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PRICE MARGINS AND CAPITAL ADJUSTMENT: CANADIAN MILL PRODUCTS AND PULP AND PAPER INDUSTRIES

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ABSTRACT

The purpose of this paper is to estimate a model incorporating noncompetitive behaviour in product and factor markets. In addition, capital accumulation is subject to adjustment costs so that firms are not constrained to be in long-run equilibrium.

The model is applied to two major Canadian manufacturing industries; pulp and paper and mill products. The results show for both industries in each of the three product markets and the wood input market that there is competitive behaviour. In addition, the industries are not in long-run equilibrium as marginal adjustment costs cause marginal profit to exceed the rental rate on capital.

With the industries exhibiting short-run competitive behaviour in product and factor markets, new estimates are derived for scale economies and rates of technological change. Unlike the results from other studies, both industries exhibit small scale economies and positive rates of technological change.

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1. Introduction*

Canadian industries tend to be more concentrated than similar industries in other countries (see Green [1985]). This can result in prices exceeding marginal costs in product markets. In addition, and especially for industries that use specific inputs, concentration can also result in marginal revenue products exceeding prices in factor markets. The first purpose of this paper is to develop and estimate a model incorporating non-competitive behaviour in product and factor markets. The model is applied to the Canadian mill products and pulp and paper industries. These two industries are selected because together they constitute the largest Canadian manufacturing industries (wood and paper and allied products account for 4.5% of shipments and 2.7% of employment in 1987). Hence there is the possibility of price-cost margins in their product markets. The two industries are also the major users of Canadian forests, which represent a significant natural resource in the economy. Thus it is feasible that the marginal revenue product can exceed the factor price for the wood input in the mill products and pulp and paper industries.

The approach adopted in this paper to model non-competitive behaviour in product and factor markets is based on duality theory (see Diewert [1982]). The significance of the dual approach is that both product and factor decisions are simultaneously modelled. Thus, non-competitive behaviour in product markets affects factor demand decisions, while conversely, non-competitive behaviour in factor markets affects product supply decisions. Geroski [1988] and Bresnahan [1989] provide excellent surveys of the empirical approaches to analysing price-cost differentials in product markets. Most applications of the dual approach to non-competitive behaviour have focused on product markets. Appelbaum [1979] for U.S. crude petroleum and natural gas industry, Appelbaum and Kohli [1979] for the Canadian manufacturing sector, Appelbaum [1982] for U.S. rubber, textiles, electrical and tobacco industries, Roberts [1984] for U.S. coffee roasting firms, Morrison [1989] for U.S., Canadian and Japanese manufacturing sectors, and Bernstein and Mohnen [1991] for Canadian chemical, electrical and nonelectrical machinery industries. In this paper non-competitive behaviour is parameterized using duality theory for both product and factor markets.

In previous studies of non-competitive pricing, production is assumed to occur in either short or long-run equilibrium.[1] Assumptions regarding the characterization of equilibrium are important for the investigation of non-competitive pricing. It is possible to wrongly infer that market power exists in a situation where product prices are above apparent long-run marginal costs. Adjustment costs associated with changes in short-run fixed factors (in other words, quasi-fixed factors) cause short-run marginal costs to exceed long-run marginal costs. It is then possible for product prices to equal short-run marginal costs. Firms behave competitively in the short-run as they adjust towards a long-run equilibrium. Thus it is important to account for firm adjustment in order to assess the existence of non-competitive behaviour.

There is a growing body of evidence suggesting that capital accumulation is subject to adjustment costs (see Morrison and Berndt [1981], Epstein and Yatchew [1985], Mohnen, Nadiri and Prucha [1986], Bernstein and Nadiri [1989]). Firms that incur adjustment costs are unable to costlessly attain long-run equilibrium. Firms adjust toward the long-run through successive short-run equilibria. Indeed, at the margin, adjustment costs characterize the deviation between short and long-run equilibrium. In this paper non-competitive pricing behaviour is modelled when firms incur adjustment costs. Non-competitive behaviour can occur in either short or long-run equilibrium.

Adjustment costs are an intrinsic part of firm technology. Consequently their existence can affect the degree of scale economies and the rate of technological change undertaken by firms. Moreover, scale economies and technological change are not invariant to the levels of output supply and input demand. Thus because non-competitive pricing affects equilibrium quantities in product and factor markets, observed degrees of scale economies and rates of technological change are influenced by deviations from competitive behaviour. In this paper the degree of scale economies and rate of technological change are measured within the context of non-competitive pricing in product and factor markets and capital adjustment costs.

The paper is organized into sections. Section 2 contains the development of the theoretical model. Section 3 details the estimation model and results regarding non-competitive pricing and adjustment costs. Section 4 investigates the degree of scale economies and rate of technological change. The last section of the paper is the conclusion.

2. The Model

In general a firm's production technology can be represented as

$$T(y(t),K(t-1),v(t),I(t),A(t)) = 0 \quad (1)$$

where T is a transformation function, y is an $\underline{l}$-dimensional vector of outputs, K is an m-dimensional vector of capital inputs, v is an n-dimensional vector of variable inputs (such as labor and materials), I is the vector of additions to the capital inputs, and A is an indicator of the level of technology. T is twice continuously differentiable, increasing and concave in y and I, and decreasing and convex in K and v. Since the production process is defined over I, the gross investment vector, then there are adjustment costs associated with expanding capital inputs. These costs are internal to the production process and are manifested by the foregone output when resources are diverted from output production to capital expansion, (see Lucas [1967], Treadway [1971] and Epstein [1982]).

The accumulation of the capital stocks is governed by

(2) $K(t) = I(t) + (I_m - \delta)K(t-1)$

where I_m is the m-dimensional identity matrix and δ is the diagonal matrix of exogenous depreciation rates.[2]

Production decisions are determined by the maximization of the expected present value of the flow of funds. This present value is given by

(3) $J(t) = \Sigma_{s=t}^{\infty} E(t)\alpha(t,s)[P^T(s)y(s) - W^T(s)v(s) - Q^T(s)I(s)],$

where E is the expectations operator conditional on information known in period t, P is the vector of product prices, W is the vector of variable input prices, Q is the vector of capital purchase prices. The superscript T represents vector transposition.

Production and investment decisions can be determined in two stages. The first stage relates to the short-run equilibrium in the product and variable factor markets. In this stage variable profit, which is denoted by

(4) $\pi^v = P^T y - W^T v,$

is maximized subject to the production technology (equation (1)) and conditional on the level and additions to the capital stocks.[3] In this model firms are not assumed to be price-takers in product and variable factor markets. Price-setting ability is introduced through product and variable factor shadow (or marginal) prices.

(5.1) $P^s = P(I_\ell + \Gamma)$

(5.2) $W^s = W(I_n + \Theta)$

where I_ℓ and I_n are identity matrixes of dimension ℓ and n, $\Gamma<0$ is a diagonal matrix of product price-marginal revenue proportions, $\Theta>0$ is a diagonal matrix of variable factor price - marginal factor cost proportions. The elements of Γ depend on product demand functions and interdependencies among product suppliers. In particular, the elements of Γ relate to the inverse price elasticities of product demand and the conjectural elasticities of firm interdependence in product markets. The elements of Θ depend on variable factor supply functions and interdependencies among variable factor demanders. Specifically the elements of Θ pertain to the inverse price elasticities of variable factor supply and the conjectural elasticities of firm interdependence in factor markets.

Diewert [1982] rigorously established that when Γ and Θ are matrices of exogeneous variables a monopolist (or monopsonist) in short-run (or long-run) equilibrium can be viewed as undertaking production decisions according to the maximization of variable profit evaluated at the prices given by equation (5). In this case the elements of Γ and Θ relate respectively to the exogeneous inverse price elasticities of product demand and variable factor supply. The Diewert result was extended to an oligopolistic framework by Roberts [1984].[4] In this context the elements of Γ relate to the inverse price elasticities of product demand and the conjectural elasticities of firm interdependence in product markets.[5] Diewert and Roberts refer to prices defined by equation set (5) as shadow prices and the variable profit evaluated at these prices as shadow variable profit.

Maximizing shadow variable profit leads to the shadow variable profit function, which is denoted as

(6) $\pi^s = \Pi^s(P^s, W^s, K, I, A).$

By applying Hotelling's Lemma with respect to the shadow prices (see Diewert [1982]), short-run product supply and variable factor demand functions are

(7.1) $y = \nabla\Pi_p^s\ (P^s, W^s, K, I, A)$

(7.2) $v = -\nabla\Pi_w^s\ (P^s, W^s, K, I, A).$

These equations show that short-run production decisions depend on product and variable factor shadow prices, the level and additions to the capital stocks and the indicator of technology.

There a number of attractive features associated with the use of the shadow variable profit function to empirically analyse non-competitive behaviour in product and factor markets. First, non-competitive behaviour in one market affects output supply and input demand functions relating to all markets in which firms operate. Any one shadow price affects the complete array of decisions on product supply and factor demand. Second, product demand and factor supply functions do not have to be specified. Through the shadow prices, non-competitive behaviour is parameterized by the elements of the Γ and Θ matrices. However, a difficulty with the use of the shadow variable profit function is that both price and conjectural elasticities cannot be identified. For example, without further information on price elasticities, it is not possible to identify the nature of firm interdependencies in product and factor markets. Nevertheless, the purpose of this paper is not to investigate the various types of firm interactions, but rather to determine whether firm decisions on product supply and factor demand equate product prices to marginal costs and variable factor prices to marginal revenue products.[6] If shadow prices differ from market prices in product markets then product prices differ from marginal costs of production. In addition, if shadow prices differ from market prices in variable factor markets then variable factor prices differ from marginal revenue products.

The second stage of production decisions pertains to the determination of the demand for the capital stocks. The equilibrium conditions relating to the capital stocks are determined by using the shadow variable profit function (equation (6)) and the capital accumulation equations (equation set (2)). In this stage the shadow flow of funds

$$(8)\qquad J^{s}(t) = \Sigma_{s=t}^{\infty} E(t)\alpha(t,s)[\Pi^{s}(P^{s}(s),W^{s}(s),K(s-1), K(s)-(I_m-\delta)K(s-1),A(s))-Q^{T}(s)(K(s) -(I_m-\delta)K(s-1))]$$

is maximized by selecting $K(s), s=t,\ldots,\infty$. The Euler equations for this stage of the production problem are

$$(9)\qquad E(s)[\nabla\Pi_k^{s}(s+1)-(I_m-\delta)\nabla\Pi_i^{s}(s+1)] + \alpha(s,s+1)^{-1}\nabla\Pi_i^{s}(s)-W_k(s)=0$$

where $W_k(s)=\alpha(s,s+1)^{-1}Q(s)-(I_m-\delta)E(s)Q(s+1)$ is the vector of rental rates. Equation (9) points out that the expected marginal benefit of the capital stocks equals the marginal capital input cost. The marginal benefit consists of two components; the marginal profit and the reduction in marginal adjustment cost due to the undepreciated capital stocks brought forward to period s+1 from periods. The marginal capital input cost consists of two components; the rental rate and the marginal adjustment cost. Another way to view equation (9) is that the expected marginal benefit of the capital stocks is equated to the respected shadow rental rates. These shadow rental rates deviate from the market rental rates by marginal adjustment costs. If shadow rental rates equal market rental rates then expected marginal profitabilities equal market rental rates. In this situation firms are in long-run equilibrium. The existence of marginal adjustment costs imply that firms are in the process of expanding (or reducing) their capital stocks. In addition, from the first stage characterizing production decisions, firms also adjust product supply and variable factor demands as capital stocks change. Therefore marginal adjustment costs (or deviations between shadow and market rental rates) signify that firms are in short-run equilibrium.

In capital input markets, as for the other markets under consideration, shadow prices govern firm decisions. However, deviations of shadow from market prices in product and variable factor markets are the result of non-competitive behaviour, while the price deviations in the capital input markets result from the production technology and reflect short-run equilibrium. It is important to account for both non-competitive behaviour and the type of equilibrium. The reason is that it is possible to incorrectly infer that product market power exists in a situation where prices are above long-run marginal costs. Firms may be in short-run equilibrium. Firms behaving competitively in the short-run set product prices to short-run marginal costs. These costs exceed long-run marginal costs because of the costs associated with capital adjustment. The equilibrium conditions (equations (6),(7) and (9)) admit the possibility of testing hypotheses relating to non-competitive behaviour and short-run equilibrium. Indeed, by parameterizing the shadow variable profit function and the relationships between market and shadow prices, hypothesis testing can be undertaken.

3. Estimation Model and Results

The model that is estimated consists of the equilibrium conditions (equations (6),(7) and (9)). The data relate to time series of variables from Canadian mill products (SIC 251) and pulp and paper (SIC 271) industries. These two industries are selected because some interpretations of the stylized facts suggest that firms producing mill products pay for their wood inputs below the marginal revenue product earned through the use of the input (see Constantino [1986] and U.S. International Trade Commission [1985]), while pulp and paper firms price their products above marginal cost (see Klein [1985] and Martinello [1985]. The two industries taken together are the largest manufacturing industries in Canada at the three digit SIC level in terms of shipments and employment. In addition, these industries are the major users of wood inputs obtained from Canadian forests, which is an important natural resource in the Canadian economy. The model is estimated for each of the two industries in order to investigate non-competitive behaviour in output and input markets.

A dynamic model is specified with capital adjustment costs so that firms are not assumed to be in long-run equilibrium. The dynamic model is preferable to estimate in order to examine deviations from competitive behaviour in product and factor markets and deviations from long-run equilibrium. The reason is that if the data are not consistent with long-run equilibrium then the equality between shadow and market prices would be rejected even if firms are acting competitively in the short-run.

The estimation of the model is carried out using industry data. In other words, deviations between shadow and market prices are measured for each of the industries. If all the firms in an industry equate shadow to market prices then at the industry level these same equalities will be satisfied. Hence unless firms exhibit non-competitive behaviour and incur capital adjustment costs, the estimated model will not indicate inequalities between shadow and market prices. Hypothesis tests regarding deviations between shadow and market prices do not test whether the product demand and factor supply curves facing the industry are horizontal, but whether firms decisions equate product prices to marginal costs, variable factor prices to marginal revenue products and expected marginal profits to rental rates. The framework is useful in determining deviations between shadow and market prices in product and factor markets.

In order to estimate the equilibrium conditions a functional form for the shadow variable profit function must be specified. It is assumed that the function is translog, (see Jorgenson [1986] and the references cited therein) which is a flexible functional form. Using equation set (5)

$$
\begin{aligned}
(10.1)\quad \ln\pi^{s} = {} & \beta_0 + \Sigma_{i=1}^{5}\beta_i \ln P_i(1+\gamma_i) + \beta_k \ln K + \beta_a \ln A \\
& + .5\ [\Sigma_{i=1}^{5}\Sigma_{j=1}^{5}\beta_{ij}\ln P_i(1+\gamma_i)\ln P_j(1+\gamma_j) + \beta_{kk}(\ln K)^2 + \beta_{aa}(\ln A)^2 \\
& + \Sigma_{i=j}^{5}\ln\beta_{ik}\ln P_i(1+\gamma_i)\ln K + \Sigma_{i=j}^{5}\beta_{ia}\ln P(1+\gamma_i)\ln A \\
& + \beta_{ka}\ln K \ln A
\end{aligned}
$$

where $\beta_{ij} = \beta_{ji}$, π^{s} is shadow variable profit normalized by the price of energy P_i i=1,2,3 are the three output prices normalized by the energy price, P_j j=4,5 are the prices of the wood and labour inputs which are normalized by the energy price, $\gamma_i<0$ i=1,2,3 are the deviations between shadow and market product prices, (γ_i are the elements in Γ in equation (5.1)), $\gamma_4>0$ is the deviation between the shadow and market factor price of wood (γ_4 is the nonzero element in Θ in equation (5.2)), the shadow and market price deviations for labour and energy are assumed to be zero. The deviations between shadow and market prices are parameterized by γ_i i=1,...,4.[7]

Marginal adjustment cost is assumed to be zero when net investment is zero so that in long-run equilibrium there is no difference between the shadow and market rental rates for capital (see Berndt and Morrison [1981], Mohnen, Nadiri and Prucha [1986]). Thus the adjustment cost function is written as

$$(10.2)\quad c^{a} = .5\beta_{ii}\,(\Delta K)^2,$$

where c^a is capital adjustment cost.[8]

From equation (10.1), the short-run equilibrium conditions (equations (7.1) and (7.2)) can be written as

$$(11)\qquad s_i^{s} = (1+\gamma_i)^{-1}[\beta_i + \Sigma_{j=1}^{5}\beta_{ij}\ln P_j(1+\gamma_j) + \beta_{ik}\ln K + \beta_{ia}\ln A]$$

where $s_i^s = P_i y_i / \pi^s$ i=1,2,3 are the revenue shadow variable profit components and $s_j^s = -P_j y_j / \pi^s$, j = 4,5 is the negative of the wood cost and labour cost shadow variable profit components. Due to the parameterization of the deviations between shadow and market prices, the short-run equilibrium conditions are nonlinear in the parameters.[9]

To complete the characterization of the equilibrium, from equation set (10), the Euler equation (9), is

$$(12)\qquad E(s)[\beta_{ik}+\beta_{kk}\ln K(s+1)+\Sigma_{i=1}^{5}\beta_{ik}\ln P_i(s+1)(1+\gamma_i)+\beta_{ka}\ln A(s+1)]$$
$$\pi^s(s+1)/K(s+1)+E(s)\beta_{ii}\Delta K(s+1)-(1+r(s))\beta_{ii}\Delta K(s)-W_k(s)=0$$

where $\alpha(s,s+1)^{-1} = (1+r(s))$, r is the discount rate. The parameter $\beta_{ii}>0$ represents the short-run deviation between the shadow and market rental rates for the capital input.

In order to estimate equation set (10), (11) and (12), shadow variable profit is replaced by $\pi^V(1+\Sigma_{i=1}^{5}\gamma_i s_i)=\pi^s$, where s_i $i=1,\ldots,5$ are respectively the revenue and negative of the wood and labour cost variable profit components. This means that the equilibrium conditions become nonlinear in the variable profit components. Error terms are appended to equation set (10) and (11) which reflect optimizing errors and technology errors. The error term in equation (12) is a conditional expectation error which arises when the conditional expectation of the future values of the variables is replaced by their predicted values. The errors are assumed to have zero expected value, and positive definite contemporaneous variance-covariance matrix. In terms of equation (12), the zero expected value assumption means that expectations are rational.

The estimator used for equations (10), (11) and (12) is the generalized method of moments estimator developed by Hansen [1982] and Hansen and Singleton [1982]. This estimator is equivalent to the three stage least squares estimator if the random errors are conditionally homoscedastic (see Pindyck and Rottemberg [1982]). The endogenous variables in the estimation model are variable profit, the five variable profit components (representing the three products, wood and labour inputs) and the capital input. The instrumental variables that are used are the lagged capital stock, lagged relative product, wood and labour prices and the time trend.[10]

The model is estimated for the mill products industry and the pulp and paper industry. The model is estimated for each industry first with $\gamma_i<0$, $i=1,\ldots 3$, $\gamma_4>0$. The estimation allows for non-competitive behaviour in the three product and wood input markets. Next the model is estimated for non-competitive behaviour in the product markets alone and then for non-competitive behaviour in the wood input market alone. Lastly the model is estimated with competitive behaviour in the product and wood input markets.

In order to test for the constancy of the γ parameters the sample is split in 1972. This year corresponds to about the midpoint in the sample and to the major oil shock experienced in the Canadian economy. With respect to the mill products industry, estimating the system of equations allowing for both non-competitive behaviour, that is $\gamma_i \neq 0$, and two different sets of the γ parameters, yields a value of the objective function of 64.465. (The objective function is the minimized weighted sum of squares of the errors for the system of equations). Constraining the γ parameters to be constant over the sample yields an objective function value of 65.422. Thus the test statistic is 0.957 which has a chi-square distribution. The critical value of the distribution with 4 degrees of freedom (where 4 is the number of restrictions) is $\chi^2_{0.05,4}=9.488$. Thus the null hypothesis that there is no difference in the γ parameters over the sample period cannot be rejected. Indeed, a similar result is obtained when $\gamma_4=0$ while $\gamma_i \neq 0$ i=1,2,3. In this case non-competitve behaviour in the product markets is investigated along with shifts in the values of the γ_i i=1,2,3 parameters. In this situation the values of the objective function are 64.549 (unconstrained γ_i i=1,2,3) and 65.681 constrained). Clearly, in this case of non-competitive pricing in product markets the null hypothesis of no changes in the γ_i parameters over the sample cannot be rejected.

This conclusion for the mill products industry is quite strong and, in fact, carries over to the pulp and paper industry. The values of the objective function when all of the γ parameters are estimated are 62.914 (unconstrained), and 66.925 (constrained). In the case with non-competitive behaviour in product markets, so that γ_i i=1,2,3 are estimated, the objective function values are 65.009 (unconstrained), and 67.385 (constrained).

The reason for the conclusion that there are no differences in the γ parameters over the sample period in the mill products and pulp and paper industries is that these parameters are not statistically different from zero. In other words, the mill products and pulp and paper industries price competitively in all three product markets and the wood input markets. This result can be seen from table 1. Table 1 shows the values of the objective functions and the test statistics relating to the parameter restrictions concerning shadow and market price deviations, when the γ parameters are constant over the sample. The test statistic is distributed as a chi-square. Clearly the non-competitive model nests both the competitive model and the partially non-competitive models.

The null hypothesis relates to the competitive model and the alternative is defined by the non-competitive model. The values of the test statistic from table 1 are less than the critical values for the mill products and pulp and paper industries. Therefore the hypothesis of competitive behaviour in the three product and wood input markets cannot be rejected. Moreover, although by the nesting of the models all partial non-competitive behaviour is rejected, it is instructive to see in table 1 how little the values of the objective function change as more competitive behaviour is imposed in the two industries.

The estimation results for the competitive model are presented in table 2 for both industries.

Table 1: Tests of Non-Competitive Behaviour in Product and Wood Input Markets

		Mills Products		Pulp and Paper	
	Restrictions*	Objective**	Statistic***	Objective	Statistic
Non-Competitive Product and Wood	N.A.	65.422	N.A.	66.925	N.A.
Non-Competitive Product, Competitive Wood	1	65.681	0.259	67.385	0.460
Competitive Product, Non-Competitive Wood	3	65.946	0.524	68.028	1.103
Competitive Product, Competitive Wood	4	66.775	1.353	69.599	2.774

* The restrictions refer to the number of parameter restrictions.

** The objective function is the minimized value of the weighted sum of squares of the errors for the system of equations.

*** The test statistic is the difference in the objective function values between the unrestricted and restricted models.

The standard errors of the estimates are small relative to the parameter estimates. The standard errors of each of the equations are also relatively small. In addition, residual plots showed that there is no serial correlation. The estimates for each industry generated positive variable profit, capital input and variable profit components at each point in the sample for both industries. The variable profit function is also convex in the product and variable factor prices at each point in the sample for both industries.[11]

The estimates of β_{ii} found in table 2 for the mill products and pulp and paper industry show that the industries are not in long-run equilibrium. The estimate of the adjustment cost parameter is positive and statistically different from zero. Indeed, with respect to the capital input there are significant marginal adjustment costs so that the shadow rental rate exceeds the market rental rate on capital. Table 3 shows the deviation between the shadow and market rental rates. The wedge is defined by the ratio of the marginal adjustment cost to the market rental rate. If the ratio is zero then the expected marginal profit of capital equals the market rental rate and there is no short-run deviation between shadow and market rental rates. On average for every $1 spent on capital services the marginal profit on capital exceeds the rental rate by $0.10 and $0.17 respectively in the mill products and pulp and paper industry. The shadow rental rate deviates from the market rental rate in the pulp and paper industry by about twice the magnitude found in mill products. Indeed, by inspection from table 3 of the minimum and maximum deviations, the relative differences between the two industries is consistent over the sample period.

Therefore, the estimation results point out that there are no differences between product prices and marginal costs, and between wood input prices and marginal revenue products in the Canadian mill products and pulp and paper industries. In addition, these industries are not in long-run

Table 2: Estimation Results: Competitive Model

Parameter	Mill Products: Estimate	Mill Products: Standard Error	Pulp and Paper: Estimate	Pulp and Paper: Standard Error
β_0	1.135	0.995	1065.575	226.270
β_1	2.419	0.411	-43.548	14.373
β_2	0.645	0.596 E-01	-40.864	8.182
β_3	-0.780	0.202	-35.968	8.559
β_4	-1.686	0.429	34.244	9.672
β_5	-0.976 E-01	0.193	33.417	7.566
β_k	0.387	0.293	-138.311	29.691
β_a	0.683 E-01	0.787 E-02	3.818	1.072
β_{11}	-0.459	0.164	0.813	0.946
β_{22}	0.111	0.259 E-01	0.620	0.300
β_{33}	0.775	0.534 E-01	1.332	0.307
β_{44}	0.119	0.106	-0.560	0.441
β_{55}	-0.213	0.315 E-01	-0.490	0.335
β_{kk}	-0.153	0.443 E-01	-9.074	1.947
β_{aa}			-0.148 E-01	0.259 E-01
β_{12}	-0.957	0.332 E-01	-0.761	0.321
β_{14}	0.132	0.128	0.479	0.607
β_{15}	0.407	0.513 E-01	0.335	0.402
β_{1k}	-0.903 E-01	0.573 E-01	3.032	0.934
β_{1a}			-0.143	0.299 E-01
β_{24}	-0.124 E-01	0.310 E-01	0.423	0.223
β_{25}	0.906 E-03	0.178 E-01	-1.115	0.234
β_{2k}	-0.763	0.104 E-01	2.785	0.540
β_{2a}			-0.818 E-01	0.223 E-01
β_{34}	-0.385	0.294 E-01	-0.520	0.159
β_{35}	-0.319	0.302 E-01	-0.119	0.192
β_{3k}	0.220	0.300 E-01	2.410	0.563
β_{3a}			-0.623 E-01	0.206 E-01
β_{45}	0.108	0.396 E-01	0.443 E-02	0.266
β_{4k}	0.916 E-01	0.615 E-01	-2.350	0.630
β_{4a}	-0.138 E-01	0.184 E-02	0.935 E-01	0.218 E-01
β_{5k}	-0.548 E-01	0.276 E-01	-2.284	0.492
β_{5a}	0.902 E-02	0.168 E-02	0.861 E-01	0.161 E-01
β_{ka}			-0.231	0.688 E-01
β_{ii}	0.173 E-03	0.692 E-04	0.848 E-07	0.348 E-01

Table 2 (continued)

Equation	Standard Error	Standard Error
Variable Profit	0.182	0.133
First Product	0.149	0.209
Second Product	0.140 E-01	0.369
Third Product	0.655 E-01	0.258
Wood Input	0.141	0.314
Labour Input	0.711 E-01	0.353
Capital Input	0.894 E-01	0.691 E-01

Table 3: Deviation Between Shadow and Market Rental Rates on Capital; $\beta_{ii}\Delta K/Wk$

	Mill Products	Pulp and Paper
Mean	0.104	0.171
Standard Deviation	0.063	0.131
Minimum	0.012	0.027
Maximum	0.206	0.486

equilibrium as there are significant marginal costs of adjustment that cause the marginal profitability of capital to exceed the rental rate in each industry. Thus the industries behave competitively in the short-run. Specifically, with respect to product markets, prices are equal to marginal costs. However, these costs are inclusive of marginal adjustment costs, and therefore exceed apparent marginal costs derived under the mistaken assumption that the industries are in long-run equilibrium.

4. Returns to Scale and Rates of Technological Change

Previous estimates of returns to scale in the mill products and pulp and paper industries in both the U.S. and Canada find that there are scale economies (see Constantino [1986] and Martinello [1985] for surveys of these results). However, scale economies are inconsistent with competitive pricing behaviour in product and factor markets and long-run equilibrium. The results in this paper show that competitive pricing cannot be rejected but simultaneously the industries are not in long-run equilibrium. Hence the issue remains open as to the extent, if any, of scale economies when both industries are in short-run equilibrium as a result of capital adjustment costs.

Caves, Christensen and Swanson [1981] developed a measure of returns to scale within a multiproduct framework with the marginal benefit of capital not equated to the rental rate and with exogenous outputs. This measure was based on the variable cost function. Output endogeneity necessitates that a measure of returns to scale be developed which is based on the variable profit function.

To develop this measure consider the definition of returns to scale based on the transformation function (1),

$$(13) \qquad \rho_y = -\left(\Sigma_{i=1}^{n} T_i v_i + \Sigma_{k=1}^{m} T_k K_k\right) / \Sigma_{j=1} T_j y_j .$$

In equilibrium $\lambda T_i = -W_i$ $i=1,\ldots,n$; $\lambda T_j = P_j$ $j=1,\ldots,\ell$; $\partial\ln\pi^V/\partial\ln K_k = -\lambda T_k K_k/\pi^V$ $k=1,\ldots,m$, where λ is the Lagrangian multiplier. Substituting these equalities into the right side of equation (13) yields

$$(14) \qquad \rho_y = (\Sigma_{i=1}^{n} s_i + \Sigma_{k=1}^{m} \partial\ln\pi^V/\partial\ln K_k)/(\Sigma_{j=1}^{\ell} s_j)$$

where $s_i = W_i v_i/\pi^V$ $i=1,\ldots,n$, $s_j = P_j y_j/\pi^V$ $j=1,\ldots,\ell$ which are the variable input cost and revenue components of variable profit.[12] The estimates of returns to scale are presented in table 4. There are small scale economies in the mill products and pulp and paper industries. On average scale is around 1.15 in both industries and the estimates are very stable through the sample period. Thus in short-run equilibrium there are small scale economies along with competitive pricing in product and variable factor markets.

Along with scale economies, the rate of technological change affects the profitability of an industry. Previous estimates of the rate of technological change for mill products and pulp and paper industries in Canada and the U.S. have been found under long-run equilibrium conditions. The rejection of long-run equilibrium implies that previous estimates of the rate of technological change may be biased. Indeed, this may be the case as previous estimates found negative rates of technological change in the two industries over long periods of time.

In general there are two measures of the rate of technological change; an output based measure and an input based measure (see Caves, Christensen and Swanson [1981]). In the context of multiple output endogeneity and short-run equilibrium, based on the variable profit function, the two measures can be derived from the transformation function (1). The output based measure relates the common output growth rate to technological change, given the levels of all inputs. It is defined as

(15) $z_y = T_t/\Sigma_{j=1}^{l} T_j y_j$

where $t = \ln A$ is the indicator of the level of technology. Translating this formula in terms of the variable profit function, and noting that $\partial \ln\pi^V/\partial t = -T_t/\pi^V$,

(16) $z_y = (\partial \ln\pi^V/\partial t)/\Sigma_{j=1}^{l} s_j$.

Table 4 shows that the output based measure of the rate of technological is positive for both industries throughout the sample period. In the mill products and pulp and paper industries, the common output growth rate averages around 2.8 and 3.3 per cent per annum respectively as a result of technological change. Indeed, in these two industries technological change exerts a greater effect on output growth relative to the effect of technological change found in other major Canadian manufacturing industries (see Bernstein and Mohnen [1991]).

The input based measure of technological change is defined as the common rate of input contraction due to technological change, given the levels of all outputs. Thus from the transformation function (1),[13]

(17) $z_v = -T_t/(\Sigma_{i=1}^{n} T_i v_i + \Sigma_{k=1}^{m} T_k K_k)$

and in terms of the variable profit function

(18) $z_v = (\partial \ln\pi^V/\partial t)/(\Sigma_{i=1}^{n} s_i + \Sigma_{k=1}^{m} \partial \ln\pi^V/\partial \ln K_k)$.

Clearly, from equations (14), (16) and (18), the two measures of the rate of technological change are equal when there is constant returns to scale, since

Table 4: Returns to Scale and Rates of Technological Change

	Mill Products			Pulp and Paper		
	ρ_y	z_y	z_v	ρ_y	z_y	z_v
Mean	1.142	0.028	0.025	1.149	0.033	0.030
Std. deviation	0.023	0.001	0.001	0.106	0.013	0.015
Minimum	1.110	0.027	0.023	0.945	0.016	0.012
Maximum	1.174	0.030	0.026	1.343	0.061	0.064

$\rho_y = z_y/z_v$. However, because there are scale economies then $z_v<z_y$. This result is found in table 4. In the mill products and pulp and paper industries, on average the input based rate of technological change is 2.5 and 3.0 per cent per annum respectively. As for the output based rates of technological change, the input based rates are relatively constant over the sample period. The results on the rate of technological change differ from other studies. Generally negative rates of technological change are estimated for the mill products industry (see Martinello [1985] for Canada, Jorgenson-Frammeni [1986] for the U.S. and Jorgenson et al [1990] for the U.S. and Japan). These estimates are found under the assumption of zero adjustment costs so that the mill products industry is in long-run equilibrium. In addition, also within a long-run equilibrium context, Martinello estimated that there is a negative rate of technological change for Canadian pulp and paper. The rejection of the assumption of long-run equilibrium, and therefore the rejection of zero adjustment costs, leads to the result that the rates of technological change are positive for both Canadian industries in short-run equilibrium.

5. Conclusion

A dynamic model with multiple products incorporating non-competitive behaviour in both product and factor markets was estimated for the Canadian mill products and pulp and paper industries. Deviations between shadow and market prices were parameterized and it was found that in both industries competitive behaviour occurs in both sets of markets.

The dynamic nature of the model arises from the existence of adjustment costs associated with the capital input. Adjustment costs cause deviations from long-run equilibrium. Indeed, it was estimated that the mill products and pulp and paper industries are in short-run equilibrium. Adjustment costs at the margin create a wedge between the marginal profit of capital and the rental rate. It was estimated that the marginal profit of capital is almost 20 per cent greater than the rental rate in the pulp and paper industry and the wedge is about 10 per cent in the mill products industry.

Competitive behaviour in short-run equilibrium was found to be coincident with scale economies in both the pulp and paper and mill products industries. It was estimated that there are slightly increasing returns to scale at around 1.15. Technological change also occurred within the context of competitive behaviour and short-run equilibrium. In fact, unlike other studies which did not account for competitive product markets or capital adjustment costs, it was estimated that there are positive rates of technological change for both industries. The rates were very stable and averaged around 2.5 and 3.0 per cent per annum respectively for the mill products and pulp and paper industries.

There are different types of extensions to the research outlined in this paper. First, the model can be applied to different industries and to firms within an industry. Second, the parameterization of the deviation between shadow and market prices in multiple product-multiple factor contexts could depend on the summary statistics of product demand and factor supply (see Baker and Bresnahan [1985]). In this way, for multiple product industries that do exhibit product and factor market power, it becomes possible to see how market power changes over time.

Data Appendix

The data for the mill products and pulp and paper industry are obtained from Statistics Canada, the sample period is 1963-1987. With respect to mill products, three products are considered, softwood lumber, hardwood lumber, and other lumber (namely shakes, shingles and wood chips). Output data is obtained from Statistics Canada Catalogues 35-204 and 65-202. Output quantities are shipments and output prices are defined as revenues divided by quantities.

There are three variable factors, labour, wood and energy. The data on the variable factors are obtained from Statistics Canada catalogue 35-204. Labour quantity is hours paid and the labour input price is defined as labour cost (wages, salaries and supplementary payments) divided by labour input quantity. The wood quantity is the wood used by sawmills and planning mills and the wood price is the cost of wood used divided by wood input quantity. The energy input quantity and price is based on a Tornqvist index of electricity, fuel oil, gasoline and natural gas used by sawmills and planning mills.

The quasi-fixed factor is a Tornqvist index of buildings and construction capital, and machinery and equipment capital. Statistics Canada provided the unpublished capital stock data which consist of gross and net end of year stocks in current and constant dollars. The capital purchase prices are defined as the ratio of current to constant dollar gross stocks. In order to generate the rental rate on capital, the corporate income tax, the investment tax credit and the capital cost allowance rates are obtained from the Canada Gazette and Statistics Canada catalogue 13-211. In addition, the discount rate is taken to be the annual average of monthly average yields of Government of Canada bonds with 10 or more years of maturity. The discount rate is obtained from the Bank of Canada Review.

With respect to pulp and paper, there are three outputs, newsprint, pulp and other paper products (namely book and writing paper, tissue, wrapping paper, building paper and paperboard). Output data is obtained from Statistics Canada catalogue 36-204. Output quantities are shipments and output prices are defined as revenues divided by quantities.

There are three variable factors, labour, wood and energy. The data on the variable factors are obtained from catalogue 36-204. The variable factors are defined in the same manner as for the mill products industry. The quasi-fixed factor is defined in the same manner as for mill products. The data is obtained from 56-506, 57-208, and from unpublished Statistics Canada sources. Lastly the rental rate on capital is defined in the same way as in the mill products industry and the various tax and interest rates are obtained from the same sources. The technology indicator is the time trend.

Notes

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1. Bernstein and Mohnen [1991] atually conduct a test between short and long-run equilibrium.

2. It is assumed that the service flow of a quasi-fixed input is proportional to it's stock.

3. The notation (t) is generally omitted for simplicity.

4. For an oligopolistic industry in short-run equilibrium producing a single product in competitive factor markets, the first order approximation to variable profit for the representative firm is,

$$[H'(Y^e)Y_y^e y^e + H(Y^e)]y - W^T v - H'(Y^e)Y_y^e y^{e2}$$

where Y is industry output, H is the inverse product demand function and the superscript e represents short-run equilibrium. The last term in the variable profit expression represents additional profit relative to the competitive level that the firm earns from oligopoly power. Defining $Y_y^e y^e/Y^e = \theta^e$ as the short-run conjectural elasticity and $H'(Y^e)Y^e/P^e = \xi^e$ as the inverse price elasticity of product demand in short-run equilibrium, the shadow product price is $P^s = P(1 + \xi^e\theta^e)$. (Notice that the elasticities are evaluated at the equilibrium magnitudes, see Geroski [1982] and Roberts [1984].) The maximization of variable profit is equivalent to the maximization of shadow variable profit, which is $P^s y - W^T v$, since the shadow product price is marginal revenue.

5. Roberts [1984] focuses on different types of oligopoly models and therefore he specifies alternative types of conjectural variations. As a consequence, he assumes that all firms are price-takers in factor markets and the price elasticity of product demand is constant and exogenously given. In our context this means that $\Theta = 0$ and the elements of Γ represent known multiples of the conjectural elasticities.

6. An alternative approach to investigate non-competitive behaviour in product markets using duality theory is through the cost and the inverse product demand functions (see Appelbaum [1979, 1982], Appelbaum and Kohli [1979], Bernstein and Mohnen [1991]).

7. An alternative interpretation of γ_i, i=1,...,4 are deviations between shadow and market relative prices (that is prices relative to the energy price).

8. Equations (10.1) and (10.2) can be combined into a single function with just a renormalization of β_{ii} to reflect the fact that the shadow variable function is defined in terms of the natural logarithms of the variables. Shadow variable profit is now gross of adjustment cost.

9. The energy cost component equation can be eliminated by the summability condition, since $\Sigma_{i=1}^{5} s_i^s(1 + \gamma_i) = 1 - s_6^s$ where $s_6^s = -P_6 y_6/\pi^s$, P_6 is the energy price and y_6 is the energy quantity.

10. The adjustment cost function is not estimated as a separate equation since parameter β_{ii} is in the equilibrium condition for the capital input. In addition, the model (equations (10.1), (11) and (12)) are estimated as a set of implicit equations using the Time Series Processor software under the nonlinear three stage least squares procedure. In addition, the instruments are the standard ones selected in this context (see Pindyck and Rotemberg [1982]). Other instruments such as , the lagged deflator for gross domestic product, the lagged wage rate for the manufacturing sector and a moving average of interest rates for long term government bonds were used in the estimation. The main conclusions of the paper, in terms of non-competitive behaviour and capital adjustment, were unaffected. The data are described in the data appendix.

11. A form of separability is imposed on the estimation in both industries between the other product category (output number three) and products one and two. The other product category is relatively more heterogenous, so $\beta_{13} = \beta_{23} = 0$ is imposed.

12. If the deviations between shadow and market prices are not found to be zero then the revenue and variable cost components in equation (14) are in terms of shadow variable profit and the marginal profit of capital is also in terms of shadow variable profit.

13. The two measures of the rate of technological change can be modified when market prices differ from shadow prices. In equations (16) and (18) the shadow variable profit function is used and the profit components are in terms of shadow variable profit.

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