University of Alberta

A Regional Analysis of Profitability, Input Demand, and Output Supply in the Pulp and Paper Sector

by

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ABSTRACT

This study is an econometric analysis of the Canadian pulp and paper industry using a normalized quadratic profit function for estimation. Two key differences between this study and previous studies are that wood input variables are split into roundwood & wood chips and there is regional representation. Statistical testing reveals that the best model contains regional dummy variables and a correction for autocorrelation. The results from the model are then used to estimate profit, own-price, and cross-price elasticities and also to simulate policy scenarios for a change in energy price policy and a change in stumpage price policy. Roundwood and wood chips inputs are substitutable in the production of total paper and wood pulp. The prices for all variables, except for total paper, are inelastic with respect to profitability.

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Finally, I would like to dedicate this thesis to my mom, Janice Merle Larsen (1938-1998). Thank you for everything and I miss you.

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CHAPTER ONE: INTRODUCTION

1.1 Background

The forest industry makes a significant contribution to the Canadian economy. The forest industry is by far the largest net exporter in Canada and without it's contribution the country's trade balance would be consistently negative (PWC, 2001). The Canadian forest industry is also one of Canada's largest industrial employers (CCPA, 2001). Canada is the world's second-largest producer of softwood lumber, with a fifth of world production, and is also the leading exporter with 51% of the world market (NRC, 2001). Canada is the world's second largest producer of wood pulp, after the United States, but it is the world's leading exporter with 25% of the international market (NRC, 2001). Canada also has a significant pulp and paper product industry. Pulp and paper products contributed approximately 58% of the $47.4 billion generated from forest industry exports in the year 2000 (NRC, 2001). Therefore, changes in government policies, that affect forest sector, could have significant impacts upon the Canadian economy (i.e. the softwood lumber dispute with the United States or greenhouse gas agreements).

There are two major subsections in the forest industry: the wood industry and the pulp and paper industry. The purpose of this study is to examine regional differences within the Canadian pulp and paper industry in profitability, technological change, the relationship between profitability and capital inputs, input demand and output supply relationships. The approach is to estimate a dual normalized quadratic profit function. In this study, several improvements upon previous studies are made. First, regional differences in profitability, demand, and input structure are studied for four different regions in Canada. Given that the pulp and paper industry produces different products (ie. pulp vs paper vs newsprint) it is important to model the industry for multiple outputs. A unique aspect of this study is that it considers multiple outputs and multiple wood inputs. A multi-input, multi-output description of the whole industry within a single model seems appropriate (Hseu and Buongiorno, 1997). Also, this study will look at possible impacts on profitability and supply and demand relationships due to potential changes in energy policy due to a carbon tax upon fossil fuel energy usage and stumpage policy due to an increase in the cost of wood inputs.

1.2 Research Objectives

The specific aims of this study are as follows:

(1) Estimate dual multiple-output and multiple-input profit functions using regional data for the Canadian pulp and paper industry.

(2) Estimate profit, own, and cross-price elasticities for each region with respect to supply outputs and demand inputs.

(3) Examine the effect of technology and capital on profitability and the demand for wood and other inputs over time amongst the regions.

(4) Effect of policy scenarios on industry profitability for each region. These scenarios will include one for a change in energy input prices and one for a change in stumpage prices.

As stated in objective 1, the approach is to estimate dual profit functions with multiple outputs (wood pulp and total paper) and multiple inputs (roundwood, wood chips, labour hours, energy) with a fixed capital input. Normalized profit functions have application in circumstances where some commodities are variable and other commodities are fixed over the period of production (Lau, 1976). The method of estimation is a systems approach using seemingly unrelated regression with cross equation coefficient restrictions. The advantage of this type of approach is that relationships implied by profit maximization theory can be imposed and tested. The results derived from this functional form provide a variety of econometric results that are discussed in the results and analysis section.

Two main aspects separate this project from previous studies. The first, in this study, is that wood inputs are separated into two parts. In previous studies, this input has been modeled as a single aggregated input but in this project wood input is separated into wood chips and roundwood. This is an important distinction because over the past 30 years the industry has been substituting wood chips for roundwood. The intention of disaggregating this input is to provide more insight into the substitutability of these two inputs. The second aspect is the breakdown of the pulp and paper sector by region in Canada. The four regions being considered are Quebec, Ontario, British Columbia, and the Rest of Canada. Such a breakdown allows for a more detailed analysis of the industry. Estimating regional differences is important given the provincial ownership of major portions of the resource base in Canada and the accompanying policy responsibilities regarding resource availability and use (Meil and Nautiyal, 1988). It can be assumed that each region has differing strengths in producing the multiple outputs and obtaining the inputs necessary for pulp and paper products. With the regional breakdown, we can then observe those differences through supply and demand relationships.

1.3 Outline of the Study

Chapter two is a review of previous studies. The review includes theories of profit functions and past studies done in the forest industry with cost and profit functions.

Chapter three details the research methodology used. This includes the theoretical and econometric aspects of the dual profit function model. In addition, derivation of formulas for the own-price, cross-price, and profit elasticities is discussed. Also, there is a description of the data sources.

Chapter four presents the estimation and results from the econometric estimations. The results include the profit, own-price, and cross-price elasticities for the nation and each region.

In Chapter five, there is an analysis of regional differences and results from policy scenarios. There are two policy scenarios that will be incorporated in this study. The first scenario is, what would happen if there is a carbon tax placed upon emission of carbon from the use of fossil fuels. This is incorporated within the energy input of the industry. The second scenario simulates a change in stumpage policy as a result of the lumber dispute with the United States. This would have an impact upon the roundwood input for the pulp and paper industry.

Chapter six includes a summary of the results found in the study. Also, the limitations of this study are noted and ideas for further research in the field are included.

CHAPTER TWO: LITERATURE REVIEW

2.1 Overview

This chapter examines literature pertinent to econometric analysis of the Canadian pulp and paper industry. First, there is a description of dual profit function theory. Second, there is a description of two widely used types of dual profit functions, quadratic and translog. Third, there is a review of previous studies and literature from the wood industries, pulp and paper industry, and other sectors. These studies are focused towards research undertaken in those industries and sectors and how they relate to the current study.

2.2 Dual Profit Function Theory

In profit function theory, it is standard practice to assume that competitive firms maximize profits given the prices of inputs and outputs and the firm's technology (Chambers, 1988). In most econometric analysis of profit functions, dual profit functions are estimated which is the approach taken in chapters 3 through 5. Hence, the remainder of this chapter emphasizes the properties and estimation procedures for dual profit functions. Duality theory shows that there is a relationship between direct profit and dual profit functions as well as the production technology and input and output supply functions. The first theorem of duality states that the optimal values of the primal and the dual objective functions are always identical, provided that optimal feasible solutions do exist (Chiang, 1984). Chambers (1988) notes the following properties of dual profit functions (where p are output prices and w are input prices):

(1) $\Pi (p,w) \geq 0$, profits must be greater than zero;

(2) if $p^1 \geq p^2$, then $\Pi (p^1,w) \geq \Pi(p^2,w)$, (non-decreasing in p);

(3) if $w^1 \geq w^2$, then $\Pi (p,w^1) \leq \Pi (p,w^2)$ (non-increasing in w);

(4) $\Pi (p,w)$ is convex and continuous in (p,w);

(5) $\Pi (tp,tw) = t\, \Pi (p,w)$, $t>0$ (positive linear homogeneity);

(6) if the profit function is differentiable in p and w, the unique profit-maximizing supply and derived-demand functions are

$$y(p,w) = \frac{\partial \Pi(p,w)}{\partial p} \text{ and } x_i(p,w) = -\frac{\partial \Pi(p,w)}{\partial w_i} \quad \forall i,$$

where $y(p,w)$ and $x_i\,(p,w)$ are the respective profit-maximizing quantities of outputs and inputs. If unique profit-maximizing supply and derived demands exist, the profit function is differentiable (Hotelling's Lemma).

Also, for the case of multiple output profit functions the above six properties exist along with the following:

(7) there exists fixed vectors $(\bar{y},\bar{x})$ and $(\hat{y},\hat{x})$ such that $\Pi\,(p,w) \geq p\bar{y} - w\bar{x}$ and $\Pi\,(p,w) \leq p\hat{y} - w\hat{x}$ (which represents a bounded production possibilities set).

Property one follows basic economic intuition. It can be assumed that a rational profit-maximizing firm would not produce any output if the profits are less than zero. By following property one, it would be assumed that if the profits are less than zero then there would be a shutdown of output. For this study, it will be assumed that each region has a positive total variable profit.

Properties 2 and 3 are fairly obvious and provide a benchmark to compare estimated econometric results. Property two states that as the price of output increases, with all other prices being equal, there will be an associated increase in profits. Conversely, property three states that as an input price increases, with all other prices being equal, then there would be a decline in profits. If both of these properties hold true, then it is evident in the results by looking at the elasticity values. For outputs, there should be a positive sign on the elasticity value. For inputs, there should be a negative sign on the elasticity value.

Property four states that the function must be convex and continuous. This suggests that when prices change, the behaviour of the firm changes to adjust its inputs and outputs accordingly. In terms of demand for inputs, this generally means a downward sloping demand curve and for outputs it means an upward sloping supply curve.

Property five states that the function must exhibit positive linear homogeneity. This implies that if a value is being multiplied or divided throughout the system, then a function that satisfies property five would have the same result. This is commonly obtained through the use of normalization.

Property six, which is Hotelling's Lemma, when it is combined with property four is a useful mechanism. Property six states that demand and output supply functions can be derived from the dual profit functions. Hence, if input and output quantities are available as well as the prices then supply and demand equations can be estimated simultaneously with the profit function. Properties one through six can be used to derive restrictions on the coefficients estimated that can be both imposed and tested.

There are two types of profit functions that are prominent in the forest sector literature. These are translog and quadratic profit functions. Both types of functions have a great deal of flexibility and are useful tools. This study uses the quadratic functional form for profits and will be described in more detail.

2.2.1 The Quadratic and Translog Profit Functions

The quadratic and translog normalized profit functions are both useful for estimation in econometric studies. Both methods of estimation are applicable for multiple-output, multiple-input profit functions and have been used in previous studies. The use of these functional forms has become increasingly popular since they are less restrictive than other functional forms such as the Cobb-Douglas or CES (Villezca-Becerrra and Shumway, 1992). The two functional forms are quite similar in form with a few differences in the formation of equations and how they satisfy the properties of profit maximization given in the previous section. Both types of profit functions are often normalized, which assures linear homogeneity of the profit function in all prices.

A generalized form of the normalized quadratic profit function is given in equation 2.1. With the application of Hotelling's Lemma, direct differentiation of the profit function will yield the derived supply and demand equations and is given in equation 2.2.

$$\pi^* = \alpha_o + \sum_{i=1}^{n} \alpha_i P_i^* + \frac{1}{2}\sum_{i=1}^{n}\sum_{h=1}^{n} \gamma_{ih} P_i^* P_h^* + \sum_{i=1}^{n}\sum_{k=1}^{m} \delta_{ik} P_i^* Z_k + \sum_{k=1}^{m} \beta_k Z_k + \frac{1}{2}\sum_{k=1}^{m}\sum_{j=1}^{m} \phi_{kj} Z_k Z_j \qquad \textbf{(2.1)}$$

where: $\gamma_{ih} = \gamma_{hi}$ for all h,i and the function is homogeneous of degree one in prices of all variable inputs and outputs;

π^* = the restricted profit (total revenue less total costs of variable inputs normalized by P_y, the price of output;

P_i^* = the price of variable input X_i normalized by P_y;

Z_k = the kth fixed inputs: i=h=1,2,3...n+k=j=1,2,3....m;

α_o, α_i, γ_{ih}, δ_{ik}, β_k, and ϕ_{kj} = the parameters.

Taking the derivative of equation 2.1 with respect to the normalized price of i yields equation 2.2. By Hotelling's Lemma this equation represents the derived input demand and output supply equations depending on whether the derivative is with respect to an input price or output price.

$$\frac{\partial \pi}{\partial (p_i / p_n)} = X_i = \beta_i + \sum_{j=1}^{n} \beta_{ij} p_j^* + \sum_{z=1}^{n} \beta_{ij} Z \qquad \textbf{(2.2)}$$

where: X_i = the ith input or output quantities;

p_j^* = the normalized price of j.

The normalized translog profit function is the most commonly used functional form in profit function literature. A generalization of this functional form is given by Diewert (1974) and is presented as equation 2.3.

$$\ln\pi^* = \alpha_o + \sum_{i=1}^{n}\alpha_i \ln P_i^* + \frac{1}{2}\sum_{i=1}^{n}\sum_{h=1}^{n}\gamma_{ih}\ln P_i^* \ln P_h^* + \sum_{i=1}^{n}\sum_{k=1}^{m}\delta_{ik}\ln P_i^* \ln Z_k + \sum_{k=1}^{m}\beta_k \ln Z_k + \frac{1}{2}\sum_{k=1}^{m}\sum_{j=1}^{m}\phi_{kj}\ln Z_k \ln Z_j \tag{2.3}$$

where: $\gamma_{ih} = \gamma_{hi}$ for all h,i and the function is homogeneous of degree one in prices of all variable inputs and outputs;

π^* = the restricted profit (total revenue less total costs of variable inputs normalized by P_y, the price of output;

P_i^* = the price of variable input X_i normalized by P_y;

Z_k = the kth fixed inputs: $i=h=1,2,3\ldots n+k=j=1,2,3\ldots m$;

ln = the natural logarithm;

α_o, α_i, γ_{ih}, δ_{ik}, β_k, and ϕ_{kj} = the parameters.

Differentiation of equation 2.3, with respect to $\ln P_i$ and $\ln P_y$, gives a system of variable input/profit ratio functions (S_i) and an output/supply profit ratio function (S_v) (Diewert 1974). This is derived by Shephard's Lemma (Diewert and Wales, 1987) and the results are given in equations 2.4 and 2.5 respectively.

$$S_i = -\frac{P_i^* X_i}{\pi^*} = \frac{\partial \ln\pi^*}{\partial \ln P_i^*} = \alpha_i + \sum_{h=1}^{n}\gamma_{ih}\ln P_h^* + \sum_{k=1}^{m}\delta_{ik}\ln Z_k \tag{2.4}$$

$$S_v = \frac{V}{\pi^*} \tag{2.5}$$

where: V is the quantity of output supply.

Diewert notes that because S_i and S_v sum to unity, the output supply equation can be ignored, and only the variable input equations and the translog profit function are required for econometric estimation. Equations 2.4 and 2.5 and the use of natural logarithms, are the key differences in application of the normalized translog profit function and the normalized quadratic profit function. One important consideration in deciding to use a translog function is that it is difficult to obtain sufficient conditions on the parameters of the translog variable profit function which will ensure that it is *globally* consistent with the conditions for profit maximization.

Preliminary estimation of the translog function resulted in parameter estimates that implied that the function did not satisfy all the profit maximizing conditions over the whole range of the data. The rationale for choosing the quadratic function, over the translog function for this study, was to provide a more direct route from estimation to derived supply and demand relationships, which is more difficult with profit shares.

2.3 Previous Studies of Profitability, Input Demand, Costs, and Technical Change in the Forest Sector

The majority of previous studies in the forest sector tend to have an emphasis on cost functions and total factor productivity. The studies are broken up into the two main sectors of the forest industry: the wood industry and the pulp and paper industry. There are only a few studies that use profit functions for either industry. The remainder of this chapter reviews these studies.

2.3.1 Wood Industries Sector

The wood industries sector is where the majority of past research studies have been done. This is likely because in the sawmilling industry there have been many important policy issues over the past 20 years, such as the Canada-United States softwood lumber dispute.

The most relevant study, in the literature for this project, is an econometric analysis of output supply and input demand in the Canadian softwood lumber industry. Latta and

Adams (2000), employ a normalized restricted quadratic profit function approach to estimate lumber supply and also analyze Marshallian demand elasticities for three Canadian regions. They chose to regionalize Canada into three producing regions being the coastal British Columbia, interior British Columbia and Alberta, and the rest of Canada. This study, along with Meil and Nautiyal (1988), are the only studies in the literature that use both a profit function approach and that use regional data. Most other studies use a national time series of the sawmilling industry. This is a significant advancement compared to the other previous studies, which have mainly used national time series data sets. However, in the estimation of the profit function in this study, the authors used a single composite output of lumber and wood chips rather than estimating as a multiple output function. The results of the model indicate that coastal British Columbia is most price sensitive compared to the interior region and the rest of Canada. The authors attribute this result to producers experiencing contracting output, declining rates of capacity utilization, and loss of market share to other regions. This paper, along with Constantino and Haley (1988), has the only developed published estimates of Marshallian own and cross-price factor demand elasticities at a regional level. Constantino and Haley studied sawmilling producers for the British Columbia coast and the U.S. Pacific Northwest.

Meil and Nautiyal (1988), as noted previously, developed a variable translog cost function to analyze production structure and factor demand in major Canadian softwood lumber producing regions. It is noted that this is the first study to "statistically test for regional and intraregional differences in softwood lumber production across Canada". Though this is a cost function, it is very useful to mention in this section because of the regional testing. The authors estimated the cost function for coastal British Columbia, interior British Columbia, Ontario, and Quebec. The results of the study indicate that the "demand for production inputs is not static, but is governed by offsetting dynamic effects". They found that output effects dominate the demand for wood and energy, while substitution and capital effects dominate the demand for labour.

Constantino and Haley (1988), chose to estimate input and output choices of sawmilling producers in the British Columbia coast and the U.S. Pacific Northwest by using a translog restricted profit function. Though this study is only looking at two separate regions it is still useful to note that it is one of the few attempts to estimate Marshallian own and cross-price elasticities at a regional level. Another significant feature of this paper is that the authors chose to incorporate multiple outputs, being lumber and pulp chips. Since this study is analyzing the sawmilling industry, they also chose to have a variable representing wood quality. The results from this paper indicate that output and input responses to price changes were found to be elastic in most cases and that the output mix is also responsive to changes in relative prices.

The remainder of the literature papers reviewed from the wood industries sector include papers focusing on a particular region in Canada (Banskota et al, 1985; Meil, Singh, and Nautiyal, 1988), the industry within a nation (Baardsen, 2000; Bigsby, 1994; Nautiyal and Singh, 1985; and Singh and Nautiyal, 1986), the Canadian forest sector (Kant et al, 1996; and Martinello, 1985) and inter-regional analysis (Bernard et al, 1997; and Smith and Munn, 1998). All of these studies, except for Bernard et al, employ restricted or unrestricted translog cost functions for estimation and primarily focus on production structure, demand, and economies of scale. Bernard et al use a normalized quadratic profit function and focus their results on lumber trade between Canada and the United States.

2.3.2 Pulp and Paper Industry Sector

The number of papers that consider the pulp and paper industry is minimal when compared to those of the wood industries. For profit functions, there are studies using a restricted profit function (Muller, 1979), nonparametric methodology (Hseu and Buongiorno, 1997) and a generalized Leontief profit function (Bergman and Brännlund, 1995). The other papers regarding this industry look at cost function methodology (Nautiyal and Singh, 1986; Quicke et al, 1990; and Andrade, 2000) or other factors of economic performance such as total factor productivity (Bernstein, 1989; Frank et al, 1988;, and Townsend and Uhler, 1986).

Muller (1979) attempts to capture the effects of changes in factor prices on pulp and paper industry prices and outputs. This is the only study in the pulp and paper literature that attempts to estimate an econometric model using a normalized quadratic restricted profit function with multiple outputs for Canada from 1947-1976. The author chose this model type because at the time most industry models did not consider the treatment of multiple outputs. Also, they chose not to include a time variable as a measure of technological change. The results indicate that the model type "has estimated plausible and reasonably stable estimates of own and cross-price elasticities of factor demand and of product supply". There is also a high degree of autocorrelation found within the estimates as well. However, the author states, "the present estimates do not take into account the demand side of the market for pulp and paper products and hence may be affected by simultaneous equations bias".

The 1997 Hseu and Buongiorno paper had the objective to estimate output supply and input demand relationships in the Canadian and United States pulp and paper industries. The purpose was to "assess complementarities and substitutions in production, and to improve forecasts". Their approach was to use methodology that would satisfy the weak axiom of profit maximization. The results from the model indicate that "there exists a range of quantity responses to a given price change that are consistent with economic theory and with a particular data set". One advantage of only using national data is the ability to separate outputs by pulp, newsprint, other paper, and paperboard. This allows for a better interpretation of what is happening within various sectors of the industry as opposed to a single aggregate output or two outputs.

Nautiyal and Singh (1986) researched long-term productivity and factor demand of the Canadian pulp and paper industry. They chose to estimate an industry translog cost function with a single output and four inputs (labour, capital, materials, and energy). The results indicate that all inputs in the industry are long-term substitutes "despite some short-run complementarities between energy and materials and energy and capital".

There are several other studies dealing with the pulp and paper industry. Bergman and Brännlund (1995), attempt to measure oligopsony power in the Swedish pulp and paper industry. To do this, they use a generalized Leontief profit function to represent the production structure. This type of methodology is used because it allows for the functional form to measure for market power and determine the type of power within the industry. The results indicate that there is support for the hypothesis that market power varies in the Swedish pulp and paper industry. Andrade (2000) considers the production technology and cost implications upon the pulp and paper industry for member states in the European Union. For this estimation, the author chose to employ a translog cost function. The results show that there are strong economies of scale within the European Union and that there is "significant but small substitutability between labour and both capital and wood, and complementarities between capital and wood".

Bernstein (1989), Frank et al (1988), and Townsend and Uhler (1986), all consider economic performance factors of the Canadian pulp and paper industry. Bernstein uses a variable translog profit function in a manner to include the possibility of tax reform to the system. This model incorporates three outputs: newsprint, pulp, and other paper products. The results show that there are increasing returns to scale in the industry and there are significant costs of adjustment that occur with an addition of capital stock. Frank et al (1988), also found that the industry experiences substantial economies of scale. Estimation in this study used a translog cost function. The authors found that input demands for the industry "were revealed to be relatively price inelastic". The Townsend and Uhler paper had the objective to determine whether the Canadian pulp and paper industry has market power in pricing. The authors chose to use a translog cost function to estimate the results. Their results indicate, "for Canadian producers of pulp and paper products the price-taking assumption is invalid". This means that the producers do have market power in pricing their own products.

2.3.3 Other Industries

The quadratic profit function is used as an estimation procedure in a wide variety of studies. Stefanou and Saxena (1988) used the quadratic profit function to evaluate for training variables to influence allocative efficiency in the Pennsylvania dairy industry. Shumway et al (1988), used the quadratic profit function to estimate output supply and input demand relationships for five commodity groups and four variable inputs. Villezca-Becerra and Shumway (1992), use a quadratic profit function (as well as translog and Leontief methodology) to test the difference in functional form used for multiple outputs in 4 major geographically dispersed agricultural states in the United States. The authors found that "while a considerable number of large differences due to functional form were noted, far fewer differences appeared to be important in a statistical sense". Dupont (1991), used a restricted quadratic profit function to test input substitution effects in a regulated fishery.

2.4 Conclusions

The survey of previous econometric analyses of the pulp and paper and wood industries in Canada suggests that there has been substantial past analysis of productivity and of elasticity of demand and supply. However, for the pulp and paper industry there has been no analysis that examines regional variability in profitability and technical change, that divides the wood input into roundwood and wood chips, or considers multiple outputs. In chapter three, an econometric model is derived that incorporates these three factors.

CHAPTER THREE: METHODOLOGY

3.1 Overview

This chapter is a description of the methodology used in this study. This includes a detailed description of the models used in estimation. This is followed by an explanation of the data used for the study. As mentioned earlier, the model used for this study is a normalized quadratic profit function. Four models were estimated. Two contain regional dummy variables for Quebec, Ontario, British Columbia, and the Rest of Canada and two do not. Two of the models contain correction for autocorrelation. Both of these models are described in this chapter. The results derived from these estimations provide the basis for own-price, cross-price, and profit elasticities estimates which are discussed in chapter four.

3.2 Seemingly Unrelated Regression

The normalized quadratic profit function together with the input demand and output supply functions can be estimated using a seemingly unrelated regressions model. The specific function estimated for this study is described in sections 3.4 and 3.5. This section details the simple seemingly unrelated regression model and provides a basis for the econometric development of the quadratic profit functions estimated for this study.

Equation 3.1 follows Kmenta (1986) matrix notation for the following simple example of a seemingly unrelated regression:

$$
\begin{aligned}
y_{1t} &= \beta_{t1} X_{1t} + \varepsilon_{t1}, \\
y_{2t} &= \beta_{2t} X_{2t} + \varepsilon_{2t}, \\
&. \\
&. \\
y_{Mt} &= \beta_{Mt} X_{Mt} + \varepsilon_{Mt}
\end{aligned}
\qquad \textbf{(3.1)}
$$

where: m=1,2,……., P, M number of equations;

T is the number of observations;

K is the number of explanatory variables;

y_M is a (TX1) vector of the sample values of the dependent variable;

X_M is a (TXK_M) matrix of the sample values of the explanatory variables;

β_M is a (K_MX1) vector of the regression coefficients;

ϵ_M is a (TX1) vector of the sample values of the disturbances.

This system of M equations is called a system of seemingly unrelated regression equations because the covariance matrix represents the only link of the disturbances between the mth and the pth equation.

The use of seemingly unrelated regression makes sense when there are reasons to believe that seemingly unrelated equations are correlated through error terms. A profit, demand, and supply system is one example. When prices increase for inputs, one expects that profits will decrease and demands for inputs will decrease. Hence, errors in the profit functions should be correlated with errors in the demand and supply functions. This type of correlation is called contemporaneous correlation.

Seemingly unrelated regressions can be estimated with cross equation restrictions on the parameters. Profit, demand and supply systems provide another example where imposing cross equation restrictions is appropriate (Kmenta, 1986). In chapter 2 it was shown that the derivative of the indirect profit function with respect to input prices yields the input demand functions. Hence, theoretically the coefficients that appear in the profit function should also appear in the input demand functions. These theoretical results can be imposed by placing cross equation restrictions on the parameter estimates.

3.3 Autocorrelation

Kmenta (1986) notes that seemingly unrelated regressions are common for functions with observations made over time such as demand or production functions. However, in time series data sets autocorrelation is often present as well. Autocorrelation occurs when disturbances in one time period tend to be correlated with the previous period disturbances. In the case of equation 3.1, it could be assumed that there is some correlation between ϵ_{2t} and ϵ_{1t}. This type of correlation is first-order autocorrelation. There are various corrections for autocorrelation. With respect to equation 3.1, the correction for autocorrelation is given as ρ in equation 3.2.

$$\begin{pmatrix} \varepsilon_{1t+1} \\ \varepsilon_{2t+2} \end{pmatrix} = \rho \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix} + \begin{pmatrix} \psi_{1t} \\ \psi_{2t} \end{pmatrix}$$

$$= \begin{pmatrix} p_1 0 \\ 0 \ p_2 \end{pmatrix} \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix} + \begin{pmatrix} \psi_{1t} \\ \psi_{2t} \end{pmatrix}$$

$$\varepsilon_{2t} = \rho \varepsilon_{1t} + \psi_{2t}, \tag{3.2}$$

$$\rho = \sum_{t=2}^{T} \varepsilon_t \varepsilon_{t-1} \Big/ \sum_{t=2}^{T} \varepsilon_{t-1}^2$$

where: ϵ is the disturbance term;

ψ is a stationary, non-autocorrelated process;

ρ is the autocorrelation coefficient;

p_t is the autocorrelation correction coefficient for disturbance t.

It is expected that the quadratic profit functions estimated in this study would have autocorrelation since this problem is common in time-series data. The correction used in this study to correct for first-order autocorrelation was based upon Pagan (1974) and this method of obtaining the correction parameter estimates by minimizing the following objective function is given in equation 3.3. It should be noted that the Pagan method of parameter estimation sets the pre-sample residuals to zero

$$S_1(\beta_1,\rho_1)=\sum_{t=2}^{T}\psi_{1t}^{2}$$
$$=\sum_{t=2}^{T}\left[(Y_{1t}-\beta_1X_{1t})-\rho_1(Y_{1t-1}-\beta_1X_{1t-1})\right]^{2} \qquad \textbf{(3.3)}$$

where: S = the residual sum of squares.

When this objective function it minimized, the parameter coefficient β and the autocorrelation coefficient ρ for the model are estimated jointly. The smaller the value of ρ means that there is a lower amount of autocorrelation remaining in the model. It is important to note that autocorrelated errors cannot be completely removed from the model but simply minimized to allow for more efficient estimation of parameters. If a model possesses autocorrelated errors, but we ignore or are unaware of the correlation then we are using an estimator that is inefficient and will be using standard errors that are not a proper reflection of the precision of a least-squares estimates (Griffiths, 1993).

3.4 Quadratic Profit Function Without Regionalization

Equation 3.4 is the first model and is a normalized quadratic profit function without any regional dummy variables.

The following variables are used in this model and for each variable there are prices and quantities (except for capital and time). The prices (X_i) are normalized by a price index of other materials used. The multiple outputs are total paper (*tp*) and wood pulp (*wp*). The multiple inputs are roundwood (*rw*), wood chips (*wc*), labour hours (*lbhr*), and energy used (*e*). There is a fixed capital stock (*k*) and time (*t*) is present as well. A description of the data used follows in section 3.7.

The model is as follows:

$$\Pi = c + \sum_{i=1}^{n} \beta_i X_i^* + \frac{1}{2}\sum_{i=1}^{n} \beta_{ii} X_i^{*2} + \sum_{i=1}^{n}\sum_{j=1}^{n} \beta_{ij} X_{ij}^{\ *} + \sum_{i=1}^{n} \beta_{ik} X_i^{\ *} K$$
$$+ \sum_{i=1}^{n} \beta_{iy} X_i^{\ *} T + \varepsilon \qquad \textbf{(3.4)}$$

where: Π = total variable profits;

c = constant term;

β = the coefficients;

X^* = the normalized prices of variable n;

K = capital;

T = time;

n = *tp, wp, rw, wc, lbhr,* and *e*;

ϵ = the error term.

By following Hotelling's Lemma, we can obtain the derived supply and input demand equations of the profit function. Equations 3.5 and 3.6 are supply and demand equations (Q_s and Q_d respectively):

$$Q_s = \beta_s + \beta_{ss} X_s^* + \sum_{i=1}^{n} \beta_{si} X_i^* + \beta_{sk} K + B_{sy} Y + \varepsilon \qquad \textbf{(3.5)}$$

where: s = total paper or wood pulp;

n = all input variables and the other output variable;

X_i^*= the normalized price of i;

B_s = the cross equation coefficient restriction;

ϵ = the error term.

$$Q_d = -1 * \left(\beta_d + \beta_{dd} X_d^* + \sum_{i=1}^{n} \beta_{di} X_i^* + \beta_{dk} K + \beta_{dy} Y \right) + \varepsilon \qquad \textbf{(3.6)}$$

where: d = the input being demanded;

n = all other input variables and both output variables;

X_i^* = the normalized price of i;

B_d = the cross equation coefficient restriction;

ϵ = the error term.

The development of the above supply and demand equations (3.5 and 3.6) are dependent upon the cross-equation restrictions imposed from the application of Hotelling's Lemma. What this means is that the cross-term coefficients determined from the profit function (equation 3.4) are used in the supply and demand equations. For example, with respect to wood chips and roundwood, the cross-price coefficient for wood chips and roundwood is used in each respective input demand equation. These allow for the development of unique profit maximizing supply and demands with respect to the estimated profit function.

The results obtained from this model can then be used to estimate elasticities and making other interpretations about the Canadian pulp and paper industry. This model also presents the foundation for estimating a normalized quadratic profit function with regionalization.

3.5 Quadratic Profit Function With Regionalization

Regionalization of the model is accomplished through the use of dummy variables. Ideally, there would be enough data points to run a separate model for each region (Quebec, Ontario, British Columbia, and the Rest of Canada). This would also allow for the regional aspects to be considered for all the cross equation restrictions and the square terms. However, it is still reasonable to estimate the model with regional considerations. In the context of this study, regionalization is taken into account for dummy variables, the initial terms of inputs and outputs, and all aspects of the fixed capital stock and time. Also, the way the data is constructed, it is possible to develop the elasticities for the regions as well.

For this model, there are the same inputs and outputs as mentioned for the model without regionalization above. The four regional factors are generalized as r for the normalized quadratic profit function with regionalization in equation 3.7:

$$\Pi = \sum_{r=1}^{v}\alpha_r D_r + \sum_{i=1}^{n}\sum_{r=1}^{v}\beta_{ir}X_{ir}^{*} + \frac{1}{2}\sum_{i=1}^{n}\beta_{ii}X_i^{*2} + \frac{1}{2}\sum_{r=1}^{v}\beta_{rk}K_r^{2} + \frac{1}{2}\sum_{r=1}^{v}\beta_{ry}Y_r^{2}$$
$$+ \sum_{i=1}^{n}\sum_{j=1}^{n}\beta_{ij}X_{ij}^{*} + \sum_{i=1}^{n}\sum_{r=1}^{v}\beta_{kir}X_i^{*}K_r + \sum_{i=1}^{n}\sum_{r=1}^{v}\beta_{yir}X_i^{*}Y_r + \varepsilon \qquad \textbf{(3.7)}$$

where: Dr = the dummy variables for region r (Quebec, Ontario, British Columbia, and Rest of Canada);

$X_{ir}^{*} = D_r X_i^{*}$ = the normalized price of each input and output (i) for each region (r);

$K_r = D_r K_r$ = the capital investment for region (r);

$Y_r = D_r Y_r$ = the time proxy for technological change for region (r);

B_i = the coefficient;

all other variables have the same notation as given in equation 3.4.

Once again, by following Hotelling's Lemma, we can obtain the derived supply and demand relationships for the normalized quadratic profit function with regionalization. These are represented by Q_s (equation 3.8) and Q_d (equation 3.9) respectively:

$$Q_s = \sum_{r=v}^{v}\beta_{sr}R_r + \beta_{ss}X_s^{*} + \sum_{i=n}^{n}\beta_{si}X_i^{*} + \sum_{r=v}^{v}\beta_{ksr}K_r + \sum_{r=v}^{v}\beta_{ysr}Y_r + \varepsilon\ , \qquad \textbf{(3.8)}$$

$$Q_d = -1*\left(\sum_{r=v}^{v}\beta_{dr}R_r + \beta_{dd}X_d^{*} + \sum_{i=n}^{n}\beta_{di}X_i^{*} + \sum_{r=v}^{v}\beta_{kdr}K_r + \sum_{r=v}^{v}\beta_{ydr}Y_r + \varepsilon\right), \qquad \textbf{(3.9)}$$

where: s and d refer to the respective supply and demand equations given in equations 3.5 and 3.6.

The development of the above supply and demand equations (3.8 and 3.9) are dependent upon the cross-equation restrictions imposed from the application of Hotelling's Lemma. What this means is that the cross-term coefficients determined from the profit function (equation 3.7) are used in the supply and demand equations. The way this differs from the cross-equation restrictions developed in the model without regionalization is with the capital and time variables and with the first order price term of the input or output being examined. These are the variables where the derivatives will also involve the regional dummy variables.

As stated in the previous section, the results from this model can be used to determine values of elasticities and other interpretations. The big difference is due to the regional differentiation. By having regional values in the profit equation, we can see differences between regions through the elasticity values. Also, because of the multi-output (multi-input) factorization of the model, we can observe the relative strength of the outputs (or inputs) within a region (i.e. if the region's profitability is better suited for production of wood pulp rather than total paper). It should be noted that the model presented, in equation 3.7, regionalizes the capital and time variables but not the price variables for the square terms. Hence, data estimates of elasticities of supply and demand will not incorporate regional variation in coefficients. Differences in elasticities for inputs and outputs for regions will be driven by differences in price and quantity. This is not true with respect to the profit elasticities. The derivative of the profit function with respect to output price, input price, capital, and time will pick up regional variation through the first order coefficients for prices and the first and second order coefficients for capital and time.

3.6 Elasticities

Elasticities are a useful measure to make interpretations about how relative changes in price affect the responsiveness of a variable. This is important when considering supply and demand effects upon the industry. There are three elasticity measures used in this study. They are:

Marshallian own-price elasticities

$$e_{ii} = \beta_{ii} * \frac{p_i^*}{Q_i}, \tag{3.10}$$

where: i = the variable being examined;

p^* = the price of i normalized by the price of other materials;

Q = the quantity of i.

The own-price elasticity measures the percentage change in quantity demanded for a given percentage change in price along the ordinary demand function or the own-price market demand function (Binger and Hoffman, 1998).

Marshallian cross-price elasticities

$$e_{ij} = \beta_{ij} * \frac{p_j^*}{Q_i}, \tag{3.11}$$

where: i and j = the variables being examined;

p^* = the price of i normalized by the price of other materials;

Q = the quantity of i.

The cross-price elasticity measures the percentage change in quantity demanded for a given percentage change in the price of another good (Binger and Hoffman, 1998).

Profit function elasticities

$$e_{\Pi x} = \frac{\partial \Pi}{\partial P_x} * \frac{\bar{p}_x^*}{\bar{\Pi}}, \tag{3.12}$$

where: x = the variable being examined;

p^* = the normalized mean value of x;

Π = the mean value of profit for the region being examined.

All three are used in the models with and without regionalization. All price and quantity values were taken at the sample means for price and quantity of the respective variables.

3.7 Description of the Data

The data being used for this study has come from a variety of sources. The majority of data has come from the pulp and paper mills (1961-1984), paper and allied products (1985-1995), and Canadian forestry statistics (1962-1995) publications from Statistics Canada. For areas where the data did not exist, estimates were made using the quantity data and price indices from the Statistics Canada CANSIM database.

The raw data set spans from 1961-1995 with the exclusion of 1991 due to a lack of data for that particular year. In total, there are 136 observations for each model being estimated with 34 data points per region. There is an analysis of the raw data in section 4.2, then the normalized quadratic profit functions results will be detailed in section 4.3.

Table 3.1 includes the units of data used in this study. It details the variables, price in dollars per unit, and quantity in units.

Total variable profit was calculated by dividing total revenue by the total variable cost of the industry. Total paper and wood pulp prices were calculated by dividing total revenue for each variable by the respective total production. Roundwood and wood chip prices were determined by dividing the respective total costs by the quantity of the wood input. Labour price was calculated by dividing the labour cost by the number of hours worked. The price of energy was provided from the Statistics Canada CANSIM database. The quantity of energy used was determined by taking the industry cost of energy and dividing by the price of energy. The capital stock data was the end-year net stock as provided by the industrial monitor data from Statistics Canada. All monetary data was converted into real 1992 dollars by an industrial product price index obtained from the Statistics Canada CANSIM database. All prices in the dataset are normalized by the price of other materials that was also obtained through the CANSIM source. The time variable was calculated by taking the observation year less 1960. Appendix one contains the data set used for this study.

Table 3.1 Units of Data in the Study

Variable	Price	Quantity
Total Variable Profit	----	1992 $ millions
Total Paper	$/tonne	10^3 tonnes
Wood Pulp	$/tonne	10^3 tonnes
Wood Chips	$\$/m^3$	$10^3\ m^3$
Roundwood	$\$/m^3$	$10^3\ m^3$
Labour	$/hour worked	millions of hrs
Energy	$/GJ	GJ
Price of Other Materials	----	price index, 1992=100
Capital	----	1992 $ millions
Time	----	year

CHAPTER FOUR: RESULTS and ANALYSIS

4.1 Overview

This chapter examines the data used to estimate the models presented in chapter 3 and presents the results of the seemingly unrelated regressions. The chapter is organized as follows. In section 4.2, there is an analysis of the raw data. This involves examining graphs of the data and making some observations and interpretations. The focus on this section is to look at the wood inputs and outputs and with a capital and labour consideration. In section 4.3, the results of the four models are presented. The models for the Canadian pulp and paper industry include either a regional or a national interpretation, along with the use of an autocorrelation command or without. There is an analysis of the coefficients and profit, own-price, and cross-price elasticities. The four models will be compared and reasoning is given as to which model is the best one and why.

4.2 Analysis of Raw Data

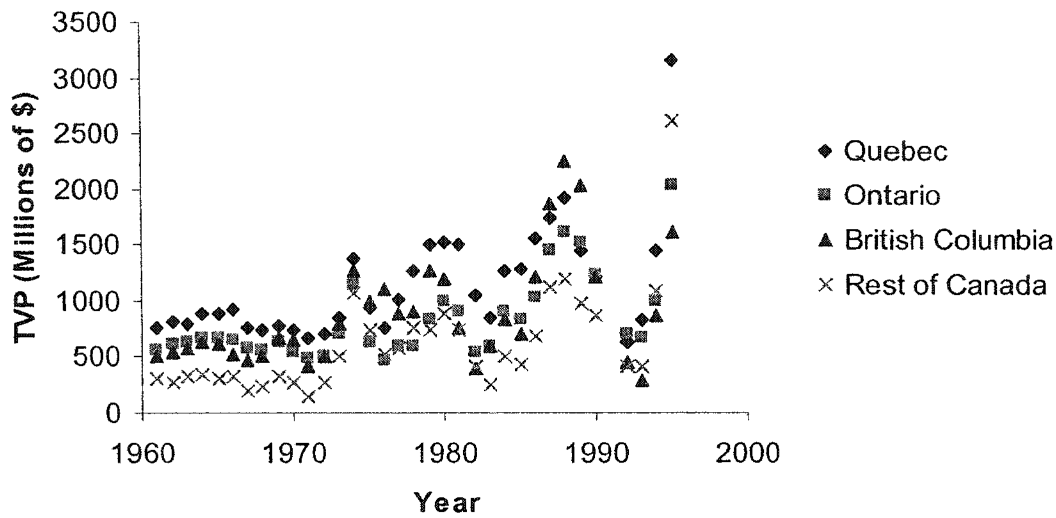
In this section, trends of input prices, output prices, input quantities and output quantities are presented, analyzed and compared. These interpretations of the historical data will put the forthcoming regression results into perspective and aid in their interpretation.

The most important variables to consider in the analysis are the wood inputs (roundwood and wood chips) and outputs (wood pulp and total paper). By examining the prices and quantities of these respective variables by region, we can observe which regions differ and whether or not these differences are large. This is useful to observe possible trends the industry may be facing and the effect upon profitability.

Total Variable Profit Observations

Figure 4.1 shows the time trend of total variable profit over time for each region. It should be noted that total variable profit is equal to the total revenue less the total variable costs faced by the industry.

Figure 4.1 Total Variable Profit (Real $1992 Cdn)



The indication from figure 4.1 is that total variable profit for the pulp and paper industry has been positive for all regions throughout the data set. The profit trend appears to be cyclical and correlated for each region. That is, on the downward trend of the profit cycle each region experiences a decline and on the peaks each region experiences an increase in total variable profits. This is not surprising since prices of outputs in the forest industry are typically cyclical.

Wood Input Observations

Figures 4.2 and 4.3 show quantity of roundwood and wood chips used by the pulp and paper industries over the sample period. The most striking feature of roundwood use in Canada is that roundwood used rises in the 1960s for all four regions and then declines thereafter for Quebec and British Columbia. For Ontario the decline does not occur until the late 1980s. However, for the Rest of Canada wood use continues to increase throughout the sample period. These rises in wood use may be associated with large expansions of the pulp and paper industries in Alberta and Saskatchewan during the late 1980s and 1990s. The most important feature of wood chip use is that it rises in all regions throughout the sample period. This suggests, together with decreases in roundwood use, that wood chips purchased from sawmills are being used as a substitute for roundwood that is harvested and directly delivered to pulp mills.

Figure 4.2 Quantity of Roundwood Used (1961-1995)

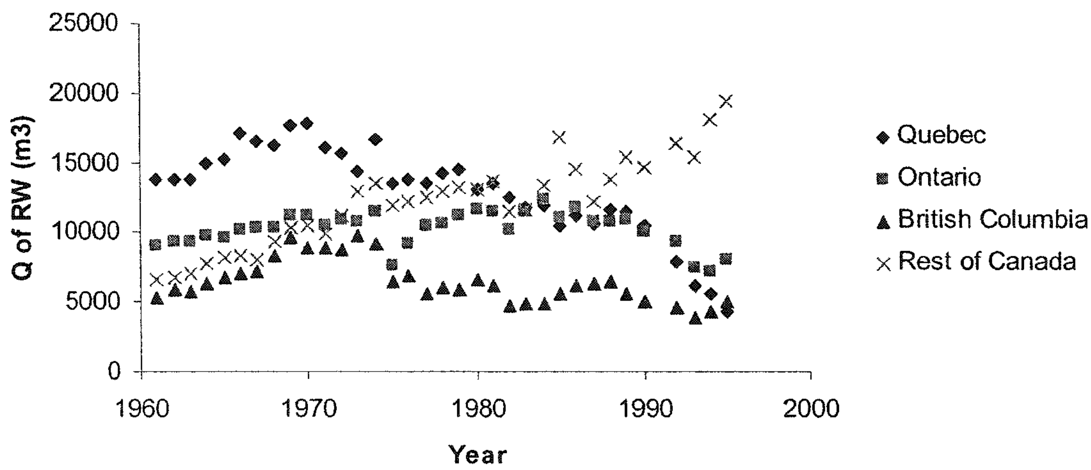
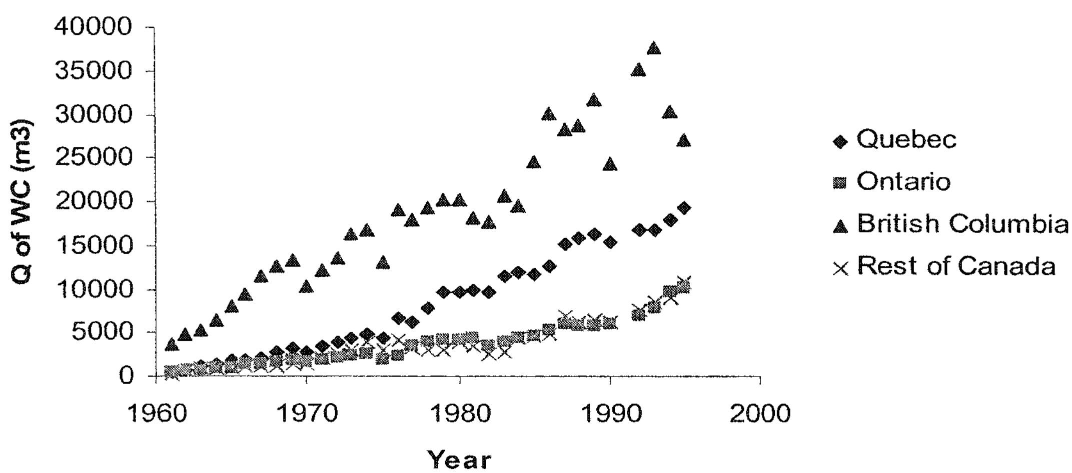


Figure 4.3 Quantity of Wood Chips Used (1961-1995)



Another important observation can be made about the relative roundwood and wood chip use in BC. British Columbia has the largest wood chip use and lowest roundwood used of all four regions. Also, British Columbia has by far the largest sawmilling industry that produces large quantities of residual wood chips. Hence, British Columbia tends to supply its pulp and paper industry with relatively more wood chips.

Wood Product Output Observations

Figures 4.4 and 4.5 show the quantity of wood pulp and total paper produced. For all regions there has been an increase in production for both outputs. The two largest contributors of wood pulp are British Columbia and the Rest of Canada. For wood pulp, the largest increase over the data set has been seen in the Rest of Canada. British Columbia has been rising with a fairly constant trend, while Ontario and Quebec have both seen a gradual increase over the data set. As mentioned previously, the increase seen in the Rest of Canada could be attributed to the expansion of pulp processing plants in Alberta and Saskatchewan in the 1980s and 1990s.

Once again, there has been a rise in the production of total paper across all regions throughout figure 4.5. The two largest contributors of total paper production are Quebec and Ontario. However, the difference between total paper and wood pulp production appears to be that the increase in total paper is more linear across all regions but Quebec and Ontario have a steeper slope for the data set.

From figures 4.2 and 4.3, it is evident that over time the quantities of wood chips used are rising and the quantities of roundwood used are in decline (except for in the Rest of Canada). When you combine this information with an increasing trend in the production of wood pulp and total paper from figures 4.4 and 4.5, it appears that there is a substitution effect occurring in the industry. If manufacturers are substituting the use of roundwood with wood chips in production of pulp and paper products, this could be the result of a price difference between the two goods and/or from technological processes.

Figure 4.4 Quantity of Wood Pulp Production (1961-1995)

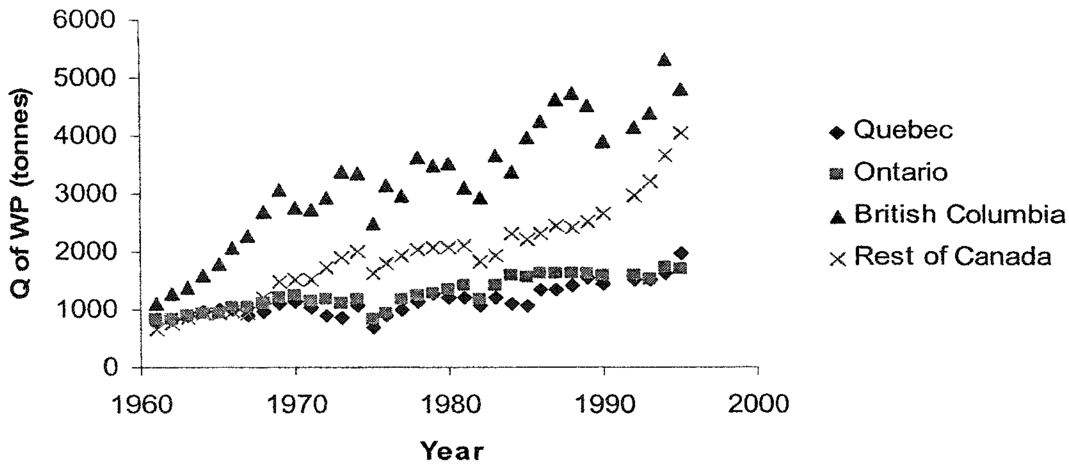


Figure 4.5 Quantity of Total Paper Production (1961-1995)

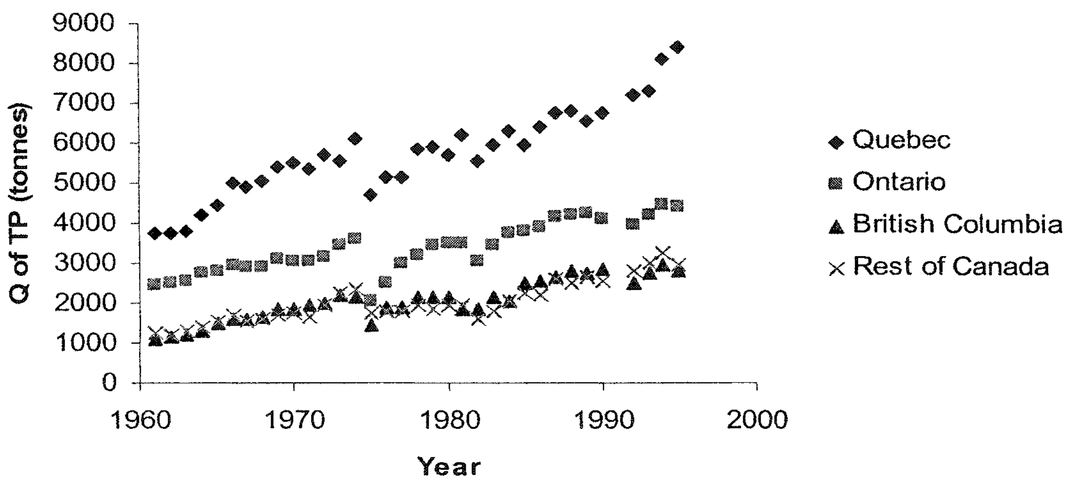


Figure 4.6 Trends in the Prices of Roundwood and Wood Chips for Quebec (real $1992 Cdn)

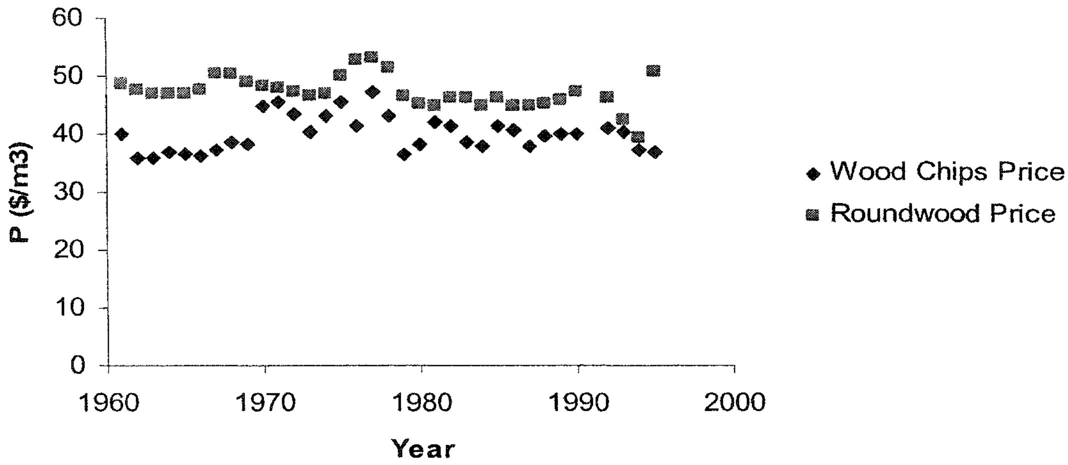


Figure 4.7 Trends in the Prices of Roundwood and Wood Chips for Ontario (real $1992 Cdn)

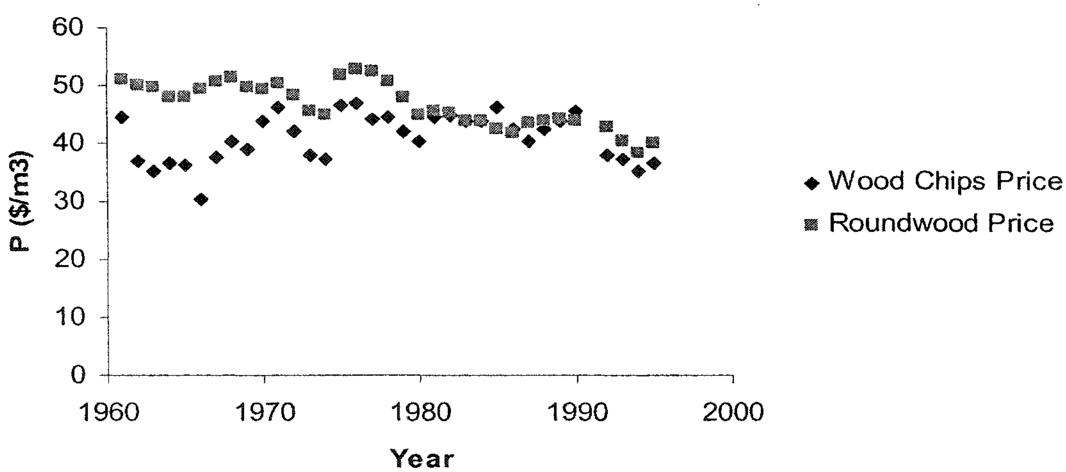


Figure 4.8 Trends in the Prices of Roundwood and Wood Chips for British Columbia (real $1992 Cdn)

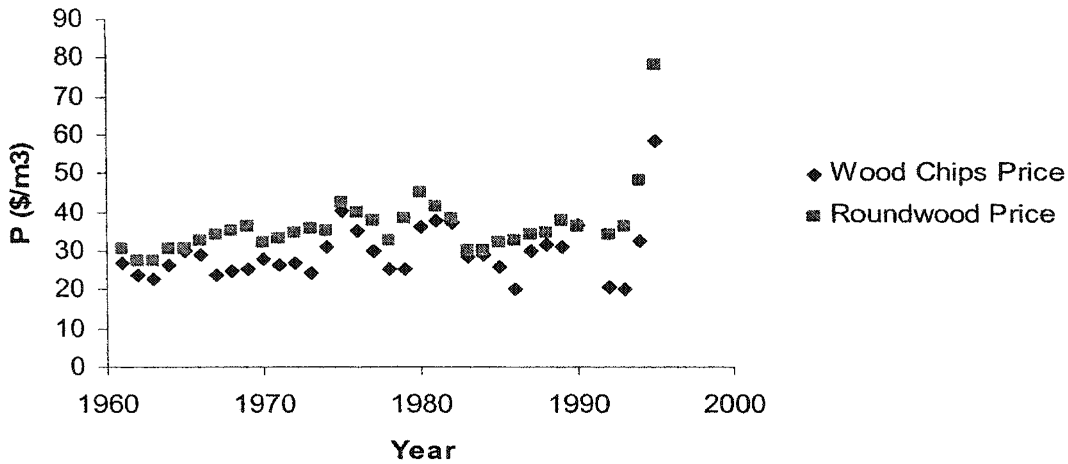
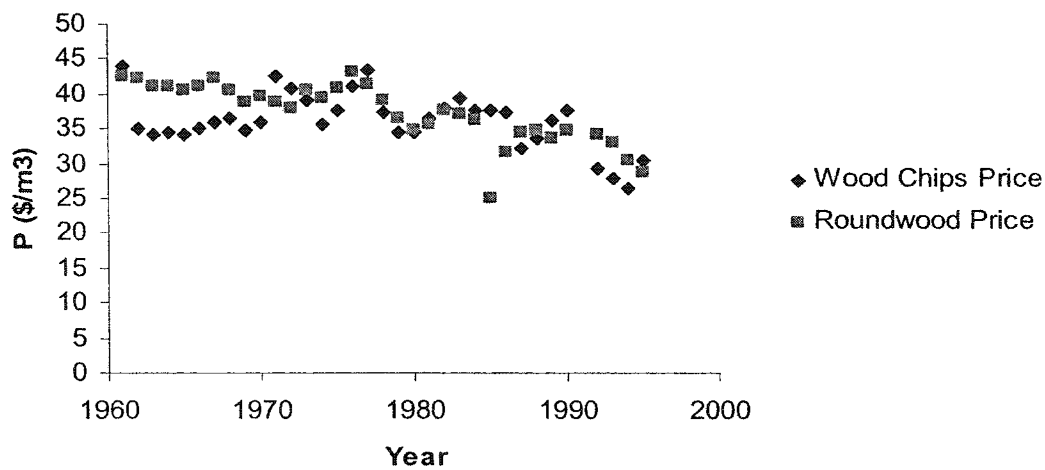


Figure 4.9 Trends in the Prices of Roundwood and Wood Chips for the Rest of Canada (real $1992 Cdn)



Wood Input Price Observations

Figures 4.6 through 4.9 demonstrate that the price of wood chips and the price of roundwood are very similar throughout the length of the data set except for the in the early 1960s, where wood chip prices tend to be lower than roundwood prices. From 1970-1995, prices of wood chips and roundwood are closer together and exhibit similar trends in the same direction.

A possible reason for the lower prices for wood chips, early in the sample period, is that the demand for wood chips was lower at that time. Over time, wood chips have become more of a substitute for roundwood. As wood chips have become more of a substitute, the demand for wood chips has increased and the price has increased accordingly. Since, it appears that roundwood and wood chips are close substitutes, it can be reasoned that this is why the prices tend to fluctuate in the same direction. This position can be supported with use of figures 4.2 and 4.3, where wood chip use is continuing to rise in all regions and roundwood use is in decline over time except for the Rest of Canada.

Given that roundwood and wood chip prices are similar, the shift in the industry towards the use of wood chips may also be due to higher valued uses for roundwood in other forest products. This could occur because there are many mills which produce not only pulp and paper products but lumber and other forest based products as well. If roundwood has a higher value use in production of the other products, then if wood chips are substitutable it makes sense to have a shift towards wood chip inputs in the pulp and paper sector.

Figure 4.10 Quebec Capital Stock vs Labour Hours (1961-1995)

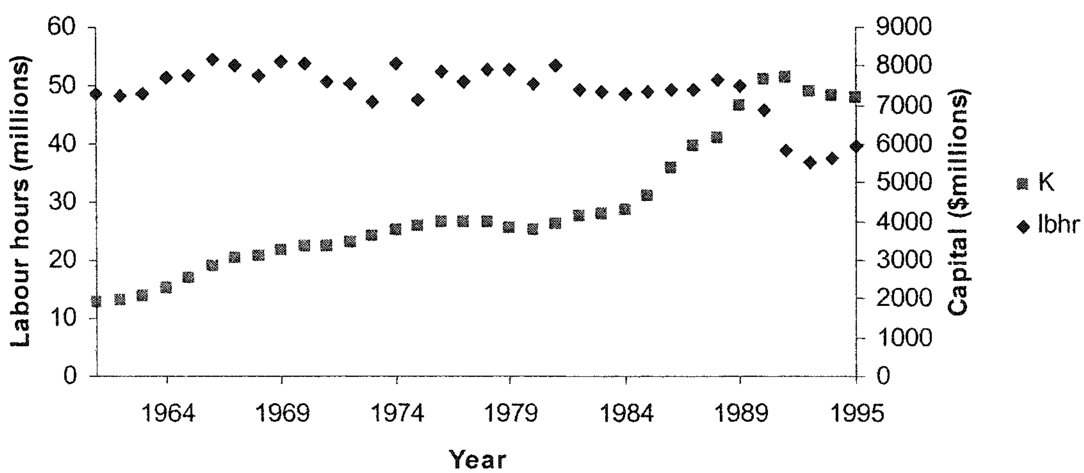


Figure 4.11 Ontario Capital Stock vs Labour Hours (1961-1995)

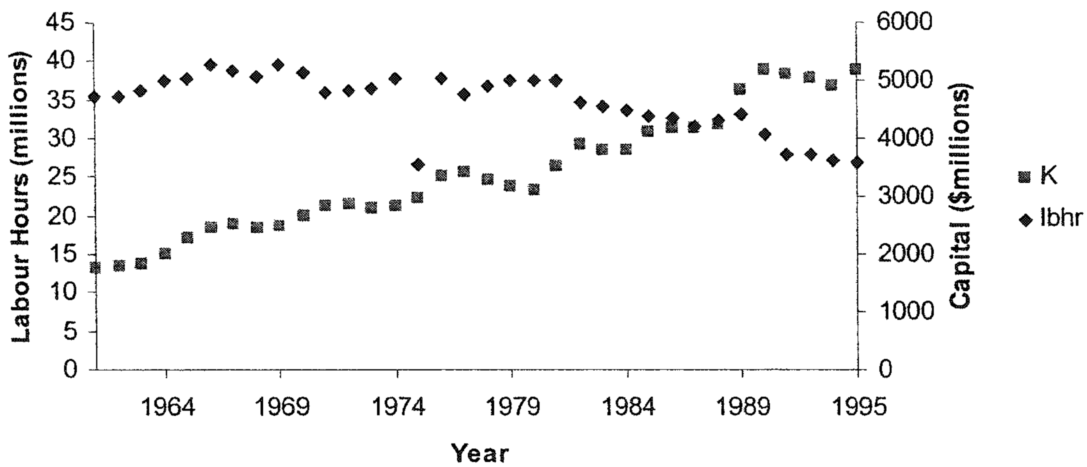


Figure 4.12 British Columbia Capital Stock vs Labour Hours (1961-1995)

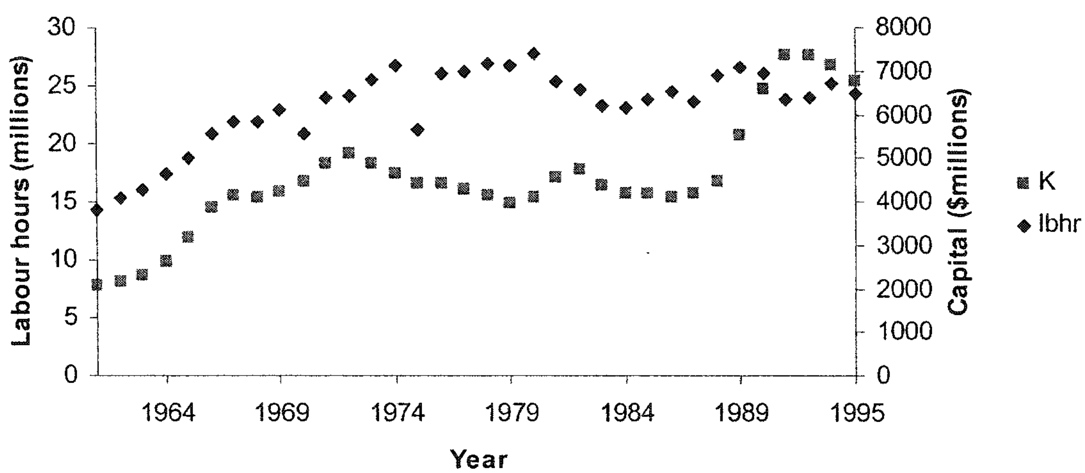


Figure 4.13 Rest of Canada Capital Stock vs Labour Hours (1961-1995)

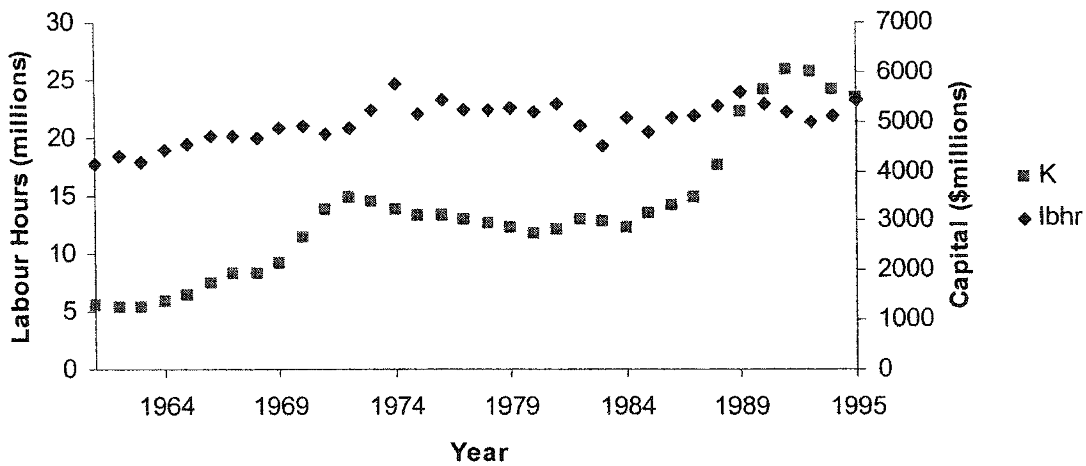
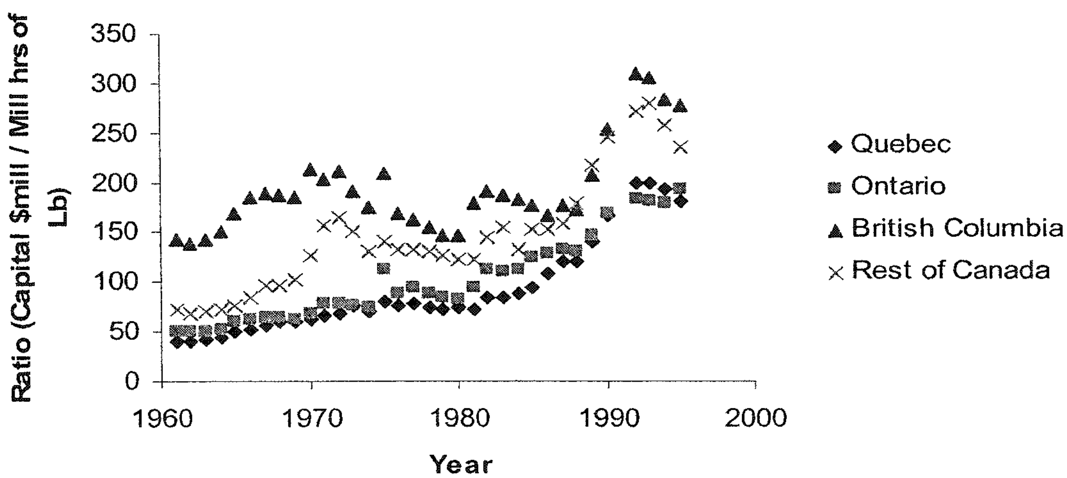


Figure 4.14 Ratio of Capital Stock to Labour Hours (1961-1995)



__Capital Stock vs. Labour Hours Observations__

From figures 4.10 –4.13, the amount of the capital stock is increasing throughout all regions across the whole sample period. Although labour hours worked has been fairly constant, it appears to be declining since 1975 in Ontario and Quebec. In British Columbia and Rest of Canada it appears to be roughly constant since 1975.

From figure 4.14, the capital-labour hours worked ratio is increasing. This is an indication that there is a substitution effect occurring shifting to a decline in labour hours purchased given an increase in capital stock. This makes sense because it could be assumed that when there is a capital increase, there could be a more time efficient use of labour that could then lead to a decline in labour hours.

As output is increasing, labour hours being used is in decline or staying relatively constant. However, the capital is increasing and the capital-labour hours ratio is increasing as well which indicates that there has likely been a shift to more capital intensive and less labour intensive technology in the pulp and paper industry.

<u>Ratio of Total Paper to Wood Pulp Production Observations</u>

Figure 4.15 Ratio of Total Paper to Wood Pulp Production (1961-1995)

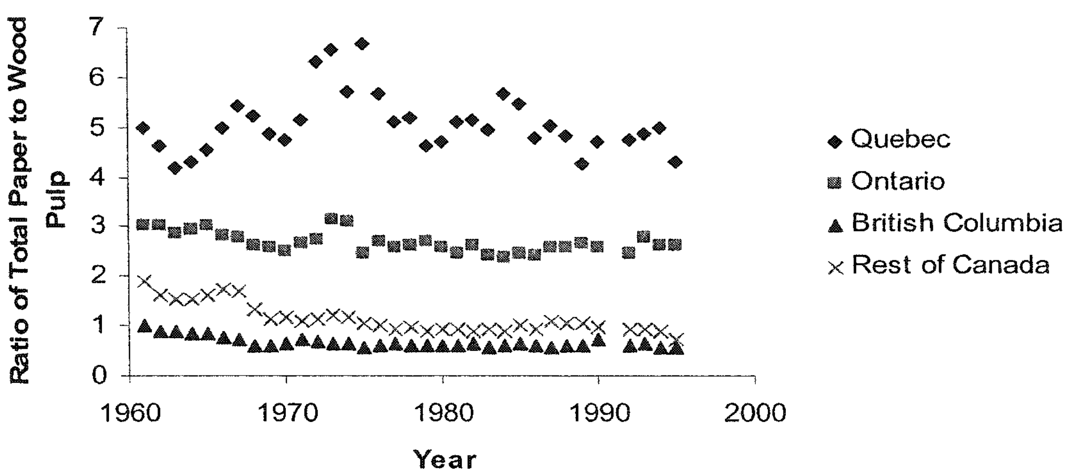


Figure 4.15 shows the ratio of total paper production to that of wood pulp production. Figure 4.15 together with Figures 4.4 and 4.5 demonstrate that Quebec and Ontario are the two main producers of the Canadian total paper, whereas British Columbia and the Rest of Canada produce greater amounts of wood pulp.

Ontario and British Columbia appear to have a slightly declining ratios of total paper to wood pulp production over the sample period. The Rest of Canada appears to have a slight decline over the sample period and this is an indication that there is a greater ratio of wood pulp to total paper in the region over time.

The trends described in this section, along with basic economic intuition, will help us interpret the results of the econometric model, which are presented in the next section.

4.3 Results of the Regional and Non-Regional Profit Function Models

In total, four different models were estimated for the data set. These models may be described as follows. Two models estimated profit functions for the Canadian pulp and paper industry with 4 regional dummy variables and regional dummy interaction terms on first order price terms, capital and time variables (Quebec, Ontario, British Columbia, and Rest of Canada). Two other models pool the regional data and one national profit function model is estimated. Both the regional and non-regional models are estimated with and without corrections for autocorrelation using the Shazam auto option for seemingly unrelated regression.

4.3.1 Summary of the Profit Function Results

As could be seen in the coefficients, there are differences in the signs and size for many of the variables. Given the objectives of this project, it is expected that the models with regional dummy variables would be a superior tool for analysis of the industry. However, this would only be true if significant improvement in model fit is obtained by including regional dummy variables. Otherwise regional variation in the industry profit elasticities would be obtained using the estimates obtained from the pooled data set where no regional dummy variables are included. The X^2 statistic in table 4.1, however, shows that inclusion of regional dummy variables has a highly significant and positive impact upon model fit at the 95 percent significance level. This is true for models with or without autocorrelation corrections.

Table 4.1 A Comparison of Key Statistical Results from Four Normalized Quadratic Profit Functions

	Autocorrelation Corrected Model		**No Correction For Autocorrelation Model**	
Statistical Test Result	Regional	Non-Regional	Regional	Non-Regional
Durbin-Watson Test Statistic Value	1.9149	2.0985	0.9963	0.6457
R^2 value between observed and predicted	0.8667	0.8172	0.7931	0.5852
Sum of Absolute Errors	139.53	158.16	181.41	265.31
Sum of Residual Errors	7.8760	33.783	3.9793	10.141
Residual Variance	2.0136	2.9339	3.1429	6.4789
First-order Autocorrelation Coefficient Value (t-statistic)	0.59349 (15.068)	0.95407 (100.08)	---	---
Log-Likelihood Function Value	-1028.361	-1312.603	-1163.648	-1913.359
X^2 statistic (degrees of freedom)	568.484 (df=73)		1499.422 (df=73)	

The Durbin-Watson statistics for the models without a correction for autocorrelation suggest that autocorrelation is present. Both Durbin-Watson statistics for these models are less than one and this indicates significant autocorrelation at the 95 percent significance level.

The R^2 values between the observed and predicted provide an indication of how well the model fits the data. The models estimated with a correction for autocorrelation are considered to be superior because they have a value closer to one. The model with regional dummy variables is closest to one so this implies that the splitting of the industry into regions is a more useful econometric exercise.

The chi-square statistic is determined through use of the log-likelihood ratio test. Both X^2 values are significantly greater than the X^2 critical value of 90.5312 with 73 degrees of freedom at a 95 percent level of significance. This result indicates that there is a significant difference between estimating the quadratic profit functions with regional dummy variables and those without regional dummy variables.

Therefore, from these results it can be concluded that the most applicable model considered is the regional normalized quadratic profit function using the correction for first order autocorrelation. The results from this model also satisfy the conditions of profit maximization, as given in section 2.2, as all the signs on coefficients are in the correct direction. Therefore, all interpretations of results from this point will refer to this model.

Tables 4.2 – 4.4 contain all of the first-order, square-term, and cross-term interaction coefficient results from the 4 models with the t-statistic values in brackets. The critical t-statistic value is 2.101 for the regional model (18 degrees of freedom) and 2.021 for the non-regional models (91 degrees of freedom) at a 95 percent significance level. The coefficients that are in bold font indicate that they have significant t-statistic values. If there is not a value for a coefficient then it was not used in that model type.

Table 4.2 First-Order Coefficient Estimates (t-statistics)

	Estimated Model			
Coefficient	**Auto[1]-Regional[2]**	**Non-Auto Regional**	**Auto Non-Regional**	**Non-auto Non-Regional**
Constant Coefficient	---	---	**-4.1691 (-2.847)**	**2.9658 (2.3528)**
Quebec Dummy Variable	1.8609 (0.57878)	1.8724 (0.74045)	---	---
Ontario Dummy Variable	1.1281 (0.25351)	1.4363 (0.34858)	---	---
British Columbia Dummy Variable	-2.9733 (-1.1216)	0.23107 (9.63E-02)	---	---
Rest of Canada Dummy Variable	1.0538 (0.6768)	1.0194 (0.83472)	---	---
Total Paper Price[3]	---	---	**2.0737 (5.612)**	**-1.5026 (-3.4463)**
Quebec[7] Total Paper Price	**2.8973 (7.1102)**	**2.5164 (7.3087)**	---	---
Ontario Total Paper Price	**1.9112 (3.4907)**	**1.1124 (2.1134)**	---	---
British Columbia Total Paper Price	0.54895 (1.3028)	-3.93E-02 (-0.10457)	---	---
Rest of Canada Total Paper Price	0.2419 (0.70233)	-1.43E-02 (-4.82E-02)	---	---
Wood Pulp Price	---	---	**-0.67516 (-2.6625)**	**1.2328 (3.808)**
Quebec Wood Pulp Price	-0.00981 (-0.3797)	0.00541 (0.26855)	---	---
Ontario Wood Pulp Price	0.54097 (1.284)	0.40148 (1.0651)	---	---
British Columbia Wood Pulp Price	**1.1078 (3.667)**	**0.95297 (4.2174)**	---	---

Table 4.2 Continued

Coefficient	Auto-Regional	Non-Auto Regional	Auto Non-Regional	Non-auto Non-Regional
Rest of Canada Wood Pulp Price	-0.1076 (-0.44964)	0.11006 (0.61119)	---	---
Roundwood Price[4]	---	---	**-12.743 (-9.4533)**	**-17.703 (-6.4072)**
Quebec Roundwood Price	**-16.109 (-8.6739)**	**-20.563 (-10.945)**	---	---
Ontario Roundwood Price	**-11.819 (-5.2094)**	**-15.695 (-5.9825)**	---	---
British Columbia Roundwood Price	**-6.5572 (-3.5984)**	**-8.3024 (-4.4957)**	---	---
Rest of Canada Roundwood Price	**-5.762 (-3.4708)**	**-8.1579 (-4.7391)**	---	---
Wood Chip Price	---	---	**5.4481 (2.7557)**	**8.4895 (2.8651)**
Quebec Wood Chip Price	0.20082 (0.00864)	4.141 (1.9951)	---	---
Ontario Wood Chip Price	-2.0767 (-0.72642)	3.0341 (1.0859)	---	---
British Columbia Wood Chip Price	-3.4882 (-1.523)	1.1352 (0.54305)	---	---
Rest of Canada Wood Chip Price	-2.0759 (-1.0297)	1.5001 (0.7815)	---	---
Labour Price	---	---	**-34.34 (-25.424)**	3.1717 (0.60038)
Quebec Labour Price	**-50.959 (-13.936)**	**-55.048 (-17.099)**	---	---

Table 4.2 Continued

Coefficient	Auto-Regional	Non-Auto Regional	Auto Non-Regional	Non-auto Non-Regional
Ontario Labour Price	**-36.366 (-8.1467)**	**-39.129 (-8.29)**	---	---
British Columbia Labour Price	**-16.298 (-4.4735)**	**-16.281 (-4.8699)**	---	---
Rest of Canada Labour Price	**-15.268 (-4.6443)**	**-15.917 (-5.3403)**	---	---
Energy Price	---	---	**-55.415 (-29.578)**	1.6043 (0.14546)
Quebec Energy Price	**-81.404 (-8.6807)**	**-82.515 (-7.3926)**	---	---
Ontario Energy Price	**-57.13 (-6.0362)**	**-62.226 (-4.1251)**	---	---
British Columbia Energy Price	**-28.087 (-3.2904)**	-23.858 (-2.0729)	---	---
Rest of Canada Energy Price	**-28.679 (-3.3056)**	**-24.786 (-2.3375)**	---	---
Capital[5]	---	---	**3.2091 (3.217)**	-0.2695 (-0.47839)
Quebec Capital	-1.3492 (-0.81742)	-0.80152 (-0.69386)	---	---
Ontario Capital	-0.72983 (-0.15978)	1.6595 (0.3656)	---	---
British Columbia Capital	2.5279 (1.5982)	1.9169 (1.3287)	---	---
Rest of Canada Capital	2.1119 (1.6769)	**2.6086 (2.8008)**	---	---
Time[6]	---	---	**-0.41571 (-2.4138)**	**-0.34218 (-4.2906)**
Quebec Time	0.10897 (0.5997)	4.01E-02 (0.30241)	---	---
Ontario Time	-3.75E-02 (-0.00814)	-0.37165 (-0.78257)	---	---

Table 4.2 Continued

Coefficient	**Auto-Regional**	**Non-Auto Regional**	**Auto Non-Regional**	**Non-auto Non-Regional**
British Columbia Time	-0.31641 (-1.7791)	**-0.37763 (-2.3759)**	---	---
Rest of Canada Time	**-0.45204 (-3.2664)**	**-0.45581 (-4.2219)**	---	---

1. Auto refers to a correction for autocorrelation in the estimated model.

2. Regional refers to presence of regional dummy variables for Quebec, Ontario, British Columbia and the Rest of Canada.

3. Total Paper and Wood Pulp refer to normalized output prices

4. Roundwood, wood chips, labor and energy refer to normalized input prices.

5. Capital = Quasi-Fixed Capital Stock Investment;

6. Time = Time Variable as a Proxy for Technological Change;

7. Quebec, Ontario, British Columbia and Rest of Canada refer to regional dummy variables.

Table 4.3 Square-Term Coefficient Estimates (t-statistics)

Coefficient	**Auto[1]-Regional[2]**	**Non-Auto Regional**	**Auto Non-Regional**	**Non-auto Non-Regional**
Total Paper Price Squared[3]	0.00839 (1.4616)	0.10412 (1.7824)	-0.00950 (-1.3867)	**1.2179** **(7.2985)**
Wood Pulp Price Squared	0.00367 (1.5244)	0.00295 (1.3488)	0.00426 (1.1568)	**0.44195** **(5.2868)**
Roundwood Price Squared[4]	**6.7646** **(3.1155)**	**8.7495** **(3.4297)**	**19.833** **(12.436)**	**30.769** **(4.7267)**
Wood Chip Price Squared	**26.628** **(8.7173)**	**27.083** **(8.9653)**	**30.021** **(12.194)**	**48.705** **(5.7663)**
Labour Price Squared	**37.84** **(5.7761)**	**16.799** **(2.3575)**	**57.201** **(31.364)**	**61.311** **(3.317)**
Energy Price Squared	**552.82** **(40.697)**	**401.74** **(4.621)**	**558.38** **(239.01)**	**356.11** **(3.6174)**
Capital Squared[5]	---	---	**-1.0482** **(-3.1584)**	-0.20924 (-0.87084)
Quebec[7] Capital Squared	1.0966 (1.5847)	0.96621 (1.6462)	---	---
Ontario Capital Squared	0.66941 (0.23353)	-1.3949 (-0.47169)	---	---
British Columbia Capital Squared	-0.81875 (-1.6283)	-0.98 (-2.0897)	---	---
Rest of Canada Capital Squared	-1.2885 (-1.6453)	**-2.5705** **(-4.0435)**	---	---
Time Squared[6]	---	---	0.000568 (0.43678)	0.000549 (0.81428)
Quebec Time Squared	0.00553 (1.6468)	**0.00579** **(2.2833)**	---	---
Ontario Time Squared	0.000928 (0.25186)	-0.000779 (-0.20797)	---	---
British Columbia Time Squared	-0.000231 (-0.20315)	-0.00109 (-1.3872)	---	---

Table 4.3 Continued

Coefficient	Auto-Regional	Non-Auto Regional	Auto Non-Regional	Non-auto Non-Regional
Rest of Canada Time Squared	0.000135 (0.00775)	-0.00264 (-2.03)	---	---

1. Auto refers to a correction for autocorrelation in the estimated model.

2. Regional refers to presence of regional dummy variables for Quebec, Ontario, British Columbia and the Rest of Canada.

3. Total Paper and Wood Pulp refer to normalized output prices

4. Roundwood, wood chips, labor and energy refer to normalized input prices.

5. Capital = Quasi-Fixed Capital Stock Investment;

6. Time = Time Variable as a Proxy for Technological Change;

7. Quebec, Ontario, British Columbia and Rest of Canada refer to regional dummy variables.

Table 4.4 Cross-Term Interaction Coefficient Estimates (t-statistics)

Coefficient	Auto[1]-Regional[2]	Non-Auto Regional	Auto Non-Regional	Non-auto Non-Regional
Total Paper[3] and Wood Pulp	**0.00820 (2.9698)**	**0.00990 (4.2544)**	-0.005 (-1.3304)	**-0.58324 (-5.591)**
Total Paper and Roundwood[4]	0.00281 (0.12425)	0.45995 (1.9239)	-0.29482 (-1.0428)	**-1.6506 (-2.8226)**
Total Paper and Wood Chip	-0.58652 (-1.8671)	**-1.0442 (-3.8113)**	0.24487 (0.762)	**2.3236 (3.3623)**
Total Paper and Labour	-0.212 (-0.4777)	0.6958 (1.5749)	-0.63326 (-1.5453)	**-10.069 (-6.8151)**
Total Paper and Energy	-0.80124 (-0.80893)	1.2943 (0.91896)	-0.26905 (-0.29339)	**-12.182 (-4.6125)**
Total Paper and Capital[5]	---	---	-9.59E-02 (-1.2201)	**0.89301 (6.31)**
Total Paper and Quebec[7] Capital	0.27045 (1.8768)	**0.29417 (3.2189)**	---	---
Total Paper and Ontario Capital	-0.15014 (-0.55291)	0.00955 (0.38399)	---	---
Total Paper and British Columbia Capital	0.00273 (0.25274)	0.00902 (1.2704)	---	---
Total Paper and Rest of Canada Capital	0.24187 (1.7978)	**0.29481 (3.3766)**	---	---
Total Paper and Time[6]	---	---	**0.00448 (4.0704)**	-0.000597 (-0.32002)
Total Paper and Quebec Time	0.00445 (1.8032)	**0.00448 (2.8645)**	---	---
Total Paper and Ontario Time	**0.00664 (2.2873)**	0.00389 (1.5908)	---	---

Table 4.4 continued

Coefficient	Auto-Regional	Non-Auto Regional	Auto Non-Regional	Non-auto Non-Regional
Total Paper and British Columbia Time	**0.00413 (2.6801)**	**0.00301 (3.2482)**	---	---
Total Paper and Rest of Canada Time	0.00238 (1.2539)	0.00033 (0.10615)	---	---
Wood Pulp and Roundwood	**-0.32527 (-2.2322)**	-0.26199 (-1.5879)	**0.54354 (2.5169)**	**2.0331 (4.9043)**
Wood Pulp and Wood Chips	-0.00918 (-0.47333)	-0.24295 (-1.3396)	-0.29569 (-1.1567)	**-3.1042 (-5.9197)**
Wood Pulp and Labour	**-0.72533 (-2.386)**	**-1.0861 (-3.5665)**	**1.1485 (3.4572)**	**3.9028 (4.1579)**
Wood Pulp and Energy	-0.64901 (-0.78467)	-1.8032 (-1.8041)	**2.6634 (3.4165)**	**5.178 (3.0442)**
Wood Pulp and Capital	---	---	0.10917 (1.4514)	0.10269 (1.1472)
Wood Pulp and Quebec Capital	**0.35188 (3.2291)**	**0.26816 (3.697)**	---	---
Wood Pulp and Ontario Capital	-0.00495 (-0.22097)	0.00337 (0.1666)	---	---
Wood Pulp and British Columbia Capital	-0.00552 (-0.61098)	0.00979 (1.7611)	---	---
Wood Pulp and Rest of Canada Capital	0.16091 (1.4777)	**0.24154 (3.4491)**	---	---
Wood Pulp and Time	---	---	**0.00561 (5.3944)**	**0.00253 (2.0727)**
Wood Pulp and Quebec Time	**-0.00433 (2.3119)**	-0.00197 (-1.6124)	---	---

Table 4.4 continued

Coefficient	**Auto-Regional**	**Non-Auto Regional**	**Auto Non-Regional**	**Non-auto Non-Regional**
Wood Pulp and Ontario Time	0.00265 (1.1004)	0.00236 (1.1238)	---	---
Wood Pulp and British Columbia Time	**0.11503 (8.9201)**	**0.0092 (12.641)**	---	---
Wood Pulp and Rest of Canada Time	**0.00727 (4.5953)**	**0.00455 (4.704)**	---	---
Roundwood and Wood Chips	**-4.9217 (-2.6452)**	**-7.8911 (-3.6766)**	**-14.832 (-8.5347)**	**-29.86 (-4.3883)**
Roundwood and Labour	4.6849 (1.7192)	2.1979 (0.68678)	**8.7335 (3.2886)**	15.994 (1.8684)
Roundwood and Energy	**15.32 (2.4141)**	1.2986 (0.11626)	**12.476 (8.4325)**	26.939 (1.571)
Roundwood and Capital	---	---	-0.13877 (-0.35216)	0.00855 (0.17691)
Roundwood and Quebec Capital	-0.92378 (-1.6458)	0.00758 (0.19269)	---	---
Roundwood and Ontario Capital	0.5557 (0.56888)	1.3145 (1.2513)	---	---
Roundwood and British Columbia Capital	-0.43732 (-1.0698)	-0.62235 (-1.9633)	---	---
Roundwood and Rest of Canada Capital	-0.50962 (-0.98767)	-0.44851 (-1.1626)	---	---
Roundwood and Time	---	---	-0.00621 (-1.0704)	-0.00438 (-0.6763)
Roundwood and Quebec Time	**0.3503 (3.6)**	**0.26995 (3.8582)**	---	---

Table 4.4 continued

Coefficient	Auto-Regional	Non-Auto Regional	Auto Non-Regional	Non-auto Non-Regional
Roundwood and Ontario Time	-0.00436 (-0.41434)	-0.00881 (-0.79277)	---	---
Roundwood and British Columbia Time	0.00612 (1.0451)	**0.12226 (3.0044)**	---	---
Roundwood and Rest of Canada Time	**-0.32186 (-4.3267)**	**-0.26129 (-4.4895)**	---	---
Wood Chips and Labour	-4.4324 (-1.31)	-13.198 (-11.901)	-3.3989 (-1.0062)	-24.439 (-2.9068)
Wood Chips and Energy	-19.036 (-2.0143)	-15.213 (-1.3108)	**-26.294 (-14.389)**	**-60.144 (-3.5779)**
Wood Chips and Capital	---	---	**-1.7319 (-3.4441)**	**-3.0894 (-5.0338)**
Wood Chips and Quebec Capital	-1.2469 (-1.7614)	**-1.078 (-2.763)**	---	---
Wood Chips and Ontario Capital	-083562 (-0.65041)	-0.4153 (-0.40634)	---	---
Wood Chips and British Columbia Capital	-0.39379 (-0.75459)	**-0.79408 (-2.5561)**	---	---
Wood Chips and Rest of Canada Capital	-1.1144 (-1.7096)	**-1.2401 (-3.1927)**	---	---
Wood Chips and Time	---	---	-0.1397 (-1.9623)	-0.00464 (0.55205)
Wood Chips and Quebec Time	**-0.29166 (-2.3818)**	**-0.32734 (-4.6458)**	---	---
Wood Chips and Ontario Time	-0.00665 (0.48549)	-0.16983 (-1.5683)	---	---

Table 4.4 continued

Coefficient	Auto-Regional	Non-Auto Regional	Auto Non-Regional	Non-auto Non-Regional
Wood Chips and British Columbia Time	**-0.73927 (10.023)**	**-0.70949 (-17.218)**	---	---
Wood Chips and Rest of Canada Time	-0.00269 (-0.2806)	0.00281 (0.47074)	---	---
Labour and Energy	**-67.369 (-3.5511)**	**-43.241 (-4.0366)**	**-17.961 (-9.8307)**	56.015 (1.7038)
Labour and Capital	---	---	**-2.0515 (-3.6132)**	**-5.2904 (-4.6381)**
Labour and Quebec Capital	-0.91083 (-0.81518)	1.3412 (1.879)	---	---
Labour and Ontario Capital	-1.5684 (-0.80775)	0.43764 (0.22053)	---	---
Labour and British Columbia Capital	-1.3156 (-1.6164)	-0.78081 (-1.3729)	---	---
Labour and Rest of Canada Capital	-1.5469 (-1.5206)	-1.0487 (-1.4978)	---	---
Labour and Time	---	---	**0.26177 (2.8836)**	**0.51972 (3.4393)**
Labour and Quebec Time	0.10008 (0.79328)	0.29603 (1.5509)	---	---
Labour and Ontario Time	0.26067 (1.247)	0.40144 (1.9211)	---	---
Labour and British Columbia Time	**-0.17812 (-2.3782)**	-0.23127 (-1.9911)	---	---
Labour and Rest of Canada Time	-0.00276 (-0.26112)	-0.12484 (-0.84194)	---	---

Table 4.4 continued

Coefficient	**Auto-Regional**	**Non-Auto Regional**	**Auto Non-Regional**	**Non-auto Non-Regional**
Energy and Capital	---	---	**-5.4021 (-4.4509)**	**-14.571 (-6.9568)**
Energy and Quebec Capital	-5.3555 (-1.726)	-2.9969 (-1.4744)	---	---
Energy and Ontario Capital	-3.8446 (-0.73768)	2.3903 (0.43495)	---	---
Energy and British Columbia Capital	-2.5907 (-1.2069)	-1.8889 (-1.117)	---	---
Energy and Rest of Canada Capital	-2.9341 (-1.0338)	-3.527 (-1.7099)	---	---
Energy and Time	---	---	**0.71122 (-3.5482)**	0.00516 (0.17881)
Energy and Quebec Time	-0.70323 (-1.2979)	-0.79704 (-2.0803)	---	---
Energy and Ontario Time	-0.36528 (-0.65216)	-0.84814 (-1.445)	---	---
Energy and British Columbia Time	**-1.9303 (-5.9868)**	**-1.8152 (-8.0152)**	---	---
Energy and Rest of Canada	**-1.5048 (-3.6461)**	**-1.117 (-3.4648)**	---	---
Capital and Time	---	---	-0.00555 (1.0648)	0.000787 (0.23908)
Capital and Quebec Time	-0.25661 (-1.6649)	**-0.26395 (-2.1129)**	---	---
Capital and Ontario Time	-0.00875 (-0.27562)	0.11953 (0.36375)	---	---
Capital and British Columbia Time	0.00553 (0.96776)	**0.10539 (2.2237)**	---	---

Table 4.4 continued

Coefficient	Auto-Regional	Non-Auto Regional	Auto Non-Regional	Non-auto Non-Regional
Capital and Rest of Canada Time	0.00962 (0.91781)	**0.27426 (3.359)**	---	---

1. Auto refers to a correction for autocorrelation in the estimated model.
2. Regional refers to presence of regional dummy variables for Quebec, Ontario, British Columbia and the Rest of Canada.
3. Total Paper and Wood Pulp refer to normalized output prices
4. Roundwood, wood chips, labor and energy refer to normalized input prices.
5. Capital = Quasi-Fixed Capital Stock Investment;
6. Time = Time Variable as a Proxy for Technological Change;
7. Quebec, Ontario, British Columbia and Rest of Canada refer to regional dummy variables.

4.3.2 First Order Coefficient Results

The results for the first order coefficients are presented in table 4.2. With respect to the first term coefficients, they are analyzed in the context of what will happen to the profit function given a price change in the respective variable being examined. While these coefficients are useful in interpreting the results, just examining them does not give a clear interpretation of what is happening in the model because price variables appear in interaction terms and squared terms. To have a clearer interpretation requires the use of elasticities and this will be discussed later in this section.

For the regional model with a correction for autocorrelation, the price coefficients for roundwood, labour, and energy inputs are all significant and all have negative signs. This means that they contribute negatively to the overall profit function for each of the regions. The other input of wood chips does not have any significant variables. For the outputs, the only significant variables are for total paper in Quebec and Ontario, and with wood pulp in British Columbia.

The most interesting result from the first term coefficients is with respect to Quebec. For each variable that is significant, Quebec has the largest coefficient value amongst the four regions. This is an indication that a price change of any variable within the Quebec pulp and paper production system would have a greater impact on profit than a change in any of the other regions. This means that the Quebec pulp and paper industry is quite price sensitive with respect to profitability.

Another interesting result is the coefficient on the British Columbia wood pulp variable. This is the only region where wood pulp has a significant coefficient. This can be interpreted, along with Figure 4.3 in the previous section, that British Columbia is the key producer of wood pulp in the nation. Thus, the effect of a change in the price of wood pulp would have the most significant effect upon the industry profit function in British Columbia.

4.3.3 Square Term Coefficient Results

The results for the square-term coefficients are presented in table 4.3. Due to data limitations, regarding lack of degrees of freedom, square terms for each variable could not be incorporated. However, regionalization is possible for a subset of the variables and it was decided to regionalize the square terms for the capital and time variables.

For the capital and time variables, the square terms have some positive and negative values depending on the region. For the squared price variables, which are not estimated by region, the results for total paper, wood pulp, roundwood, wood chips, labour, and energy all have a positive sign. This is important with respect to the convexity properties of profit maximization. A negative term would indicate non-convexity and would result in an upward sloping demand function and/or a downward sloping supply function. This type of result would violate property four of profit maximization which states that the function must be convex and continuous. Hence, the estimated model is consistent with profit maximization.

4.3.4 Profit Elasticities Results

Profit elasticity estimates are interpreted as the percentage change in profits that arises with a small (or one) percent change in prices, capital stocks or time. The estimates of profit elasticities for the regional model with a correction for autocorrelation are presented in table 4.5. Note that the Canada column results are estimated from this model and are estimated by using the Canadian mean quantities.

Table 4.5 Profit Elasticities Regional Model Estimation with a correction for autocorrelation

Variable	Canada*	Quebec	Ontario	BC	Rest of Canada
Total Paper	4.887342	3.049696	2.75359	1.38257	2.04037
Wood Pulp	3.707697	0.525483	0.95167	2.09507	1.95017
Labour Hours	-1.08557	-0.89112	-0.8462	-0.6947	-0.7373
Roundwood	-0.70255	-0.55053	-0.57561	-0.2704	-0.7936
Wood Chips	-1.45009	-0.28613	-0.19047	-0.6105	-0.2462
Energy	-0.81957	-0.40055	-0.3466	-0.2999	-0.406
Capital	-1.26373	0.46365	-0.78187	-0.5534	0.54524
Time	3.641903	0.116538	0.98207	0.92798	0.61546

* Note that the Canada column results are estimated from this model and are estimated by using the Canadian mean quantities and the square coefficients because the coefficients are not regionalized.

Profit elasticities, for outputs and inputs prices have the expected signs. Profit elasticity with respect to total paper price is elastic for all regions while wood pulp price is only elastic for Canada, British Columbia, and the Rest of Canada. Profit elasticities for labour price, wood chips price, capital, and time are all elastic for Canada and inelastic for the other regions. Roundwood and energy are price inelastic for all regions.

Quebec and Ontario obtain much higher percentage profit increases when there is an increase in the price of total paper than for the same percentage price increase in wood pulp. Conversely, profits in British Columbia are more sensitive to prices of wood pulp than paper production prices. These results correspond to the analysis of the figures 4.3 and 4.4 presented earlier in this chapter regarding outputs of each industry. The Rest of Canada appears more equally sensitive to price changes in the two major outputs. Note that these results are obscured for the national model.

With respect to capital, the profit elasticities have differing signs across the regions. Canada, Ontario and British Columbia have negative signs while Quebec and the Rest of Canada have positive signs and all regions are inelastic. In theory, the difference in signs is an indication of the capital effect upon profitability. For British Columbia and Ontario, it appears that increasing capital stock decreases profitability while for Quebec and the

Rest of Canada increasing capital stock increases profitability. This may indicate some overcapacity in British Columbia and Ontario. However, these results need to be treated with some caution because of the correlation between time and capital stock. With respect to time, the profit elasticities are all positive and inelastic for all regions except for Canada which is positive and elastic. The fact that the sign on capital for the national model is negative and is positive for the sign on time may also illustrate that there is some multi-collinearity. Moreover, capital elasticities are largest for Quebec and the Rest of Canada while elasticities on time for these two regions are the smallest. The situation is reversed for Ontario and BC where the capital elasticities are the smallest and the time elasticities are the largest. However, the result on the time coefficients appear to make sense because as shown in figures 4.3 and 4.4, production of outputs and profits have been increasing for all regions over time. The time effect may be interpreted as the effect of technological change. Hence, the results indicate that technological change has increased profitability in all regions with the largest effects being in BC and Ontario whereas profitability in Quebec and the Rest of Canada has been most affected by increases in capital. In practice, the collinearity between these two variables may be hard to eliminate since new capital investments will usually incorporate new technology.

4.3.5 Own-Price Elasticity Results

Tables 4.6 displays the own-price elasticity results. The table displays the elasticities for Canada as a whole and for each respective region. Because square terms are not regionalized, each variable has the same coefficient value for each region and hence a weakness of these elasticities is that differences are generated by differences in regional price and quantity values only.

For each of the regions, the elasticities have the sign that would be expected under the assumption of profit maximization. As the price an output increases, there is a corresponding increase expected in production of that output. Conversely, as the price of an input increases, there is a corresponding decrease expected in use of that input. The differences across regions can be readily seen through these elasticities. Though they have the same sign, the amount of change across regions given the same percent increase in price is different across regions. An interesting result is with respect to the outputs. As noted in the section 4.2, Quebec and Ontario produce more total paper while British Columbia and the Rest of Canada produces more wood pulp. With the own-price elasticities, if there is an increase in the price of each region's respective less significant output, there is a far larger increase expected in production as opposed to the more significant output. For example, British Columbia is a relatively stronger producer of wood pulp than total paper. If there was an 1% to small increase in the price of total paper then there would be a larger increase in production than if there were a similar change in the price of wood pulp. Such a change would present a shift amongst each region's production possibilities frontier. This makes sense following basic economic theory because if a slight reallocation of outputs can produce greater profit for a firm, then they will shift the resources to produce more of the good that provides a greater marginal revenue product.

Table 4.6 Own-Price Elasticities for The Regional Model Estimation With a Correction for Autocorrelation

Variable	Canada	Quebec	Ontario	BC	Rest of Canada
Total Paper	0.146279	0.084338	0.15785	0.220595	0.22778
Wood Pulp	0.106469	0.176091	0.16854	0.060186	0.1014
Labour Hours	-0.2371	-0.14594	-0.2042	-0.39235	-0.3319
Roundwood	-0.25376	-0.23038	-0.28995	-0.35405	-0.1951
Wood Chips	-1.06833	-1.20995	-2.79245	-0.39196	-1.0914
Energy	-0.24008	-0.1761	-0.25761	-0.24534	-0.3338

The own-price elasticities in both regional models are relatively inelastic. The only exceptions, to this result, are the wood chip elasticities which are elastic for each region except British Columbia. This means that a percentage change in price results in a large percentage change in quantity. The inelastic elasticity computed for British Columbia is due to the fact that it uses a high proportion of wood chips in the production process relative to other regions. Therefore, a change in the price of wood chips would not have the same substitution impact that it has in the other regions.

4.3.7 Cross-Price Elasticities Results

Table 4.7 represents the cross-price elasticities for the model. The results indicate that wood chips and roundwood are substitutes. If there is an increase in the price of roundwood, then there is an associated increase in the demand for wood chips. Conversely, if there is an increase in the price of wood chips, then there is an associated increase in the demand for roundwood. Also, total paper and wood pulp are found to be complements for each other. That is, if there is a 1% or small increase in the price of total paper, then there would be an associated increase in the production of wood pulp. Conversely, if there is a 1% or small increase in the price of wood pulp, then there would be an associated increase in the production of total paper.

One of the most interesting results is with respect to the relationship between total paper and roundwood. As the price of roundwood increases, the quantity of total paper produced increases and as the price of total paper increases, the amount of roundwood used decreases. Whereas, with the other wood inputs and outputs, if the price of an input increases there is an associated decrease in output and if the price of an output increases then there is an increased demand of the input.

The cross-price result for roundwood and total paper is interesting because if there is an increase in the price of total paper, it would be expected that there would be an increase of production with a resulting increase in demand for inputs. This is perhaps a result of the substitutability of wood chips and roundwood, which is shown by the positive cross-price elasticity estimate for wood chips and roundwood. From the cross-price elasticity results for wood chips and total paper we know that total paper demand increases when wood chip prices decrease. Hence, a shift from roundwood use to wood chip use due to a price increase in roundwood may result in an increase in paper production.

Table 4.7 Cross-Price Elasticities for Regional Model Estimation with a Correction for Autocorrelation

Variable	Quebec	Ontario	BC	Rest of Canada
TP-WP	0.078692	0.142423	0.210572	0.217088
WP-TP	0.41211	0.407892	0.137681	0.232316
TP-WC	-3.83E-02	-6.69E-02	-7.76E-02	-9.86E-02
WC-TP	0.40988	1.01373	0.17144	0.86114
TP-RW	0.002166	0.00367	4.61E-03	4.91E-03
RW-TP	-0.01247	-0.017338	-0.023534	-0.012599
WP-WC	-3.00E-02	-2.77E-02	-7.76E-03	-1.61E-02
WC-WP	0.06126	0.14652	0.02622	0.13148
WP-RW	-0.1255	-0.11243	-3.41E-02	-5.93E-02
RW-WP	0.13793	0.18545	0.26631	0.14235
WC-RW	0.2639	0.5908	8.99E-02	4.65E-01
RW-WC	1.42E-01	1.84E-01	2.08E-01	1.37E-01

4.4 Summary

Of the four models estimated, it was found that the normalized quadratic profit function with regional dummy variables and correcting for autocorrelation is the most appropriate choice. The results indicate that Quebec is the most price sensitive with respect to profitability. For the profit elasticities, total paper was elastic for all regions. However, for the rest of the variables, it was found that the regions are price inelastic. The capital and time profit elasticities indicate that there is a multicollinearity issue. For the own-price elasticities, it was found that the elasticities by region are inelastic with the exception of wood chips. The cross-price elasticity results indicate that the wood chips and roundwood are substitutes, while total paper and wood pulp are complements.

CHAPTER FIVE: SCENARIOS

5.1 Overview

The purpose of this chapter is to simulate two policy change scenarios using the estimated profit and demand system. The first is meant to simulate an increase in energy price due to a carbon tax. The second policy scenario is meant to simulate an increase in stumpage prices, and thereby delivered roundwood prices, due to a change in stumpage pricing policies. This scenario is of interest because of the recent softwood lumber dispute. The assumption in the scenario analysis is that changes in stumpage prices for softwood lumber companies might also affect the pulp and paper industry. Carbon tax simulations range from \$0-200 per tonne of carbon emitted and roundwood price simulations range from \$0-20 per m^3. The simulations show the impact of the input price changes on own input quantities as well as profits and other input demands and output supplies.

5.2 Energy Price Scenario

The energy price scenario is based upon a potential change in energy policy. An example of this would be if the Canadian Government ratifies the Kyoto Protocol. The idea for the model is that if there were ratification of the protocol there could be an associated rise in the price of energy. This would be placed upon the market system with the use of a carbon tax. The tax would then be set at a level that would encourage firms to use less carbon in their production process. This type of tax could be in the form of a dollar amount per unit of carbon produced from fossil fuel energy. For this scenario, there will be a range of potential taxes used from \$0/t of Carbon, which is the baseline, to \$200/t of Carbon. This range in carbon prices is consistent with the range of prices found in Hourcade (1996).

However, simulating a carbon tax in the model is not completely straightforward. For the Canadian pulp and paper industry, energy use in the estimated model is given in terms of dollars per Gigajoule of energy used. To properly incorporate a carbon tax, it is necessary to determine how much carbon is being used in the pulp and paper energy system, because there are a variety of fuel types including coal, natural gas, refined petroleum products, hydro and nuclear electricity, steam, coke, and bio-energy. For this analysis, the variable carbon contents of coal, natural gas and refined petroleum products are used to calculate a carbon emission per Gigajoule emission rate. One difficulty with this approach is that if carbon taxes are applied they will have differential impacts on fuel prices that could lead to substitution among coal, natural gas and refined petroleum and also with other energy sources. These substitutions are not explicitly modeled here.

Table 5.1 provides the CO_2 conversion factors for fuels. The CO_2 factors for fuels are given in terms of kilograms of CO_2 produced per Gigajoule of energy generated (Simons Consulting Group (1999). For this study, these numbers are taken and are converted into kilograms of carbon per Gigajoule of energy and tonnes of carbon per Gigajoule of energy.

Table 5.1 CO_2 Factors for Fuels

Fuel Type	Kg CO_2 / GJ	Kg C / GJ	TC / GJ
Electric	0	0	0
Purchased Steam	0	0	0
Coal	90	24.561	0.024561
Residual Oil (#6)	75	20.4675	0.0204675
Distillate (#2)	70	19.103	0.019103
Natural Gas	50	13.645	0.013645
Light Petroleum gases	65	17.7385	0.0177385
Hog Fuel	0	0	0
Pulping Liquor	0	0	0

The conversion is done by taking the percent of carbon per molecule of CO_2 and using that percentage along with the Kg of CO_2 per Gigajoule generated given in table 5.1. In a molecule of CO_2, carbon is 27.29 % of the mass of the molecule. Therefore, 27.29% of a kilogram of CO_2 will give the amount of carbon produced, which is then easily converted into tonnes.

Data on the percentage of coal and natural gas used in the Canadian pulp and paper industry was obtained from Statistics Canada. The data obtained is the quarterly supply and demand of primary and secondary energy in Terajoules (Statistics Canada, d) and is from the years of 1978 to 2000. Table 5.2 includes the average percentage of coal, natural gas, and refined petroleum products used in the pulp and paper industry energy process. It also includes the respective values used in the year 2000.

Table 5.2 Percentage of Energy Used in The Canadian Pulp and Paper Industry

	Average Percentage (1978-200)			Year 2000 Value		
Region	**Coal**	**Natural Gas**	**Refined Petroleum Products**	**Coal**	**Natural Gas**	**Refined Petroleum Products**
Canada	1.3	27.7	24.6	0.6	29.4	14.9
Quebec	0.6	14.7	30.1	0.0	18.0	22.0
Ontario	3.4	51.9	9.2	1.2	48.9	6.0
British Columbia	0.0	4.7	22.1	0.0	4.6	7.5
Rest of Canada	1.9	52.4	35.8	1.4	54.4	20.6

Equation 5.1 is the formula used to determine the energy equivalent tax (EET). The formula is constructed in a way to represent a range of carbon tax values given the amount of carbon produced within the pulp and paper energy use system. Coal, natural gas, and refined petroleum products are used because they are the only fossil fuel energy sources given that emit CO_2 into the atmosphere. To estimate the amount of CO_2 generated from refined petroleum products it is assumed that the value would be close to that of residual oil. The year 2000 percentage values for energy type are used in the formula because it provides a more accurate representation of the current energy regime in the pulp and paper industry.

The formula for the energy equivalent tax is:

$$EET = t * (\alpha_c * p_c + \alpha_n * p_n + \alpha_r * p_r) \quad \textbf{(5.1)}$$

where: EET= Energy Equivalent Tax ($/GJ);

t= Carbon tax ($/t of Carbon produced);

α= Conversion factor (tonnes of carbon per GJ of energy);

p= percentage of total energy in pulp and paper industry;

c= coal;

n= natural gas;

r= refined petroleum products.

The above formula is used for carbon taxes ($ x/t) ranging from $0/t (the baseline) and $200/t. The conversion factors are the CO_2 factors for fuels provided earlier in table 5.2. This energy equivalent tax is then added to the mean price of energy value for the respective region to create the newly adjusted price of energy. This new adjusted energy price is placed into the estimated profit-demand-supply model to estimate the impacts on input and output quantities and profits given the carbon tax.

Tables 5.3 – 5.7 present the results from the scenarios for each region.

Table 5.3 Predicted Profit-Demand-Supply Quantities for Canada

C Tax $/t	EET $/GJ	PI $ millions	TP million Tonnes	WP million Tonnes	RW million m^3	WC million m^3	LB millions of hours	E GJ
0	0.000	8.803	3.224	1.852	10.312	8.551	32.171	80.601
10	0.072	8.749	3.223	1.851	10.302	8.564	32.200	80.231
20	0.144	8.695	3.223	1.851	10.291	8.577	32.229	79.860
30	0.216	8.642	3.222	1.850	10.281	8.590	32.258	79.489
40	0.288	8.588	3.222	1.850	10.271	8.602	32.287	79.119
50	0.360	8.535	3.221	1.849	10.261	8.615	32.316	78.748
75	0.541	8.404	3.220	1.848	10.235	8.647	32.388	77.821
100	0.721	8.275	3.218	1.847	10.209	8.679	32.461	76.894
125	0.901	8.146	3.217	1.846	10.184	8.711	32.533	75.968
150	1.081	8.020	3.216	1.845	10.158	8.743	32.606	75.041
175	1.261	7.895	3.214	1.844	10.132	8.775	32.678	74.114
200	1.441	7.771	3.213	1.843	10.107	8.807	32.751	73.188

Where: C tax = the value of a carbon tax;

EET = the energy equivalent tax;

PI = the Predicted total variable profit;

TP = the Predicted quantity of total paper produced;

WP = the Predicted quantity of wood pulp produced;

RW = the Predicted input use of roundwood;

WC = the Predicted input use of wood chips;

LB = the Predicted input use of labour hours;

E = the Predicted input use of energy.

Table 5.4 **Predicted Profit-Demand-Supply Quantities for Quebec**

C Tax	EET	PI	TP	WP	RW	WC	LB	E
$/t	$/GJ	$ millions	million Tonnes	million Tonnes	million m^3	million m^3	millions of hours	GJ
0	0.000	11.565	5.325	0.723	12.310	6.872	48.522	109.865
10	0.070	11.494	5.325	0.723	12.300	6.884	48.550	109.507
20	0.139	11.423	5.324	0.722	12.290	6.897	48.578	109.149
30	0.209	11.352	5.324	0.722	12.280	6.909	48.606	108.791
40	0.278	11.282	5.323	0.722	12.270	6.921	48.634	108.434
50	0.348	11.212	5.323	0.721	12.260	6.934	48.662	108.076
75	0.522	11.038	5.321	0.720	12.235	6.965	48.732	107.182
100	0.696	10.865	5.320	0.719	12.210	6.995	48.802	106.288
125	0.869	10.694	5.319	0.718	12.186	7.026	48.872	105.393
150	1.043	10.524	5.317	0.717	12.161	7.057	48.942	104.499
175	1.217	10.356	5.316	0.716	12.136	7.088	49.012	103.605
200	1.391	10.189	5.315	0.715	12.111	7.118	49.082	102.710

Table 5.5 **Predicted Profit-Demand-Supply Quantities for Ontario**

C Tax	EET	PI	TP	WP	RW	WC	LB	E
$/t	$/GJ	$ millions	million Tonnes	million Tonnes	million m^3	million m^3	millions of hours	GJ
0	0.000	8.147	3.308	1.239	10.009	3.746	34.176	76.002
10	0.082	8.089	3.307	1.239	9.997	3.760	34.209	75.582
20	0.164	8.032	3.307	1.238	9.985	3.775	34.242	75.161
30	0.245	7.975	3.306	1.238	9.974	3.789	34.275	74.740
40	0.327	7.918	3.305	1.237	9.962	3.804	34.308	74.319
50	0.409	7.862	3.305	1.237	9.951	3.818	34.340	73.899
75	0.613	7.722	3.303	1.236	9.921	3.855	34.423	72.847
100	0.818	7.584	3.302	1.235	9.892	3.891	34.505	71.795
125	1.022	7.449	3.300	1.233	9.863	3.927	34.587	70.744
150	1.227	7.315	3.299	1.232	9.834	3.963	34.670	69.692
175	1.431	7.184	3.297	1.231	9.805	3.999	34.752	68.640
200	1.636	7.054	3.296	1.230	9.776	4.036	34.834	67.589

Table 5.6 Predicted Profit-Demand-Supply Quantities for British Columbia

C Tax	EET	PI	TP	WP	RW	WC	LB	E
$/t	$/GJ	$ millions	million Tonnes	million Tonnes	million m^3	million m^3	millions of hours	GJ
0	0.000	13.231	2.062	3.193	6.458	18.018	23.220	73.940
10	0.022	13.216	2.061	3.193	6.455	18.021	23.229	73.829
20	0.043	13.201	2.061	3.193	6.452	18.025	23.238	73.718
30	0.065	13.186	2.061	3.192	6.449	18.029	23.246	73.607
40	0.086	13.171	2.061	3.192	6.446	18.033	23.255	73.496
50	0.108	13.157	2.061	3.192	6.442	18.037	23.264	73.385
75	0.162	13.120	2.060	3.192	6.435	18.046	23.285	73.107
100	0.216	13.083	2.060	3.192	6.427	18.056	23.307	72.829
125	0.270	13.047	2.060	3.191	6.419	18.065	23.329	72.551
150	0.324	13.010	2.059	3.191	6.412	18.075	23.351	72.274
175	0.378	12.974	2.059	3.191	6.404	18.085	23.372	71.996
200	0.432	12.938	2.058	3.190	6.396	18.094	23.394	71.718

Table 5.7 Predicted Profit-Demand-Supply Quantities for Rest of Canada

C Tax	EET	PI	TP	WP	RW	WC	LB	E
$/t	$/GJ	$ millions	million Tonnes	million Tonnes	million m^3	million m^3	millions of hours	GJ
0	0.000	6.873	2.072	2.028	12.556	4.016	21.596	63.419
10	0.120	6.802	2.071	2.027	12.539	4.037	21.644	62.803
20	0.240	6.733	2.071	2.026	12.522	4.058	21.692	62.187
30	0.359	6.664	2.070	2.026	12.505	4.079	21.741	61.571
40	0.479	6.595	2.069	2.025	12.488	4.101	21.789	60.954
50	0.599	6.528	2.068	2.024	12.471	4.122	21.837	60.338
75	0.899	6.362	2.066	2.022	12.428	4.175	21.958	58.798
100	1.198	6.200	2.063	2.021	12.385	4.228	22.078	57.257
125	1.498	6.043	2.061	2.019	12.343	4.281	22.199	55.717
150	1.797	5.890	2.059	2.017	12.300	4.334	22.319	54.176
175	2.097	5.741	2.057	2.015	12.257	4.387	22.440	52.636
200	2.396	5.596	2.055	2.013	12.214	4.440	22.560	51.096

The effect of an energy equivalent tax, upon the pulp and paper profit-demand-supply system, is most significant in the Rest of Canada region. The percent change from baseline to the $200/t of carbon produced would decrease total variable profit by approximately 18% and would increase wood chip use by approximately 11%. This effect is not unexpected since the amount of CO_2 used is greatest in this region since close to 76% of energy use produces CO_2. Conversely, the influence of a carbon tax would have a lesser effect in British Columbia since the system produces CO_2 from fossil fuel sources for only about 12% of it's total energy sources. In British Columbia, the total variable profit decreases by about 2% and the wood chip demand increase would be about 0.4%. In Quebec and Ontario, respectively, the amount of CO_2 producing energy types account for approximately 40% and 56% of energy use in the pulp and paper industry and hence the effects in Quebec and Ontario are greater than in British Columbia.

Across all regions there are decreases in total variable profit, total paper produced, wood pulp produced, roundwood use, and energy consumption. There is an increase in labour hours used and wood chip use across all regions indicating a substitution effect that shifts wood input from roundwood to wood chips. The results show this substitution effect is greater in regions using higher amounts of carbon emitting energy. An interesting factor is the impact upon the outputs in each region. As noted in the chapter 4, Quebec and Ontario are large producers of total paper whereas British Columbia and the Rest of Canada are large producers of wood pulp. When the tax is applied, the percent decrease from baseline output for each region is greatest for the smallest output level among the two outputs (wood pulp for Quebec and Ontario; total paper for British Columbia and Rest of Canada). Another interesting factor is the effect upon total labour hours. As the tax increases, there is an increasing use of labour hours. This implies that labour is substituted for energy at a higher energy price.

The results illustrate the importance of examining regional differences. For Canada as a whole, fossil fuel energy use is approximately 45% of the total energy use in the pulp and paper industry. If this value were to be used, then the far-reaching impact upon the Rest of Canada and British Columbia would not be fully explored. It should also be mentioned that this scenario only takes into account CO_2 emissions from fossil fuel energy generation. The pulp and paper industry also uses bio-energy, from wood waste, to generate steam which creates CO_2 output. This value is not taxed in this model. This could be another reason for the increase in wood chip use in the results presented here. That would be an indication that as energy price increases wood chips are a substitute for purchased energy, which may indicate a shift toward bio-energy embodied in the wood chips.

5.3 Roundwood Scenario

This scenario is motivated by recent changes in Canada-United States trade policy regarding softwood lumber. The United States has been arguing that Canadian companies receive an unfair subsidy in harvesting wood under Canada's stumpage system. This argument has lead to a tariff on Canadian lumber products being shipped into the United States. In this section, it is assumed that the threat of a lumber tariff could lead policy makers to increase Canadian stumpage prices and that this would apply to both wood and pulp and paper industries.

For this analysis, the range of stumpage prices explored is $\$0/m^3$ to $\$20/m^3$. The high end of this range would be roughly equivalent to a 29% increase in the price of lumber due to a tariff. The simulation presented here assumes that provincial lumber sectors have a choice between operating under the tariff or increasing stumpage prices, since low stumpage prices are allegedly the source of the subsidy in the lumber dispute. However, raising the price of stumpage for the lumber sector may have to be accompanied by an increase in stumpage prices for the pulp and paper sector. This is the assumption made in this analysis. As in the energy scenario section, the scenario is run at the mean input and output prices for each region. The only variable that changes is the price of roundwood.

The following tables 5.8-5.12 are the results by region given an associated increase in the price of roundwood.

Table 5.8 Predicted Profit-Demand-Supply Quantities for Canada

Prw increase	PI	TP	WP	RW	WC	LB	E
$\$/m^3$	$ millions	million Tonnes	million Tonnes	million m^3	million m^3	millions of hours	GJ
0	8.803	3.224	1.852	10.312	8.551	32.171	80.601
5	8.330	3.225	1.836	9.997	8.780	31.953	79.889
10	7.872	3.226	1.821	9.683	9.009	31.735	79.176
15	7.429	3.228	1.806	9.368	9.238	31.517	78.463
20	7.001	3.229	1.791	9.053	9.467	31.299	77.751

Where: Prw Increase = the increase in the price of roundwood;

PI = the Predicted total variable profit;

TP = the Predicted quantity of total paper produced;

WP = the Predicted quantity of wood pulp produced;

RW = the Predicted input use of roundwood;

WC = the Predicted input use of wood chips;

LB = the Predicted input use of labour hours;

E = the Predicted input use of energy.

Table 5.9 Predicted Profit-Demand-Supply Quantities for Quebec

Prw increase	PI	TP	WP	RW	WC	LB	E
$\$/m^3$	$ millions	million Tonnes	million Tonnes	million m^3	million m^3	millions of hours	GJ
0	8.778	5.513	0.996	12.977	8.012	48.932	113.276
5	8.182	5.514	0.981	12.663	8.241	48.714	112.563
10	7.600	5.515	0.966	12.348	8.470	48.496	111.850
15	7.033	5.517	0.951	12.033	8.699	48.278	111.138
20	6.480	5.518	0.936	11.719	8.928	48.060	110.425

Table 5.10 Predicted Profit-Demand-Supply Quantities for Ontario

Prw increase	PI	TP	WP	RW	WC	LB	E
$/m³	$ millions	million Tonnes	million Tonnes	million m^3	million m^3	millions of hours	GJ
0	7.948	3.306	1.238	9.968	3.796	34.290	74.540
5	7.491	3.307	1.223	9.654	4.025	34.072	73.828
10	7.050	3.308	1.207	9.339	4.254	33.854	73.115
15	6.623	3.310	1.192	9.024	4.483	33.637	72.402
20	6.210	3.311	1.177	8.710	4.712	33.419	71.690

Table 5.11 Predicted Profit-Demand-Supply Quantities for British Columbia

Prw increase	PI	TP	WP	RW	WC	LB	E
$/m³	$ millions	million Tonnes	million Tonnes	million m^3	million m^3	millions of hours	GJ
0	13.231	2.062	3.193	6.458	18.018	23.220	73.940
5	12.938	2.063	3.178	6.143	18.246	23.002	73.228
10	12.659	2.064	3.163	5.829	18.475	22.784	72.515
15	12.395	2.066	3.147	5.514	18.704	22.566	71.803
20	12.146	2.067	3.132	5.199	18.933	22.349	71.090

Table 5.12 Predicted Profit-Demand-Supply Quantities for Rest of Canada

Prw increase	PI	TP	WP	RW	WC	LB	E
$/m³	$ millions	million Tonnes	million Tonnes	million m^3	million m^3	millions of hours	GJ
0	6.617	2.069	2.025	12.493	4.094	21.774	61.150
5	6.043	2.070	2.010	12.178	4.323	21.556	60.438
10	5.484	2.072	1.995	11.864	4.552	21.338	59.725
15	4.940	2.073	1.980	11.549	4.781	21.120	59.013
20	4.410	2.074	1.965	11.234	5.010	20.902	58.300

As the roundwood price increases, there is a percentage decrease in total variable profit, wood pulp production, roundwood use, labour hours, and energy use for all regions.

There is an increase in wood chip use and total paper production for all regions. The impact upon total variable profit is greatest in the Rest of Canada with approximately 33% decline at the $\$20/m^3$ level and has the least impact in British Columbia with about an 8% decline at the same level. There is a substitution effect that shifts wood input use from roundwood to wood chips. The largest percent decline for roundwood use is in British Columbia at close to 19% and the smallest decline is in Quebec and Rest of Canada at close to 10%. The wood chip use percentage increase is greatest in Ontario at approximately 24% and is lowest in British Columbia at approximately 5%. The total paper production percentage increase is minimal across all regions ranging from about 0.1-0.25%. Labour hours and energy use have similar percentage decreases in variable use and are relatively minimal ranging from about 2-5%.

A limiting factor in this analysis is that the price of roundwood is increasing while the price of wood chips is being held constant. It should be noted that a potential change in stumpage prices could also have an impact upon the price of wood chips and likely limit the observed substitution effect between roundwood and wood chips. This is because a stumpage price increase in the wood industry would likely lead to a decrease in the supply of wood chips, thus raising the price of wood chips. It is also interesting how total paper production is relatively unchanged while there is more of a decline in wood pulp production. The decline in the production of wood pulp is greatest in Quebec and Ontario where there is less wood pulp production. This could mean that the use of roundwood has a much higher priority in total paper production than in wood pulp production. With an overall decrease in production activity, it is expected that there would be an associated decrease in labour hours and energy use.

5.4 Summary

The main result of this chapter is the effect of energy and roundwood prices on profitability. Under both scenarios, it is observed that there could be substantial decreases in profitability across all regions, depending on the size of the price increases. Under the energy and stumpage price scenarios, the region that would experience the greatest percentage loss in profitability is the Rest of Canada and the region that would have the least change in profitability is British Columbia.

Under the energy scenarios there was a decrease in both outputs while in the roundwood price scenario there was a slight increase in total paper production but a decrease in wood pulp production. As in chapter 4, the scenarios demonstrate a substitution effect between the input use of roundwood and wood chips with a trend towards using more wood chips. The use of energy declines under both policy scenarios for all regions, while labour use increases with an increase in energy price and decreases with a increase in roundwood price.

The benefits of doing the regional analysis are revealed by the results presented above. If the analysis had been limited to a national level, then it would not have been apparent where the greatest impacts of potential policy changes occur.

CHAPTER 6: CONCLUSIONS and SUMMARY

6.1 Overall Results and Conclusions

One of the main objectives of this thesis was to estimate a dual multiple-output and multiple-input normalized quadratic profit function for the Canadian pulp and paper industry using regional data for Quebec, Ontario, British Columbia, and the Rest of Canada. Quadratic profit function estimation techniques were used for four different model types. It was found that the best model, given this data set, is a normalized quadratic profit function with regional dummy variables and a correction for autocorrelation. The estimated function satisfies the properties for profit maximization. Given the results from this function, it was then possible to estimate profit, own-price, and cross-price elasticities with respect to the multiple outputs and inputs. For the profit elasticities, total paper was elastic for all regions. However, for the remainder of the variables it was found that regional profits are price inelastic with respect to profitability. The difference occurs with respect to the capital variable. Canada and British Columbia had positive influence on profitability, while Quebec, Ontario, and the Rest of Canada had a negative influence. This may mean that the industry is at capacity in Canada and British Columbia for the pulp and paper industry. It was also found that over time, technology is a positive factor on profits in all regions. There is, however, an issue of multicollinearity between the capital and technology variables. This occurs because with new capital investments, usually incorporate new technology. Hence, if capital stocks increase over time, the time trends that are used as proxy for technological change will be naturally correlated with capital stocks. From the own-price elasticity results, it was found that the regional elasticities are inelastic with the exception of wood chips. Wood chips demand is elastic in all regions except for British Columbia. Cross-price elasticities are all relatively inelastic and many of them are positive which indicates that the wood variables are substitutable with each other. The key cross-price elasticity result is that there is a substitution effect regarding the prices and quantities of roundwood and wood chips. Total paper and wood pulp outputs were found to be complementary.

One of the key differences between this study and previous research was the separation of wood inputs from a total materials input. This was a useful approach as there is an apparent substitution effect occurring from the use of roundwood towards the use of wood chips over time.

Two policy scenarios were simulated using the results from the regional profit function. One was a simulation with an increase in the price of energy due to a change in energy policy. The second was a simulation with an increase in the price of roundwood due to a change in Canadian stumpage policy. It was found for both scenarios that there would be a decline in profitability for all regions given the inputs increase in price change. The region most affected is the Rest of Canada and the region least affected is British Columbia for both scenarios. From the results, it was found that there would be an expected substitution effect from roundwood use to wood chip use for all regions.

6.2 Limitations and Future Research

A limitation of this study is the lack of data provided that is needed to estimate the model from a complete regional perspective. If there were a greater amount of regional data available, it would have been beneficial to run the model with regional price square terms as well as the regional terms for capital and time. In the models presented here regional differences in own-price and cross-price elasticities were entirely driven by differences in quantity and price among the regions.

Significant regional differences were found by separating outputs into total paper and wood pulp. Further, benefits might be obtained by separating the paper output into newsprint and other papers. This might be difficult to do, however, because of the lack of data. Another possible extension would be to treat capital as a variable input rather than as a fixed stock. Yet another possible way of dealing with the capital input would be to estimate a capital investment equation. This would make it possible to study in a more dynamic framework, the long-term impacts upon capital investment on profitability, input demand and output supply.

An idea for future research would be to estimate supply and demand systems for each region separately without the use of a profit function. This would allow for a great comparison of results between regions because this type of estimation would require fewer variables, than this study, and have more degrees of freedom. This could allow for having regional differences in all prices rather than just capital and time variables. This notion assumes that there is sufficient data that can be obtained for estimation.

If the data were available, then it would be useful to estimate profit systems given every type of output in the industry rather than grouping the outputs as total paper and wood pulp. This would allow for interpretations of the various industries within the pulp and paper industry such as paperboard and fine papers. Then it could be seen how these industries are changing over time and then attempt to gain an understanding of how the demand for these products has been changing over time as well. This could not be attempted with this data set because the lack of data would not allow sufficient degrees of freedom.

Finally, it would be useful to develop a multiple-output-multiple input profit function for the entire forest sector in Canada. This system would use data from both the wood industries and the pulp and paper industry to examine dynamic effects between the two industries within the forest sector. An ideal study would examine these effects at both the national and regional levels. This type of model would be especially useful for policy scenarios that affect both industries, such as the previously mentioned change in stumpage pricing.

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APPENDIX ONE

Table A.1 Quebec Price Data

Year	Plb	Pwc	Prw	Pe	Pwp	Ptp	Capital	Pom
1995	26.7138	36.7677	50.5948	5.5055	745.5005	795.9141	7168.0022	123.5372
1994	28.5398	37.1370	39.1783	5.7387	552.5506	588.9938	7252.0293	100.6494
1993	29.8431	40.3471	42.3926	5.9507	482.3541	589.7007	7370.1227	96.5093
1992	29.6774	40.9272	46.2352	5.9533	557.1703	590.4230	7730.8417	104.6469
1990	27.5778	40.1714	47.2846	5.5385	747.7505	673.8980	7633.5073	120.0950
1989	26.0212	40.1274	45.9609	5.3306	833.7624	704.6298	6993.2092	126.4744
1988	24.9417	39.7565	45.0224	4.8063	783.1016	760.6542	6153.1308	120.9008
1987	25.3576	37.8624	44.8044	4.8053	748.2401	710.4664	5943.1069	116.1497
1986	25.0104	40.7864	44.7018	5.0340	607.2626	721.2362	5387.1826	106.8884
1985	23.1308	41.3607	46.2998	5.9696	580.6121	696.9731	4678.2815	102.5825
1984	22.7881	37.9948	44.6981	6.0727	358.2552	648.7581	4269.5824	109.4748
1983	22.4134	38.7092	46.3474	6.4360	545.3247	613.7256	4164.3080	103.8880
1982	21.4801	41.2944	46.2952	5.5328	654.7411	678.8996	4160.6294	111.8301
1981	20.1610	42.1191	44.9390	4.9801	724.0357	657.4863	3915.1010	117.1373
1980	19.5979	38.2489	45.0250	4.1706	780.5542	675.1895	3767.9184	119.2004
1979	20.0143	36.5431	46.6425	4.2636	677.2985	672.3406	3812.5509	112.3038
1978	21.0822	43.2156	51.4083	3.9638	598.5438	678.4084	3958.1167	106.1502
1977	21.7780	47.3257	53.1812	3.6706	648.5596	681.6167	3971.2392	113.6940
1976	21.5486	41.4186	52.6504	3.2961	685.2165	644.9314	3996.2617	121.1278
1975	19.7118	45.5325	50.0933	3.1119	814.2040	660.1061	3862.3237	126.2139
1974	18.4810	43.2227	47.0084	2.8467	800.1058	582.8093	3800.5148	114.7730
1973	19.6169	40.4409	46.6715	2.4308	569.9385	515.8189	3611.3323	97.5759
1972	19.9141	43.3836	47.1430	2.4723	489.7882	515.3424	3457.7464	96.1521
1971	19.2549	45.5254	47.8522	2.5601	483.5693	527.8479	3361.4222	96.7398
1970	18.0241	44.6713	48.1903	2.2875	491.5290	531.4039	3347.0210	97.7770
1969	15.8631	38.2206	48.8899	2.3429	471.9344	530.4109	3279.1086	96.0070
1968	15.3914	38.7622	50.2803	2.3732	482.8058	537.4672	3121.0837	97.4693
1967	14.2684	37.3979	50.4342	2.4456	473.6311	537.1950	3060.2986	98.6536
1966	13.7833	36.1770	47.7276	2.4931	473.5293	550.0601	2826.8537	99.2601
1965	13.0094	36.4196	46.7698	2.5292	494.2522	551.4436	2558.5994	101.6012
1964	12.6059	36.7625	46.7592	2.5212	487.9044	557.5093	2287.0719	101.1313
1963	12.5254	35.8583	47.0501	2.5581	477.1394	565.6623	2055.6375	99.1484
1962	12.3392	35.9349	47.4935	2.6261	485.8646	570.3311	1962.0873	99.3008
1961	12.0967	40.0334	48.4880	2.6083	494.9982	566.4992	1936.2069	99.6121

Where: Plb = Price of Labour ($/hr worked);

Pwc = Price of Wood Chips ($\$/m^3$);

Prw = Price of Roundwood ($\$/m^3$);

Pe = Price of Energy ($/GJ);

Pwp = Price of Wood Pulp ($/tonne);

Ptp = Price of Total Paper ($/tonne);

Capital = Capital End of Year Stock ($ millions);

Pom = A Price Index for the Price of Other Materials (1992=100);

Note all prices are in Real 1992 Canadian Dollars.

Table A.2 Ontario Price Data

Year	Plb	Pwc	Prw	Pe	Pwp	Ptp	Capital	Pom
1995	26.0278	36.4378	40.1291	4.4917	882.8389	818.2549	5187.8738	123.5372
1994	26.8206	35.0277	38.4093	4.9529	546.2565	639.6105	4892.6218	100.6494
1993	27.6108	37.0992	40.4886	4.6727	473.5422	624.1825	5045.3111	96.5093
1992	29.0387	37.9604	42.6024	4.8671	578.7130	645.2094	5094.9229	104.6469
1990	26.0080	45.4417	43.8500	4.3366	777.6136	717.5513	5171.8618	120.0950
1989	24.1058	43.6992	44.2646	4.4522	858.1271	753.8211	4821.9539	126.4744
1988	24.5747	42.4257	43.7128	4.5155	798.6084	800.4785	4235.7145	120.9008
1987	25.1190	40.4044	43.5012	4.6572	735.0130	772.6706	4169.2717	116.1497
1986	24.4417	42.5513	41.7904	4.9446	561.6399	762.4611	4188.7096	106.8884
1985	23.5399	46.0522	42.4958	4.9760	533.9421	713.9727	4110.5267	102.5825
1984	22.5856	43.7241	43.8410	5.5620	615.4576	672.3147	3782.6863	109.4748
1983	22.3359	43.8701	43.6307	5.4940	550.4873	635.1233	3789.0866	103.8880
1982	21.5510	44.7303	45.2602	5.5094	608.8571	735.3618	3902.1414	111.8301
1981	19.8991	44.3750	45.4379	4.9825	697.1372	716.4566	3533.7160	117.1373
1980	19.6105	40.4991	44.8380	4.7574	797.0462	704.2800	3107.7528	119.2004
1979	20.1194	42.0994	47.9335	4.7443	720.5466	734.4045	3159.0872	112.3038
1978	21.2798	44.6437	50.7954	4.6805	631.1512	722.5849	3280.5373	106.1502
1977	21.8383	44.0842	52.4832	4.4645	716.7109	739.6951	3414.5844	113.6940
1976	18.3983	46.9344	52.7326	3.9185	806.4627	727.4408	3337.2183	121.1278
1975	20.3199	46.6707	51.6355	3.2103	873.8712	727.2018	2975.7296	126.2139
1974	18.0430	37.0759	44.8315	2.8467	808.4357	654.1114	2830.8880	114.7730
1973	19.0326	37.9325	45.6806	2.4308	605.2383	593.4897	2791.1179	97.5759
1972	19.4383	42.1316	48.2630	2.4723	526.2038	589.1959	2846.8552	96.1521
1971	18.8235	46.1626	50.4286	2.5601	521.3172	597.2069	2818.4889	96.7398
1970	17.7111	43.8802	49.4223	2.2875	523.0158	599.5918	2639.5619	97.7770
1969	15.8587	39.0186	49.8201	2.3429	486.9493	606.5653	2499.1643	96.0070
1968	15.7121	40.2226	51.2098	2.3732	508.0908	629.3943	2448.5893	97.4693
1967	14.5875	37.6785	50.7808	2.4456	523.7323	625.1878	2508.8085	98.6536
1966	14.2234	30.5113	49.4068	2.4931	536.7256	623.0254	2446.4930	99.2601
1965	13.5324	36.3319	48.0812	2.5292	549.5560	620.8537	2286.3028	101.6012
1964	13.0830	36.5066	47.9965	2.5212	542.1785	630.8448	1990.9404	101.1313
1963	13.0300	35.0466	49.6669	2.5581	526.3936	641.6040	1828.0295	99.1484
1962	12.9284	36.9814	50.0290	2.6261	536.8439	637.3772	1778.4878	99.3008
1961	12.6149	44.6035	51.1727	2.6083	531.8923	628.2846	1773.7069	99.6121

Where: Plb = Price of Labour ($/hr worked);

Pwc = Price of Wood Chips ($/m^3);

Prw = Price of Roundwood ($/m^3);

Pe = Price of Energy ($/GJ);

Pwp = Price of Wood Pulp ($/tonne);

Ptp = Price of Total Paper ($/tonne);

Capital = Capital End of Year Stock ($ millions);

Pom = A Price Index for the Price of Other Materials (1992=100);

Note all prices are in Real 1992 Canadian Dollars.

Table A.3 British Columbia Price Data

Year	Plb	Pwc	Prw	Pe	Pwp	Ptp	Capital	Pom
1995	33.3841	58.2862	78.1508	3.9153	793.6554	738.9732	6780.9890	123.5372
1994	32.1839	32.6963	48.0081	4.2839	502.0035	566.0805	7115.8956	100.6494
1993	34.0395	20.0503	36.2339	4.1406	420.6898	555.8316	7352.8475	96.5093
1992	33.6757	20.6298	34.0759	4.0986	500.8907	563.1135	7347.4098	104.6469
1990	31.6537	36.8746	36.2165	4.0953	701.6284	634.9489	6594.3823	120.0950
1989	30.2049	31.2369	37.7948	4.1851	781.7222	669.3009	5517.4855	126.4744
1988	29.4524	31.3758	34.4540	4.3023	713.6229	727.4812	4468.8162	120.9008
1987	30.4150	29.8810	34.2872	4.3224	653.2140	698.4308	4169.9086	116.1497
1986	29.2963	20.3302	32.5249	4.7143	511.7100	680.9918	4104.4837	106.8884
1985	29.7408	25.6670	31.8332	5.4586	451.1408	648.5553	4191.3044	102.5825
1984	27.6869	29.1288	29.7899	5.4122	561.5179	628.4703	4196.1014	109.4748
1983	29.3660	28.3853	30.2397	5.1970	479.0654	595.2860	4366.3958	103.8880
1982	29.2576	37.2430	38.1644	5.2128	571.1947	619.1695	4715.0213	111.8301
1981	28.5495	37.7170	41.4092	4.2994	661.2521	633.5568	4531.6062	117.1373
1980	28.2984	36.1779	44.9110	3.7276	715.4005	620.1127	4071.1173	119.2004
1979	27.9827	25.0966	38.4360	3.6966	645.2110	607.8354	3944.0913	112.3038
1978	29.4329	25.2756	32.7646	3.7234	541.8331	602.7370	4136.6137	106.1502
1977	29.3113	30.2021	37.7855	3.7521	650.7298	617.0905	4269.0464	113.6940
1976	30.3280	34.9772	39.6792	3.1467	740.8147	645.8818	4401.7592	121.1278
1975	29.2258	40.4117	42.6332	2.8405	809.5886	676.4087	4426.0367	126.2139
1974	26.4517	30.8192	35.2063	2.8467	692.9476	540.5484	4662.8057	114.7730
1973	26.0443	24.1418	35.5831	2.4308	522.4861	455.4964	4854.2113	97.5759
1972	26.6415	26.7806	34.6180	2.4723	493.3375	454.8710	5103.5792	96.1521
1971	25.6103	26.4855	32.9320	2.5601	475.5146	456.7426	4887.1111	96.7398
1970	25.1211	28.0170	32.1784	2.2875	487.1637	468.0888	4437.2039	97.7770
1969	19.7827	25.1516	36.2503	2.3429	451.3759	472.1008	4217.6416	96.0070
1968	19.5111	25.0005	35.4205	2.3732	435.2864	478.3035	4080.4680	97.4693
1967	18.4940	23.8425	34.3142	2.4456	459.7321	486.7025	4122.4277	98.6536
1966	17.1141	29.0803	32.6247	2.4931	490.1722	488.7517	3874.5491	99.2601
1965	16.1286	30.0825	30.7207	2.5292	532.3757	501.9871	3164.1607	101.6012
1964	15.3845	26.1867	30.6572	2.5212	539.7823	539.1309	2636.3230	101.1313
1963	14.4232	22.9032	27.4567	2.5581	501.4616	546.0938	2303.8988	99.1484
1962	14.1641	23.5576	27.1747	2.6261	491.1396	576.1734	2143.1310	99.3008
1961	13.9806	26.6651	30.5648	2.6083	476.0795	581.9158	2053.8793	99.6121

Where: Plb = Price of Labour ($/hr worked);

Pwc = Price of Wood Chips ($/m^3);

Prw = Price of Roundwood ($/m^3);

Pe = Price of Energy ($/GJ);

Pwp = Price of Wood Pulp ($/tonne);

Ptp = Price of Total Paper ($/tonne);

Capital = Capital End of Year Stock ($ millions);

Pom = A Price Index for the Price of Other Materials (1992=100);

Note all prices are in Real 1992 Canadian Dollars.

Table A.4 Rest of Canada Price Data

Year	Plb	Pwc	Prw	Pe	Pwp	Ptp	Capital	Pom
1995	25.6289	30.4107	28.8387	4.6794	683.8950	822.3163	5469.1762	123.5372
1994	27.2671	26.3173	30.4253	4.6262	490.0242	614.9031	5645.7249	100.6494
1993	28.7015	27.8822	33.1226	5.1454	416.1096	602.9876	5978.9417	96.5093
1992	28.4307	29.3222	34.1388	5.2064	491.8513	592.8424	6045.3018	104.6469
1990	25.9600	37.5268	34.7891	4.5476	659.1630	695.2499	5623.0674	120.0950
1989	24.4091	36.1321	33.6771	4.9195	700.1889	715.1576	5192.4055	126.4744
1988	24.2810	33.7406	34.7932	4.9025	716.1970	774.4836	4105.9875	120.9008
1987	24.6444	32.1331	34.6247	5.2333	720.4177	707.7381	3478.7805	116.1497
1986	24.1370	37.3662	31.5864	5.4921	618.0964	700.0609	3309.5748	106.8884
1985	23.4271	37.5895	24.9286	6.3743	509.6590	568.6711	3133.2710	102.5825
1984	22.0039	37.5524	36.0858	6.3494	549.2283	654.8739	2857.2785	109.4748
1983	23.1563	39.2862	37.0556	5.6473	499.1186	631.0625	2978.9628	103.8880
1982	21.5758	37.9098	37.5405	5.8028	570.3676	677.3018	3036.9281	111.8301
1981	20.3806	36.5280	35.6441	5.6088	621.8917	695.8682	2805.7833	117.1373
1980	19.8992	34.4535	34.7969	4.8118	677.3990	662.2068	2722.4645	119.2004
1979	20.2559	34.4350	36.5032	4.7610	646.7719	623.9088	2840.5868	112.3038
1978	21.5260	37.2570	38.9626	4.9794	579.0275	636.9980	2931.1983	106.1502
1977	21.8566	43.2685	41.2577	4.0900	629.6009	647.9130	3002.9577	113.6940
1976	21.4958	41.2193	43.2174	3.3480	703.8802	600.2427	3105.8824	121.1278
1975	19.5347	37.6868	40.8084	2.9982	779.8858	615.2810	3103.0793	126.2139
1974	17.9669	35.6978	39.3873	2.8467	771.8172	531.0628	3230.1158	114.7730
1973	18.8359	39.0220	40.6352	2.4308	572.4031	436.0683	3374.2726	97.5759
1972	19.4870	40.6980	38.0408	2.4723	483.7511	423.3740	3445.4945	96.1521
1971	19.0665	42.4255	38.8738	2.5601	481.4326	438.4450	3204.9778	96.7398
1970	17.3372	35.8050	39.5326	2.2875	496.3946	440.9341	2652.9717	97.7770
1969	15.9657	34.7624	38.9118	2.3429	465.9317	468.4081	2147.4466	96.0070
1968	15.4217	36.5327	40.5781	2.3732	470.3424	471.0733	1924.1670	97.4693
1967	14.6564	35.8825	42.1499	2.4456	492.0549	484.3353	1948.6769	98.6536
1966	13.8002	34.9515	41.0347	2.4931	501.6193	485.8644	1716.6333	99.2601
1965	13.0941	34.1358	40.5818	2.5292	517.4503	493.5757	1480.9475	101.6012
1964	12.7528	34.5541	40.9884	2.5212	498.3003	514.9465	1375.2546	101.1313
1963	12.5824	34.1977	41.0274	2.5581	503.4126	522.0873	1247.2076	99.1484
1962	12.5275	35.1752	42.2502	2.6261	512.3031	534.4287	1255.8040	99.3008
1961	12.7111	44.0298	42.5487	2.6083	539.9274	544.8604	1284.9138	99.6121

Where: Plb = Price of Labour ($/hr worked);

Pwc = Price of Wood Chips ($\$/m^3$);

Prw = Price of Roundwood ($\$/m^3$);

Pe = Price of Energy ($/GJ);

Pwp = Price of Wood Pulp ($/tonne);

Ptp = Price of Total Paper ($/tonne);

Capital = Capital End of Year Stock ($ millions);

Pom = A Price Index for the Price of Other Materials (1992=100);

Note all prices are in Real 1992 Canadian Dollars.

Table A.5 Quebec Quantity Data

Year	Ve	Qwc	Qrw	Qwp	Qtp	Qlbhr	TVP
1995	745.9893	19370.0787	4316.0000	1952	8378	39.7650	3160.2263
1994	745.6412	17818.8976	5665.0000	1623	8102	37.4550	1457.8859
1993	754.3164	16808.3990	6215.0000	1506	7324	36.9827	830.9447
1992	770.5640	16892.3885	7841.0000	1516	7187	38.9655	630.8524
1990	746.3087	15461.9423	10436.0000	1439	6748	45.8532	1208.352
1989	684.3633	16207.3491	11499.0000	1542	6574	49.9102	1458.5722
1988	657.8941	15811.0236	11686.0000	1404	6782	51.1310	1916.0936
1987	614.7017	15265.1337	10580.5602	1339	6730	49.3492	1735.7282
1986	623.5115	12711.2861	11173.2283	1332	6377	49.3149	1563.7427
1985	691.2323	11800.5249	10551.1811	1084	5927	49.0194	1284.7391
1984	729.0441	11856.7610	11874.2990	1112	6321	48.6160	1270.6552
1983	652.1171	11473.2380	11734.5210	1198	5929	48.8256	846.8777
1982	581.5368	9635.2310	12429.4260	1077	5529	49.2112	1059.2627
1981	574.2305	9993.5700	13477.7400	1211	6203	53.5281	1511.9706
1980	510.9383	9693.5660	13024.2100	1204	5683	50.3448	1530.946
1979	516.2184	9763.9440	14485.3310	1282	5909	52.5949	1508.8835
1978	508.7914	7867.6050	14219.0780	1123	5829	52.7487	1275.0591
1977	432.6364	6262.5460	13454.9940	1008	5156	50.5869	1006.8332
1976	396.9214	6779.8930	13741.1060	905	5151	52.4224	757.5591
1975	325.6546	4406.0000	13491.0000	702	4676	47.4284	937.4415
1974	360.1030	4823.7222	16728.0198	1070	6100	53.8031	1381.982
1973	265.2374	4324.4617	14325.8020	848	5573	47.1826	851.7611
1972	291.6623	3938.0202	15679.8387	904	5707	50.3468	711.969
1971	300.8000	3373.9370	16056.8573	1036	5326	50.5223	672.7111
1970	281.9689	2709.8164	17748.9969	1151	5476	53.9295	735.7285
1969	290.0650	3294.1729	17662.3270	1112	5418	54.2009	781.8013
1968	271.0800	2755.5817	16197.1444	964	5035	51.8351	749.6154
1967	265.1395	2016.6208	16472.3696	899	4885	53.5721	766.3512
1966	264.5291	1816.9398	17114.4856	1003	5003	54.3191	921.0421
1965	249.2276	1753.2227	15299.4293	986	4463	51.8361	886.0968
1964	235.4831	1388.0523	14991.9632	979	4220	51.4624	882.5387
1963	215.3846	1187.2035	13822.8957	909	3798	48.6261	794.942
1962	208.3067	711.2608	13785.8675	811	3765	48.4011	807.2417
1961	205.1724	495.2756	13796.5229	748	3726	48.6025	757.7586

Where: Ve = The Cost of Energy ($ millions);

Qwc = The Quantity of Wood Chips Used (10^3 m^3);

Qrw = The Quantity of Roundwood Used (10^3 m^3);

Qwp = The Quantity of Wood Pulp Shipments (10^3 tonnes);

Qtp = The Quantity of Total Paper Shipments (10^3 tonnes);

Qlbhr = The Quantity of Labour Hours Worked (millions);

TVP = Total Variable Profit ($ millions).

Table A.6 Ontario Quantity Data

Year	Ve	Qwc	Qrw	Qwp	Qtp	Qlbhr	TVP
1995	373.2911	10228.3465	8116.0000	1680	4414	26.9820	2026.7157
1994	395.0242	9677.1654	7117.0000	1711	4452	27.1870	1000.8008
1993	392.7927	7916.0105	7506.0000	1522	4211	28.0047	662.0535
1992	402.9334	7005.2493	9404.0000	1603	3931	27.9823	702.1583
1990	367.6858	5866.1417	10063.0000	1602	4096	30.5533	1236.2913
1989	363.9700	5713.9108	10989.0000	1620	4270	33.0065	1518.6024
1988	354.8924	5643.0446	10721.0000	1629	4180	32.4269	1604.9522
1987	371.6233	5895.2886	10741.3780	1604	4161	31.5920	1447.1124
1986	384.2533	5322.8346	11742.7822	1616	3912	32.5896	1039.5131
1985	402.0175	4698.1627	11078.7402	1538	3800	32.8005	835.2895
1984	420.7632	4278.9640	12413.2890	1578	3750	33.6657	907.6593
1983	413.3936	4003.0820	11471.1150	1430	3456	34.0901	593.3817
1982	387.7320	3477.1270	10163.3700	1167	3062	34.6494	542.6536
1981	383.7337	4319.3480	11434.5080	1417	3488	37.4074	903.2942
1980	366.4552	4153.2870	11709.4360	1360	3497	37.4101	991.1111
1979	377.9951	4107.9500	11191.1470	1265	3432	37.4132	830.3178
1978	393.0297	3881.1570	10663.4310	1241	3221	36.7901	600.4672
1977	370.0153	3368.4560	10450.8870	1170	2992	35.7736	607.4452
1976	288.7301	2337.9570	9132.5610	923	2480	37.7572	462.4519
1975	191.3712	1763.0000	7672.0000	840	2053	26.5704	635.1305
1974	217.2458	2561.7940	11448.5667	1165	3608	37.8475	1136.4221
1973	207.0444	2406.1436	10707.5354	1088	3433	36.5618	705.6662
1972	210.6639	2067.9109	10866.4522	1159	3160	36.2244	512.1957
1971	206.9333	1794.6227	10449.0878	1154	3041	35.9456	497.7778
1970	192.8116	1627.1178	11205.2630	1230	3071	38.5120	540.0175
1969	181.2442	1779.9761	11212.1035	1215	3109	39.5320	626.5552
1968	170.8228	1716.0321	10293.3687	1105	2891	37.9173	555.6562
1967	170.0821	1417.8047	10411.5730	1044	2906	38.8559	587.2348
1966	165.9319	1405.5704	10172.7863	1035	2935	39.6762	658.517
1965	162.7188	1020.4583	9561.5753	934	2810	37.7779	666.9413
1964	161.0319	859.2917	9786.3753	935	2729	37.5008	676.3342
1963	149.6312	721.6044	9343.5989	884	2527	36.1006	625.922
1962	149.0948	598.9833	9391.7760	830	2516	35.4208	609.5847
1961	144.3966	492.8478	9004.3252	812	2454	35.5012	560.3448

Where: Ve = The Cost of Energy ($ millions);

Qwc = The Quantity of Wood Chips Used (10^3 m^3);

Qrw = The Quantity of Roundwood Used (10^3 m^3);

Qwp = The Quantity of Wood Pulp Shipments (10^3 tonnes);

Qtp = The Quantity of Total Paper Shipments (10^3 tonnes);

Qlbhr = The Quantity of Labour Hours Worked (millions);

TVP = Total Variable Profit ($ millions).

Table A.7 British Columbia Quantity Data

Year	Ve	Qwc	Qrw	Qwp	Qtp	Qlbhr	TVP
1995	409.5445	27123.3596	5028.0000	4798	2787	24.3450	1617.0865
1994	459.1781	30238.8451	4280.0000	5296	2927	25.0880	875.9509
1993	437.7660	37784.7769	3934.0000	4392	2742	24.0001	290.4929
1992	413.1343	35233.5958	4596.0000	4122	2494	23.7847	451.0374
1990	437.4845	24275.5906	5057.0000	3885	2840	26.0556	1207.5565
1989	396.8768	31632.5459	5662.0000	4519	2774	26.5232	2027.4623
1988	369.3405	28721.7848	6488.0000	4737	2789	25.9372	2252.3664
1987	387.2270	28329.9890	6293.8554	4619	2644	23.6376	1871.1727
1986	415.8925	30191.6010	6165.3543	4255	2544	24.4819	1209.6013
1985	469.0387	24503.9370	5559.0551	3955	2498	23.7378	707.0797
1984	419.8588	19459.1040	4895.3360	3373	2065	23.0204	830.5608
1983	418.4753	20742.1790	4873.4030	3669	2127	23.3052	599.0543
1982	389.0770	17676.4640	4802.6270	2946	1866	24.6742	405.9508
1981	323.1922	18075.2570	6125.4050	3120	1864	25.3281	765.3797
1980	293.5667	20210.8360	6594.2460	3530	2157	27.6927	1205.1761
1979	306.9275	20263.9660	5958.3240	3483	2145	26.7892	1270.7416
1978	286.2301	19331.9760	6046.2200	3611	2150	26.8210	915.451
1977	276.1856	18018.9910	5662.8220	2960	1917	26.2563	895.0535
1976	261.2424	19049.5670	6955.1780	3153	1905	26.0012	1108.0814
1975	194.8381	13017.0000	6435.0000	2480	1437	21.1467	1003.5431
1974	242.2136	16720.5685	9153.6187	3355	2128	26.6628	1276.4479
1973	190.1991	16302.3817	9812.4719	3380	2194	25.4720	805.513
1972	173.2276	13597.6167	8769.2519	2916	2025	24.0542	515.599
1971	176.7111	12283.4721	8842.4650	2715	1928	23.9904	422.7556
1970	146.0584	10400.5417	8841.5108	2769	1833	20.8617	658.1689
1969	150.7892	13245.5735	9661.4990	3079	1872	22.8856	662.2098
1968	145.3729	12709.2699	8349.9243	2701	1660	21.8978	502.4428
1967	134.3373	11400.5339	7223.1393	2277	1609	21.8340	464.2887
1966	116.6333	9358.3757	7051.7081	2054	1603	20.8433	520.6413
1965	103.3986	8024.6296	6691.2920	1789	1521	18.8239	624.9228
1964	88.6721	6372.9893	6330.4859	1573	1315	17.3999	625.7241
1963	80.5058	5263.3616	5818.1420	1381	1201	16.0437	580.4004
1962	78.3813	4773.8296	5909.7666	1288	1161	15.4285	543.983
1961	71.5517	3782.5459	5302.4669	1110	1117	14.3363	509.9138

Where: Ve = The Cost of Energy ($ millions);

Qwc = The Quantity of Wood Chips Used (10^3 m^3);

Qrw = The Quantity of Roundwood Used (10^3 m^3);

Qwp = The Quantity of Wood Pulp Shipments (10^3 tonnes);

Qtp = The Quantity of Total Paper Shipments (10^3 tonnes);

Qlbhr = The Quantity of Labour Hours Worked (millions);

TVP = Total Variable Profit ($ millions).

Table A.8 Rest of Canada Quantity Data

Year	Ve	Qwc	Qrw	Qwp	Qtp	Qlbhr	TVP
1995	412.1703	10692.9134	19353.0000	4031	2939	23.1980	2608.4636
1994	402.4861	9041.9948	18047.0000	3647	3227	21.8760	1082.0624
1993	425.8954	8393.7008	15361.0000	3206	2988	21.4192	423.6757
1992	422.8351	7619.4226	16405.0000	2955	2791	22.2278	425.2353
1990	364.3052	6154.8556	14716.0000	2648	2558	22.8655	861.745
1989	342.3312	6485.5643	15412.0000	2534	2656	23.9887	974.9409
1988	319.1794	6317.5853	13835.0000	2409	2483	22.8166	1201.3231
1987	347.7401	6963.5205	12160.6004	2443	2607	21.9752	1121.7695
1986	343.1222	4908.1365	14538.0577	2307	2176	21.7505	680.6803
1985	364.4900	4564.3045	16872.0787	2212	2230	20.5473	428.87
1984	392.6144	4452.3800	13414.4170	2309	2052	21.6499	501.2531
1983	315.1860	2854.7640	11675.8910	1925	1787	19.3426	252.3143
1982	315.7124	2622.2520	11530.2380	1822	1596	21.0140	412.4314
1981	336.5009	3421.9580	13679.4920	2088	1930	22.9193	742.1547
1980	319.5880	3797.1580	13134.1160	2072	1938	22.2519	896.9454
1979	297.6365	3024.7300	13275.4560	2059	1847	22.5075	739.0383
1978	302.1007	3036.9540	12895.5190	2046	1968	22.4738	754.6916
1977	282.7129	3172.6740	12473.6920	1928	1816	22.4914	584.3957
1976	254.4255	4107.8810	12227.0730	1787	1805	23.2834	526.2232
1975	209.6300	2956.0000	11905.0000	1627	1726	22.0302	752.5418
1974	233.7194	3973.0025	13527.6641	2013	2333	24.5697	1070.5277
1973	166.3093	3068.9093	12949.0495	1884	2263	22.4719	501.3783
1972	156.2112	2433.4328	11200.9446	1718	1956	20.8002	270.2215
1971	143.6444	2145.4611	9896.4199	1514	1644	20.3079	149.6889
1970	119.6012	1356.3836	10542.9863	1515	1738	20.9882	279.7943
1969	115.1346	1472.2554	10403.7481	1493	1694	20.7967	332.0334
1968	111.4397	1245.4980	9379.2503	1215	1598	20.0032	237.918
1967	107.2342	1116.5754	8107.6114	930	1563	20.1004	203.0772
1966	108.2164	1112.3348	8390.1730	974	1702	20.2141	321.8437
1965	107.5180	941.2951	8130.9586	941	1532	19.5684	314.7271
1964	94.1096	968.3717	7755.3981	925	1425	18.9244	346.3232
1963	85.9852	936.7228	7078.4683	849	1300	17.9219	327.0811
1962	85.6230	702.4025	6775.3925	760	1219	18.5322	272.2045
1961	83.6207	303.4777	6645.5338	665	1261	17.7011	312.069

Where: Ve = The Cost of Energy ($ millions);

Qwc = The Quantity of Wood Chips Used (10^3 m^3);

Qrw = The Quantity of Roundwood Used (10^3 m^3);

Qwp = The Quantity of Wood Pulp Shipments (10^3 tonnes);

Qtp = The Quantity of Total Paper Shipments (10^3 tonnes);

Qlbhr = The Quantity of Labour Hours Worked (millions);

TVP = Total Variable Profit ($ millions).