WAGE AND EMPLOYMENT DETERMINATION IN A UNIONIZED INDUSTRY: THE IWA IN THE B.C. WOOD PRODUCTS INDUSTRY

By

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Abstract

A new data set isolates the behaviour of the International Woodworkers of America and the British Columbia wood products industry 1963-79. Two non-nested models of wage and employment determination in a unionized industry are derived, specified, and estimated using the new data set. In one model (monopoly union model) the union chooses the wage unilaterally to maximize its ojective function subject to the industry labour demand function. The industry chooses employment subject to the union wage and an inefficient wage-employment package results. In the other model (cooperative union model) the union and industry bargain about wages and employment and reach, by some unspecified means, an efficient wage-employment package.

The estimated union objective function is increasing in real wages and employment and decreasing in the workers' real alternative wage. At the mean of the data the estimated elasticity of substitution between real wages and employment is 0.7 and the union is indifferent to a 1.5% decrease in employment and a 1% increase in real wages. Popular hypotheses about union behaviour (rent maximization and wage bill maximization) are rejected as are hypotheses that the union is indifferent to the alternative wage and the level of employment.

The estimated production technology shows that labour is substitutable with materials and capital, and materials and capital are complements. Industry cost functions are not concave in input prices, but input demand functions slope down. The estimated elasticity of the demand for labour is less than minus one in the

monopoly union model so the union is operating on an elastic portion of the demand for labour function.

The cooperative union model is argued to be the appropriate model since it predicts an efficient outcome. This preference for the cooperative union model is supported by the data when the two models are tested against one another.

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Chapter 1

Introduction

In a unionized industry the union is the sole and exclusive representative of labour. Individual workers and firms do not negotiate conditions of employment. Firms are forced to negotiate the conditions of employment with the union and the negotiated terms cover all workers in the industry (bargaining unit). Workers are forced to accept the negotiated conditions or work outside the industry.

Theoretical models of the behaviour of unions and firms in this situation abound. However, little empirical work has been done on these models.[1] The purpose of this thesis is to put models of the behaviour of unions and firms to an empirical test.

Two popular models of wage and employment determination in a unionized industry are presented, specified, and estimated using annual data on the International Woodworkers of America (IWA) and the wood products industry in British Columbia, 1963-79. The first model is a monopoly union model, where the union chooses the wage to maximize its objective function subject to the industry's demand for labour function. The firm chooses the level of employment subject to the union wage and an inefficient outcome results.[2] The second model, herein referred to as the cooperative union model assumes that the union and industry bargain about wages and employment to reach an

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1. Farber (1978), Dertouzos and Pencavel (1981), de Menil (1971), Pencavel (1981), and MaCurdy and Pencavel (1983) are notable exceptions.

2. See, for example, Cartter (1959), pp. 77-94 for an exposition of monopoly models.

outcome on the contract curve, thereby insuring an efficient outcome.[3]

The estimation of the models provides estimates of the IWA's preferences and allows common propositions about union preferences to be tested. The estimation of the models also provides estimates of the technology of the B.C. wood products industry.

Once the models are estimated, the empirical performance of each is evaluated. The models are compared to see which is the true model of the observed behaviour of the IWA and wood products industry in B.C.

Chapter 2 presents a survey of the theoretical and empirical literature on union models while Chapter 3 provides sources, descriptions and definitions of the data used in the study. Estimates of the technology of the B.C. wood products industry, under the assumptions of exogenous input prices and price taking behavior, are reported in Chapter 4. Chapters 5 and 6 show the derivation, specification and estimation results of the two union models assuming cost minimizing and profit maximizing behaviour by the industry. Chapter 7 presents the attempt to choose between the two union models and conclusions are drawn in Chapter 8.

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3. See, for example, De Menil (1971), pp. 1-27 or Hall and Lilien (1979) for an exposition of a cooperative model.

Chapter 2

Survey of the Literature

This chapter surveys the theoretical and empirical literature on economic models of union behaviour. A truly exhaustive survey requires a study of bargaining and strike theories. These topics are outside the scope of this project and will therefore be mentioned briefly rather than surveyed carefully.

The economic models of unions can be divided into two categories: monopoly models and cooperative models. The monopoly model is simply the standard textbook model of monopoly behaviour. The model can be written as a constrained maximization problem where the union maximizes some objective function of wages, employment, and other variables, subject to a market opportunities set defined by the demand for labour function. The demand for labour function which constrains the union's behaviour is the horizontal sum of the demand for labour functions of firms within the union's bargaining unit. If the union is the bargaining agent for all labour in an industry, the union is constrained by the industry demand for labour function. If the union only bargains for the workers in a single firm, then that firm's demand for labour function is the constraint in the union's maximization problem.

The union, in this category of models, unilaterally chooses the wage which maximizes its objective function. The demanders of union labour accept the union wage as an exogenous parameter and choose the level of employment which yields them the highest level of profit possible given that union wage. This amount of employment is shown by the demand for labour function. Thus, the union chooses the wage which maximizes its objective function subject to the appropriate demand for labour function.

In Figure 1, DD is the appropriate demand for labour function; π_0, π_1 and π_2 are isoprofit curves; u_0 and u_1 are union indifference curves; and CC is the contract curve. According to the monopoly model, the union chooses a wage w_1 and the firms react to w_1 by employing L_1 units of labour.

Formally, the monopoly model can be written

$$\underset{w}{\text{Max}}[U(X) : w \in Z],$$

where $Z \equiv [w : L(w,Y) > 0,\ w > 0]$, $U(X)$ is the union's objective function, X is a vector of variables (usually including w and $L(w,Y)$), w is the average rate of compensation paid to labour, $L(w,Y)$ is the demand for labour function, and Y is a vector of exogenous variables which affect the demand for labour function.

Different types of monopoly models are differentiated from one another by the objective function $[U(X)]$ which is specified. The most commonly cited monopoly model is the rent maximization model where

$$U(X) = [w - A]L, \tag{2.1}$$

A is the opportunity cost of labour's time and L is the amount of labour employed.[1]

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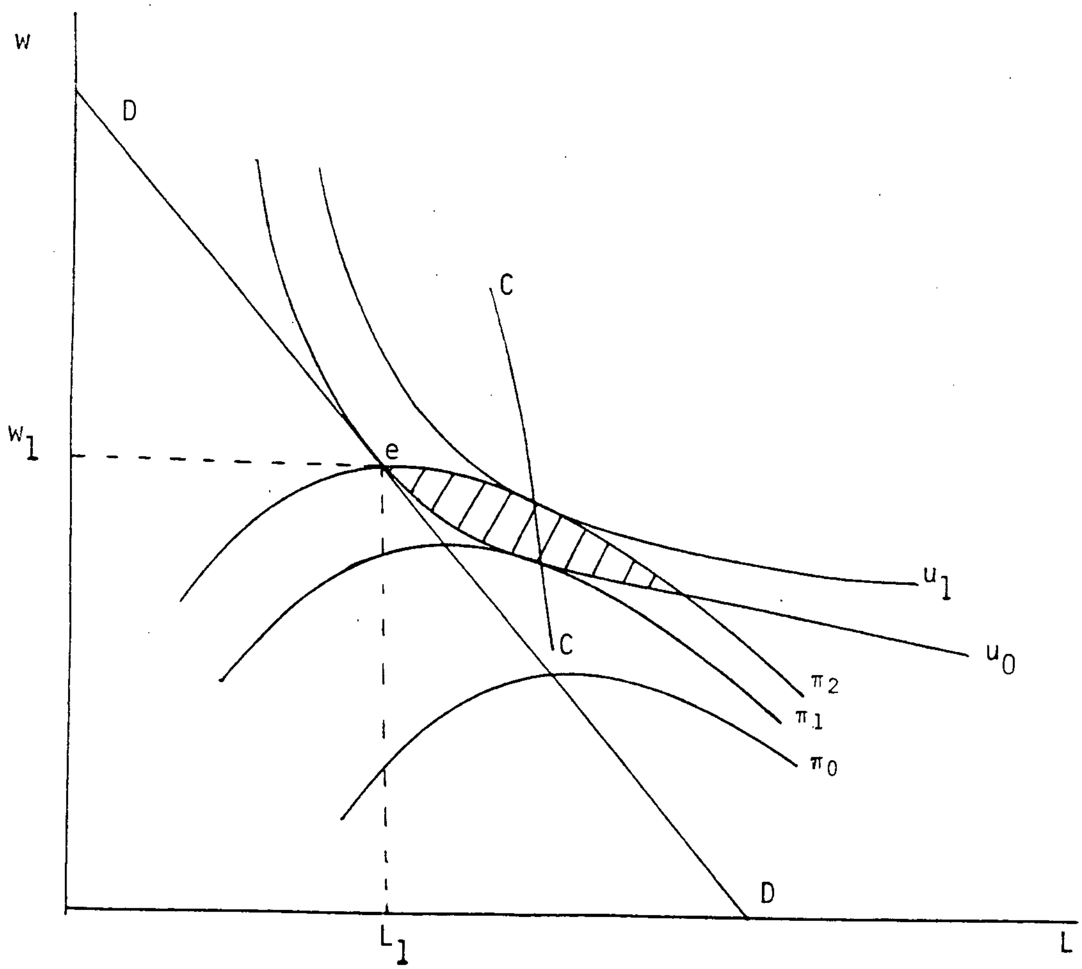
1. Cartter (1959), p. 80, Dunlop (1944), p. 41, Rosen (1970), Reynolds (1981), and McDonald and Solow (1981), pp. 897-899 all discuss this model. McDonald and Solow (1981) actually specify

FIGURE 1



An often suggested extension to the rent maximization model is to have the union maximize rents minus the cost of providing union services.[2] Hence, the union's maximand is

$$U(X) = [w - A]L - C(L,P) \tag{2.2}$$

where C(L,P) is the minimum cost of providing union services to L union members given input prices P. Finally, equation 2.1 nests another popular monopoly model, the wage bill maximization model.[3] In this case, the union's objective function is given by

$$U(X) = wL. \tag{2.3}$$

The micro foundations and interpretation of the rent maximization models have been the subject of much controversy. Reynolds (1981, p. 164) suggests that the rent maximization models are reasonable because union decision makers want to maximize the amount of wealth

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$$U(X) = (L/N)[U(w)-D] + [(N-L)/N]U(A)$$

where N is the number of union members, D is the disutility of work, U(w) is the utility function of every union member, and employment is allocated to union members by a lottery. Maximizing the McDonald and Solow objective function is equivalent to maximizing

$$U(X) = [U(w)-D-U(A)]L = [U(w) - U_0]L$$

since N and D are assumed to be exogenous to the union.

2. See, for instance, Rosen (1970), p. 269, Lewis (1959), and Martin (1980), pp. 58-60.

3. Cartter (1959), p. 82, Rees (1977), p.5. Note that this model is different from Dunlop's (1944), p. 36 famous model in that there does not exist a wage-membership function which constrains the union's choices.

which can be distributed to themselves or others. Reynold's basic premise is that the model can produce correct conclusions without specifying the recipients of the rents which the union earns. This premise is somewhat difficult to maintain given the work of Martin (1980) who explores very carefully how the assignment of the rights to earn rents can affect the behavior of a union.

Two alternate and extreme assignments of the rights to earn rents which predict and, therefore, justify the rent maximization models, have been suggested by Lewis (1959, pp. 197-198). The first is the boss dominated union (or racket) where the union boss makes all the decisions and earns all the rents. The boss chooses the union wage which maximizes union rents in order to maximize his income. The union can be thought of as a firm which hires labour at its opportunity cost and re-sells it to firms at the union rate. The difference between the union rate and labour's opportunity cost is extracted through initiation fees and union dues.

The second assignment of the rights to earn rents is the worker dominated union where workers share all the rents amongst themselves. The workers set the union wage to maximize total rents so as to maximize their income from the rents. Union leaders can be considered employees of the workers, being paid the market wage for their skills, and working to negotiate and enforce the wage chosen by the workers.

Neither of the two extreme assignments of rights which justify the rent maximization models appear to correspond too well with the established folklore about the nature of unions. As a result, the rent maximization models have been criticized by many authors with Ross (1948) being the most influential.

The concept of a "boss dominated union" is rejected completely by Ross (1948, pp. 22, 28), Dunlop (1944, p. 32), Cartter (1959, p. 78) and others. They maintain that unions do not purchase labour for resale to firms and cannot, therefore, be modelled as firms. Hence, the boss dominated justification of rent maximization models is rejected by those critics.

The worker dominated extreme appears to be much closer to Ross' (and other critics') notion of the nature of unions than the boss dominated extreme. However, three strong arguments are made against the reasonableness of the worker dominated justification of a rent maximizing union. The first argument points out that union workers are not a homogeneous group.[4] There are rank and file members and union leaders who have been elected to office by the members, but who remain a part of the union. Further, within each of those groups there exist other subgroups of members which are different from one another. Ross (1948, pp. 31-32) maintains that the different groups have different and often conflicting goals for the union.

This problem becomes much more serious when one recognizes that a union produces many local public goods. The private costs and benefits of choices differ across groups, and these private costs and benefits are different from the collective costs and benefits.[5]

Ross (1948) argues that it is unreasonable to believe that the conflicting preferences of different groups, as well as the

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4. See Ross (1948), pp. 31-32.

5. See Ross (1948), pp. 23-24. Ross refers to the collective goals (i.e., the collective costs and benefits) as the institutional goals and points out the difference between the member's or leader's private goals and the institutional or collective goals.

differences between private and collective incentives, can be accommodated and expressed by the simple rent maximizing objective function.

The second argument follows from the first. Given that there exist different groups within the union which have different goals, some sort of process or system is needed to choose which goals the union actually pursues. The particular process or system used to reconcile the conflicting goals affects the behaviour of the union and must therefore, be explicitly included in any model of union behaviour.[6] The rent maximization models do not model this decision process so it is again argued that the rent maximization models are inadequate models of union behaviour.

The third argument asserts that uncertainty about the ultimate employment effects of negotiated wage rates makes it impossible for the union to consider the employment effects of wage bargains.[7] Ross (1948, pp. 79-80) asserts that the decision makers within the union are unable or unwilling to adjust observed employment for any changes in exogenous variables which may have occurred. Hence, the decision-makers observe no relation between wages and employment and neglect the employment effects of negotiated wage rates.

To summarize, Ross (among others) rejects the idea that unions can be fruitfully modelled as rent maximizing agents. Ross rejects completely the notion of a boss dominated union and argues convinc-

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6. See Atherton (1973), p. 20 and Ross (1948), pp. 32, 37-40.

7. See Ross (1948), pp. 79-80.

ingly that a worker dominated union will not behave as if it were maximizing an objective function like equation 2.1.

The final word on the theoretical reasonableness of rent maximizing models will be given to Martin (1980). Essentially, Martin argues that if the rights to rents are transferable, and if enough efficient markets exist, then all the objections outlined above are overcome by the markets and the union will maximize total rents. For example, consider Martin's simplest case. Martin (1980, p. 13) specifies that if (a) the rights to rents are assigned to union members and are transferable, (b) an efficient market for those rights exists, (c) monitoring leaders is costless, and (d) an efficient market for leaders exists, then the union will behave so as to maximize the total rents accruing to the union.

A number of models which nest the rent maximization model have been put to an empirical test by Dertouzos and Pencavel (1981) and Pencavel (1981), using annual data from a number of newspaper printing operations involving the International Typographical Union (ITU). Only the results obtained from the Cincinnati Post local (1946-1965) are reported, since the data from the other newspapers are not as good as the excellent data on the Cincinnati Post.

Dertouzos and Pencavel (1981) argue that the monopoly model is appropriate for the ITU because the union holds a much stronger bargaining position than the newspapers and strikes are uncommon. The union's dominance occurs because of the newspaper's vulnerability to strikes. This vulnerability results from the existence of very close substitutes for advertisers (e.g., radio or flyers) and the impossibility of building up an inventory of output. The ITU is also very democratic and the members are quite homogeneous (i.e., they are all printers). Therefore there should be few divergent preferences between members and leaders and between different groups of members.

Three basic models are estimated. The first model specifies the following Stone-Geary objective function for the union, and cost minimizing demand for labour function:

$$U(w/p,L) = (w/p-A)^{\theta}(L-B)^{1-\theta} \qquad (2.4)$$

$$L = b_0 + b_1(w/r_1) + b_2(r_2/r_1) + b_3Q + b_4D \qquad (2.5)$$

where p is an index of consumer prices, Q is output measured by advertising linage, r_1 is the price of newsprint, r_2 is the wholesale price index of machinery and equipment, and D is a dummy variable which reflects the effects of mergers with other newspapers. Clearly equation 2.4 nests both the rent maximization and wage-bill maximization models. Reduced form equations for w and L are derived and FIML estimates of the parameters are obtained. The estimated elasticity of substitution of union preferences between real wages and employment, evaluated at the same mean, is .69. Further, it is estimated that $0 < \theta < .5$, indicating that the union is not indifferent to the level of employment, and $A > 0$. The wage bill maximization hypothesis, $\theta = .5$ and $A = B = 0$, is rejected using a likelihood ratio test; as is the rent maximization hypothesis, $\theta = .5$, $B = 0$; where A is defined as a linear function of the hourly earnings of non-supervisory workers in the retail trade.

The second model specifies the following log-linear reduced form equations for lnw and lnL:

$$\ln w = a_0 + a_1 \ln p + a_2 \ln r_1 + a_3 \ln r_2 + a_4 \ln Q + a_5 D \qquad (2.6)$$

$$\ln L = b_0 + b_1 \ln p + b_2 \ln r_1 + b_3 \ln r_2 + b_4 \ln Q + b_5 D. \qquad (2.7)$$

Equations 2.6 and 2.7 are estimated using OLS and FIML techniques, and yield estimates of the elasticities of wages and employment with respect to the exogenous variables.

The third model is novel in that the log of the first order condition of the maximization problem is estimated rather than the reduced form equations. An addilog objective function is specified;

$$U(w/p,L) = K + \mu(1+\lambda)^{-1}(w/p)^{1+\lambda} + (1-\mu)(1+\eta)^{-1}L^{1+\eta} \qquad (2.8)$$

where $K = -\mu(1 + \lambda)^{-1} - (1 - \mu)(1 + \eta)^{-1}$, $0 < \mu < 1$, and $\lambda, \eta < 0$. If $\lambda = \eta$ a CES function is obtained while $\lambda = \eta = -1$ implies a Cobb-Douglas functional form.

The advantage of the addilog specification is that the log of the marginal rate of substitution is linear in lnw, lnp, and lnL. The first order condition of the maximization problem implies that the marginal rate of substitution equals the slope of the demand for labour function. The slope of the demand for labour function is specified to be $(e^{\alpha Q})/r_1$. Hence the first order condition can be rewritten as

$$\ln w/p = (1/\lambda)(\ln[(1-\mu)/\mu] + \ln p/r_1 + \eta \ln L + \alpha Q). \qquad (2.9)$$

Non-linear 2SLS is used to estimate the parameters of equation 2.9. The elasticity of substitution of union preferences between real wages and employment is estimated to be .469 at the sample mean, while the estimates of u, λ, η, and α are .91, -2.146, .167, and -.045 respectively. Clearly, the estimates do not satisfy all the restrictions implied by equation 2.8.

A number of models which incorporate aspects of the arguments against rent maximization models have been proposed. Berkowitz (1954) and Atherton (1973, pp. 71-80) propose a model where the institutional goal of the union is allowed to be different from union members' goals, and the institutional goal is pursued. The union maximizes its net revenue or profit subject to the constraint that the union retains the bargaining rights of the workers. The union's objective function can be written

$$U(w,L,D,S) = wDL - C(L,P,S), \qquad (2.10)$$

where D is the proportion of worker's earnings collected as dues, S is the level of services provided by the union to each worker, C(L,P,S) is the minimum cost of providing services S to L workers given input prices P, and D and S must be such that the union is not decertified by the workers.

Atherton (1973, pp.80-157) also proposes a number of more general models where the membership is not homogeneous, and the strike length needed to achieve bargaining outcomes is included in the economic calculus. The union is assigned lexicographic preferences over winning (de)certification elections and earning profits and is assumed to maximize its utility. The model is extended to include uncertainty about exogenous variables so that the union maximizes some lexicographic combination of the probability of the leader's re-election and expected profits. Unfortunately the model's level of abstraction is very high and no testable predictions are made. Further, Atherton (1973) does not show that any of the voting equilibria exist.

Farber (1978) develops a much simpler model where the preferences of leaders and members are allowed to differ and union members are not homogeneous. All workers are equally risk averse and face a once and for all lottery for union jobs. Workers who win union jobs receive union wages while working, pension benefits when retired and health and welfare benefits when they are working and when they are retired. The utility of workers is a function of the present value of their income stream and benefits package, so young and old workers value the same wage, health and pension benefits package differently. It is assumed that union leaders maximize the probability of their re-election. Therefore, union leaders choose a wage and health and pension benefits package which maximizes the median aged worker's expected utility subject to the demand for union labour function. The value of the pension and health and welfare benefits is assumed to be equal to the contributions made to the health and pension funds by the employer. The employer contributes a fixed charge per unit output, so the union leaders actually choose the wage and output tax which maximizes the median aged worker's utility.

Farber (1978) estimates his model using annual data on the United Mine Workers (UMW) in the coal industry (1947-1973). Farber (1978, p. 926) argues that the monopoly model is appropriate because the union was dominant in a coal industry made up of many small firms.

Hence it is plausible to assume that the union sets the wage unilaterally.

The estimated index of relative risk aversion is 2.98, indicating that the mine workers were risk averse. Given the lottery for union jobs this indicates that the union behaved as if it considered the employment effects of wage demands.[8] The union's discount rate is estimated to be 3.5%-4.5%, and nontaxed payments in kind were valued 40% higher than wage payments.

Farber (1978, p. 932) does address the issue of whether the voting equilibrium exists. A sufficient condition for the existence of the majority voting equilibrium is that the voter's preferences be single peaked over a single variable. Farber (1978, p. 932) argues that union member's preferences will be single peaked over the set of wages and output taxes which are Pareto optimal (from the union member's point of view). Unfortunately Blair and Crawford (1983) prove that the voting equilibrium specified in Farber (1978) does not exist.

A final group of monopoly models which do not belong in the two above mentioned groups (i.e., those based on rent maximization and those based on the criticisms of the rent maximization models) will now be surveyed. Monopoly models are included in this group if their objective functions are considered reasonable but are not derived from any assumption about the nature of unions. This contrasts with the models above whose objective function is derived (however roughly) from the preferences of agents within the union.

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8. Whether it is appropriate to say that the union considers employment effects, or the collective bargaining framework merely causes unions to act as if they considered employment effects (as discussed by Reder (1952)) is not known.

The simplest models in this group are those surveyed by Cartter (1959, pp. 83-90). The union is assumed to maximize wages, employment, the wage bill plus private or public unemployment insurance, union membership, or some arbitrary, increasing, quasiconcave, function of wages and employment.

Atherton (1973, pp. 41-70) presents a monopoly model which is interesting in that the union faces two constraints: a demand for labour function and a strike length function. The union's objective function is an arbitrary increasing function of after-tax real income and employment, and a decreasing function of the length of strike endured before a settlement is reached. The union still chooses the wage unilaterally. However, associated with each wage rate is a level of employment, given by the demand for labour function, and a strike of a certain length (possibly zero), given by the strike length function.[9] The union chooses the wage which maximizes its objective function subject to the two constraints.

All the above mentioned models specify the union maximand as a function of the levels of wages, employment, and other variables. Cartter (1959, pp. 89-92) specifies a union objective function which is a function of the changes in the levels of wages and employment from a status quo point. The status quo point is the union's optimal wage-employment combination in the previous time period.

Cartter (1959, pp. 89-90) asserts that internal political considerations make the union unwilling to trade wages for employment or

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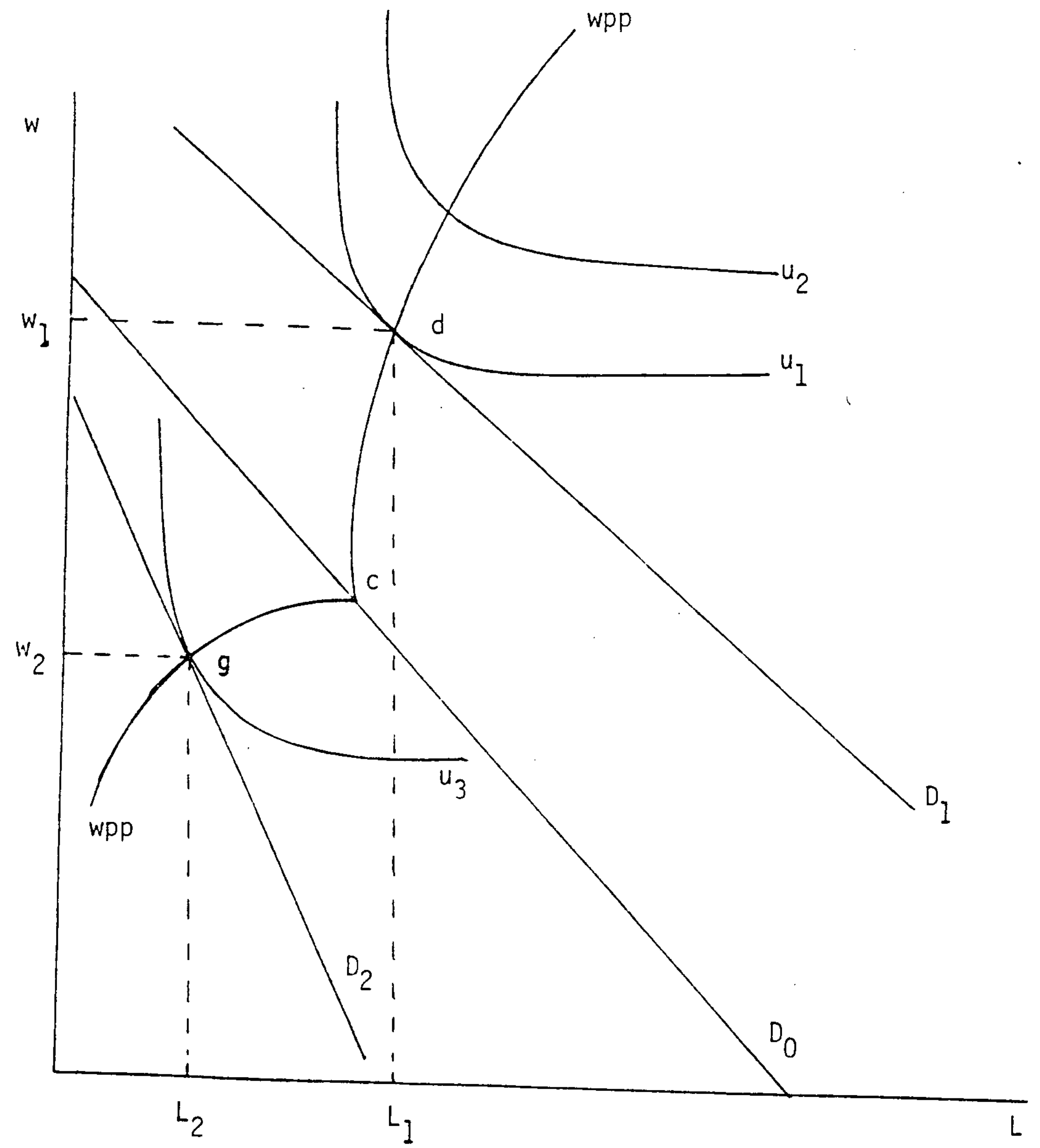
9. How the strike length function is derived from a theory of the firm, or why the firm endures a strike of a given length only to yield to the same wage demand eventually, in a model with perfect information, is not specified.

FIGURE 2



vice-versa. Other things equal, the union requires large increases in wages to compensate it for small decreases in employment and large increases in employment to compensate it for small decreases in wages. In other words, the union indifference curves in wage-employment space are almost Leontief in shape. Cartter (1959) further asserts that when the demand for labour increases (other things equal) the union presses for large wage increases at the expense of small increases in employment. When the demand for labour decreases (other things equal) the union accepts large decreases in employment in order to suffer only small decreases in wages. A typical indifference map for a union of this sort is shown in Figure 2 in wage-employment space. Referring to Figure 2, u_1, u_2, and u_3 are union indifference curves, the previous period's demand for union labour function is shown by D_0, point "c" is the status quo point, and "wpp" is the union's wage preference path. If D_1 represents the demand for union labour in the present period, then the union will maximize its objective function by choosing wage w_1. Point "d" will be the status quo point next period. If D_2 represents the present demand for union labour then the union will choose w_2 and point "g" will be next period's status quo point.

The survey of monopoly models is complete save for a few general comments. First, all the models outlined above could be extended so that the firm and the union bargain over wages while the firm still chooses the level of employment. Any sort of bargaining model or model or arbitration scheme could be used.[10] The final outcome would

10. The bargaining model of Hicks (1963), the Ashenfelter and Johnson (1969) variation of the Hicks (1963) model, or the Nash arbitration scheme could all be used.

lie on the demand for labour curve, somewhere between the union's optimum, the point reached in the models above, and the firm's optimum, the point where the supply of labour curve (in the absence of a union) intersects the demand for labour curve.

Second, the monopoly models yield inefficient or Pareto inferior solutions. Referring to Figure 1, it is clear that all the wage-employment combinations in the shaded lens area are Pareto superior to point "e", the monopoly model solution.[11] This feature distinguishes the monopoly models from the other category of models; the cooperative models. In cooperative models the union and the demanders of union labour identify their contract curve and choose, by some means or another, a wage-employment combination on that contract curve. Hence, an efficient outcome is achieved.

To reach a point on the contract curve the union and firms must bargain over more than just the level of wages. The firms must be forced off their demand for labour function. Therefore, a bargain which determines both the level of wages and the level of employment must be struck between the union and the firms in order to keep the firms off their demand for labour functions.[12]

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11. The monopoly model solution is inefficient and the lens of Pareto superior wage employment combinations exists as long as the level sets of the union objective function are not Leontief in shape, or (as pointed out by Pencavel (1981), p. 13 as long as the union's objective function is not independent of the level of employment.

12. A formal presentation of the cooperative model requires a definition of the contract curve and the specification of a mechanism which chooses a unique point on that contract curve. While the former is straightforward, the latter requires the invocation of a bargaining scheme which is, as noted earlier, outside the scope of this survey. Hence a formal statement of the cooperative model will not be presented.

McDonald and Solow (1981) and de Menil (1971) present very similar cooperative models where the union's objective function is a function of the rents accruing to labour and an arbitration rule is used to choose a point on the contract curve.[13] The union and firm reach their contract curve by bargaining over both the level of wages and the level of employment. de Menil (1971) derives a wage equation from his model and extends it into a Phillips curve with bargaining related variables on the right hand side. The extended Phillips curve is then estimated using data on heavily unionized two digit U.S. manufacturing industries. McDonald and Solow (1981) derive the comparative static responses of their model to variations in the demand for labour due to the business cycle.

Hall and Lilien (1979) also propose a model where the union maximizes the rents accruing to labour. Their model is novel in that the union and firms do not bargain directly about the level of employment. Instead, the unions and firms reach their contract curve by choosing a compensation function (where total compensation paid to labour is some function of employment) which supports an efficient equilibrium. The compensation function is chosen so that when both sides choose their optimal levels of employment (i.e., when both sides maximize their objective functions) subject to the compensation function, both sides choose the same level of employment. Hence, an efficient solution is reached.

Hall and Lilien's (1979) model does not predict a unique outcome. No bargaining mechanism is specified to choose a particular point on

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13. McDonald and Solow (1981) actually specify a different objective function for the union. However, that objective function implies rent maximization in their model. See footnote 1.

the contract curve. The model is used to explain some stylized facts of collective bargaining when there is uncertainty about the demand and supply of labour.

In conclusion, one finds two types of union models in the literature: monopoly models which yield inefficient solutions, and cooperative models which yield efficient solutions. Given the usual neoclassical paradigm, one would expect the monopoly model to be discarded in favour of the cooperative model. The ability of economic agents to exploit all gains from trade is a central tennent of almost all textbook economics. However, an argument which appeals to factors assumed away in the neoclassical paradigm suggests that the monopoly model may be the more appropriate of the two models.

This argument claims that unions and firms will not have enough information about the other side's objective function to exploit all the gains from trade.[14] This lack of information may arise from the costs of transmitting and receiving information. However, the bluffs, threats, deceptions, and other bargaining tactics used by both sides to gain bargaining advantages will contribute a great deal of uncertainty and false information. Thus, one can expect imperfect information between unions and firms and this imperfect information may cause unions and firms to be unable to exploit all of the available gains from trade.

While the above argument does raise a valid criticism against the cooperative model, it does nothing to suggest why one should expect the monopoly model to be appropriate. Imperfect information may indeed cause unions and firms to deviate from an efficient solution.

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14. See Pencavel (1981), p. 13.

However, the argument does not explain why imperfect information should imply the monopoly solution. Further, the same argument may be used against the monopoly model. Uncertainty, imperfect information, or attempts at deception by the firm may cause the union to misperceive the demand for labour function and choose a suboptimal wage rate. Therefore, imperfect information does not aid the choice of the more appropriate model.[15]

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15. One could argue: (a) both models are reasonable a priori, (b) the monopoly model has lower information requirements than the cooperative model, (c) firms and union possess only imperfect information. Therefore the monopoly model is more appropriate. I agree with (b) and (c), but am unconvinced that (a) is tenable.

Chapter 3

The Data[1]

This chapter outlines the definitions and sources of the raw data, and describes how the final data set is produced from the raw data. The data set consists of annual observations on establishments (mills) in the following British Columbia wood products industries: (i) sawmills and planing mills (S.I.C. 2513), (ii) shingle mills (S.I.C. 2511), and (iii) veneer and plywood mills (S.I.C. 2520). Observations from 1963 to 1979 were collected. Fortunately, separate data are available for interior and coast sawmills, yielding a total of 4 x 17 = 68 observations in the data set.

All data (unless otherwise specified) are published in the Statistics Canada publication Annual Census of Manufactures "Sawmills and Planing Mills and Shingle Mills" (Catalogue 35-204) and "Plywood and Veneer Mills" (Catalogue 35-206).

Institutional Setting[2]

The British Columbia wood products industry is large and very active in world markets. B.C. sawmills produce almost 70% of the softwood lumber sawn in Canada and export almost 80% of their output. These exports, in turn, account for a little less than 10% of world trade in softwood lumber.

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1. I would like to thank Karen Kalderbank (Statistics Canada, Vancouver) and Paul Martin (Statistics Canada, Ottawa) for their invaluable assistance with the collection of the data.

2. All of the data reported in this section on B.C. and Canadian production, exports and market shares, are found in Pearse (1976), Volume 2, Appendices A, B, C, and E; Pearse (1980), pp. 1-30; and Industry, Trade and Commerce (1978), pp. 1-50.

The shingle industry in B.C. produces virtually all of the cedar shingles and shakes made in Canada and is North America's major producer. A high proportion of the industry's output is exported, mainly to the United States.

B.C. also has 80% of the Canadian capacity for the production of softwood plywood and veneer. Exports are not as important to the plywood mills since high tariffs throughout the world have stifled trade. However, B.C. plywood mills still export about 20% of their output.

The B.C. wood products industry can be described as concentrated since most of the mills are owned and operated by a small number of large integrated firms. This is especially true for sawmills and plywood mills. However, it is not unreasonable to assume that the industry is a price taker in output markets since so much of the industry's output is sold in world markets. Indeed, Pearse (1980, p. 23) writes: "Forest products produced in British Columbia are, for the most part, sold in highly competitive international markets."

It is much more unreasonable to assume that the industry is a price taker in the market for materials. Import tariffs on roundwood (logs) protect logging operators from competition. Also, both the logging operations and the mills they deliver their output to, are usually owned and operated by the same large, vertically integrated firm. Therefore, the market for roundwood is very limited and logging operations may not sell roundwood to mills at the firm's true shadow price. This may be done to decrease the royalties or stumpage fee paid by the logging operations to the B.C. government. This stumpage fee is set equal to the remainder of the value of timber minus the costs of production. Hence, logging operations and mills owned by the same firm, may trade at false prices in order to decrease the profitability of the logging operations. This, in turn, would decrease the stumpage fee and increase the overall profitability of the firm. In spite of the above, price taking behaviour in the materials market is assumed in order to keep the analysis simple.

Virtually all labour employed in the B.C. wood products industry is organized by the International Woodworkers of America (IWA). Since the industry is so concentrated the union has been able to keep the industry unionized over the whole period of the study. The IWA claims that 95-98% of output is produced by IWA members.[3]

The bargaining structure is centralized. Union representatives from IWA Regional Council #1 negotiate a coast master contract, covering all workers employed in the coast region, with the employer's association known as Forest Industrial Relations (FIR). The coast master is then used as a basis for master agreements between IWA regional councils and employer associations in the northern interior and southern interior regions. All of the collective agreements contain union shop provisions.

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3. A small part of the remaining 2-5% of output is produced by workers organized by the Carpenter's Union or the Pulp, Paper, and woodworkers of Canada (PPWC), a recently formed union. The rest of the output is produced by unorganized workers. There are a few small unorganized sawmills and shingle mills, and there is a cooperative plywood mill.

Labour

The labour input (L) is measured in thousands of man-hours paid for manufacturing activity.[4] Total compensation paid to labour is total wages paid to production and related workers for manufacturing activity in thousands of current dollars. Total compensation includes all wages before deductions, overtime payments, bonuses, and paid vacations and other payments for work not performed. The average nominal rate of compensation paid to labour (w) is simply total nominal compensation paid to labour divided by the labour input. Total real compensation paid to labour (B) is total compensation divided by the Canadian consumer price index (p).

Capital Services

The construction of price and quantity variables for capital services proved to be quite difficult since capital stock for four digit S.I.C. industries, by province, is not tabulated by Statistics Canada. Aggregate capital stock for the whole B.C. wood products industry (two digit S.I.C.) are the most disaggregated data available. However, the aggregate data on capital stock and data on energy consumption can be combined to produce price and quantity series for capital services.

Let the production function for the wood products industry be a function of labour (L), materials (M), flow of capital services from

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4. Man-hours paid includes time paid but not worked, e.g. vacations and statutory holidays. During the period of interest the workers received two more statutory holidays and longer vacations, so the data overstates the true labour input, especially in later years. Adjusting the labour input variable for the extra time off left the estimated union models virtually unchanged. Therefore the adjustment was dropped and the raw data was used.

the capital stock (S) which is assumed to be a constant proportion of the capital stock, and consumption of fuels and electricity (E), i.e.,

$$Q_{it} = f(L_{it},M_{it},S_{it},E_{it}) \quad i = 1,4 \quad t = 1,17 \tag{3.1}$$

where i is the runner for the four observations (coast sawmills, interior sawmills, shingle mills, plywood mills) observed at each time t.

Assume f() is weakly separable over S_{it} and E_{it} and can, therefore, be written

$$Q_{it} = F(L_{it},M_{it},K(S_{it},E_{it}))$$

where $K(S_{it},E_{it})$ is the flow of capital services as a function of energy consumption and the stock of capital.

Specify a constant returns to scale CES production function for capital services

$$K_{it} = (\delta E_{it}^{-\beta} + (1 - \delta)S_{it}^{-\beta})^{-1/\beta} \tag{3.3}$$

Cost minimization implies the following first order condition

$$P_{it}^{E}/P_{it}^{S} = MP_{it}^{E}/MP_{it}^{S} = [\delta/(1 - \delta)][S_{it}/E_{it}]^{\beta + 1}$$

where P_{it}^{E} is the price of energy and P_{it}^{S} is the user cost of capital.

Therefore,

$$S_{it} = E_{it}[(1 - \delta)P^E_{it}/\delta P^S_{it}]^{(\beta + 1)^{-1}} \quad (3.4)$$

$$\rightarrow \sum_{i=1}^{4} S_{it} = [(1 - \delta)/\delta]^{(\beta + 1)^{-1}} [\sum_{i=1}^{4} E_{it}(P^E_{it}/P^S_{it})^{(\beta + 1)^{-1}}]$$

$$\rightarrow \ln \sum_{i=1}^{4} S_{it} = (\beta + 1)^{-1} \ln((1 - \delta)/\delta) + \ln \sum_{i=1}^{4} E_{it}(P^E_{it}/P^S_{it})^{(\beta + 1)^{-1}} \quad (3.5)$$

$\sum_{i=1}^{4} S_{it}$ is available for all t from Statistics Canada.[5] P^E_{it} is a chained Fisher ideal price index of the prices of gasoline, fuel oil, liquefied petroleum gases, natural gas, and electricity.[6] E_{it} is the total cost of fuel and electricity divided by P^E_{it} and is, therefore, an implicit Fisher ideal index of the quantity of energy used. P^S_{it} is obtained by multiplying the sum of the Canadian interest rate

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5. Statistics Canada, <u>Fixed Capital Flows and Stocks: British Columbia</u>, Catalogue 13-211, unpublished, 1980. Note that Statistics Canada reports aggregate capital stock for the entire wood products industry, including wooden box manufactures, coffin and casket manufactures, and miscellaneous wood industries. Therefore, the Statistics Canada series used overstates $\sum_{i=1}^{4} S_{it}$.
   However, the two series should not be too far apart since wooden box, coffin and casket, and miscellaneous are quite small compared to sawmills, shingle mills, and plywood mills. In fact, S.I.C. 252, 2513 and 2511 made up 92% of the value added of the wood products industry, on average.

6. Statistics Canada, <u>Consumption of Purchased Fuel and Electricity by the Manufacturing, Mining, Logging, and Electric Power Industries</u>, Catalogue 57-208, 1975-79; unpublished data, 1963-74. See Diewert (1976) for definitions of indices.

(McLeod, Young, Weir 10 industrials bond yield) and the depreciation rate (capital consumption allowance for the B.C. wood products industry divided by mid-year gross capital stock) times the Canadian price index of building construction, engineering construction, machinery, and equipment for the wood products industry.[7] Since capital price indices and depreciation rates are not available for three and four digit S.I.C. industries, P^s_{it} is the user cost of capital for the whole wood products industry. Therefore it is assumed that sawmills, shingle mills, and plywood mills all face the same user cost of capital, i.e.,

$$P^s_{it} = P^s_{mt} \qquad i,m = 1,4 \text{ and } t = 1,17.$$

A stochastic error term e_t, $e_t \sim N(0,\sigma^2)$, is added on to equation 3.5, and maximum likelihood estimates of β and δ are obtained. The estimate of the elasticity of substitution between energy and capital stock obtained from equation 3.5 is 0.1, which is consistent with other estimates found in the literature (see, for example, McFadden (1978b), Dhrymes and Kurz (1964), or Fuss (1977)).

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7. The bond yield is found in the Bank of Canada Review. The capital consumption allowance and mid-year gross stock are reported in Statistics Canada, Catalogue 13-211, unpublished 1980. The price index for capital is published in Statistics Canada, Fixed Capital Flows and Stocks, Catalogue 13-211 and 13-568, various years.

The estimates of δ and β are substituted into equation 3.4 to produce predicted capital stocks for each of the observations.[8] The estimates of S_{it} from equation 3.4 are then substituted into equation 3.3 (along with the estimates of δ and β) to produce estimates of the flow of capital services, K_{it}.

The price of capital services is found by deriving the unit cost function dual to equation 3.3,

$$r_{it} = \left[(1 - \delta)^{\frac{1}{\beta + 1}} {P^{S}_{it}}^{\frac{\beta}{\beta + 1}} + \delta^{\frac{1}{\beta + 1}} {P^{E}_{it}}^{\frac{\beta}{\beta + 1}}\right]^{\frac{\beta + 1}{\beta}} \qquad (3.6)$$

where r_{it} is the cost of one unit of capital services. Estimates of r_{it} are then calculated by substituting P^{E}_{it}, P^{S}_{it} and the estimates of δ and β into equation 3.6. Hence estimates of the price and quantity of capital services are obtained for all observations.

Materials

A chained Fisher ideal price index of the price of materials (m) is constructed for each of the observations from detailed data on the quantity and value of materials and supplies used.[9] The materials price index for sawmills is simply the price of roundwood (logs)

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8. Since predicted values of the dependent variable are used, a measure of goodness of fit of the stochastic version of equation 3.5 is desirable. The average percentage difference between the actual and predicted dependent variable is 5%.

9. Statistics Canada, Catalogue 35-204, and unpublished Statistics Canada data.

while the price index for shingle mills is an index of the prices of roundwood, and unfinished shingles and shakes from other establishments.

The materials price index for plywood mills aggregates the prices of different species of roundwood (Douglas fir, balsalm and hemlock, spruce and pine) and the price of glue.

An implicit Fisher ideal index of the quantity of materials and supppies used (M) is obtained by dividing total cost of materials and supplies used by the materials price index.

Output

Detailed data on the value and quantity of the different types of shipments made by the industries are used to construct a chained Fisher ideal output price index (q).[10] The output price index for coast sawmills aggregates the prices of rough and planed sawn lumber, pulp chips, and shingles and shakes while the interior sawmills price index aggregates the prices of rough and planed sawn lumber, and pulp chips.

The output price index for shingle mills indexes the prices of shakes and two types of shingles while the plywood mills' index aggregates the prices of softwood veneer, Douglas fir plywood and other types of plywood.

The total value of output is defined to be the net value of shipments (i.e., excluding discounts and returns) plus the value of

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10. Statistics Canada, Catalogue 35-204, and unpublished Statistics Canada data.

the change in inventories. Thus, the value of output equals the sum of value added, the cost of materials and supplies, and the cost of fuel and electricity. An implicit Fisher ideal index of the quantity of output (Q) is obtained by dividing total value of output by the output price index.

Alternative Wage

The best alternative wage of IWA members is defined to be the amount an average B.C. industrial worker would receive if they separated from their current employment. The alternative wage is a weighted average of: (i) what workers receive if they find other work immediately - the B.C. average weekly wage for the industrial composite; (ii) what workers receive if they suffer a spell of unemployment and qualify for unemployment insurance (UI) - the B.C. average weekly payment of UI; and (iii) what workers receive if they suffer a spell of unemployment and do not qualify for UI - nothing.[11]

The weight on average weekly industrial wage (w1) is the probability of working, which is defined to be B.C. employment divided by B.C. labour force. The weight on the UI payment (w2) is (1 - w1) times the probability of qualifying for UI. The probability of qualifying for UI is defined to be the number of weeks of UI paid in B.C. divided by the number of weeks of unemployment in B.C.[12] The weight

11. Industrial composite average weekly wage is published in Statistics Canada, Employment Earnings and Hours, Catalogue 72-002. The UI average weekly payment is reported in Statistics Canada, Statistical Report on the Operation of the Unemployment Insurance Act, Catalogue 73-001.

12. Employment, labour force and unemployment are reported in Statistics Canada, Historical Labour Force Statistics, Catalogue 71-201. Number of weeks of UI paid are reported in Statistics Canada, Catalogue 73-001.

on the no work, no UI state is (1 - w1 - w2), but it is multiplied by zero so it drops out. The best real alternative wage (A) is the alternative wage divided by the Canadian consumer price index.

Scaling the Data

There are two reasons for scaling the data. First, scaling is done to ensure that the estimated parameters are between one and minus one. This reason is important only if a non-linear optimization routine is used to estimate the parameters. Scaling the data to keep the estimated parameters in the unit simplex increases the probability that the optimizing routine will converge, and helps avoid problems of false convergence.

The second reason for scaling is to ensure that the data used to calculate parameter estimates, truly reflect the world. Many of the data are just index numbers which can be arbitrarily scaled up and down. Therefore scaling must be done so that profit is greater than or equal to zero for most observations, and each input's share of total cost is close to its true share.

Clearly a researcher must take a lexicographic approach and scale to satisfy the second reason first.

The scaling done to produce the final data set will not be reported here. However, with the scaling used, profit is greater than zero for most years with 1970, 1974, and 1975 being the worst years. Averaged over all observations, the share of capital is 0.15, the share of labour is 0.25, and the share of materials is 0.59.

The ITC review reports that costs of materials make up one-half to two-thirds of total cost, while the principal statistics of the industries show that the share of materials divided by the share of labour averages 2.44.[13] Therefore it seems that the scaling satisfies the very important second criterion.

Two Flaws in the Data

Small establishments are given special treatment by Statistics Canada. Specifically, small establishments include the cost of fuel and electricity with the cost of materials and supplies. Also, all principle statistics, except for number of working owners and partners, are classified to manufacturing activity. This presents no problem for sawmills and plywood mills since those industries are made up of large establishments. However, shingle mills tend to be smaller and the different conventions for small establishments may show up in the data. Unfortunately there is no way to either determine the seriousness of the problem, or adjust the data for the different convention.

The second flaw is missing data. The 1970 unpublished detailed data on the composition of shipments, materials, and energy are unavailable for B.C. plywood mills while the composition of materials and energy are unavailable for B.C. shingle mills. These data are necessary for the construction of the price indices.

For each missing piece of data the B.C. share of the Canadian total is calculated for 1969 and 1971. The shares are averaged and that average B.C. share, multiplied by the 1970 Canadian total,

13. Industry, Trade, and Commerce, Review of the Forest Products Industry, (1978), p. 9. Also, Statistics Canada, Catalogue 35-206 and 35-204, 1964-79.

yields the 1970 B.C. figure. The procedure is arbitrary. However, for many items, the B.C. totals for 1969 and 1971 are virtually 100% of the Canadian totals, so it is not unreasonable to assume the 1970 shares are almost 100% also.

Chapter 4

The Wood Products Technology

This chapter provides a characterization of the technology of the B.C. wood products industry assuming exogenous input prices and price taking behaviour in all input markets. The parameters of the technology are estimated independently from any union objective function parameters. Thus, the parameter estimates are equivalent to estimates which would be obtained if perfect competition in the input markets was assumed. Cost minimizing behaviour is assumed, and all adjustment costs are assumed to be such that equilibrium levels of inputs are achieved within one year - the time period of each observation in the data. Therefore, the industry is on its long run cost curve, and a cost function can be used to characterize the technology of the industry.

Define a cost function for the industry

$$C(r,m,w,Q) \equiv \min_{K,L,M} \{rK + mM + wL : (K,M,L,Q) \in T\} \tag{4.1}$$

where r,m, and w are prices of capital services, materials and labour; K,M,L, and Q are quantities of capital services, materials, labour and output; and T is the production possibilities set.[1] The production possibilities set is the set of all feasible inputs

1. The useful and convenient properties of the cost function are well documented and will not be discussed here. See, for example, Diewert (1974) and (1978a).

and outputs, and it is assumed to be well behaved.[2]

Two different functional forms are used to specify the cost function. Both cost functions are estimated and the results are reported below.

Translog Specification

Specify a translog cost function

$$\begin{aligned}
\ln C(r,m,w,Q) = {} & \alpha_0 + \alpha_1 \ln r + \alpha_2 \ln m + \alpha_3 \ln w \\
& + \tfrac{1}{2}\gamma_{11}(\ln r)^2 + \gamma_{12}\ln r \ln m + \gamma_{13}\ln r \ln w \\
& + \frac{1}{2}\gamma_{22}(\ln m)^2 + \gamma_{23}\ln m \ln w \qquad (4.2) \\
& + \frac{1}{2}\gamma_{33}(\ln w)^2 \\
& + \beta_1 \ln Q + \frac{1}{2}\beta_2(\ln Q)^2 + \beta_{11}\ln r \ln Q + \beta_{12}\ln m \ln Q + \beta_{13}\ln w \ln Q \\
& + \omega_1 \ln t + \omega_{11}\ln r \ln t + \omega_{12}\ln m \ln t + \omega_{13}\ln w \ln t
\end{aligned}$$

2. See Diewert (1974), p. 134 for a rigorous statement of the properties assigned to T when constant returns to scale is imposed. Generally T is assumed to be closed, bounded, and convex. There is also free disposal. Note that for the translog specification T is not assumed to be a cone, while the conditional cost function specification does assume that T is a cone.

where $$\alpha_1 + \alpha_2 + \alpha_3 = 1$$

$$\gamma_{11} + \gamma_{12} + \gamma_{13} = 0$$

$$\gamma_{12} + \gamma_{22} + \gamma_{23} = 0$$

$$\gamma_{13} + \gamma_{23} + \gamma_{33} = 0$$

$$\beta_{11} + \beta_{12} + \beta_{13} = 0$$

$$\omega_{11} + \omega_{12} + \omega_{13} = 0$$

and t is a trend variable. The translog cost function provides a second order approximation to an arbitrary cost function. Note that the cost function allows biased technical change and does not force the technology to be homothetic or exhibit constant returns to scale.

Shephard's lemma implies the following share equations

$$rK/C = s_K = \alpha_1 + \gamma_{11}\ln r + \gamma_{12}\ln m + \gamma_{13}\ln w + \beta_{11}\ln Q + \omega_{11}\ln t \quad (4.3)$$

$$mM/C = s_M = \alpha_2 + \gamma_{12}\ln r + \gamma_{22}\ln m + \gamma_{23}\ln w + \beta_{12}\ln Q + \omega_{12}\ln t \quad (4.4)$$

$$wL/C = s_L = \alpha_3 + \gamma_{13}\ln r + \gamma_{23}\ln m + \gamma_{33}\ln w + \beta_{13}\ln Q + \omega_{13}\ln t. \quad (4.5)$$

Since the shares sum to one, only two of the share equations can be included in a system of estimating equations. A maximum likelihood estimation technique should be used to estimate the parameters of the technology, so as to make the estimates invariant to the share equation dropped.

Stochastic error terms e_1, e_2, e_3, where $(e_1, e_2, e_3) \sim N(0,\Sigma)$, are added to equations 4.2, 4.4 and 4.5 respectively. Error terms corresponding to the same observation are allowed to be correlated with one another, while error terms corresponding to different observations are assumed to be independent of each other. Thus, the stochastic versions of 4.2, 4.4 and 4.5 form a seemingly unrelated regression system. Note however, that there is only very limited contemporaneous correlation, since the data is pooled cross section and time series, and not times series.

Dummy variables for observations on shingle mills and plywood mills are also added to equations 4.2, 4.4, and 4.5. This covariance approach to pooled cross-section and time series data accounts for unspecified, constant, across industry differences in the input shares. The estimates are asymptotically equivalent to estimates obtained from the error components approach. The stochastic versions of equations 4.2, 4.4, and 4.5 (with the dummy variables) are then estimated as a seemingly unrelated regression system using the iterative Zellner procedure. This procedure yields estimates asymptotically equivalent to maximum likelihood estimates. The estimated coefficients and their asymptotic t-statistics are reported in Table I. Table II shows the matrix of estimated price elasticities and other characteristics of the estimated technology, evaluated at the mean of the data. Letter subscripts on C represent partial derivatives of the cost function, where the arguments of the derivatives are omitted for convenience.

A number of hypothesis tests are performed on the estimated system using likelihood ratio tests. The hypotheses of no bias in technical change ($\omega_{11} = \omega_{12} = \omega_{13} = 0$), no technical change ($\omega_1 = \omega_{11} = \omega_{12} = \omega_{13} = 0$), and homotheticity of the production technology ($\beta_{11} = \beta_{12} = \beta_{13} = 0$) are all rejected easily, even at the 99.5% confidence level.[3]

The rejection of no bias in technical change means that Hicks' neutral technical change is rejected. The rejection of homotheticity means that a constant returns to scale specification of the production technology is also rejected.

Conditional Cost Function Specification

The technology of the B.C. wood products industry is re-estimated using a cost function derived from a conditional cost function suggested by Diewert (1974, p. 137). This unusual specification is used since the same conditional cost function is used to represent the production technology of the industry in the union models. Hence, one can observe the effects of letting the wage be endogenous and jointly estimating production and union preference parameters on the estimated production technology without the possibility that any differences are due to the use of different functional forms.

3. The restricted, maximized log likelihoods for each of the hypotheses are 459.04, 458.88 and 454.63, respectively.

TABLE I

Estimated Coefficients of the Translog Cost Function

Asymptotic t-statistics are in parentheses

α_0	0.5812	(3.995)
α_1	0.2559	(5.712)
α_2	0.3548	(9.335)
α_3	0.3893	(12.25)
γ_{11}	0.1359	(7.879)
γ_{12}	-0.1191	(-9.556)
γ_{13}	-0.0169	(-0.976)
γ_{22}	0.211	(15.091)
γ_{23}	-0.0191	(-12.0)
γ_{33}	0.1088	(5.042)
β_1	0.9072	(11.945)
β_2	0.0133	(0.5)
β_{11}	-0.0049	(-0.314)
β_{12}	0.0614	(4.828)
β_{13}	-0.0565	(-4.876)
ω_1	0.0543	(4.084)
ω_{11}	0.0254	(4.899)
ω_{12}	-0.0121	(-2.507)
ω_{13}	-0.0133	(-3.903)

Natural log of likelihood function = 470.07

TABLE II

Estimated Characteristics of the Technology: Translog Cost Function and Exogenous Wages

All estimates are evaluated at the mean of the data.

Monotonicity

$C_r = 3.38,\ C_m = 6.69,\ C_w = 3.72,\ C_Q = 4.1$

Curvature

The determinants of the minors of the hessian of the cost function are: 0.001, -0.014, 0.0.

Substitution

The matrix of price elasticities is

	r	m	w
K	0.0006	-0.133	0.132
M	-0.034	-0.046	0.080
L	0.097	0.228	-0.325

The elasticities of substitution are:

$$\sigma_{KL} = 0.606,\ \sigma_{ML} = 0.366,\ \sigma_{KM} = -0.213$$

Returns to Outlay

$$\partial \ln C/\partial \ln Q = 0.96$$

Therefore the elasticity of scale is 1.041 and there are increasing returns to outlay.

Technical Change

$$(\partial s_K/\partial t)(t/s_K) = 0.159$$

$$(\partial s_M/\partial t)(t/s_M) = -0.02$$

$$(\partial s_L/\partial t)(t/s_L) = -0.061$$

$$(\partial C/\partial t)(t/C) = 0.043$$

Assume the production possibilities set is a cone so that the production technology exhibits constant returns to scale. Define a conditional cost function[4]

$$D(r,m,L,Q) \equiv \min_{K,M} \{rK + mM : (K,M,L,Q) \in T\}, \qquad (4.6)$$

where $D(r,m,L,Q)$ is the minimum cost of materials and capital required to produce output Q, given a fixed labour input L, and input prices r and m.

McFadden (1978a, p. 61) notes that a conditional cost function is minus a variable profit function where the outputs and some of the inputs of the variable profit function are fixed. Therefore, adjusting for the sign change and letting output be a negative input, $D(r,m,L,Q)$ possesses the properties of variable profit functions outlined in Diewert (1974, p. 136). For our purposes we need only note that $D_L \leq 0$ and $D_{LL} \geq 0$.[5]

An ordinary cost function, possessing all the usual properties and characterizing the production possibilities set, can be defined:

$$C(r,m,w,Q) \equiv \min_{L} \{D(r,m,L,Q) + wL\}. \qquad (4.7)$$

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4. This type of cost function is also referred to as a restricted cost function, or joint cost function. For profit functions the names are conditional, restricted, or variable profit function.

5. Diewert (1974), p. 136 shows that a variable profit function is nonincreasing and concave in its fixed inputs. Since the cost function is minus the profit function and inputs are measured as negative numbers in Diewert, but as positive numbers here, D() is nonincreasing in L. Likewise, the cost function is convex in its fixed inputs, so $D_{LL} \geq 0$ whether labour is measured as a negative number or not. See Chapter 5 for a complete list of the properties of $D(r,m,L,Q)$.

The first order condition for the minimum is

$$D_L(r,m,L,Q) + w = 0 \qquad (4.8)$$

and the second order condition is satisfied since $D_{LL} > 0$. Let $L^*(r,m,w,Q)$ be the amount of labour which satisfies the first order condition (4.8) and, therefore, minimizes equation 4.7 with respect to L.

Hence,

$$C(r,m,w,Q) \equiv D(r,m,L^*(r,m,w,Q),Q) + wL^*(r,m,w,Q). \qquad (4.9)$$

The cost minimizing demand functions for capital and materials are derived by using Shephard's lemma on the cost function given by equation 4.9.

Therefore,

$$K^*(r,m,w,Q) = \partial C(r,m,w,Q)/\partial r = \partial D(r,m,L,Q)/\partial r\big|_{L=L^*} \qquad (4.10)$$

and

$$M^*(r,m,w,Q) = \partial C(r,m,w,Q)/\partial m = \partial D(r,m,L,Q)/\partial m\big|_{L=L^*} \qquad (4.11)$$

by the envelope theorem. The cost minimizing demand for labour function is given in implict form by equation 4.8.

Specify the conditional cost function to be

$$D(r,m,L,Q) = c_{11}rL + c_{12}rQ + c_{21}mL + c_{22}mQ + 2b_{12}(r + m + 2X)(LQ)^{\frac{1}{2}} + 2a_{12}XZ \tag{4.12}$$

where $X \equiv (\frac{1}{2} r^2 + \frac{1}{2} m^2)^{\frac{1}{2}}$ and $Z \equiv L + Q + 2(LQ)^{\frac{1}{2}}$. Note that equation 4.12 provides a second order approximation to an arbitrary conditional cost function given a constant returns to scale technology and no technical change.[6]

Equations 4.8, 4.10, 4.11, and 4.12 imply the following simultaneous system of cost minimizing input demand functions:

$$K = c_{11}L + c_{12}Q + 2b_{12}(LQ)^{\frac{1}{2}}(1 + r/X) + a_{12}rZ/X \tag{4.13}$$

$$M = c_{21}L + c_{22}Q + 2b_{12}(LQ)^{\frac{1}{2}}(1 + m/X) + a_{12}mZ/X \tag{4.14}$$

$$L^{-\frac{1}{2}} = -[w + c_{11}r + c_{21}m + 2a_{12}X][b_{12}(r + m + 2X)Q^{\frac{1}{2}} + 2a_{12}XQ^{\frac{1}{2}}]^{-1}. \tag{4.15}$$

Stochastic error terms e_1, e_2, e_3, where $(e_1,e_2,e_3) \sim N(0,\Sigma)$, are added on to equations 4.13, 4.14, and 4.15 respectively. The error structure is the same as the one specified for the translog cost function. Error terms corresponding to the same observation are allowed to be correlated with one another, while error terms corresponding to different observations are assumed to be independent of each other.

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6. Diewert (1974), p. 138.

TABLE III

Estimated Coefficients of the Conditional Cost Function

Asymptotic t-statistics are in parentheses

c_{11}	0.7090	(1.639)
c_{12}	1.0541	(7.825)
c_{21}	1.5352	(2.912)
c_{22}	1.1151	(11.198)
b_{12}	-0.8649	(-3.683)
a_{12}	0.4406	(3.956)

Natural log of likelihood function = 293.4247.

TABLE IV

Estimated Characteristics of the Technology:

Conditional Cost Function and Exogenous Wages

All estimates are evaluated at the mean of the data.

Monotonicity

$C_r = 3.13,\ C_m = 7.10,\ C_w = 3.50,\ C_Q = 4.32.$

Curvature

The determinants of the minors of the hessian of the cost function are: -0.235, -0.063, 0.0.

Substitution

The matrix of price elasticities is

	r	m	w
K	-0.1372	-0.2576	0.3948
M	-0.0665	0.0185	0.0479
L	0.2907	0.1368	-0.4274

The elasticities of substitution are:

$$\sigma_{KL} = 1.81,\ \sigma_{ML} = 0.219,\ \sigma_{KM} = -0.414$$

Dummy variables for observations on plywood mills and shingle mills are added on to each stochastic input demand equation to account for unspecified, constant, across industry differences in input demands. Full information maximum likelihood estimates of the parameters of the conditional cost function are obtained from the stochastic system of input demand functions. The estimates and their asymptotic t-statistics are reported in Table III.

Given the maximum likelihood estimates of the parameters of the conditional cost function, an estimate of the ordinary cost function is derived using equations 4.8 and 4.9. The ordinary cost function provides estimates of the characteristics of the production technology. The matrix of estimated price elasticities and other characteristics of the estimated technology, evaluated at the mean of the data, are reported in Table IV.

In the work shown above, input demand functions are estimated from pooled cross section and time series data. Implicit in the above is the assumption that the parameters of the technology are the same in all three industries after the adjustments made by the dummy variables. These pooling restrictions are tested and overwhelmingly rejected by a likelihood ratio test performed on the conditional cost function specification of the technology.

It should be noted that the error structure appended to equations 4.13, 4.14 and 4.15 is rather arbitrary. Adding error terms is usually justified by assuming some sort of optimization error. Assuming that observed levels of inputs are normally distributed around their optimal levels (as in equations 4.13 and 4.14) is generally accepted and intuitively reasonable. However, assuming that the inverse of the square root of the observed labour input is normally distributed around the inverse of the square root of the optimal labour input (as in equation 4.15) is not as well accepted or as intuitively reasonable. The very same argument applies to the dummy variables which enter linearly in the input demand equations.

The additive error structure and the linear specification for the dummy variables are used for convenience. However, it should be noted that the results are not too different from the ones obtained from the translog cost function specification, with its more conventional error structure. Hence, although it is unknown what results would be obtained with a different error structure, the rather arbitrary specification may not taint the estimates too strongly.

Discussion and Comparison of the Results with other Studies.[7]

Comparing the results reported above with the results of other studies of the Canadian manufacturing sector is difficult for a number of reasons.

First, other studies break inputs up into different sub-aggregates than the ones used above.[8] Second, the other studies use data on the whole Canadian manufacturing sector, while the results given above refer to only a small part of that sector. The other

7. Other studies of the Canadian manufacturing sector are: Denny and May (1977), Denny and May (1978), Fuss (1977), Kotowitz (1968), Tsurumi (1970) and Woodland (1975).

8. For example, Denny and May (1978) specify labour and capital to be inputs, but break each of the inputs into two sub-aggregates. They specify that output is a function of four inputs: production labour, non-production labour, structures, and equipment. Therefore, comparisons between their four input model and the three input model shown above are difficult.

studies also use data from an earlier time period than the one used here. Finally, capital serices is defined quite differently in this work than in other studies.[9] However, I believe it is worthwhile to report other estimates found in the literature.

Both of the estimated cost functions satisfy their monotonicity properties. This is also true in other studies of Canadian manufacturing. Unfortunately, the estimated cost functions do not satisfy the curvature property and are not concave with respect to input prices. However, the own and cross price elasticities of the input demand functions are very close to possessing the properties that concavity of the cost function imposes on them, so the cost functions cannot be too far from being concave. Woodland (1975) also finds that the cost function is not concave, but the price elasticities are not unreasonable. The cost functions of the other studies satisfy the curvature property.

The estimated own price elasticities of capital and materials are quite small. When one of the elasticities has the wrong sign it is very close to zero. Other studies find these elasticities to be somewhat higher. For example, Denny and May (1977) find estimated price elasticities of capital and materials of -1.1 and -0.5, while Fuss (1977) estimates them to be -0.7 and -0.358.

Capital and materials are complements with estimates of σ_{KM} between -0.2 and -0.5.[10] No other study corroborates this result For

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9. See Chapter 3 for details of the definition of capital services.

10. The ranges given here are very rough and are intended only to give the general character of the results.

example, Denny and May (1977) estimate σ_{KM} to be 1.8. Fuss (1977), however, finds that energy and materials are complements and capital, in this study, is defined to include energy.

Capital and labour are substitutes. Unfortunately, the estimates of σ_{KL} are quite far apart, so $0.5 \leq \sigma_{KL} \leq 2$ is the narrowest estimated range that can be given for the elasticity of substitution between capital and labour. This rather wide range extends quite far above the upper limit found in the literature. For example, Tsurumi (1970), Fuss (1977), and Woodland (1975) estimate σ_{KL} to be 1.0, 0.8 and 0.295 respectively while Kotowitz (1968) gives an estimated range of $0.3 \leq \sigma_{KL} \leq 0.5$. On the other hand, Denny and May (1977) estimate σ_{KL} to be between -0.3 and -0.53 and claim that this strikingly different result occurs because they do not use a value added framework. This study does not use a value added framework either, but finds that capital and labour are substitutes and not complements.

Labour and materials are substitutes with σ_{LM} estimated to be between 0.2 and 0.4. Both Fuss (1977) and Denny and May (1977) also find labour and materials to be substitutes, but Denny and May (1977) report a much higher estimated elasticity of substitution of 1.2.

The own price elasticity of the demand for labour is estimated to be between -0.3 and -0.5. This is slightly bigger than the -0.15 reported in Hamermesh's (1976) influential study. Woodland (1975) also estimates a smaller elasticity (-0.0996), while Fuss (1977) and Denny and May (1977) report estimated elasticities of -0.49 and -0.74 respectively. Therefore, the price elasticity reported here is not inconsistent with other estimates found in the literature.

Homotheticity of the production technology is rejected with the translog cost function and increasing returns to outlay are found. The elasticity of scale is estimated to be 1.041. Most other studies impose constant returns to scale, but Woodland (1975) also rejects homotheticity and finds increasing returns to outlay.

Finally, both the hypotheses of no technical change and Hicks' neutral technical change are rejected. Technical change is labour and materials saving and capital using. Further, the estimate of the elasticity of costs with respect to time is 0.043, so the net result of time is negative technical change. Negative technical change is not too surprising since Woodland (1975) also reports negative technical change. Pearce (1980, p. 10) states:

> "Technical innovations, stimulated by the declining size and quality of timber available, have stimulated the conversion of mills to high volume, small log processing systems which have enabled the Interior [B.C. sawmilling] industry to achieve higher levels of wood utilization and greatly improved labour productivity."

The coast region has also suffered from declining size and quality of wood stocks. Hence, it seems that although the declining size and quality of materials available has sparked materials and labour saving, and capital using technical change; the ultimate effect of the deterioration of the wood stocks is to increase costs over time.

Chapter 5

Union Models: Cost Minimization

In this chapter two different models of wage and employment determination in a unionized industry are derived, specified and estimated. The estimated parameters of the models provide estimates of the preferences of the union and show how estimates of the production technology can change when the wage is endogenous to the model and production and union preference parameters are estimated jointly within a specific model of union and firm behavior.

In order to facilitate the analysis, the following assumptions are made.

A1. All divergent preferences and goals held by different groups within the union can be accommodated and expressed by a single union objective function.

A2. The union has organized and bargains for all workers in the industry and is secure. The union has a union shop so all workers are union members, and no union member worries about being replaced by a nonunion worker.

A3. The industry's cost function is independent of the union's behaviour. Hence the union cannot enforce job restrictions which in turn affect the industry's demand for labour.

A4. The firms in the industry and the union operate in a static world. Union preferences are atemporal and any adjustment costs incurred by the union or the industry are such that equilibrium is achieved within one observation (one year). Further, the labour contract does not impose any dynamic constraints on either party.

A5. Both the union and the firms in the industry have perfect information.

A6. The industry is a price taker in the markets for capital services and materials, and it minimizes the costs of those inputs subject to an exogenous output constraint.

A7. The production possibilities set is a cone, so the technology exhibits constant returns to scale. The production possibilities set also satisfies the other properties (closed, bounded, non-empty, convex, free disposal) given in Diewert (1974, p. 134).

The reasonableness of some of the assumptions has been discussed elsewhere. Chapter two surveys the literature on the reasonableness of specifying a simple objective function to represent the preferences of a union which is not homogeneous and which is run according to a political system. Chapter three discusses the reasonableness of assuming price taking behavior in the materials market given the concentrated, vertically integrated industrial structure of the B.C. wood products industry.

Assumption A4 should also be discussed. The well established importance of "catch up" in empirical studies of wage determination provides strong evidence that multi-year collective agreements do impose dynamic constraints on firms and unions. There would be no problem if the IWA and the forest products industry negotiated only one year collective agreements, since each contract would cover only one observation. Table V reports the collective agreements negotiated in the coast and interior regions over the period of interest and shows that the contracts are definitely not renegotiated for every observation (year).[1] Most of the contracts have two year durations, so a single contract determines the conditions of employment for more than one observation.

No dynamic constraints from multi-year contracts could be rationalized by assuming that both the union and the industry have perfect foresight. In that case the conditions of employment for the second and third years of the collective agreement are exactly the same as what they would be if the union and the industry could renegotiate the terms in that second or third year.

Clearly, assumption A4 is a very strong and restrictive assumption which is maintained only because it keeps the analysis tractable. Unfortunately, the effects (if any) of this assumption on the estimates presented below are unknown.

The conditional cost function

$$D(r,m,L,Q) \equiv \min_{K,M} \{rK + mM : (K,M,L,Q) \in T\}, \tag{5.1}$$

described in chapter 4 and dual to the constant returns to scale technology, is used to characterize the production technology. As noted in chapter 4, a conditional cost function possesses all the properties of minus a variable profit function where all outputs and some inputs are fixed.[2]

1. The interior region is the southern interior region. No information is provided for the northern interior region since it has only recently been formed into a single bargaining unit, and since it is very small compared to the sourthern interior and coast regions.

2. See McFadden (1978a), p. 68, and remember that outputs are negative inputs and vice-versa.

TABLE V

Collective Agreements for the Coast and Interior Regions

Coast

June 15	1962	to	June 14	1964
"	1964	to	"	1966
"	1966	to	"	1968
"	1968	to	"	1970
"	1970	to	"	1972
"	1972	to	"	1974
"	1974	to	"	1975
"	1975	to	"	1977
"	1977	to	"	1979
"	1979	to	"	1981

Interior

September 1	1962	to	August 31	1964
September 1	1964	to	August 31	1967
September 1	1967	to	June 30	1970
July 1	1970	to	June 30	1972
"	1972	to	"	1974
"	1974	to	"	1975
"	1975	to	"	1977
"	1977	to	"	1979
"	1979	to	"	1981

Therefore, as shown by Diewert (1974, p. 136), $D(r,m,L,Q)$ possesses the following properties.

(i) $D(r,m,L,Q)$ is a non-negative function for $r,m > 0$, $L,Q \geq 0$ but both L and Q cannot equal zero.

(ii) $D(r,m,L,Q)$ is homogeneous of degree one in r and m. This property is imposed by the functional form used.

(iii) $D(r,m,L,Q)$ is concave and continuous in r and m.

(iv) $D(r,m,L,Q)$ is homogeneous of degree one in L and Q.

(v) $D(r,m,L,Q)$ is non-increasing in L ($D_L \leq 0$) and non-decreasing in Q ($D_Q \geq 0$).

(vi) $D(r,m,L,Q)$ is convex and continuous in L and Q, which implies $D_{LL} \geq 0$.

Finally it is proved in the appendix to this chapter that:

(vii) $D(r,m,L,Q)$ is non-decreasing in r and m.

A functional form suggested by Diewert (1974, p. 137) is used to specify $D(r,m,L,Q)$:

$$D(r,m,L,Q) = c_{11}rL + c_{12}rQ + c_{21}mL + c_{22}mQ$$

$$+ 2b_{12}(r + m + 2X)(LQ)^{\frac{1}{2}} + 2a_{12}XZ, \qquad (5.2)$$

where $X \equiv (\frac{1}{2} r^2 + \frac{1}{2} m^2)^{\frac{1}{2}}$ and $Z \equiv L + Q + 2(LQ)^{\frac{1}{2}}$. As noted in Chapter 4, this functional form provides a second order approximation to an arbitrary conditional cost function, given the conditions on the technology and no technical change.

Total expenditures made by the industry for inputs (E), given input prices, output and the labour input, are

$$E(r,m,w,L,Q) \equiv wL + D(r,m,L,Q), \qquad (5.3)$$

where wL is total compensation paid to labour, and w is total compensation paid to labour divided by the total amount of labour employed; i.e., the average compensation paid to a unit of labour. Iso-expenditure curves in compensation-employment space are shown in Figure 3 by the family of curves EE, and are defined by

$$wL = pB = E - D(r,m,L,Q) \qquad (5.4)$$

where E is a constant and p is the Canadian consumer price index. Clearly,

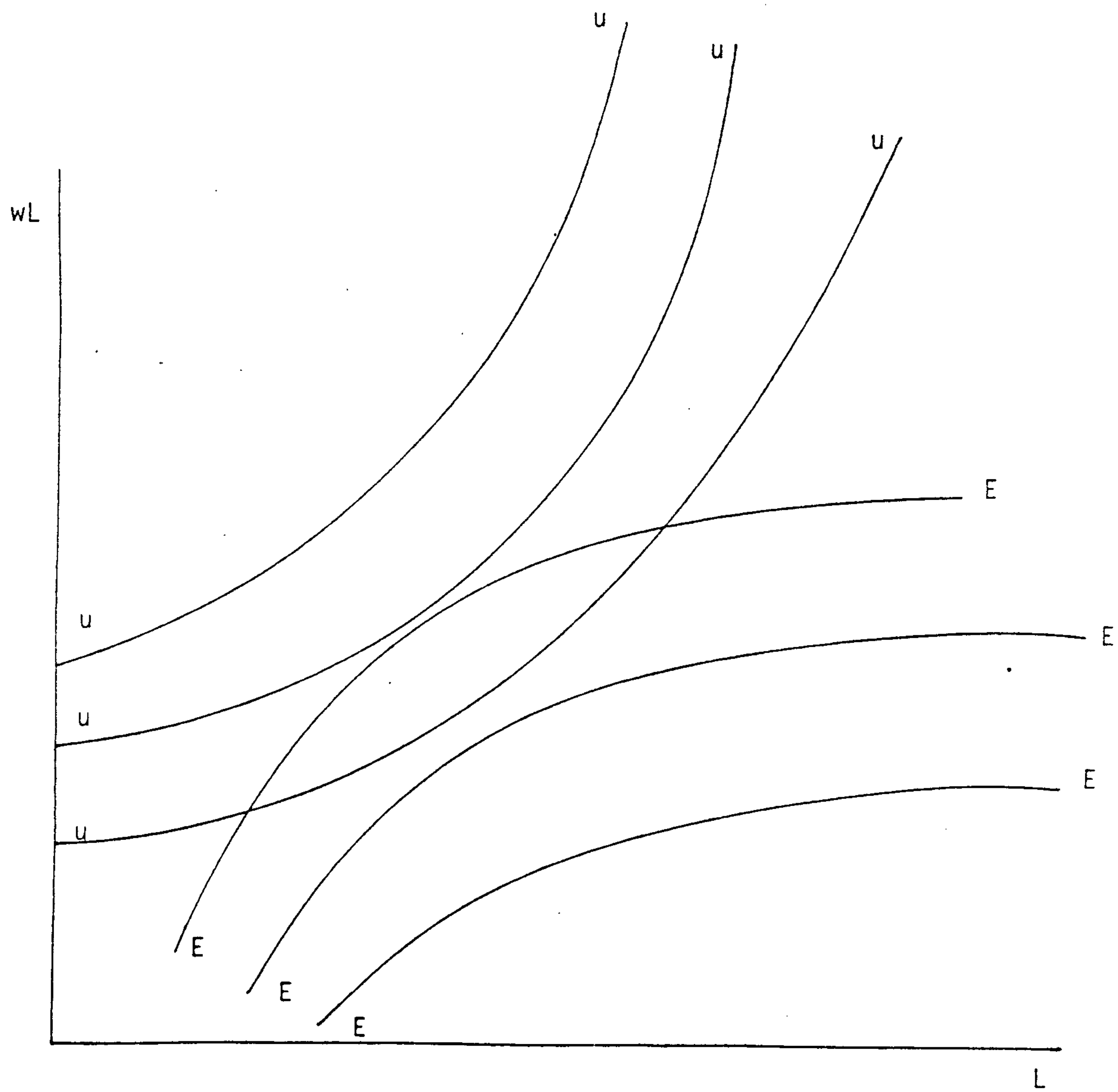
$$\partial(wL)/\partial L = -D_L \geq 0, \text{ and}$$

$$\partial^2(wL)/\partial L^2 = - D_{LL} \leq 0,$$

so the iso-expenditure curves are increasing and concave functions of employment. Note that the slope of the iso-expenditure curve is independent of wL, implying that the iso-expenditure curves are parallel from below.

Assume union preferences are defined over total real compensation paid to labour (B, B = wL/p where p is the Canadian consumer price index), and the amount of labour employed (L). Assume union preferences are conditional upon the best real alternative wage available to labour (A). The best real alternative wage available to

FIGURE 3



labour is also the real opportunity cost of working in a union job, and it is assumed to be the same for all workers.

Let union preferences be characterized by the function U(B,L;A) where $U_B > 0$, $U_L < 0$, and U(B,L;A) is quasiconcave in real compensation and labour. Thus, the marginal rate of substitution between real compensation and labour is an increasing function of labour and the union requires ever increasing increases in real compensation to compensate it for one more man-hour of work. Typical union indifference curves, given the alternative wage and the price level, are shown in nominal compensation-employment space by the curves uu in Figure 3. A possible rationalization for the quasiconcavity assumption is that the union incurs increasing real costs in providing union services as the number of man-hours worked increases. Another is that the supply of labour curve is upward sloping and ever increasing rates of real compensation are required for more labour to be supplied.

Specify,

$$U(B,L;A) = u_1B + u_2L + \frac{1}{2}u_{11}B^2 + u_{12}BL + u_{13}BA + \frac{1}{2}u_{22}L^2 + u_{23}LA. \tag{5.5}$$

The average real rate of compensation (w/p) is defined to be B/L. Therefore we can define

$$\phi(w/p,L;A) \equiv U(wL/p,L;A) = U(B,L;A) \tag{5.6}$$

where $\phi_{w/p} > 0$ and $\phi_L > 0$ if $w/p > -U_L/U_B$,

$$\phi_L < 0 \text{ if } w/p < -U_L/U_B.$$

Monopoly Union Model

In the monopoly union model (MUM) the union chooses the average nominal rate of compensation paid to each worker unilaterally, in order to maximize U(B,L;A). The industry then chooses the cost minimizing level of employment given by its demand for labour function and the union wage. Hence the union chooses the wage which maximizes U(B,L;A) subject to the industry's demand for labour function. This model conforms to the conventional wisdom about wage and employment determination in a unionized industry. Unions affect wages, but firms choose the level of employment unilaterally, subject to the negotiated wage.

The industry's demand for labour function is given by the solution to the minimization problem

$$\underset{L}{\text{Min}} \ \{E(r,m,w,L,Q)\} = \underset{L}{\text{Min}} \ \{wL + D(r,m,L,Q)\}. \quad (5.7)$$

The first order condition is

$$w + D_L(r,m,L,Q) = 0 \quad (5.8)$$

which is also the industry's demand for labour function written in implicit form. The second order condition is satisfied since $D_{LL} > 0$. Multiply equation 5.8 by L/p and substitute the product (the union's constraint) into the union's objective function. The union's maximization problem can then be written

$$\operatorname*{Max}_{L} \{U(-LD_L/p, L; A)\}$$

which yields the first order condition

$$\partial U/\partial L = U_B(-D_L - LD_{LL})/p + U_L = 0$$

$$\rightarrow D_L + LD_{LL} = pU_L/U_B. \qquad (5.9)$$

The second order condition of the union's maximization problem involves the third derivative of the conditional cost function, so the usual curvature properties of U(B,L;A) and D(r,m,L,Q) are not enough to ensure a maximum. However, the third derivative of the functional form used to specify D(r,m,L,Q) (equation 5.2), is such that the second order condition is always satisfied. See the appendix to this chapter for the details on the second order condition.

Equations 5.8 and 5.9 define the compensation-employment solution to the monopoly model. Point 'm' in Figure 4 shows this solution in nominal compensation-employment space. EE are iso-expenditure curves, uu are union indifference curves (given the alternative wage and the price level), D is the demand for labour curve and oa is the compensation function whose slope equals the nominal wage. Firms choose employment to minimize expenditure subject to oa and the union chooses oa to maximize its objective function.

Cost minimizing input demand functions for capital and materials can be derived from the conditional cost function as they were in chapter 4. Define an ordinary cost function, which is also dual to the technology,

$$C(r,m,w,Q) \equiv \underset{L}{\text{Min}} \{wL + D(r,m,L,Q)\} = wL^*(r,m,w,Q)$$
$$+ D(r,m,L^*(r,m,w,Q),Q) \qquad (5.10)$$

where $L^*(r,m,w,Q)$ is the solution to equation 5.8. Shepard's lemma, applied to equation 5.10, implies

$$K^*(r,m,w,Q) = \partial C(r,m,w,Q)/\partial r = \partial D(r,m,L,Q)/\partial r\Big|_{L=L^*} \qquad (5.11)$$

and

$$M^*(r,m,w,Q) = \partial C(r,m,w,Q)/\partial m = \partial D(r,m,L,Q)/\partial m\Big|_{L=L^*} \qquad (5.12)$$

by the envelope theorem.

Equations 5.2, 5.5, 5.8, 5.9, 5.11, 5.12 imply the following nonlinear system of equations:

$$K = c_{11}L + c_{12}Q + 2b_{12}(LQ)^{\frac{1}{2}}(1 + r/X) + a_{12}rZ/X \qquad (5.13a)$$

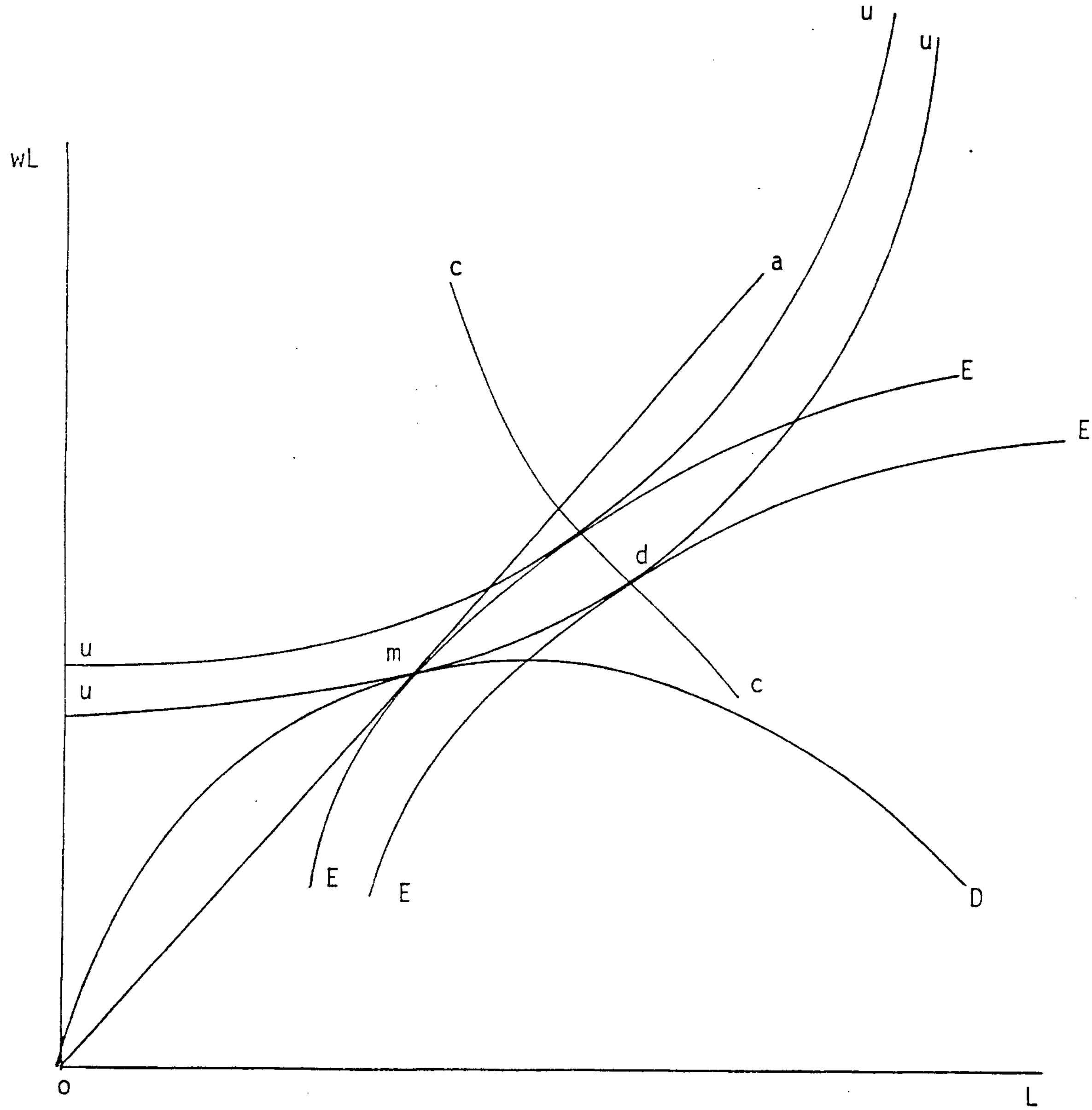
$$M = c_{21}L + c_{22}Q + 2b_{12}(LQ)^{\frac{1}{2}}(1 + m/X) + a_{12}mZ/X \qquad (5.13b)$$

$$-w = c_{11}r + c_{21}m + b_{12}(Q/L)^{\frac{1}{2}}(r + m + 2X) + 2a_{12}X(1 + (Q/L)^{\frac{1}{2}}) \qquad (5.13c)$$

$$L^{-\frac{1}{2}} = [-c_{11}r - c_{21}m - 2a_{12}X + p(u_2 + u_{22}L + u_{12}B + u_{23}A) \qquad (5.13d)$$

$$(u_1 + u_{11}B + u_{12}L + u_{13}A)^{-1}][\frac{1}{2}\, b_{12}Q^{\frac{1}{2}}(r + m + 2X) + a_{12}XQ^{\frac{1}{2}}]^{-1}.$$

FIGURE 4



Equations 5.13a and b are the cost minimizing input demand functions given by 5.11 and 5.12. Equation 5.13c is the inverse demand for labour function given by 5.8 and 5.13d is the first order condition of the union's maximization problem given by 5.9. There are four endogenous variables: K, M, w, and L.

Normally distributed error terms are added onto equations 5.13 and the identifying restriction, $u_1 = 1$, is imposed on union preferences. Error terms corresponding to the same observation are allowed to be correlated with one another, while error terms corresponding to different observations are assumed to be independent of one another. This means that the error terms appended to equations 5.13 are correlated with one another only for a given time and industry. There is no correlation across time or across industries.

Unfortunately, numerical problems prevented the estimation of the complete system of equations (5.13), so the restriction $u_{11} = u_{13} = 0$ is imposed on union preferences. Full information maximum likelihood (FIML) estimates of the parameters of the restricted system are obtained and reported (with their asymptotic t-statistics) in Table VI.

In order to adjust for constant, across industry differences in equations 5.13, the complete system is re-estimated with dummy variables for observations on plywood mills and shingle mills added on to each equation. The FIML estimates, and their asymptotic t-statistics are also reported in Table VI.

Characteristics of the estimated union preferences and production technology, evaluated at the sample means, are reported in Table VII. Table VIII reports the estimated characteristics when the dummy variables are included in equations 5.13. Letter subscripts on U and

TABLE VI

Estimated Coefficients of the Monopoly Union Model

Asymptotic t-statistics are in parentheses

	No Dummy Variables		Dummy Variables for Observations on Shingle Mills and Plywood Mills	
c_{11}	-0.2319	(-3.657)	-0.0482	(-0.729)
c_{12}	0.6963	(23.567)	0.6368	(25.040)
c_{21}	0.0329	(0.709)	0.0393	(1.031)
c_{22}	0.9336	(21.361)	0.9675	(29.072)
b_{12}	-0.2378	(-11.181)	-0.2527	(-11,788)
a_{12}	0.1328	(3.860)	0.1365	(4.884)
u_1	1.0		1.0	
u_2	-0.1297	(-1.69)	-0.1921	(-1.860)
u_{11}	0.0		-0.0040	(-1.069)
u_{12}	-0.0124	(2.098)	0.0160	(2.583)
u_{13}	0.0		-0.4449	(-50.419)
u_{22}	-0.0012	(-0.062)	-0.0542	(-4.099)
u_{23}	-0.3368	(-6.436)	0.0856	(1.897)
Natural log of likelihood function		352.804		424.618
Correlation Coefficients between actual and predicted values of K,M,w, and $L^{-\frac{1}{2}}$		0.93,0.99, 0.96,0.99		0.93,0.99, 0.96,0.99

TABLE VII

Estimated Characteristics of Union Preferences and Production Technology: Monopoly Union Model and No Dummy Variables

All estimates are evaluated at the mean of the data

Union Preferences

Monotonicity

$U_B = 0.957$, $U_L = -0.844$, $U_A = -1.163$, $\phi_{w/p} = 3.305$, $\phi_L = 1.201$

Curvature

Determinant of bordered hessian of the union's objective function = 0.021.

$MRS_{BL} = 0.882$, $MRS_{w/p\ L} = 0.363$, $\sigma_{w/p\ L} = 0.768$.

Production Technology

Monotonicity

$C_r = 3.130$, $C_m = 6.762$, $C_w = 4.010$, $C_Q = 4.325$

Curvature

Determinants of minors of the hessian of the cost function are: -0.879, -0.172, 0.0

The matrix of price elasticities is

	r	m	w
K	-0.514	-0.746	1.260
M	-0.193	-0.175	0.368
L	0.928	1.049	-1.977

The elasticities of substitution are:

$\sigma_{KL} = 5.78$, $\sigma_{ML} = 1.68$, $\sigma_{KM} = -1.20$

TABLE VIII

Estimated Characteristics of Union Preferences and Production Technology: Monopoly Union Model with Dummy Variables

All estimates are evaluated at the mean of the data

Union Preferences

Monotonicity

$U_B = 0.208$, $U_L = -0.105$, $U_A = -2.959$, $\phi_{w/p} = 0.718$, $\phi_L = 0.341$

Curvature

Determinant of bordered hessian of the union's objective function = 0.0017

$MRS_{BL} = 0.503$, $MRS_{w/p\ L} = 0.489$, $\sigma_{w/p\ L} = 0.737$.

Production Technology

Monotonicity

$C_r = 3.242$, $C_m = 6.982$, $C_w = 3.618$, $C_Q = 4.327$

Curvature

Determinants of minors of the hessian of the cost function are: -0.399, -0.118, 0.0

The matrix of price elasticities is

	r	m	w
K	-0.233	-0.568	0.801
M	-0.147	-0.198	0.345
L	0.590	0.983	-1.573

The elasticities of substitution are:

$\sigma_{KL} = 3.68$, $\sigma_{ML} = 1.58$, $\sigma_{KM} = -0.91$

C represent partial derivatives of the union objective function and the industry cost function respectively.

A number of hypothesis tests are performed on the estimated systems using likelihood ratio tests. The restricted and unrestricted maximized values of the log likelihood function are reported in Table IX.

The hypothesis that the union maximizes the wage bill ($u_2 = u_{11} = u_{12} = u_{13} = u_{22} = u_{23} = 0$) and the hypothesis that the union maximizes rents ($u_2 = u_{11} = u_{12} = u_{13} = u_{22} = 0$, $u_1 = -u_{23}$) are both rejected, even at the 99.5% confidence level. The hypothesis that the union's objective function is independent of the alternative wage ($u_{13} = u_{23} = 0$) is also rejected at the 99.5% confidence level. The same results are obtained from the unrestricted system when the dummy variables are included in the estimating equations.

The hypothesis that the union maximizes some function of the wage, and is indifferent to the level of employment ($\phi_L = 0$) cannot be tested directly. However the estimated standard error of the estimate of ϕ_L is 0.0785 in the restricted model without dummy variables and 0.0274 in the unrestricted model with dummy variables. Since the two estimates of ϕ_L are 1.201 and 0.341 respectively, it is clear that $\phi_L = 0$ is overwhelmingly rejected in both models.

It is very interesting to compare the estimates of the production technology from the monopoly union model with the estimates obtained in chapter four, where all input prices are assumed to be exogenous and production parameters are not estimated jointly with any union preference parameters. The union model shows much larger (in absolute value) price elasticities and elasticities of substitution. Hence, the union model suggests much greater substitutability

TABLE IX

Maximized Values of the Log Likelihoods of the Union Models: Constant Returns to Scale

	Monopoly Union Model		Cooperative Union Model	
	No Dummy Variables $u_{11}=u_{13}=0$	Dummy Variables	No Dummy Variables	Dummy Variables
Unrestricted	352.804	424.618	395.357	436.435
Wage bill maximization hypothesis	266.213	351.682	296.294	375.199
Rent maximization hypothesis	260.439	307.385	309.193	389.333
Union preferences independent of the alternative wage hypothesis	336.245	408.967	380.627	434.991
$u_{11} = u_{13} = 0$			372.048	

between the factors of production and greater responsiveness to price changes than the model which is consistent with perfect competition in all input markets.

The most striking difference is in the estimate of the price elasticity of the demand for labour function. The translog cost function, the conditional cost function estimated in chapter 4, and almost all of the estimates found in the literature, show the price elasticity of the demand for labour to be smaller than 0.5 (in absolute value). In the monopoly union model, however, the estimated elasticity jumps to an absolute value greater than 1.5. Other evidence of this phenomenon is found in the literature. Dertouzos and Pencavel (1981) also find that a monopoly union model yields a very high estimate of the elasticity of the demand for labour. They report a negative estimated elasticity ranging from 1.8 to 1.0, with a value of 1.23 at the means of the variables.

Therefore it seems that estimates of production technology are very sensitive to the explicit modeling of union behavior in the labour market. If the MUM has any validity (compared to the assumption of perfect competition in the labour market) then the estimates of price elasticities and elasticities of substitution found in the literature should be seriously questioned. In Canada, most manufacturing industries are organized by unions which have a significant impact on the industries' labour market. Estimates of the Canadian manufacturing sector's technology could be very different from the ones found in the literature if the unions' behavior had been modelled and wages were assumed to be endogenous. This seems to be especially true for the price elasticity of the demand for labour, which is so important for policy applications.

Cooperative Union Model

In the cooperative union model (CUM) the industry and union use some unspecified means to choose a compensation-employment combination which lies on the contract curve. It is important to realize that the compensation-employment solution to the model is not on the firm's demand for labour function. The firm employs more labour than it would like to, given the negotiated wage. Clearly, the two sides must bargain about more than just the average rate of compensation (the wage) to force the firm off its demand for labour function. The union and firm could use many different mechanisms to reach a point on the contract curve. For example, they could negotiate work rules which tie the amount of labour employed to output or the use of some other input. Another alternative is to negotiate compensation rules which are not homogeneous of degree one in the amount of labour employed (see Chapter 7). Assume, for the sake of exposition, that the union and firm bargain directly about the level of wages and the level of employment. Note that this assumption is completely innocuous and does not affect the estimating equations. The estimating equations simply specify a point on the contract curve. How the point on the contract curve is reached or supported is not specified.

The industry's expenditure on inputs is given by

$$E(r,m,w,L,Q) = wL + D(r,m,L,Q) \tag{5.3}$$

and an iso-expenditure curve can be written

$$wL = pB = E - D(r,m,L,Q) \tag{5.4}$$

where E is a constant.

By substituting the constraint (equation 5.4) into the union's objective function U(B,L;A), the maximization problem which characterizes this model can be written

$$\max_{L} \{U(E/p - D(r,m,L,Q)/p, L; A)\}.$$

The first order condition is

$$\partial U/\partial L = -U_B D_L/p + U_L = 0$$

$$\rightarrow \qquad D_L = pU_L/U_B. \qquad (5.14)$$

The curvature properties of D(r,m,L,Q) and U(B,L;A) ensure that the second order condition is satisfied. See the appendix to this chapter for the details on the second order condition.

Equations 5.4 and 5.14 define the compensation-employment solution to the CUM. Point "d" in Figure 4 is a possible solution to the cooperative model in nominal compensation-employment space, where cc is the contract curve.

It is important to note that the CUM is not completely specified. The bargaining mechanism used by the two parties to choose the industry's level of expenditure and the union's level of utility is left unspecified. The model does not predict where on the contract curve the solution will be; it only predicts that the solution will be on the contract curve. The union and industry simply choose the observed level of expenditure and no account is given to the determinants of that level of expenditure.

Cost minimizing demands for capital and materials, conditional upon output and the labour input chosen with the union, are derived by applying Shepard's lemma to the conditional cost function:

$$K^*(r,m,L,Q) = \partial D(r,m,L,Q)/\partial r \qquad (5.15)$$

and

$$M^*(r,m,L,Q) = \partial D(r,m,L,Q)/\partial m. \qquad (5.16)$$

Equations 5.2, 5.5, 5.4, 5.14, 5.15, and 5.16 imply the following nonlinear simultaneous system of equations:

$$K = c_{11}L + c_{12}Q + 2b_{12}(LQ)^{\frac{1}{2}}(1 + r/X) + a_{12}rZ/X \qquad (5.17a)$$

$$M = c_{21}L + c_{22}Q + 2b_{12}(LQ)^{\frac{1}{2}}(1 + m/X) + a_{12}mZ/X \qquad (5.17b)$$

$$-w = -E/L + c_{11}r + c_{12}rQ/L + c_{21}m + c_{22}mQ/L + 2b_{12}(r + m + 2X)(Q/L)^{\frac{1}{2}} + 2a_{12}X(1 + Q/L + 2(Q/L)^{\frac{1}{2}}) \qquad (5.17c)$$

$$L^{-\frac{1}{2}} = [-c_{11}r - c_{21}m - 2a_{12}X + (u_2 + u_{22}L + u_{12}B + u_{23}A) p(u_1 + u_{11}B + u_{12}L + u_{13}A)^{-1}][b_{12}Q^{\frac{1}{2}}(r + m + 2X) + 2a_{12}XQ^{\frac{1}{2}}]^{-1}. \qquad (5.17d)$$

TABLE X

Estimated Coefficients of the Cooperative Union Model

Asymptotic t-statistics are in parentheses

	No Dummy Variables		Dummy Variables for Observations on Shingle Mills and Plywood Mills	
c_{11}	0.3847	(1.647)	0.2069	(1.604)
c_{12}	0.6444	(10.645)	0.5991	(10.706)
c_{21}	0.4800	(2.494)	0.3027	(2.769)
c_{22}	0.9465	(13.563)	0.9079	(22.260)
b_{12}	-0.3938	(-3.489)	-0.3005	(-4.139)
a_{12}	0.2123	(3.431)	0.1682	(3.681)
u_1	1.0		1.0	
u_2	-0.4616	(-2.989)	-0.3513	(-2.125)
u_{11}	0.0648	(2.632)	0.0514	(1.822)
u_{12}	-0.0924	(-2.053)	-0.0879	(-1.487)
u_{13}	-0.4660	(-24.458)	-0.3520	(-4.447)
u_{22}	0.0947	(1.472)	0.0781	(0.865)
u_{23}	0.2474	(3.799)	0.1735	(2.709)
Natural log of likelihood function	395.357		436.435	
Correlation Coefficients between actual and predicted values of K,M,w, and $L^{-\frac{1}{2}}$	0.93,0.99, 0.92,0.99		0.93,0.99, 0.92,0.99	

TABLE XI

Estimated Characteristics of Union Preferences and Production Technology: Cooperative Union Model and No Dummy Variables

All estimates are evaluated at the mean of the data

Union Preferences

Monotonicity

$U_B = 0.299$, $U_L = -0.356$, $U_A = -2.554$, $\phi_{w/p} = 1.046$, $\phi_L = 0.286$

Curvature

Determinant of bordered hessian of the union's objective function = 0.003

$MRS_{BL} = 1.192$, $MRS_{w/p\ L} = 0.273$, $\sigma_{w/p\ L} = 0.599$

Production Technology

Monotonicity

$D_r = 3.424$, $D_m = 7.047$, $D_Q = 4.032$, $D_L = -1.714$, $D_{LL} = 0.796$

Curvature

Determinants of minors of the hessian of the conditional cost function are: 0.179, 0.0

The matrix of price elasticities is

	r	m K
K	0.105	-0.105
M	-0.027	0.027

$\sigma_{KM} = -0.16$

TABLE XII

Estimated Characteristics of Union Preferences and Production Technology: Cooperative Union Model with Dummy Variables

All estimates are evaluated at the mean of the data

Union Preferences

Monotonicity

$U_B = 0.425$, $U_L = -0.406$, $U_A = -1.976$, $\phi_{w/p} = 1.481$, $\phi_L = 0.505$

Curvature

Determinant of bordered hessian of the union's objective function = 0.008

$MRS_{BL} = 0.955$, $MRS_{w/p\ L} = 0.341$, $\sigma_{w/p\ L} = 0.675$.

Production Technology

Monotonicity

$D_r = 3.444$, $D_m = 7.129$, $D_Q = 4.031$, $D_L = -1.615$ $D_{LL} = 0.598$

Curvature

Determinants of minors of the hessian of the cost function are: 0.177, 0.0

The matrix of price elasticities is

	r	m
K	0.104	-0.104
M	-0.027	0.027

$\sigma_{KM} = -0.16$

Equations 5.17a and b are the cost minimizing, conditional, input demand functions given by 5.15 and 5.16. Equation 5.17c is the iso-expenditure curve (5.4) chosen by the industry and union, divided by the amount of labour employed and 5.17d is the first order condition (5.14) to the maximization problem. There are four endogenous variables; K,M, w, and L.

Normally distributed error terms which are correlated when they correspond to the same observation and independent when they correspond to different observations are added onto equations 5.17 and an identifying restriction, $u_1 = 1$ is imposed on union preferences. FIML estimates of the parameters of the system are reported, along with their t-statistics, in Table X. The system is re-estimated with dummy variables for shingle mills and plywood mills added on to each equation and the parameter estimates are also reported in Table X.

Characteristics of the estimated union preferences and production technology, with and without dummy variables and evaluated at the sample means, are reported in Tables XI and XII. It is clear that the dummy variables do not affect the estimates of the characteristics very much, even though the hypothesis that the dummy variables have zero coefficients cannot be accepted.

The wage bill and rent maximization hypotheses about union preferences are overwhelmingly rejected, both with and without dummy variables, using likelihood ratio tests (see Table IX). The hypothesis that union preferences are independent of the alternative wage is also overwhelmingly rejected in the model without dummy variables, but it can only be rejected at the 75% confidence level in the model with dummy variables.

The estimated values and standard errors of ϕ_L are 0.286 and 0.059 without the dummy variables and 0.505 and 0.162 with the dummy variables, so the hypothesis that the union is indifferent to the level of employment is also rejected in both cases.

Finally, the hypothesis that the technology is Leontief ($\sigma_{MK} = 0$, $b_{12} = a_{12} = 0$) is tested in a slightly modified version of the CUM. The restricted maximized value of the log likelihood function is 278.478. The log likelihood of the unrestricted model reached 312.3, although the maximum value was not found. Therefore, in spite of a very low estimate of σ_{MK}, Leontief technology is rejected decisively.

The wrong signs on the estimated price elasticities are due to the strong restrictions economic theory and the functional form place on the production technology in the CUM. Although there are three inputs, the labour input is determined by some mechanism outside the model, so the industry has only two variable inputs; capital and materials. Economic theory insists that with only two inputs, the inputs must be substitutes and the cross price elasticities must be positive. Economic theory also insists that the own price elasticities must be negative. It turns out that, consistent with economic theory, the functional form forces the cross price elasticity to have the opposite sign from the own price elasticity in the two input case. In fact, as can be seen from the estimates, the functional form forces the cross price elasticities to be exactly equal to minus the own price elasticities. Unfortunately, all the work reported above indicates that capital and materials are complements and not substitutes. That fact is corroborated once again by the negative cross price elasticities shown in Tables XI and XII. Given the functional form, the negative cross price elasticities imply positive own price elasticities and the matrix of price elasticities has all the wrong signs. It seems clear that the two input production technology specified in the CUM is just not rich enough to accommodate the complementarity of capital and materials found in the data, and very questionable estimates result.

Non Constant Returns to Scale

Since the work in Chapter 4 shows that constant returns to scale is not an acceptable characterization of the production technology, the MUM and CUM are re-estimated using a conditional cost function which does not constrain the technology to constant returns to scale. The MUM and CUM remain exactly as they are shown above. Only the specification of $D(r,m,L,Q)$ changes. $D(r,m,L,Q)$ retains all of the properties outlined above except homogeneity of degree one in Q and L. The new specification of $D(r,m,L,Q)$ still ensures that the second order conditions of the union models are satisfied.

By using the same general functional form (Diewert, 1974, p. 137) and adding one more fixed input which is constant and defined equal to minus one, one can specify

$$D(r,m,L,Q) = c_{11}rL + c_{12}rQ + c_{13}r + c_{21}mL + c_{22}mQ + c_{23}m$$

$$+ 2[b_{12}(LQ)^{\frac{1}{2}} + b_{13}L^{\frac{1}{2}} + b_{23}Q^{\frac{1}{2}}][r + m + 2X] + 2a_{12}XZ \tag{5.18}$$

where $X \equiv (\frac{1}{2} r^2 + \frac{1}{2} m^2)^{\frac{1}{2}}$ and $Z \equiv 1 + L + Q + 2((LQ)^{\frac{1}{2}} + L^{\frac{1}{2}} + Q^{\frac{1}{2}})$.

In the MUM equations, 5.5, 5.8, 5.9, 5.11, 5.12, and 5.18 imply the following simultaneous system of equations:

$$K = c_{13} + c_{11}L + c_{12}Q +$$

$$2[b_{12}(LQ)^{\frac{1}{2}} + b_{13}L^{\frac{1}{2}} + b_{23}Q^{\frac{1}{2}}][1 + r/X] + a_{12}rZ/X \qquad (5.19a)$$

$$M = c_{23} + c_{21}L + c_{22}Q +$$

$$2[b_{12}(LQ)^{\frac{1}{2}} + b_{13}L^{\frac{1}{2}} + b_{23}Q^{\frac{1}{2}}][1 + m/X] + a_{12}mZ/X \qquad (5.19b)$$

$$-w = c_{11}r + c_{21}m + [b_{12}(Q/L)^{\frac{1}{2}} + b_{13}L^{-\frac{1}{2}}][r + m + 2X] \qquad (5.19c)$$

$$+ 2a_{12}X(1 + L^{-\frac{1}{2}} + (Q/L)^{\frac{1}{2}})$$

$$L^{-\frac{1}{2}} = [-c_{11}r - c_{21}m - 2a_{12}X +$$

$$p(u_2 + u_{22}L + u_{12}B + u_{23}A)(u_1 + u_{12}L + u_{11}B + u_{13}A)^{-1}]$$

$$[\frac{1}{2}(b_{12}Q^{\frac{1}{2}} + b_{13})(r + m + 2X) + a_{12}X(1 + Q^{\frac{1}{2}})]^{-1}. \qquad (5.19d)$$

In the CUM equations 5.5, 5.4, 5.14, 5.15, 5.16, and 5.18 imply the following simultanous equations system:

$$K = c_{13} + c_{11}L + c_{12}Q +$$

$$2[b_{12}(LQ)^{\frac{1}{2}} + b_{13}L^{\frac{1}{2}} + b_{23}Q^{\frac{1}{2}}][1 + r/X] + a_{12}rZ/X \qquad (5.20a)$$

$$M = c_{23} + c_{21}L + c_{22}Q +$$

$$2[b_{12}(LQ)^{\frac{1}{2}} + b_{13}L^{\frac{1}{2}} + b_{23}Q^{\frac{1}{2}}][1 + m/X] + a_{12}mZ/X] \qquad (5.20b)$$

$$-w = -E/L + c_{11}r + c_{12}rQ/L + c_{13}r/L + c_{21}m + c_{22}mQ/L$$

$$+ c_{23}m/L + 2[b_{12}(Q/L)^{\frac{1}{2}} + b_{13}L^{-\frac{1}{2}} + b_{23}Q^{\frac{1}{2}}L^{-1}]$$

$$[r + m + 2X] + 2a_{12}XZ/L \qquad (5.20c)$$

$$L^{-\frac{1}{2}} = [-c_{11}r - c_{21}m - 2a_{12}X + p(u_2 + u_{22}L + u_{12}B + u_{23}A)$$

$$(u_1 + u_{12}L + u_{13}A + u_{11}B)^{-1}]$$

$$[(b_{12}Q^{\frac{1}{2}} + b_{13})(r + m + 2X) + 2a_{12}X(1 + Q^{\frac{1}{2}})]^{-1}. \qquad (5.20d)$$

Normally distributed errors and dummy variables for observations on shingle and plywood mills are added on to each equation in the two systems and the identifying restriction $u_1 = 1$ is imposed. The error structure specified for the constant returns to scale models is used again here. Errors corresponding to the same observation are correlated while errors corresponding to different observations are independent. Unfortunately numerical problems prevented the estimation of the CUM (equations 5.20) so the restriction $u_{11} = u_{13} = 0$ is imposed on union preferences in the CUM.

The FIML estimates of the parameters and their asymptotic t-statistics are reported in Table XIII. The characteristics of the estimated union preferences and production technology are reported in Tables XIV and XV. The results of hypothesis tests performed on the CUM and MUM are reported in Table XVI. The wage bill and rent maximization hypotheses, as well as the hypothesis that union preferences are independent of the alternative wage, are all overwhelmingly rejected in both the CUM and MUM. The estimated standard errors of the estimates of ϕ_L are 0.026 in the MUM and 0.37 in the CUM. Since the two estimates of ϕ_L are 0.369 and -1.0 respectively, the hypothesis that ϕ_L equals zero can be rejected in both models at the 99% confidence level.

Allowing the technology to exhibit non-constant returns to scale affects the magnitudes of many of the estimated characteristics but changes few of the qualitative results. On the production side labour is still estimated to be a substitute for capital services and materials, and capital services and materials are still estimated to be complements. In the MUM however, non-constant returns to scale decreases both the estimated substitutability between capital services and labour and the estimated complementarity between capital services and materials. The estimated elasticities of the demand for labour function and the demand for capital services function are also much lower. In the CUM, specifying non-constant returns to scale increases the estimated complementarity of capital services and materials slightly.

On the union side, the monotonicity and quasiconcavity properties of the union objective function, in real compensation-employment space, are maintained in both non-constant returns to scale models. In the CUM, the average real wage is less than the estimated average

TABLE XIII

Estimated Coefficients: Non-Constant Returns to Scale

With Dummy Variables

Asymptotic t-statistics are in parentheses

	Monopoly Union Model		Cooperative Union Model	
c_{11}	0.201	(2.187)	0.1385	(0.433)
c_{12}	0.8349	(12.679)	1.2147	(8.468)
c_{13}	-2.4014	(-1.638)	0.2971	(2.390)
c_{21}	0.1051	(1.461)	1.4534	(3.480)
c_{22}	1.0054	(16.957)	1.2054	(13.440)
c_{23}	1.2816	(0.778)	-0.8227	(-4.817)
b_{12}	-0.2889	(-9.970)	-0.7819	(-4.724)
b_{13}	-0.0836	(-3.118)	-0.2914	(-3.086)
b_{23}	-0.1279	(-0.596)	0.0489	(1.376)
a_{12}	0.1383	(3.016)	0.3046	(4.628)
u_1	1.0		1.0	
u_2	0.0848	(0.628)	-1.0218	(-2.797)
u_{11}	-0.0065	(-3.101)	0.0	
u_{12}	0.0193	(4.518)	-0.0806	(-9.647)
u_{13}	-0.4505	(-102.05)	0.0	
u_{22}	-0.0571	(-4.812)	0.2402	(2.529)
u_{23}	-0.0381	(-0.629)	-0.9576	(-3.658)
Natural log of likelihood function	454.701		450.939	
Correlation Coefficients between actual and predicted values of K,M,w, and $L^{-\frac{1}{2}}$	0.95,0.99, 0.95,0.99		0.94,0.99, 0.91,0.99	

TABLE XIV

Estimated Characteristics of Union Preferences and Production Technology: Monopoly Union Model with Non-Constant Returns to Scale and Dummy Variables

All estimates are evaluated at the mean of the data

Union Preferences

Monotonicity

$U_B = 0.192$, $U_L = -0.041$, $U_A = -3.427$, $\phi_{w/p} = 0.66$, $\phi_L = 0.369$

Curvature

Determinant of bordered hessian of the union's objective function = 0.0018.

$MRS_{BL} = 0.215$, $MRS_{w/p\ L} = 0.559$, $\sigma_{w/p\ L} = 0.773$.

Production Technology

Monotonicity

$C_r = 2.122$, $C_m = 7.363$, $C_w = 3.619$, $C_Q = 4.401$

Curvature

Determinants of minors of the hessian of the cost function are: -0.108, -0.103, 0.0

The matrix of price elasticities is

	r	m	w
K	-0.063	-0.423	0.487
M	-0.109	-0.219	0.328
L	0.358	0.937	-1.295

The elasticities of substitution are:

$\sigma_{KL} = 2.23$, $\sigma_{ML} = 1.51$, $\sigma_{KM} = -0.68$

TABLE XV

Estimated Characteristics of Union Preferences and Production Technology: Cooperative Union Model with Non-Constant Returns to Scale and Dummy Variables

All estimates are evaluated at the mean of the data

Union Preferences

Monotonicity

U_B=0.722, U_L=-2.542, U_A=-3.307, $\phi_{w/p}$=2.492, ϕ_L=-1.005

Curvature

Determinant of bordered hessian of the union's objective function = 0.171

MRS_{BL} = 3.522, $MRS_{w/p\ L}$ = -0.403, $\sigma_{w/p\ L}$ = 0.401.

Production Technology

Monotonicity

D_r = 3.32, D_m = 7.25, D_Q = 5.05, D_L = -5.47, D_{LL} = 1.87

Curvature

Determinants of minors of the hessian of the conditional cost function are: 0.27, 0.0

The matrix of price elasticities is

	r	m
K	0.158	-0.158
M	-0.041	0.041

σ_{KM} = -0.25

TABLE XVI

Maximized Values of the Log Likelihoods of the Union Models: Non-Constant Returns to Scale with Dummy Variables

	Monopoly Union Model	Cooperative Union Model $u_{11} = u_{13} = 0$
Unrestricted	454.701	450.939
Wage bill maximization hypothesis	410.902	407.863
Rent maximization hypothesis	314.757	417.987
Union preferences independent of the alternative wage hypothesis	431.554	443.022
$u_{11} = u_{13} = 0$	432.436	

marginal rate of substitution between labour and real compensation, so the estimate of ϕ_L is less than zero. As noted above, this result cannot be rejected at the 99% confidence level and it means that the estimated marginal rate of substitution between real wages and employment is negative. It also means that the estimate of the elasticity of substitution between real wages and employment is difficult to interpret. In the MUM, the estimated union objective function is still increasing in real wages and employment and the estimated marginal rate of substitution is slightly higher than the constant returns to scale estimates. The estimated elasticity of substitution between real wages and employment is unaffected, in the MUM, by non-constant returns to scale in the production technology.

Summary

The estimates shown above satisfy almost all the restrictions placed upon the union's preferences and the production technology. Given the model, these results provide detailed answers to questions about the IWA's preferences and the production technology in the period studied.

The estimates of the objective function used to characterize the IWA's preferences are increasing in total real compensation, decreasing in man-hours of work, decreasing in the real alternative wage, and quasiconcave in real compensation and hours. When written as a function of the real wage and man-hours of work the estimated union objective function is generally increasing in both the real wage and man-hours. The estimated elasticity of substitution between real wages and man-hours ranges between 0.6 and 0.8, with the estimates in the CUM slightly lower than the estimates in the MUM.

Real wage bill maximization and real rent maximization by the IWA are both rejected as is the hypothesis that the IWA maximizes only the real wage and is indifferent to the level of employment. Further, the IWA's estimated objective function is not independent of the real alternative wage as it is specified.

The results for the IWA are surprisingly close to the results Dertouzos and Pencavel (1981) report for the ITU in the Cincinnati local. The ITU's estimated objective function is also increasing in the real wage and labour input, decreasing in the alternative wage, and the estimated elasticity of substitution between real wages and employment is 0.69. Further, the real wage bill maximization and rent maximization hypotheses are rejected for the ITU, and the ITU is not indifferent to the level of employment.

The IWA's estimated marginal rate of substitution between real wages and man-hours employed is about 0.4 in the MUM and 0.3 in the CUM. This low value is the reason why the elasticity of the demand for labour is so high in the MUM. Given the scaling of the variables, a marginal rate of substitution of 0.4 means that the union is indifferent between a decrease in employment of one worker (2000 hours) and a 0.032¢ increase in the real hourly wage. Put another way, the union is indifferent to one less worker (for a whole year) or a $64.00 increase in the real gross annual pay of all the remaining employees. The corresponding elasticity is estimated to be about -1.5, so the union is indifferent between a 1% rise in real wages and a 1.5% decrease in employment.

The estimates of the production technology show that capital and materials are complements while all other pairs of inputs are substitutes. In both models, the estimated cost functions satisfy their monotonicity properties, but are not concave with respect to input prices. Unfortunately, the technology specified for the CUM is not rich enough to accommodate the complementarity of capital services and materials, so the estimated matrix of input price elasticities has all the wrong signs. In the MUM, all the estimated input demand functions slope down and they are much more elastic than those estimated in chapter four. For example, the elasticity of the demand for labour function is estimated to be about -0.4 in chapter four while the estimates from the MUM range between -1.3 and -2.0. Hence, the union is on an elastic part of the demand for labour curve in the MUM. The elasticities of substitution estimated in the MUM are also much larger (in absolute value) than those estimated in chapter four. Thus, it is observed that the estimates of the production technology are very sensitive to the explicit modelling of union behavior. The estimates of the technology in the MUM are also sensitive to whether or not constant returns to scale is imposed on the technology.

Finally, as noted in Chapter 4, the specification of the error structure and the dummy variables is rather arbitrary. The specification was chosen for its simplicity in an already messy system of equations, and not for any beliefs about errors or across industry differences in the estimating equations.

Appendix to Chapter 5

Proof that D(r,m,L,Q) is Non-decreasing in r and m

For r,m, ≥ 0 and L,Q ≥ 0 but both L and Q cannot be zero, let $r^1 \geq r^0$.

$$\begin{aligned}
D(r^1,m,L,Q) &\equiv \min_{K,M} \{r^1K + mM : (K,M,L,Q) \in T\} \\
&= r^1K^* + mM^* \quad \text{where } K^* \text{ and } M^* \text{ are the solutions to the minimization problem} \\
&\geq r^0K^* + mM^* \\
&\geq \min_{K,M} \{r^0K + mM : (K,M,L,Q) \in T\} \\
&\equiv D(r^0,m,L,Q)
\end{aligned}$$

Therefore $\quad D(r^1,m,L,Q) \geq D(r^0,m,L,Q)$

The same proof can be used to show D(r,m,L,Q) is non-decreasing in m, and D(r,m,L,Q) is non-decreasing when both r and m increase.

Marginal Rate of Substitution of the Union Objective Function

The union objective function is U(B,L;A), where $U_L < 0$, and $U_B > 0$. Define $B \equiv Z(L)$ such that $U(Z(L),L;A) \equiv U^0$. Differentiate the union objective function and obtain:

$$U_B(\partial Z(L)/\partial L) + U_L = 0$$

$$\rightarrow \partial Z(L)/\partial L = \partial B/\partial L\big|_{U^0} = -U_L/U_B.$$

Therefore,

$$MRS_{BL} = \partial B/\partial L\big|_{U^0} = -U_L/U_B \tag{A5.1}$$

Second Order Condition for the Maximization Problem in the Monopoly Union Model

The maximization problem in the monopoly union model is:

$$\max_{w,L} \{U(B,L;A) : w = -D_L(r,m,L,Q)\} \tag{A5.2}$$

which, by substituting the constraint into the objective function (noting that $B = wL/p$), can be rewritten as:

$$\max_{L} \{U(-LD_L(r,m,L,Q)/p,\ L;A)\}. \tag{A5.3}$$

The first order condition is

$$\partial U/\partial L = U_B[-D_L - LD_{LL}]/p + U_L = 0 \tag{A5.4}$$

$$\rightarrow \qquad (D_L + LD_{LL})/p = U_L/U_B \tag{A5.5}$$

The second derivative of A5.3 is

$$\partial^2 U/\partial L^2 = -[D_L + LD_{LL}][U_{BB}(\partial B/\partial L) + U_{BL}]/p -$$

$$U_B[2D_{LL} + LD_{LLL}]/p + U_{LB}(\partial B/\partial L) + U_{LL} \tag{A5.6}$$

The second order condition (A5.6) must be evaluated at a point where both the first order condition A5.5 and the constraint ($w = -D_L$) are satisfied. The constraint implies

$$wL/p = B = -LD_L/p$$

$$\rightarrow \quad \partial B/\partial L = (-D_L - LD_{LL})/p$$

$$\rightarrow \quad \partial B/\partial L = -U_L/U_B = (-D_L - LD_{LL})/p. \qquad \text{(A5.7)}$$

by the first order condition. Substitute A5.7 into A5.6 and obtain

$$\partial^2 U/\partial L^2 = -(U_L/U_B)[-U_{BB}(U_L/U_B) + U_{BL}] - U_B[2D_{LL} + LD_{LLL}]/p -$$

$$U_{LB}(U_L/U_B) + U_{LL}$$

$$= [U_{BB}U_L^2 - 2U_{BL}U_LU_B + U_{LL}U_B^2]U_B^{-2} + U_B[-2D_{LL} - LD_{LLL}]/p$$

$$= U_B^{-2}[-H + U_B^3[-2D_{LL} - LD_{LLL}]/p]$$

where H is the determinant of the bordered hessian of the union's objective function.

It is assumed that $p > 0$, $U_B > 0$ and $H > 0$ since $U(B,L;A)$ is quasiconcave in B and L. Therefore, a sufficient condition for the second order condition to be satisfied ($\partial U^2/\partial L^2 < 0$) is

$$-2D_{LL} - LD_{LLL} < 0$$

$$\rightarrow \quad 2D_{LL} > - LD_{LLL} \qquad \text{(A5.8)}$$

Repeating equation 5.2:

$$D(r,m,L,Q) = c_{11}rL + c_{12}rQ + c_{21}mL + c_{22}mQ$$

$$+ 2b_{12}(r + m + 2X)(LQ)^{\frac{1}{2}} + 2a_{12}XZ \qquad (A5.9)$$

where $X \equiv (\frac{1}{2} r^2 + \frac{1}{2} m^2)^{\frac{1}{2}}$ and $Z \equiv L + Q + 2(LQ)^{\frac{1}{2}}$.

Clearly,

$$D_L = c_{11}r + c_{21}m + b_{12}(r + m + 2X)(Q/L)^{\frac{1}{2}} + 2a_{12}X(1 + (Q/L)^{\frac{1}{2}})$$

$$\rightarrow \; D_{LL} = -[\frac{1}{2} b_{12}Q^{\frac{1}{2}}(r + m + 2X) + a_{12}XQ^{\frac{1}{2}}]L^{-3/2}$$

$$\rightarrow \; D_{LLL} = [(3/4)b_{12}Q^{\frac{1}{2}}(r + m + 2X) + (3/2)a_{12}XQ^{\frac{1}{2}}]L^{-5/2}$$

$$\rightarrow \; LD_{LLL} = [(3/4)b_{12}Q^{\frac{1}{2}}(r + m + 2X) + (3/2)a_{12}XQ^{\frac{1}{2}}]L^{-3/2}$$

Therefore,

$$-LD_{LLL} = (3/2)D_{LL} < 2D_{LL},$$

since $D_{LL} > 0$, equation (A5.8) is satisfied, and the second order condition of the maximization is satisfied.

Second Order Condition for the Maximization Problem in the Cooperative Union Model

The maximization problem in the cooperative union model is:

$$\max_{w,L} \{U(B,L;A) : B = E/p - D(r,m,L,Q)/p\},$$

which, by substituting the constraint into U(B,L;A), can be rewritten as:

$$\max_{L} \{U(E/p - D(r,m,L,Q)/p,\ L;A)\}. \qquad \text{(A5.10)}$$

The first order condition is:

$$\partial U/\partial L = -U_B D_L/p + U_L = 0 \qquad \text{(A5.11)}$$

$$\rightarrow D_L/p = U_L/U_B.$$

The second derivative of A5.10 is

$$\partial^2 U/\partial L^2 = -D_L[U_{BB}(\partial B/\partial L) + U_{BL}]/p - D_{LL}U_B/p + U_{LB}(\partial B/\partial L) + U_{LL}$$

(A5.12)

The constraint (B = E/p - D(r,m,L,Q)/p) and the first order condition imply

$$\partial B/\partial L = -D_L/p = -U_L/U_B,$$

which when substituted into A5.12 yields

$$\partial^2 U/\partial L^2 = -(U_L/U_B)[-U_{BB}(U_L/U_B) + U_{BL}] - U_B D_{LL}/p - U_{LB}(U_L/U_B) + U_{LL}$$

$$= U_B^{-2}[U_{BB}U_L^2 - 2U_{LB}U_L U_B + U_{LL}U_B^2 - U_B^3 D_{LL}/p]$$

$$= U_B^{-2}[-H - U_B^3 D_{LL}/p] < 0$$

where H is the determinant of the bordered hessian of the union objective function, $p > 0$, $U_B > 0$ $D_{LL} > 0$ and $H > 0$ by assumption. Therefore the second order condition of the maximization problem is satisfied.

Chapter 6

Union Models: Profit Maximization

All the union models presented in Chapter 5 assume that the firms in the industry minimize variable costs subject to some exogenously given output constraint. It is somewhat naive to assume that the level of output is independent of the union's actions, the wage, the labour input, and the prices of capital and materials. Hence the MUM and CUM are re-estimated in this chapter assuming that the industry is a price taker in the markets for output, capital and materials; and that the industry chooses output, capital, and materials to maximize variable profit.

Assumptions A1 to A5 are still assumed to be true. The production technology is assumed to be well behaved (closed, bounded, nonempty, convex, free disposal; see Diewert (1974, p.134)) but decreasing returns to outlay are assumed so that the industry's profit function exists in the MUM.

Define a variable profit function

$$V(q,r,m,L) \equiv \max_{Q,K,M} \{qQ - rK - mM : (K,M,L,Q) \in T\} \tag{6.1}$$

where q is the price of output and all the other notation is the same as in the earlier chapters. $V(q,r,m,L)$ is the maximum possible revenue minus variable costs, given technology and input and output prices, when the labour input is given exogenously to the industry. Diewert (1974, p. 136) shows that variable profit functions possess the following properties.

(i) $V(q,r,m,L)$ is a non-negative function for $q,r,m, > 0$ and $L > 0$.

(ii) $V(q,r,m,L)$ is homogenous of degree one in q,r, and m.

(iii) $V(q,r,m,L)$ is convex and continuous in q,r, and m.

(iv) $V(q,r,m,L)$ is non-decreasing in L ($V_L > 0$). Recall that the input L is not defined as a negative value here.

(v) $V(q,r,m,L)$ is concave and continuous in L, which implies $V_{LL} < 0$.

Moreover it can be shown that $V(q,r,m,L)$ is non-decreasing in q and non-increasing in r and m. The proof is exactly analogous to the proof that $D(r,m,L,Q)$ is non-decreasing in r and m shown in the appendix to Chapter 5, so it will not be repeated here. Notice that $V(q,r,m,L)$ is not homogeneous of degree one in L since constant returns to scale is not imposed on the technology.

A functional form suggested by Diewert (1974, p. 137) is used to specify $V(q,r,m,L)$:

$$
\begin{aligned}
V(q,r,m,L) = {} & c_{12}q + c_{22}r + c_{32}m + c_{11}qL + c_{21}rL + c_{31}mL \\
& + 2(a_{12}X + a_{13}Y + a_{23}Z)(1 + L + 2L^{\frac{1}{2}}) \\
& + 2b_{12}L^{\frac{1}{2}}(q + r + m + 2X + 2Y + 2Z) \qquad (6.2)
\end{aligned}
$$

where $X \equiv (\frac{1}{2}q^2 + \frac{1}{2}r^2)^{\frac{1}{2}}$, $Y \equiv (\frac{1}{2}q^2 + \frac{1}{2}m^2)^{\frac{1}{2}}$, $Z \equiv (\frac{1}{2}r^2 + \frac{1}{2}m^2)^{\frac{1}{2}}$ and a constant fixed input, defined equal to minus one, is included to impose decreasing returns to outlay on the technology dual to 6.2. Note that equation 6.2 provides a second order approximation to an arbitrary variable profit function.

Define a function, $G(q,r,m,w,L)$, which is equal to total profit and is a function of input and output prices and the amount of labour employed,

$$G(q,r,m,w,L) \equiv V(q,r,m,L) - wL. \tag{6.3}$$

Iso-profit curves in compensation-employment space can be written

$$pB = wL = V(q,r,m,L) - G, \tag{6.4}$$

where G is a constant,

$$\partial(wL)/\partial L = V_L > 0,$$

and

$$\partial^2(wL)/\partial L^2 = V_{LL} < 0.$$

Union preferences are exactly the same as they are in Chapter 5.

Monopoly Union Model

This model is the very same as the MUM shown in Chapter 5, except now the industry chooses Q,K,M, and L to maximize profits rather than choosing K,M, and L to minimize costs subject to a given level of output.

The industry's demand for labour function is the solution to the maximization problem

$$\max_L \{G(q,r,m,w,L)\} = \max_L \{V(q,r,m,L) - wL\}.$$

The first order condition is

$$V_L(q,r,m,L) - w = 0 \tag{6.5}$$

which is also the industry's profit maximizing demand for labour function written in implicit form. The second order condition is satisfied since $V_{LL} < 0$.

The union's maximization problem in the MUM is

$$\max_L \{U(LV_L/p,L;A)\} \tag{6.7}$$

since the constraint implies $wL/p = LV_L/p = B$. The first order condition to the maximization problem is

$$\partial U/\partial L = U_B[V_L + LV_{LL}]/p + U_L = 0$$

$$\rightarrow \qquad V_L + LV_{LL} = -pU_L/U_B. \tag{6.8}$$

The second order condition involves the third derivative of the variable profit function, so the usual curvature properties of U(B,L;A) and V(q,r,m,L) are not enough to guarantee a maximum. Fortunately the third derivative of equation 6.2, the functional form used to specify V(q,r,m,L), is such that the second order condition is always satisfied. See the appendix to this chapter for the details on the second order condition.

Equations 6.8 and 6.5 define the compensation-employment solution to the MUM. The profit maximizing supply function and input demand functions can be derived from the variable profit function. Define an ordinary profit function possessing all the usual properties and dual to the technology

$$\Pi(q,r,m,w) \equiv \underset{L}{\text{Max}} \{V(q,r,m,L) - wL\}$$

$$= V(q,r,m,L^*(q,r,m,w)) - wL^*(q,r,m,w) \qquad (6.9)$$

where $L^*(q,r,m,w)$ is the solution to equation 6.5.

Hotelling's lemma applied to equation 6.9 implies

$$Q^*(q,r,m,w) = \partial\Pi(q,r,m,w)/\partial q = \partial V(q,r,m,L)/\partial q\big|_{L=L^*}, \qquad (6.10)$$

$$K^*(q,r,m,w) = -\partial\Pi(q,r,m,w)/\partial r = -\partial V(q,r,m,L)/\partial r\big|_{L=L^*}, \qquad (6.11)$$

and

$$M^*(q,r,m,w) = -\partial\Pi(q,r,m,w)/\partial m = -\partial V(q,r,m,L)/\partial m\big|_{L=L^*} \qquad (6.12)$$

by the envelope theorem.

Equations 5.5, 6.2, 6.5, 6.8, 6.10, 6.11, and 6.12 imply the following simultaneous system of equations:

$$Q = c_{12} + c_{11}L + q(a_{12}/X + a_{13}/Y)(1 + L + 2L^{\frac{1}{2}})$$

$$+ 2b_{12}L^{\frac{1}{2}}(1 + q/X + q/Y) \tag{6.13a}$$

$$-K = c_{22} + c_{21}L + r(a_{12}/X + a_{23}/Z)(1 + L + 2L^{\frac{1}{2}})$$

$$+ 2b_{12}L^{\frac{1}{2}}(1 + r/X + r/Z) \tag{6.13b}$$

$$-M = c_{32} + c_{31}L + m(a_{13}/Y + a_{23}/Z)(1 + L + 2L^{\frac{1}{2}})$$

$$+ 2b_{12}L^{\frac{1}{2}}(1 + m/Y + m/Z) \tag{6.13c}$$

$$w = c_{11}q + c_{21}r + c_{31}m + 2(a_{12}X + a_{13}Y + a_{23}Z)(1 + L^{-\frac{1}{2}})$$

$$+ b_{12}L^{-\frac{1}{2}}(q + r + m + 2X + 2Y + 2Z) \tag{6.13d}$$

$$-L^{-\frac{1}{2}} = [c_{11}q + c_{21}r + c_{31}m + 2(a_{12}X + a_{13}Y + a_{23}Z) +$$

$$p(u_2 + u_{22}L + u_{23}A + u_{12}B)(u_1 + u_{11}B + u_{12}L + u_{13}A)^{-1}]$$

$$[a_{12}X + a_{13}Y + a_{23}Z + \frac{1}{2}b_{12}(q + r + m + 2X + 2Y + 2Z)]^{-1}. \tag{6.13e}$$

Equation 6.13a is the supply curve for output given by 6.10. Equations 6.13b and c are the profit maximizing input demand functions given by 6.11 and 6.12. Equation 6.13d is the inverse demand for labour function given by 6.5 while equation 6.13e is the first

TABLE XVII

Estimated Coefficients of the Monopoly and Cooperative Union Models: Profit Maximization

Asymptotic t-statistics are in parentheses

	Monopoly Union Model		Cooperative Union Model	
c_{12}	7.3087	(12.280)	-1.1262	(-1.721)
c_{22}	-5.3727	(-9.693)	0.9812	(4.975)
c_{32}	-5.8537	(-8.677)	-0.6706	(-2.736)
c_{11}	0.0805	(0.387)	2.6610	(4.968)
c_{21}	1.0508	(8.991)	-0.5792	(-2.900)
c_{31}	-0.3580	(-1.494)	-3.4090	(-16.239)
a_{12}	-0.0538	(-0.674)	-0.3084	(-1.663)
a_{13}	0.2780	(2.092)	0.8853	(3.838)
a_{23}	0.0084	(0.093)	0.2147	(1.852)
b_{12}	-0.0831	(-1.303)	-0.2542	(-3.051)
u_1	1.0		1.0	
u_2	-2.4332	(-4.367)	6.2455	(1.412)
u_{11}	0.0		0.7598	(1.882)
u_{12}	0.0157	(2.017)	-1.0157	(-2.090)
u_{13}	-0.3428	(-21.587)	-0.4389	(-5.352)
u_{22}	0.2749	(2.439)	1.0673	(2.146)
u_{23}	0.2805	(1.512)	-4.9605	(-1.628)
Natural log of likelihood function		263.253		281.324
Correlation Coefficients between actual and predicted values of K,M,w, and $L^{-\frac{1}{2}}$		0.97,-0.84, 0.93,0.99,-0.83		0.98,0.84,0.99, 0.91,-0.06

TABLE XVIII

Estimated Characteristics of Union Preferences and Production Technology: Monopoly Union Model with Profit Maximization

All estimates are evaluated at the mean of the data

Union Preferences

Monotonicity

$U_B = 0.424$, $U_L = -0.853$, $U_A = -1.539$, $\phi_{w/p} = 1.466$, $\phi_L = 0.055$

Curvature

Determinant of bordered hessian of the union's objective function = -0.06.

$MRS_{BL} = 2.011$, $MRS_{w/p\ L} = 0.037$, $\sigma_{w/p\ L} = -0.055$.

Production Technology

Monotonicity

$\Pi_q = 7.882$, $\Pi_r = -4.471$, $\Pi_m = -5.76$, $\Pi_w = -1.373$

Curvature

Determinants of minors of the hessian of the profit function are: -0.316, -0.148, 0.035, 0.0

The matrix of price elasticities is

	q	r	m	w
Q	-0.155	-0.237	0.011	0.382
K	1.628	2.212	-0.543	-3.297
M	-0.019	-0.140	-0.049	0.208
L	-1.930	-2.427	0.593	3.764

The elasticities of substitution are:

$\sigma_{KL} = -1.54$, $\sigma_{ML} = 0.097$, $\sigma_{KM} = -0.089$

order condition shown by 6.8. Normally distributed error terms are added on to equations 6.13 and an identifying restriction, $u_1 = 1$ is imposed on union preferences. The same error structure is specified. Error terms corresponding to the same observation are correlated while error terms corresponding to different observations are independent.

Unfortunately numerical problems prevented the estimation of the complete system, so the restriction $u_{11} = 0$ is imposed on union preferences. FIML estimates of the parameters of the restricted system are reported with their asymptotic t-statistics in Table XVII. Characteristics of the estimated union preferences and production technology, evaluated at the sample means, are reported in Table XVIII.

It is clear that the profit maximizing version of the MUM does not perform well empirically. The estimated union objective function satisfies all the monotonicity properties, but it is not quasiconcave and the marginal rate of substitution between real wages and labour is much lower than the other estimates. Further, the estimated elasticity of substitution is negative. On the production side the estimated supply curve slopes down while the estimated demand curves for capital and labour slope up. Capital and materials are still estimated to be complements, but capital and labour are also estimated to be complements and materials and labour are estimated to be barely substitutable. Materials and labour are also found to be inferior inputs.

The estimates of the input price elasticities and the elasticities of substitution of the production technology are all functions of the estimates of c_{11}, c_{21}, c_{31}, a_{12}, a_{13}, a_{23}, and b_{12}.

Table XVII shows that only the estimates of c_{21} and a_{13} have asymptotic t-statistics greater than two, with the asymptotic t-statistic for the estimate of a_{13} only slightly above two. Thus, although no confidence intervals for the estimates of the elasticities are computed, it is not unreasonable to believe that the estimates have very large confidence intervals which include zero in their range for any reasonable confidence level.

More confidence can be placed in the estimates of the characteristics of union preferences since all of the estimates of the parameters of the union objective function (except for the estimate of u_{23}) have asymptotic t-statistics greater than two. Despite this, the estimate of ϕ_L is 0.07 and a 95% confidence interval for ϕ_L is $-0.085 < \phi_L < 0.195$. Therefore, one cannot say with 95% confidence that the union is not indifferent to the level of employment in real wage-employment space.

Cooperative Union Model

This model is exactly the same as the CUM shown in Chapter 5 except the industry chooses Q,K, and M to maximize variable profits rather than choosing K and M to minimize variable costs given a level of output.

The industry's profit, given some quantity of labour is

$$G(q,r,m,w,L) \equiv V(q,r,m,L) - wL \tag{6.3}$$

which implies the following iso-profit curve

$$wL = pB = V(q,r,m,L) - G \tag{6.4}$$

where G is constant.

The CUM can be written as the maximization problem

$$\underset{w,L}{\text{Max}} \; \{U(B,L;A) \; : \; B = V(q,r,m,L)/p - G/p\}$$

$$= \underset{L}{\text{Max}} \; \{U(V(q,r,m,L)/p - G/p,L;A)\} \qquad (6.14)$$

which implies the first order condition

$$\partial U/\partial L = U_B V_L/p + U_L = 0$$

$$\rightarrow \; V_L = -pU_L/U_B. \qquad (6.15)$$

The curvature properties of V(q,r,m,L) and U(B,L;A) ensure that the second order condition is satisfied. See the appendix to this chapter for the details of the second order condition.

Equations 6.4 and 6.15 define the compensation-employment solution to the CUM. As with the CUM outlined in Chapter 5, the model is not completely specified. The model predicts an outcome on the contract curve, but it does not predict where on the contract curve the final outcome will be.

The supply function, and variable profit maximizing demand functions for capital and materials, all conditional on the labour input chosen with the union, are derived by applying Hotelling's lemma to the variable profit function:

$$Q^*(q,r,m,L) = \partial V(q,r,m,L)/\partial q \qquad (6.16)$$

$$K^*(q,r,m,L) = -\partial V(q,r,m,L)/\partial r \tag{6.17}$$

and

$$M^*(q,r,m,L) = -\partial V(q,r,m,L)/\partial m. \tag{6.18}$$

The equations used to actually estimate the parameters of the CUM are: (i) the input and output functions given by 6.13a, b and c; (ii) the iso-profit curve given by equation 6.4 divided by labour

$$\begin{aligned} w = {} & -G/L + c_{11}q + c_{21}r + c_{31}m + c_{12}q/L + c_{22}r/L + c_{32}m/L \\ & + 2(a_{12}X + a_{13}Y + a_{23}Z)(1 + L^{-1} + 2L^{-\frac{1}{2}}) \\ & + 2b_{12}L^{-\frac{1}{2}}(q + r + m + 2X + 2Y + 2Z); \end{aligned} \tag{6.19d}$$

and (iii) the first order condition to the maximization problem given by 6.15

$$\begin{aligned} -L^{-\frac{1}{2}} = {} & [c_{11}q + c_{21}r + c_{31}m + 2(a_{12}X + a_{13}Y + a_{23}X) + \\ & p(u_2 + u_{22}L + u_{23}A + u_{12}B)(u_1 + u_{11}B + u_{12}L + u_{13}A)^{-1}] \\ & [2(a_{12}X + a_{13}Y + a_{23}Z) + b_{12}(q + r + m + 2X + 2Y + 2Z)]^{-1}. \end{aligned} \tag{6.19e}$$

The usual error structure is appended onto the estimating equations (6.13a, b and c, 6.19d and e) and the same identifying restriction ($u_1 = 1$) is imposed. FIML estimates of the parameters are reported in Table XVII, and characteristics of the estimated technology and union preferences are reported in Table XIX.

Table XIX shows that the CUM performs no better than the MUM. The estimated union objective function satisfies the monotonicity properties but it is decreasing in the level of employment in real wage-employment space. The estimate and standard error of ϕ_L are -1.778 and 1.0 respectively, so a 95% confidence interval for ϕ_L is $-3.738 \leq \phi_L \leq 0.182$. Thus, ϕ_L may be positive or negative at the 95% confidence level. The negative estimate of ϕ_L means that the estimated marginal rate of substitution between real wages and employment is negative and the elasticity of substitution is difficult to interpret. The estimated union objective function is also not quasiconcave in real compensation-employment space.

On the production side, the estimated variable profit function satisfies the monotonicity properties, but it is not concave with respect to labour. The estimated supply function slopes up and the estimated demand curve for materials slopes down, but the estimated demand curve for capital services slopes up. Capital services and materials are estimated to be substitutes rather than complements for the first time, although the estimated elasticity of substitution is very close to zero. Finally, capital services is estimated to be an inferior input.

TABLE XIX

Estimated Characteristics of Union Preferences and Production Technology: Cooperative Union Model with Profit Maximization

All estimates are evaluated at the mean of the data

Union Preferences

Monotonicity

$U_B = 2.243$, $U_L = -6.614$, $U_A = -20.343$, $\phi_{w/p} = 7.925$, $\phi_L = -1.778$

Curvature

Determinant of bordered hessian of the union's objective function = -8.47.

$MRS_{BL} = 2.948$, $MRS_{w/p\ L} = -.224$, $\sigma_{w/p\ L} = 0.125$

Production Technology

Monotonicity

$V_q = 9.59$, $V_r = -3.31$, $V_m = -6.89$, $V_L = 4.49$, $V_{LL} = 0.123$

Curvature

Determinants of minors of the hessian of the cost function are: 0.424, -0.373, 0.0

The matrix of price elasticities is

	q	r	m
Q	0.208	0.070	-0.278
K	-0.479	0.354	0.125
M	0.493	0.032	-0.525

The elasticities of substitution are:

$\sigma_{KM} = 0.02$

Summary

As noted in the introduction to this chapter, it is naive to believe that output is independent of prices or the behaviour of the union, as is assumed in chapter 5. The industry surely adjusts the level of output in response to changes in prices or union policies. Hence, the union models are re-estimated allowing the industry to choose the level of output which maximizes its profits rather than taking output as an exogenous constraint.

The change in the assumption about industry behaviour affects the estimates of union preferences. The estimated union objective function is still increasing in real compensation and decreasing in employment and the real alternative wage. Written as a function of real wages and employment, the estimated union objective function is increasing in the real wage but an increasing or decreasing function of the level of employment. Hence, the estimates of the marginal rates of substitution and the elasticities of substitution between real wages and employment are rather uninformative. Further, the estimated union objective function is not quasiconcave in real compensation-employment space in either the MUM or CUM.

The production side is also affected by the change in assumptions and very poor results obtain. Estimated supply and demand functions slope the wrong way, inputs are found to be inferior, and pairs of inputs jump indiscriminately from complements to substitutes and vice-versa. The only reasonable information obtained from these models is that the demand for materials slopes down and labour and materials are substitutes. All other results contradict either economic theory, all other evidence, or both.

Appendix to Chapter 6
Second Order Condition for the Union's Maximization Problem in the MUM

The union's maximization problem can be written:

$$\max_{w,L} \{U(B,L;A) : w = V_L\} \tag{A6.1}$$

$$= \max_{L} \{U(LV_L/p\ ,L;A)\}. \tag{A6.2}$$

The first order condition is

$$\partial U/\partial L = U_B[V_L + LV_{LL}]/p + U_L = 0$$

$$\rightarrow \qquad V_L + V_{LL} = -pU_L/U_B. \tag{A6.3}$$

The second derivative of equation A6.2 is

$$\partial^2 U/\partial L^2 = [LV_{LL} + V_L][U_{BB}(\partial B/\partial L) + U_{BL}]/p + U_B(2V_{LL} + LV_{LLL})/p$$

$$+ U_{LB}(\partial B/\partial L) + U_{LL}. \tag{A6.4}$$

The second order condition (A6.4) must be evaluated at a point where both the first order condition (A6.3) and the constraint ($w = V_L$) are satisfied. The constraint implies

$$wL/p = B = LV_L/p$$

$$\rightarrow \quad \partial B/\partial L = (LV_{LL} + V_L)/p$$

$$\rightarrow \quad \partial B/\partial L = (LV_{LL} + V_L)/p = -U_L/U_B \qquad \text{(A6.5)}$$

by the first order condition. Substitute A6.5 into A6.4 and obtain

$$\partial^2 U/\partial L^2 = U_{BB}(U_L/U_B)^2 - U_{BL}(U_L/U_B) + U_B(2V_{LL} + LV_{LLL})/p -$$

$$U_{LB}(U_L/U_B) + U_{LL}$$

$$= U_B^{-2}[-H + U_B^{3}(2V_{LL} + LV_{LLL})/p]$$

where H is the determinant of the bordered hessian of the union's objective function and p, U_B and H are assumed to be greater than zero. Therefore a sufficient condition for the second order condition to be satisfied ($\partial^2 U/\partial L^2 < 0$) is

$$2V_{LL} + LV_{LLL} < 0$$

$$\rightarrow \quad LV_{LLL} < -2V_{LL}. \qquad \text{(A6.6)}$$

Repeating equation 6.2,

$$V(q,r,m,L) = c_{12}q + c_{22}r + c_{32}m + c_{11}qL + c_{21}rL + c_{31}mL +$$

$$2(a_{12}X + a_{13}Y + a_{23}Z)(1 + L + 2L^{\frac{1}{2}}) +$$

$$2b_{12}L^{\frac{1}{2}}(q + r + m + 2X + 2Y + 2Z)$$

where $X \equiv (\frac{1}{2} q^2 + \frac{1}{2} r^2)^{\frac{1}{2}}$, $Y \equiv (\frac{1}{2} q^2 + \frac{1}{2} m^2)^{\frac{1}{2}}$ and $Z \equiv (\frac{1}{2} r^2 + \frac{1}{2} m^2)^{\frac{1}{2}}$.

Clearly,

$$V_L = c_{11}q + c_{21}r + c_{31}m + 2(a_{12}X + a_{13}Y + a_{23}Z)(1 + L^{-\frac{1}{2}})$$

$$+ b_{12}L^{-\frac{1}{2}}(q + r + m + 2X + 2Y + 2Z)$$

$$\rightarrow V_{LL} = -(a_{12}X + a_{13}Y + a_{23}Z)L^{-3/2} -$$

$$\frac{1}{2} b_{12}(q + r + m + 2X + 2Y + 2Z)L^{-3/2}$$

$$\rightarrow V_{LLL} = (3/2)[a_{12}X + a_{13}Y + a_{23}Z +$$

$$\frac{1}{2} b_{12}(q + r + m + 2X + 2Y + 2Z)]L^{-5/2}$$

$$\rightarrow LV_{LLL} = -(3/2)V_{LL}.$$

Therefore,

$$LV_{LLL} = -(3/2)V_{LL} \leq -2V_{LL}$$

since $V_{LL} < 0$, equation A6.6 is satisfied and the second order condition of the maximization problem is satisfied.

Second Order Condition for the Maximization Problem in the CUM

The maximization problem in the CUM is

$$\max_{w,L} \{U(B,L;A) : B = V(p,r,m,L)/p - G/p\} \tag{A6.7}$$

$$= \max_{L} \{U(V(q,r,m,L)/p - G/p,L;A)\}. \tag{A6.8}$$

The first order condition is

$$\partial U/\partial L = U_B V_L/p + U_L = 0$$

$$\rightarrow V_L = -pU_L/U_B. \tag{A6.9}$$

The second derivative of A6.8 is

$$\partial^2 U/\partial L^2 = V_L[U_{BB}(\partial B/\partial L) + U_{BL}]/p + U_B V_{LL}/p + U_{LB}(\partial B/\partial L) + U_{LL} \tag{A6.10}$$

The constraint and the first order condition imply

$$\partial B/\partial L = V_L/p = -U_L/U_B$$

which, when substituted into A6.10, yields

$$\partial^2 U/\partial L^2 = (U_L/U_B)[U_{BB}(U_L/U_B) - 2U_{BL}] + U_B V_{LL}/p + U_{LL}$$

$$= U_B^{-2}(-H + U_B^3 V_{LL}/p) < 0$$

since $p > 0$, $U_B > 0$, $H > 0$ and $V_{LL} < 0$. Therefore the second order condition is satisfied.

Chapter 7

On Choosing a True Model

Until now the CUM and MUM have been treated as two equally reasonable and equally likely alternative models of the behaviour of unions and firms. However, the two models are non-nested and predict different outcomes. If one model is true, then the other model must be false.[1] Hence, it is desirable to choose which of the two models is the true model of the behaviour of unions and firms. The purpose of this chapter is to choose the model which is consistent with the observed behaviour of the IWA and the wood products industry in B.C., 1963-79.

On a theoretical basis, given the assumptions outlined in Chapter 5, the choice is obvious. The CUM is the correct, or more reasonable model, because it predicts an efficient Pareto optimal outcome while the MUM predicts an inefficient Pareto inferior outcome. However, as noted in Chapter 2, arguments appealing to factors outside the neoclassical paradigm have been made suggesting that the CUM is not such a clear favourite over the MUM.

These arguments basically say that while one expects unions and firms to exploit all possible gains from trade and reach efficient solutions, the outcome predicted by the CUM is unattainable since the competitive bargaining relationship makes the two parties unable or unwilling to convey enough information about their valuations of

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1. This is not always the case. For example, if union indifference curves are Leontief in wage and employment space, or if the union is indifferent to th level of employment, then the solutions of the MUM and CUM coincide.

outcomes to reach a point on the contract curve (see Pencavel 1981). Further, since conditions change during the life of a contract, it is necessary to negotiate a set of contingent contracts covering all possible changes in input and output prices and variables affecting the union. Even if a complete set of contingent contracts are negotiated, they still have to be enforced. Problems observing and accurately measuring the variables describing the contingencies limit the workability of the contingent contracts.[2] A moral hazard problem also exists if the union or employers can influence the perceived value of the contingency variables.

These problems make a solution on the contract curve seem unlikely and they are valid criticisms counting against the reasonableness of the CUM. However all these arguments can be applied with equal force against the MUM. Lack of information about the industry's demand for labour function or false information supplied by the firm can cause the union to choose a non-optimal wage. Further, the demand for labour curve shifts and twists as prices change, just as union indifference curves change when the alternative wage, price level, or tax rates change. So contingent contracts are also necessary in the MUM, and that leads to the same problems of measuring the contingency variables and moral hazard. Therefore, while uncertainty, imperfect information, and moral hazard are important factors which ought to be included in the union models; they do not help in the choice between the MUM and CUM.

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2. See Hall and Lilien (1979, p. 870) for a discussion of the problems of contingent contracts in the CUM.

It is true that the information requirements of the CUM are greater than those of the MUM since more than just the wage has to be negotiated in the CUM. It is also true in general, that one observes that unions and firms negotiate the wage rate but firms choose the level of employment unilaterally. Despite these facts, efficient contracts can be achieved by negotiating work rules or, more importantly, by negotiating compensation functions which are not homogeneous of degree one in the level of employment.[3]

Referring to Figure 5a, it is easy to see that the compensation function oab, with its combination of a lump sum payment oa and a wage equal to the slope of ab, results in an efficient outcome. The union and firm bargain only about compensation and the firm chooses employment unilaterally to minimize costs, but an efficient solution results. Compensation functions like oab are not uncommon. If employment is measured in hours worked, oa can be payment for work not performed such as vacations or statutory holidays, while the slope of ab is just the hourly wage. If employment is measured by number of people working, holding hours per worker fixed, and employment is decreasing, then the compensation function oab results from the firm paying unemployment insurance benefits or severance pay to laid off workers. In that case the wage seen by the firm is the worker's wages minus what the firm would pay if the worker was laid off. If employment is increasing, labour is homogeneous, and seniority provisions ensure that workers with more seniority cannot be displaced by workers with less seniority then the marginal cost of

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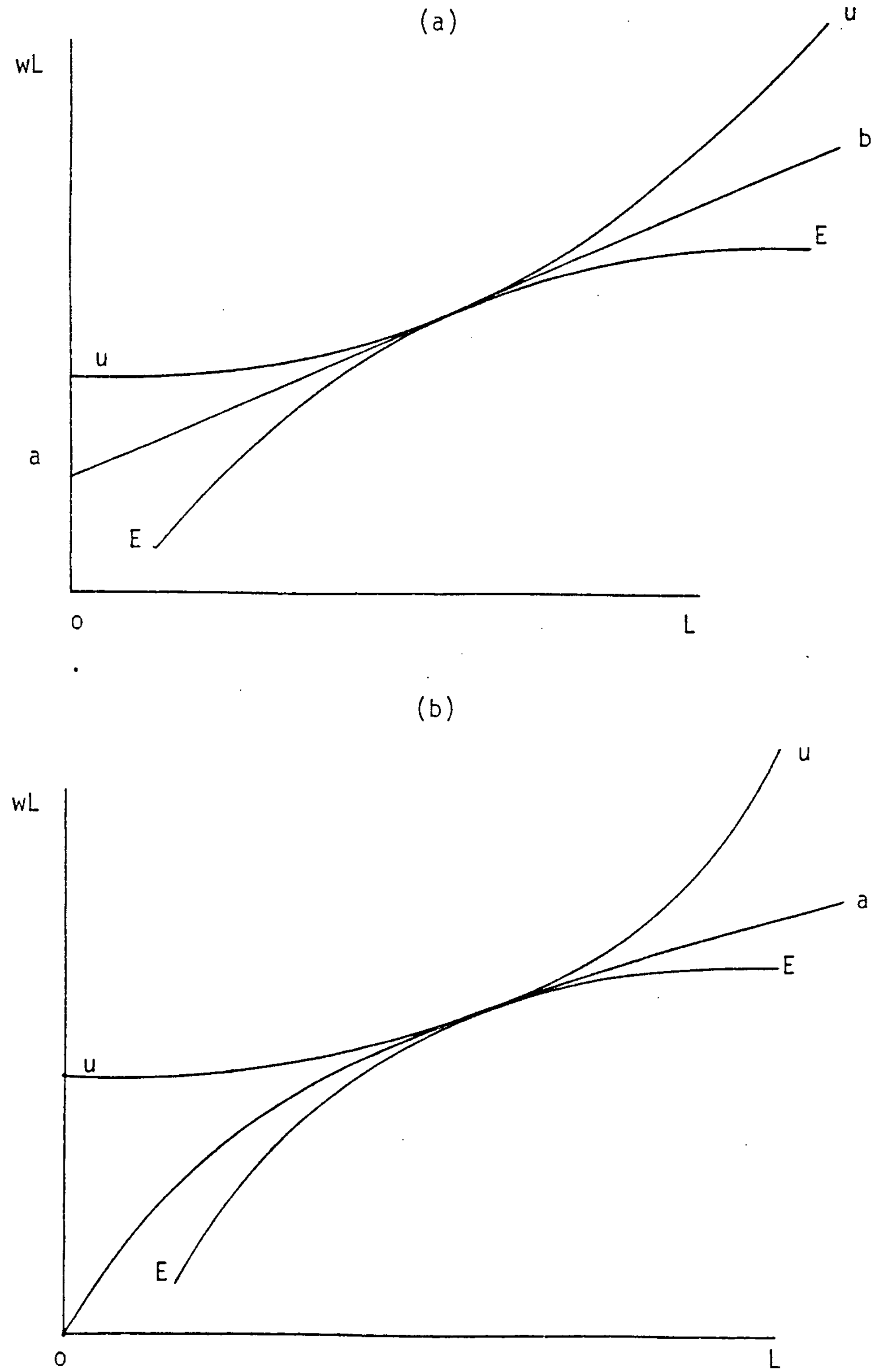
3. Hall and Lilien (1979) show how non-homogeneous of degree one compensation functions can support efficient equilibria.

FIGURE 5



a worker is less than the average cost. This occurs because the workers with more seniority earn higher wages and receive more paid time off and benefits. Hence, the compensation function looks like oa in Figure 5b and it supports an efficient outcome when the firm chooses employment unilaterally to minimize costs. Other common contract provisions which make the compensation function non-linear are overtime premiums, contributions to pension funds and other benefits, and shift premiums. So although bargaining in the CUM must be more complicated than in the MUM and must cover more than just the wage, the bargaining necessary to achieve an efficient outcome is not beyond the abilities or even the common practice of unions and firms. Payment provisions which make the compensation function not homogeneous of degree one, so that efficient outcomes can be achieved, are included in almost all collective agreements currently in effect.

Therefore, any arguments stating that efficient outcomes are not achieved because they are too difficult to bargain for or because unions and firms do not bargain about employment cannot be accepted as valid arguments against the CUM. Although I have argued that firms and unions could use non-linear compensation functions to achieve efficient outcomes, the CUM outlined in Chapter 5 assumes that efficient outcomes are reached by bargaining directly over the average cost of a unit of labour (the wage) and the level of employment. This assumption is made to keep the analysis simple, and it does not affect the performance of the CUM. The CUM consists of the demands for capital services and materials, an iso-expenditure curve and the tangency condition between the iso-expenditure curve and the union indifference curve. None of the equations in the CUM change if a non-linear compensation function is used to achieve an efficient solution. The CUM shows only the final outcome and is independent of how the outcome is reached or supported.

One final rationale of the MUM should be mentioned. Farber (1978, p. 926) states that the MUM is appropriate for the coal mining industry because there is one powerful union which can dictate its terms to a large number of small uncoordinated firms. The union acts as a monopolistic supplier of labour to the firms. Given the union's power relative to the firms, why does the union dictate an inefficient solution instead of an efficient one where the union is better off holding the firm's welfare constant? If the union can dictate and enforce a level of wages and pension fund contributions across all firms, there is no reason to believe that the union would not dictate a compensation function (including wages and pension fund contributions) which supports an efficient outcome.

To sum up, one must conclude that despite the popularity of the MUM in the literature and the arguments outlined above, there is no good reason for believing that unions and firms settle at inefficient outcomes like those predicted by the MUM rather than the efficient outcomes predicted by the CUM. The next question is: does the data bear out this preference for the CUM over the MUM? That is to say: does the CUM provide a better model of the observed behaviour of the IWA and the B.C. forest products industry in the years 1963-79?

Nested Test

An answer to this empirical question can be found by nesting the two models in single equation as done by MaCurdy and Pencavel (1983). The MUM solution is on the industry's demand for labour function. In our model that implies

$$D_L + w = 0. \tag{7.1}$$

The CUM requires that the slope of the union's objective function equals the slope of the industry's iso-expenditure curve:

$$D_L - pU_L/U_B = 0. \tag{7.2}$$

Equation 7.1 is nested in equation 7.2. It should be emphasized, however, that the MUM and the CUM are non-nested models. If the models are written out completely, restrictions imposed on one model cannot produce the other model. It just turns out (fortuitously) that the constraint in the MUM (7.1) is nested in the first order condition of the CUM (7.2). The complete models cannot be tested against one another in a nested test, but the value of D_L can be tested in a single equation; thereby allowing a hypothesis test of the MUM given the alternative hypothesis that the CUM is true.

The constant returns to scale version of D(r,m,L,Q) is specified as it is in Chapter 5 (equation 5.2). Unfortunately, numerical problems prevented the estimation of equation 7.2 when U(B,L;A) is specified as in Chapter 5 (equation 5.5), so the following specification is used

$$U(B,L;A) = u_1B + u_2L + u_{12}BL \tag{7.3}$$

where $u_{12} = -1$ is an identifying restriction.

Non-linear 2SLS is used to estimate equation 7.2 since it is just one equation out of a simultaneous system of equations. The instrumental variables are: a constant, dummy variables for the industries, a trend term, the trend term times the dummy variables, trend squared, price of output, price of capital, and the squares of the prices. The likelihood ratio test analogue derived in Gallant and Jorgenson (1979) is used to test the null hypothesis that equation 7.1 is true subject to the alternative hypothesis that equation 7.2 is true. The estimated test statistic, which Gallant and Jorgenson prove is asymptotically distributed as a χ^2 with two degrees of freedom ($u_1 = u_2 = 0$), is 92.202. Thus, the hypothesis that equation 7.1 and the MUM is true is overwhelmingly rejected.

The specification of U(B,L;A) used for the hypothesis test (equation 7.3) is a special case of the more general specification used in the union models (equation 5.5). Since equation 7.1 is rejected when tested against a restricted version of equation 7.2, it is clear that equation 7.1 and the MUM are also rejected when the more general specification of U(B,L;A) is used.

Likelihood Comparison Test

More support for the CUM is found by comparing the maximized values of the log likelihoods of the CUM and MUM. The log likelihod of the CUM is always at least eleven points higher than the log likelihood of the MUM for the cost minimizing models when one compares models with an equal number of free parameters.[4] Thus, the MUM can be rejected in favour of the CUM. This follows because the MUM would be convincingly rejected if it was tested against a hypothetical general model which nests the two models and has one more parameter. This is true since the log likelihood of the general model must be greater than or equal to the log likelihood of the CUM.[5]

The advantage of this type of test is that it compares the performance of the complete models against one another. This is different from the nested test shown above, where just one equation from one model is tested against a different equation from the other model.

Another difference between the two tests should be emphasized. The nested test assumes that the alternative hypothesis, equation 7.2 from the CUM, is true with certainty. The consistency or reasonableness of the restrictions on the CUM (which yield the MUM) is then tested against the observed data given the truth of the CUM - i.e., given that the data are organized according to the alternative hypothesis. Given the qualitative arguments in favour of the CUM presented at the beginning of the chapter, it may not be unreasonable to let the CUM be the alternative hypothesis, which is believed with certainty. However, given the MUM's popularity and acceptance in the

4. The difference in the cost minimizing, constant returns to scale models is 11.8 points with dummy variables and 19 points without dummy variables. The difference is 18 points in the non-constant returns to scale, cost minimizing models. See Tables IX and XVI.

5. Justifying the likelihood comparison test by testing the models against a hypothetical general model was suggested to me by James MacKinnon in personal correspondence.

literature, it is desirable to choose the true model with a test which does not weight the result so strongly in favour of the CUM.

The likelihood comparison test does not assume that a particular model is true a priori and test other models against that assumed true model. Instead it assumes that the true model is included in the set of alternative models. A log likelihood at least two points higher than the log likelihoods of the other models identifies the true model from among all the false alternatives at the 95% confidence level.[6] Thus the test is essentially model "discrimination." Given a fixed set of alternative models, which we believe with certainty contains the true model, choose the true model from among the alternatives contained in the set. In general, it is possible that no log likelihood is significantly larger than all the others, and no 'best' model is found. This only means that there is not enough information in the models to discriminate one model from all the others. Since there is no way that all the alternative models can be rejected, the test still assumes that the true model is contained in the set of alternatives. In our case the likelihood comparison test implicitly assumes that one of the CUM or the MUM is true, and given only those two alternatives, the CUM is chosen over the MUM.

Non-nested Test

The non-nested test relaxes the a priori assumptions about the truth of the models still further. As in the likelihood comparison

6. This follows because all the other models would be rejected when tested against a hypothetical general model with one more parameter.

test, no model is assumed to be true a priori, and the alternatives may not contain enough information to reject any model as false. Unlike the likelihood comparison test, the true model is not assumed to be in the set of alternatives with certainty. In a non-nested hypothesis test all alternative models may be accepted as true or rejected as false.

The basic procedure is to let the MUM and CUM be the null and alternative hypotheses respectively, and to test the null hypothesis given the alternative hypothesis. Then the null and alternative hypotheses are reversed and the test is repeated. Therefore one model may be accepted, both models may be accepted, or both models may be rejected.

The assumption underlying the procedure is that there is no alternative or maintained hypothesis which is believed to be true with certainty. That is why both models can be rejected and why both models are allowed to be the alternative hypothesis. Each model is on an equal footing with the other. Further, each model is tested against the other so that the test looks for inconsistency of the null hypothesis with the data in directions suggested by the other model. The non-nested test is an hypothesis test on the "truth" of a model where no hypotheses about the true model are believed with certainty.[7]

The non-nested test is done on the cost minimizing, constant returns to scale versions of the CUM and MUM (with dummy variables),

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7. The preceding discussion and comparison of tests is taken from Pesaran and Deaton (1978, pp. 677-680), Dastoor (1983, p. 213), and Davidson and MacKinnon (1982, p. 551).

using a variant of the J test suggested by MacKinnon, White and Davidson (1983, p. 55). Stochastic versions of the MUM and CUM models are written in implicit form as

$$M(K,M,w,L,\beta;r,m,Q,A,p) = e$$

and

$$C(K,M,w,L,\gamma;r,m,Q,A,p) = e$$

respectively, where β and γ are the vectors of parameters to be estimated and e is the vector of normally distributed errors. Error terms corresponding to the same observation are correlated while error terms corresponding to different observations are independent. Nest the two models in an artificial compound model

$$(1 - \alpha)M() + \alpha C() = e. \tag{7.4}$$

To test the null hypothesis that the MUM is true given the alternative hypothesis that the CUM is true, replace γ by its ML estimate, obtain estimates of β and α and test if $\alpha = 0$. The asymptotic t-statistic for the estimate of α is 13.727, so α is significantly different from zero. The hypothesis that the MUM is true is rejected given the alternative hypothesis that the CUM is true. Thus the results of the nested test are confirmed.

Reversing the null and alternative hypotheses, one obtains the artificial compound model

$$(1 - \alpha)C() + \alpha M() = e, \tag{7.5}$$

where the notation is the same as before. Replace β by its ML estimate, estimate α and γ and test if $\alpha = 0$. The asymptotic t-statistic for the estimate of α is 13.03, so α is significantly different from zero. The hypothesis that the CUM is true is rejected given the alternative hypothesis that the MUM is true.

Davidson and MacKinnon (1982) do show that the J test tends to reject the null hypothesis too often in small samples. However, the very high t-statistics leave no other conclusion than the rejection of both models in a non-nested test.

Summary

It is argued that the CUM is the more appropriate or correct of the two models because one expects unions and firms to exploit all possible gains from trade and reach efficient outcomes. Arguments explaining why the CUM solution may be unattainable and the inefficient MUM solution may result are found unconvincing.

This preference for the CUM over the MUM is supported by the data. When the CUM is assumed to be true, the MUM is found to be inconsistent with the data and the MUM is rejected. When the IWA and forest products industry are assumed to behave according to one of either the CUM or MUM, the CUM provides a better model of the data than the MUM. So in a test between the MUM and CUM, the MUM is rejected in favour of the CUM (given the data) and the qualitative arguments favouring the CUM over the MUM are confirmed.

However once we allow that neither model may be true, both models are rejected. This is also consistent with the arguments presented above. Factors such as aggregation of union members' preferences, uncertainty, imperfect information, moral hazard, dynamic constraints, non-price taking behaviour, the costs of negotiations, and strikes are assumed away by both models and their neglect lessens the validity of both models. The rejection of both models by the non-nested test only shows that more work needs to be done on the specification of models of union and firm behaviour.

In conclusion, given the choice between the CUM and MUM, the CUM must be chosen as the true model. However, the non-nested test shows that the truth of either model may not be very great.

Chapter 8

Conclusion

Two models of union and industry behaviour are derived, specified and estimated using annual data on the IWA and wood products industry in B.C., 1963-79. Different versions of the models are specified and estimated assuming cost minimizing and profit maximizing behaviour by the firms in the industry and constant and non-constant returns to scale. The technology of the wood products industry is also estimated independently of any union objective function parameters, assuming cost minimizing behavior and exogenous wages. Thus, the estimates of the technology are equivalent to those which would be obtained if perfect competition in all input markets was assumed.

The estimated union objective function is found to be increasing in total real compensation, decreasing in employment and the real alternative wage, and quasiconcave over real compensation and employment. Written as a function of the average rate of real compensation (the real wage) and employment, the estimated union objective function is increasing in both real wages and employment, and the elasticity of substitution between real wages and employment ranges from 0.6 to 0.8. The union is found to be indifferent to the firing of one worker (2000 hours) and a 0.032¢ an hour increase in the real wages of all other workers. In percentage terms, the union is indifferent to a 1.5% decrease in employment and a 1% increase in the real wage. Many popular hypotheses about union preferences are tested. The hypothesis tests indicate that the IWA does not maximize rents or the wage bill and the IWA is not indifferent to the level of employment or the alternative wage available to labour. The estimates of union preferences are surprisingly robust to changes in the model and the technology, although they are sensitive to whether cost minimizing or profit maximizing behavior is assumed. The estimates of union preferences are also very similar to other estimates found in the literature (see Dertouzos and Pencavel (1981)).

On the production side, the industry's estimated cost function is not concave in prices and the industry's estimated profit function is not convex in prices. In the exogenous wage rate model, homotheticity of the production technology is rejected as is no technical change and Hicks' neutral technical change. Capital and materials are estimated to be complements while capital and labour, and labour and materials are found to be substitutes. The estimates of the production technology are very sensitive to whether or not the union's behaviour is explicitly modelled. The estimates of the substitutability of the factors of production increase dramatically when wages are endogenous to the model and production and union preference parameters are estimated jointly.

With regard to the choice of an appropriate model of union and firm behaviour, it is clear on both theoretical and empirical grounds that if one has to choose between the MUM and the CUM, the CUM dominates the MUM. If, however, one wants to test the "truth" of the models empirically, with no certain maintained or alternative hypothesis, then both the MUM and the CUM are rejected by a non-nested hypothesis test.

The rejection of both models in the non-nested test underlines some of the faults of the work reported above. There is the ubiquitous fault of assuming away uncertainty and imperfect information. Such important factors as the costs of bargaining, bargaining strategies, strikes, job restrictions, and divergent preferences within the union are all assumed away. The dynamics of the relationship between the firm and the union are also ignored as is the vertical integration of the firms in the industry and a number of flaws in the data. From an econometric standpoint the error structure is arbitrary and the sample is too small to place a lot of confidence in the asymptotic properties of the estimates.

In spite of the faults listed above, a positive contribution has been made. First, a new data set which isolates the behaviour of a union and its unionized industry is developed. Empirical work on unions has been hindered by a lack of data on the behaviour of unions and the firms they organized. The data usually contain some unknown mix of union and non-union workers and union and non-union firms. This data set provides observations on a single union and the firms it bargains with, with very little contamination from non-union workers and firms.

Second, estimates of the IWA's preferences are obtained thereby providing an answer to the very old question "What do unions maximize?". Estimates of the production technology of the B.C. wood products industry are also obtained thereby adding to the stock of knowledge about factor substitution and showing the sensitivity of the technology estimates to the explicit modelling of union behaviour.

Finally, the MUM, which is so popular in the literature, is rejected in favour of the CUM (with its efficient outcomes) when the two models are compared to one another.

Appendix

More on the Data

The purpose of this appendix is to provide more infomraiton on the data, the union and the industries. Table XX shows the means and standard deviations of the variables in the data set and Figures 6 and 7 show the levels and movements of real wages and employment in each of the industries.

Figure 6 shows that the real wages trend upwards. However, there is still variation in each industry's real wages after a constant term and trend is removed (where each industry is allowed a different constant and trend). This remaining variation is independent of the cycles of the industry, where both output and the price of output were used to measure the industry's cycle.

The real wages of each industry move closely together with simple correlation coefficients ranging from .99 to .97. This is not surprising since the industries are very similar, in the same province, and the bargaining structure is centralized. Bargaining takes place with the IWA Regional Council #1 negotiating a collective agreement which (effectively) sets the wages for every worker or occupation hired by each industry. However, the real wages of each industry are different since each industry hires a different mix of occupations. The hypothesis that all the industries have the same mean or trend is rejected at the 95% confidence level. Real wages in interior saw-

TABLE XX

Means and Standard Deviations of the Data

Standard deviations are in parentheses below the mean.

Variable	Coast Sawmills	Interior Sawmills	Shingle Mills	Plywood Mills
q	1.94 (0.99)	1.50 (0.71)	2.53 (1.52)	1.56 (0.63)
r	3.30 (1.43)	3.34 (1.42)	3.79 (1.60)	3.21 (1.46)
m	1.98 (0.99)	1.18 (0.53)	2.24 (1.54)	1.63 (0.50)
w/p	4.32 (0.88)	3.97 (0.99)	4.61 (0.82)	4.21 (0.79)
Q	34.55 (5.67)	41.99 (12.05)	2.26 (0.26)	17.05 (2.79)
M	20.80 (3.87)	26.97 (7.26)	1.38 (0.21)	8.77 (2.16)
K	6.54 (1.96)	14.53 (5.83)	0.42 (0.14)	5.33 (1.56)
L	24.93 (2.50)	28.06 (5.24)	2.75 (0.30)	13.33 (0.93)
A	3.67 (0.48)	-	-	-

FIGURE 6

Wages in Constant 1971 Dollars

CC is coast sawmills
II is interior sawmills
SS is shingle mills
PP is plywood mills

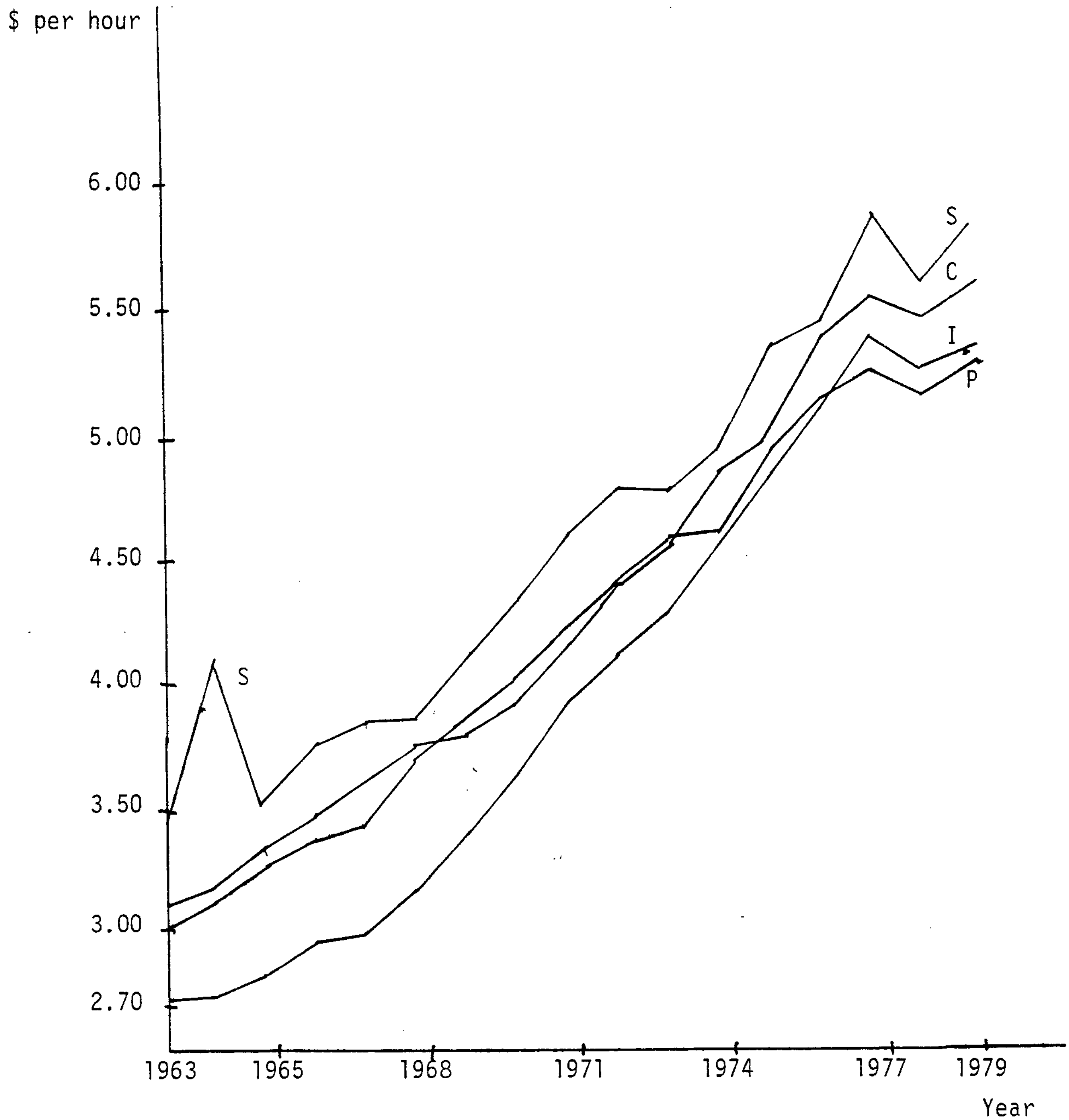
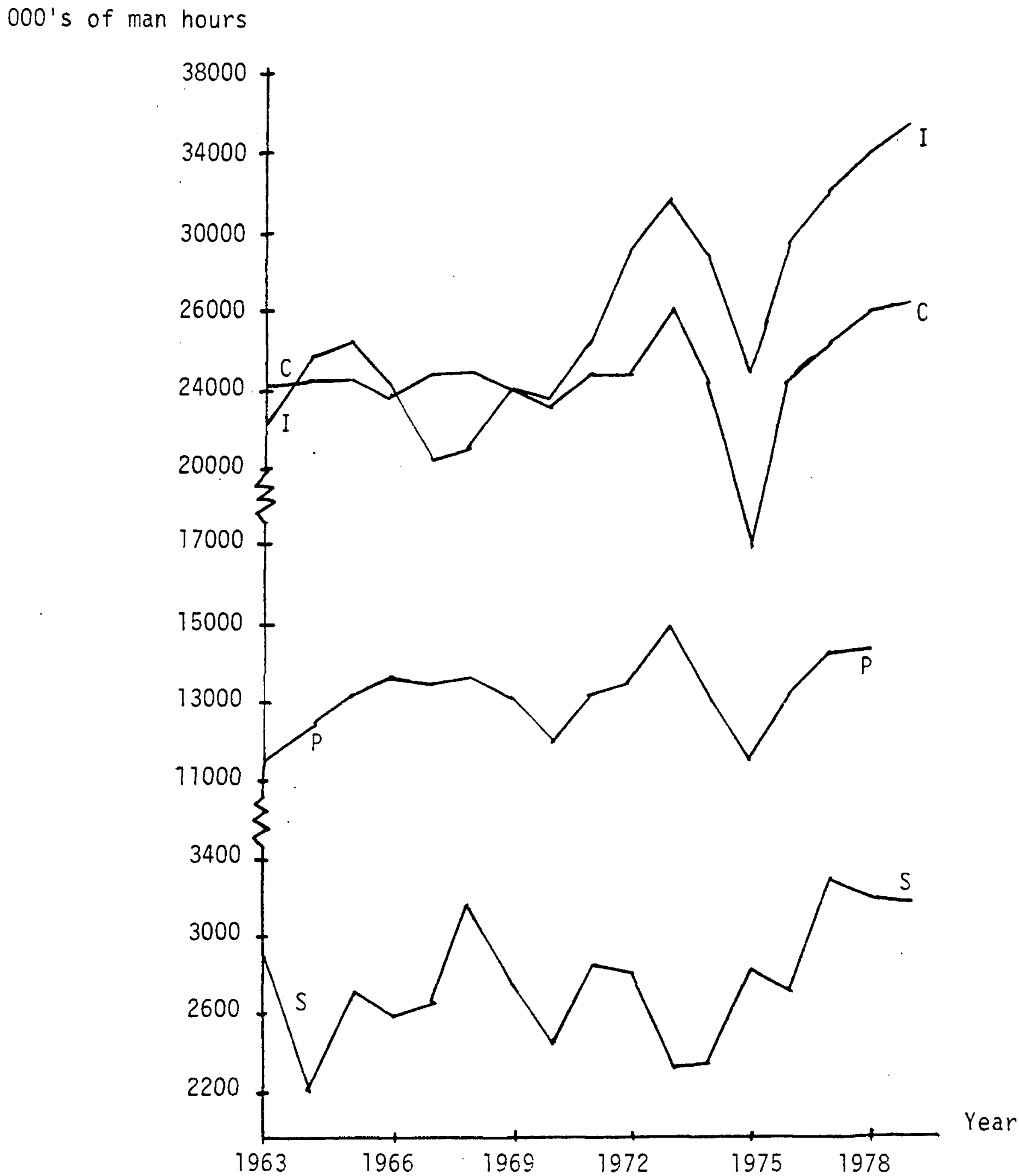


FIGURE 7

Employment

CC is coast sawmills
II is interior sawmills
PP is plywood mills
SS is shingle mills



mills have the steepest trend followed by the real wages in coast sawmills, shingle mills and plywood mills.

The data on inputs and outputs show that the industries are not very stable from year to year with periods of boom and bust. This is shown in Figure 7 where employment in each industry is plotted. There is a great deal of variability in employment both with and without industry trends removed, and only employment in interior sawmills has a statistically significant trend. The variation remaining after the industry trend is removed is positively correlated with the price of output in interior and coast sawmills and shingle mills, but not in plywood mills. Employment in the industries does not move together. The simple correlation coefficients range from .37 between employment in shingle mills and interior sawmills and .77 between employment in plywood mills and coast sawmills. The hypotheses that each industry's employment has the same mean or trend is rejected at the 95% level.

In the work above, all four industries are assumed to have the same technology, although different constant terms are permitted in some of the estimating equations. Even though the aggregation of technology across industries is rejected by a hypothesis test (using the model contained in Chapter 4), the aggregation assumption is easy to defend. All of the industries do basically the same thing. They purchase logs and bolts; saw, peel or split them into smaller pieces and then do some further processing; such as planing, or gluing the pieces. Since the industries are so similar, they are all included in the same two digit SIC level (see, for example, Woodland [1985] or Denny and May [1977 and 1978]). Therefore the aggregation of three and four digit SIC industries is not unreasonable when compared to the standards found in the literature.

To consider the reasonableness of the aggregation of different groups of workers and union leaders into an entity possessing a single consistent objective function one must know the characteristics of the workers and the leaders. Census data shows that, in general, the workers are not well educated, slightly younger than the average worker in the labour force and virtually all male. They do strenuous and dangerous sorts of work in fairly unpleasant conditions. Much of the work is classed as unskilled, but there are industry specific skills such as operating large, expensive and specialized machinery.

The union leaders are secure and powerful. Since 1958 the IWA Regional Council #1 has governed the activities of the IWA in British Columbia. The members of the regional council possess most of the power for collective bargaining and the other functions of the union. There is little turnover on the regional council and the councillors enjoy long tenures on the council.

Despite the centralized power structure of the union and the lack of competition and turnover in the leadership, the IWA is a relatively democratic union with lots of public debate. Since the union is an industrial union representing all of the different workers in the industries, conflicts between different groups within the membership are inevitable. However in the IWA the affected groups are very vocal about their plight, and the leaders generally listen and take some remedial action.

A good example, common to most industrial unions, is the skilled trades. Additive (rather than percentage) wage increases have decreased their relative wage differentials. The trades have been very vocal about the erosion of their relative wages and the leaders have responded. Most of the collective agreements contain extra increases for the trades, and one collective agreement was even re-opened in the middle of its term to adjust the trades wage scales.

Thus there are no warring factions within the union, or large upheavals causing changes in ideology, direction or goals. There is stable and powerful leadership which seems to respond closely to the membership. Hence it is not unreasonable to treat the union as an entitiy with a single consistent objective function whose parameters are constant over time.

Another issue which must be addressed is how the industry and union reach an outcome off the industry's demand for labour curve, and on the contract curve. One alternative is the union and management joint committees which administer the sawmill and plywood job evaluation plans. However these plans deal mainly with job classification and it is unlikely that they have a significant effect upon the level of employment. There are no other significant job restrictions so the union cannot control employment directly.

Another alternative is the non-homogeneous of degree one compensation functions specified in the collective agreements. The agreements state that the industry must pay for vacations; statutory holidays; medical, disability, dismemberment and life insurance; a dental plan; personal safety equipment; and severance pay. These are all fixed costs of employment and they can be used to support an outcome on the contract curve as shown in Chapter 7.

The final issue to be addressed is whether or not each industry provides independent observations (information) on the production technology and the union objective function. The industries are assumed to have the same production technology. However, each industry chooses a different point on its production technology frontier because they face different input prices. Energy and materials prices vary because of different locations and the different bundles of trees and fuels used. The price of labour varies because the industries choose different mixes of occupations. Each industry operates at a different point on the same production technology, and this provides independent observations on the production technology as well as independent observations of different points on the same union objective function. Therefore each industry provides independent information on the production technology and the union objective function.

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