statistically different from zero. In Table 4 the capital adjustment term for the nonelectrical machinery industry in 1983 was 0.10%, for a 1% increase in the capital stock. This figure means that there was a net positive benefit from increases in capital at the margin. The same result was observed for electrical and chemical products. The net benefit percentages for these two industries in 1983 was 0.14% and 0.99%, for a 1% increase in their respective capital stocks. Thus for all three industries in short-run equilibrium, the percentage reduction in variable cost exceeded the ratio of capital to variable cost.

TFP growth and its decomposition are given in Table 5. TFP growth fell over the sample period. Each industry exhibited a slowdown in productivity growth and, in fact, over the first part of the 1980's the average annual rates of TFP growth for the industries were negative. The rate of technological change was the major contributor to TFP growth in the

TABLE 4: Rates of Technological Change and Capital Adjustment

Industry	Year	Technological Change	Capital Adjustment
Nonelectrical Machinery	1969	0.0157	-0.0518
	1976	0.0168	-0.0114
	1983	0.0155	-0.0971
Electrical Products	1969	0.0000	-0.1541
	1976	0.0000	-0.1109
	1983	0.0000	-0.1417
Chemical Products	1969	0.0076	-0.9922
	1976	0.0080	-0.8982
	1983	0.0081	-0.9891

TABLE 5: TFP Average Annual Growth Rates and Decomposition

Industry	Period	TFPG	Technological Change	Returns to Scale	Price-Cost Margins	Capital Adjustment
Nonelectrical Machinery	1965-1970	0.0208	0.0159	0.0043	-0.0006	0.0012
	1971-1978	0.0138	0.0162	-0.0018	0.0010	-0.0016
	1979-1983	-0.0005	0.0160	-0.0030	-0.0137	0.0002
Electrical Products	1965-1970	0.0255	0.0000	0.0190	0.0015	0.0050
	1971-1978	0.0195	0.0000	0.0221	0.0001	-0.0027
	1979-1983	-0.0121	0.0000	-0.0280	0.0002	0.0157
Chemical Products	1965-1970	0.0650	0.0072	0.0554	-0.0014	0.0038
	1971-1978	0.0393	0.0081	-0.0056	-0.0003	0.0371
	1979-1983	-0.0160	0.0078	0.0241	-0.0008	-0.0471

nonelectrical machinery industry. Although from 1979 to 1983, price-cost margins offset the rate of technological change and were a major element in the slowdown of TFP growth for nonelectrical machinery. TFP growth in the electrical products industry was governed by the returns to scale component. Although in the period from 1979 to 1983, the capital adjustment term was also a major element in the average annual growth rate of TFP for the electrical products industry. Indeed the capital adjustment component offset, in part, the negative influence of returns to scale during the latter part of the sample period. Next for chemical products, returns to scale was the major component in the last half of the 1960's and capital adjustment was the major component in the first half of the 1970's. Since that time, both scale and capital adjustment terms have governed TFP growth. However these two effects have worked in opposite directions over the first half of the 1980's.

Thus the estimation results point out that price - cost margins were not major contributors to the growth rate of TFP and to its slowdown in two of the three industries. Technological change contributed to TFP growth and price-cost margins to its slowdown in the nonelectrical machinery industry, while returns to scale and capital adjustment contributed to productivity growth in electrical and chemical products. These results differ from Hall [1980] and Domovitz, Hubbard and Peterson [1986b] who found for the same industries operating in the U.S. that markups had a positive and significant effect on TFP growth. Their models, however, assumed constant returns to scale and long-run equilibrium. Thus they assumed away the elements which contributed to TFP growth in the Canadian electrical products and chemical products industries.

5. SUMMARY

A model of an oligopolistic industry producing multiple outputs in short-run equilibrium was developed and estimated. There were two outputs; one sold in the domestic market and the other exported. The model was applied to three Canadian manufacturing industries who export a significant portion of their output. It was estimated that there was significant oligopoly power in the three industries. The results for nonelectrical machinery showed that the price-cost margin for the domestic product was 47% while the exported product had a markup of 39%. The degree of oligopoly power for the electrical products industry was 32% and this markup was the same for products sold in domestic and foreign markets. The export market for chemical products was competitive as Canadian producers were price-takers in this market. However, these producers did exhibit oligopoly power in the domestic market with a price-cost margin of 17%.

Returns to scale, the rates of technological change and capital adjustment were computed for each industry. These measures indicate important production characteristics. In particular, they are components of productivity growth and thereby can indicate the sources of the slowdown in this growth rate. Returns to scale were increasing for electrical and chemical products, with magnitudes of 1.3 and 1.1 respectively in 1983. There were constant returns to scale for the nonelectrical machinery industry. In computing returns to scale, it was found that the cost flexibilities between output sold in the domestic market and exports were significantly different from each other. A 1% increase in exports led to a much smaller rise in variable cost than a 1% increase in output sold domestically. This result occurred for each industry. Hence it paid for Canadian producers to diversify to export markets. There were cost complement- arities between the two outputs.

The estimation results showed that the rate of technological change for nonelectrical machinery was 1.6%, 0.8% for chemical products and essentially zero percent for electrical products. However, the rates of capital adjustment for each industry were significantly different from zero. This rate measures the extent to which producers are in short-run equilibrium, and reflects the percentage difference between the marginal benefit (variable cost reduction) and marginal cost (rental rate) from a 1% expansion in the capital stock. It was estimated that in 1983 the net marginal benefit from a 1% increase in capital was 0.10% for nonelectrical machinery, 0.14% for electrical products and 0.99% for chemical products. Indeed tests were conducted and it was found that each industry was not in long-run but rather in short-run equilibrium.

TFP growth was computed and decomposed for each industry. Over the sample period there was a slowdown in the TFP growth rate. The slowdown began in the mid 1970's and resulted in negative growth rates for the three industries. TFP growth for nonelectrical machinery fell from an average annual rate of 2.1% over the period 1965-1970 to a rate of 0.05% over 1979-1983 period. For these same periods the TFP growth rate for electrical products fell from 2.6% to -1.2% and for chemical products the rate went from 6.5% to -1.6%.

The decomposition of TFP growth rates determine the source of the slowdown. It was found that, although price-cost margins were significant, the differentials were generally not important influences on TFP growth in each of the industries. In the nonelectrical machinery, the rate of technological change was the major component of productivity growth, while price-cost margins caused the slowdown. Returns to scale and capital adjustment were the main elements governing productivity growth and its slowdown in the electrical and chemical products industries.

FOOTNOTES

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1. The work of Iwata [1974], Gollop and Roberts [1979] and Porter [1983], although dealing with oligopolistic industries, focused solely on output markets. Their research omitted the interaction between output and input markets.

2. The quasi-fixed factors are fixed in the short-run and variable in the long-run.

3. The variable cost function is derived from the problem $\min_{(v^j)} wv^j$ subject to $T^j(y^j, v^j, K^j) = 0$ where v is the vector of variable factors and T is the transformation function.

4. The industry degree of oligopoly power for each product is a Lerner index (see Cowling and Waterson [1976]).

5. The proportionality parameters are assumed to be constant, otherwise a complicated random parameter estimation problem arises. However, the model is estimated for discrete changes in the proportionality parameters by the use of dummy variables.

6. In the firm variable cost functions (equation (1)), a firm specific technology indicator could have been introduced. Thus for aggregation it would be necessary to assume that $t^j = t + \psi^j$ where ψ^j is the difference among firms of technology indicators. Since the technology indicator is an exogenous time trend, it was assumed that $t^j = t^k$ $j \neq k = 1, \ldots, F$.

7. More general logarithmic inverse product demand functions were used in the estimation of the model, but they did not perform as well as the linear logarithmic form given by equation (8).

8. If the marginal cost for product i does not vary across firms then as a consequence of a unique equilibrium $\theta_i^j = \theta_i^k$.

9. Output quantities and product prices are endogenous so the aggregate ratios of revenue to variable cost are defined in terms of their components in the estimating equations.

10. The capital cost to variable cost ratio is written in terms of its components in the estimating equations because the capital input is endogenous.

11. The labour input quantity and price are defined in terms of the total activity concept as opposed to the manufacturing activity concept. For example hours worked include labour used for merchandising commodities for resale and for carrying out construction for own use.

12. The variable z was constructed for machinery and equipment (M & E) and building and construction (B & C). For the period 1962-1981 which was outside the half-year rule for claiming capital cost allowances,

$$z_m = \Sigma_{t=1}^{L} \propto_m(1 - \nu)/(1 + \rho)^{t-1}$$

$$z_b = \propto_b(1 - \nu)(1 + \rho)/(\rho + \propto_b)$$

where the subscript m relates to M & E and the subscript b relates to B & C, $\propto_m$ is the straightline capital cost allowance rate for M & E, $L = 1/\propto_m$ is the tax life of M & E, $\propto_b$ is the declining balance capital cost allowance rate for B & C. Notice that the investment tax credit reduces the capital cost allowance. Inside the half-year rule, which pertains to 1982 and 1983,

$$z_m = \frac{\alpha_m(1-\nu)}{2} + \Sigma_{t=1}^{L-1} \frac{\alpha_m(1-\nu)}{(1+\rho)^t} + \frac{\alpha_m(1-\nu)}{2(1+\rho)^L}$$

$$z_b = \frac{\alpha_b(1-\nu)}{2} + (1-\frac{\alpha_b}{2})(\frac{\alpha_b(1-\nu)}{(\rho+\alpha_b)}.$$

13. Each of the remaining foreign markets had significantly smaller shares of Canadian exports relative to the U.S.

14. TSP version 4.0 was the statistical software that was used for all the empirical results. The full information maximum likelihood estimator was used in order to account for the fact that the equation system was simultaneous and the error terms were correlated across equations in any given time period. Also all the industry level parameters in the equation system were identified.

15. An alternative way to incorporate the concavity conditions is to impose parameter restrictions through a Cholesky factorization of the relevant parameter matrix (see Jorgenson [1986]). These restrictions result in a set of equations with a greater number of parameters, which are nonlinear in the parameters, and which have nonlinear parameter restrictions within and between equations. A Cholesky factorization of the parameter matrix was attempted for each industry's model. However, the estimator failed to converge in each case. In addition this method does not account for the structural change in the industry outputs and capital input data.

16. There were 87 degrees of freedom for the nonelectrical machinery industry short-run model and 88 degrees of freedom each for the short-run models of electrical products and chemical products industries.

17. An alternative test proposed by Kulatilaka [1985] does not lead to a single test statistic for all observations.

18. The definition of TFP growth is based on a divisia index (see Hulten [1973]).

19. The price-cost components of TFP growth were discussed in the previous section, when the degrees of oligopoly power were computed.

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