Wage and Employment Contracts as Equilibria to a Bargaining Game: An Empirical Analysis

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Abstract

The object of this research is to study how unions and firms divide the surplus or rents available to them. Many instruments are used in practice to make this division, but standard micro data only includes two: wages and employment. I use a new approach to study wage and employment contracts as I consider them equilibrium points in a noncooperative bargaining game.

This work is an extension of wage-employment determination models, the extension being the incorporation of a bargaining model, specifically, a Rubinstein bargaining game. Given the objective functions of the two players, the wage and employment equations are specified by the equilibrium conditions for the game. Also, additional determinants of the contracts are identified. One of the characteristics of the model is that the wage and employment contracts are affected by the relative strike costs of the two negotiating parties even in the absence of strikes.

The data involve the B.C. wood products industry and the IWA, a powerful union believed to have been successful at capturing rents. The data include input and output quantities and prices and equations representing input demands and output supply are estimated simultaneously with the negotiated wage and employment equations. Four estimation models are derived corresponding to two bargaining frameworks and two sets of assumptions on the firms' technology. The two bargaining frameworks correspond to two polar cases that have been assumed in the wage-employment determination literature: in one case, the wage is set through bargaining while the employment level is chosen by the firm, in the second case, both the wage and employment level are negotiated. In one pair of models, output is treated as exogenous to the bargaining while in the second set of models, output is endogenous and capital is exogenous.

The bargaining game is successfully implemented in the sense that technology and union utility parameters are generally reasonable and comparable to previous estimates. Also, the determinants of relative strike costs enter significantly in the estimation. The union is seen to care about employment as well as the wage with slightly more weight being placed on the employment level. Rent maximization is always rejected. Bargaining powers are calculated at each data point and results indicate that the 1980's recession increased the relative power of the union. The hypotheses of equal bargaining powers and complete union bargaining power are tested and rejected. Also, the proportion of rents captured by the firm is found to be a poor indicator of its bargaining power.

Although the qualitative results mentioned above are robust across the four models, parameter values are generally sensitive to both the technology assumptions and the bargaining framework. Ignoring the simultaneity of wages, employment and other variables chosen by the firm can be very misleading. Finally, the model in which both wages and employment are negotiated consistently performs better than the framework in which employment is unilaterally set by the firm.

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Chapter 1

Introduction

The object of this research is to study how unions and firms divide the surplus or rents available to them. Many instruments are used in practice to make this division, but standard micro data only includes two: wages and employment. I use a new approach to study wage and employment contracts as I consider them equilibrium points in a noncooperative bargaining game.

This work is an extension of wage-employment determination models, the extension being the incorporation of a bargaining game.[1] In wage-employment determination models, micro data on wage-employment contracts usually between a single union and industry are studied. Contrary to Phillips' curve models of wage determination, these studies are based on rigorous models of union objectives and firm technologies. It is recognized that negotiated agreements are the results of firm-union bargaining and consequently, factors affecting the bargaining relationship or either party's objectives can also influence the contract.

In previous wage-employment determination studies, either a particular wage-employment outcome was not

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[1]Examples of wage-employment determination studies are: Brown and Ashenfelter (1986), Card (1986), Carruth and Oswald (1983), Dertouzos and Pencavel (1981), Eberts and Stone (1986), Farber (1978), MaCurdy and Pencavel (1986), Martinello (1984).

predicted or one of the agents was allowed to impose his preferred choice. With a bargaining game, a wage-employment outcome is predicted without this extreme assumption on the bargaining powers of the agents. Given the objective functions of the two players, the wage and employment equations are specified by the equilibrium conditions for the game. Also, the game is helpful in identifying additional determinants of the contracts.

The use of game theoretic models in empirical research is still very new. There are several reasons for this. The theoretical models are themselves fairly recent and also, they easily become very complex. Characterization of the equilibria often requires severely simplifying assumptions especially when adding the requirement that the set of possible equilibrium points be small. The fact that the equilibria are often very sensitive to particular parameter values of the game magnifies the difficulties. Finally, when doing empirical applications there is the additional problem that variables that are crucial to the game are often not observable (e.g. prior beliefs).

The paper by Fudenberg, Levine and Rudd (1985) is the only other example of the use of a noncooperative bargaining game to study firm-union negotiations. They emphasize the prediction of strike lengths rather than the distribution of the surplus although their model also predicts the wage rate. Their framework is very different from the one adopted here. They assume that employment is exogenous to the negotiation process, that the union cares only about the level of the wage rate and only the union can make offers. Also, their data cover several unions bargaining with firms in different industries. No variation is allowed in union behavior, firm behavior, and in the bargaining framework in which they negotiate. These assumptions conflict with results of the empirical studies of wage and employment determination mentioned above. Finally, a paper by Gul and Sonnenschein (1985) raises questions concerning the validity of their underlying model.[2]

The game I use is a version of the Rubinstein game as it was first presented in Rubinstein (1982) and extended in Binmore (1987b and 1987C). Rubinstein's bargaining model has the advantage of allowing both parties to make offers, a practice which is generally observed in collective negotiations. In this study, estimation models are derived under the assumptions of perfect information, continuous time and discounting costs. (The role of continuous time and delay costs is explained in Chapter 3.) The resulting equilibrium is unique and it can be written as the solution to an optimization problem. More specifically, it can be represented by a generalized Nash bargaining solution with

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[2]Gul and Sonnenschein (1985) argue that equilibria involving delays (strikes) can only occur in discrete time games, whereas Fudenberg, Levine, and Rudd (1985) have a continuous time model.

the weights on the players' gains in utility being functions of the costs of delay. This is important as it allows for quite general specifications of the players' objective functions. The derived equilibrium wage and employment equations represent a relationship between the observed contract, the parameters of the union utility, the firm's profit function, and the costs of delaying the agreement. In this framework, costs of delay are strike costs and they measure the bargaining powers of the negotiating parties.

Because of the particular version of the game which was chosen and the consequent representation of the equilibrium as a generalized Nash bargaining solution, this study is in some sense comparable to the work by Svejnar (1986). Svejnar studies wages and employment levels in 12 industries in the U.S. Wage and employment equations are derived from a generalized Nash bargaining solution in which utility weights are exogenously determined bargaining powers. In one set of estimates, the bargaining powers are assumed to be fixed. In a second set of estimates, the bargaining powers are represented by linear functions of several exogenous factors: COLA clauses, wage controls and guidelines, the regional unemployment rate, and the rate of inflation.

This study offers several advantages over Svejnar's research. The fact that the wage and employment equations are generated by the equilibrium to a non cooperative bargaining game implies that threat points and bargaining powers have natural interpretations based on the model of the underlying negotiation process.[3] For example, bargaining powers are measured by relative strike costs of the players. Also, my modelling of union preferences is more general and outputs and inputs other than labour are not treated as exogenous to the bargaining process. Finally, only one industry is considered in this study. Results from wage-employment studies concerning workers' objectives, and Svejnar's estimates involving fixed bargaining powers show large variations across industries. However, in his subsequent modelling of bargaining powers, Svejnar assumes that the coefficients of the factors affecting the bargaining powers are constant across industries, and, with the exception of COLA clauses, there are no union or industry specific determinants.

I consider the bargaining relationship between a single union, the International Woodworkers of America (IWA) and the B.C. wood products industry over the period 1963-1983. This union is a good candidate for this type of research in the sense that it is a stable, powerful organization believed to have been successful in capturing rents in the B.C. lumber and plywood industry. The existence of rents

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[3]Svejnar (1986) justifies the use of the generalized Nash bargaining solution by a Zeuthen-Harsanyi negotiation model. However this model is based on the assumption of irrational behavior of the players over time.

not captured by government in the British Columbia forestry sector has been argued by several observers and is the result of a relatively low stumpage fee for the harvesting of timber on Crown Lands. Moreover, because of the high level of vertical integration in the sector and government policies concerning the calculation of stumpage fees and tax rates, logging companies have incentives to pass on available rents to their operations in the wood products industry in the form of low prices for logs.

This data set also has the advantage of including input and output quantities and prices. My system of equations will include input demands and the output supply in addition to the wage and employment equations. Competition is assumed in the output and nonlabour inputs markets. The assumption of an exogenous price for materials is very restrictive given the role of log prices as transfer prices. Nevertheless, the assumption is maintained in order to avoid the modelling of the whole forestry sector. Competition in the output market is not unreasonable for this industry given that a large portion of the products are sold in highly competitive international markets. Also, there are indications that firms selling their products in Canada are faced with strong competition from the United States.

This industry was studied in Martinello (1984) who considers two possible bargaining frameworks. In one case, the union unilaterally chooses the wage while the firm imposes its choice of employment level after the wage is set by the union. In the second model, the union and the firms bargain efficiently over both wages and employment. In such a framework, the resulting contract is located on the Pareto frontier which is the locus of tangency points between union indifference curves and firms' iso-profit curves. This frontier is called the contract curve. In Martinello (1984), the contract curve is specified and estimated but no explanation is provided for the location of the particular contract which is observed. One contribution of Martinello's work was the treatment of input demands and output supplies as endogenous and hence as determined in part by the bargaining outcome. As mentioned above, I also adopt this method.

Other than the differences in the bargaining framework, this study differs from Martinello (1984) in the specification of the union's and firms' objectives (which are more simple and straightforward[4]) and in the data set. Although the raw industry data is the same, important changes are made in the treatment of the data and the sample period is extended to include the early 1980's (see Appendix A for details).

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[4]In particular, Martinello expressed the union objectives in terms of employment and compensation (wage times employment) rather than the usual representation which is done in terms of wages and employment.

I assume the union has a CES utility function defined over wages and employment while the firms maximize profits subject to a Cobb-Douglas technology. Four models are estimated based on different technological and bargaining assumptions. Two of the models are based on the assumption that the firms and the union bargain over the wage only with the employment level then being chosen optimally by the firm. This implies that the contract will be located on the labour demand curve. The other two models are efficient contracting models in which the wage and the employment levels are jointly determined by bargaining. In each of the two bargaining frameworks, the two models that are estimated differ with respect to assumptions concerning the adjustment of inputs and output to the labour contract. Specifically, in one case, output is treated as exogenous while all inputs are chosen optimally as functions of the negotiated contract. In the second case, output is endogenous and capital is now independent of the wage employment contract.

Each of the four systems of simultaneous, nonlinear, structural equations is estimated by a FIML procedure. The estimates of the parameters of the union utility function are quite robust to the changes in the technology and the bargaining framework. The estimates imply that the union cares about both wages and employment with relatively more weight being placed on employment. The difference in the weights placed on wages and employment is smaller when output is treated as endogenous and in fact, the hypothesis of equal weights cannot be rejected in that case. The union indifference curves are convex with an elasticity of substitution of .87 on average when output is endogenous and of approximately 1.0 when output is exogenous. In the latter case, a Cobb-Douglas representation of the union preferences cannot be rejected. For all models, the hypothesis of rent maximization is rejected at the 1% level of significance.

When output is treated as exogenous, the union bargaining power as measured by the weight given to union utility in the Nash bargaining solution is on average .86 (out of a total of 1). It falls slightly in the 1970's followed by a rapid increase in the 1980's. When output is treated as endogenous, union bargaining power is closer to the firms' power. Specifically, it averages .53 in the case of bargaining on the labour demand and .32 when contracts are located on the contract curve. The time profile is also different from the exogenous output estimation in that union bargaining power now rises slowly in the 1970's. In all four models, the hypotheses of complete union power and equal union and firm power are tested and rejected. Finally, the results suggest that the 1980's recession caused a deterioration in the firms' bargaining position since in all models, the bargaining power of the union increases sharply.

The proportion of rents captured by the firm is calculated when possible and is compared to the firm bargaining power.[5] The proportion of rents is often used to measure bargaining power and it is interesting to see whether it is a good measure since rent maximization is not accepted as a good description of union behaviour in this study. The two measures turn out to be considerably different. For example, in the efficient contracting model, when output is exogenous, the proportion of rents captured by the firm is on average 42% compared to a bargaining power of 16%, and when output is endogenous, the two measures are 77% and 68% respectively. Furthermore, the time profiles of the two measures are not monotonically related.

As mentioned previously, in Rubinstein's bargaining theory, the bargaining powers of the players are functions of their relative costs of delay or strike costs. In this study, these strike costs are allowed to vary over time and across groups of firms according to exogenous factors. These factors are commonly used in the empirical strike literature as determinants of strike costs. In all four models, the hypothesis that the strike costs did not matter is rejected.[6] However, the coefficients on the strike cost

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[5]The bargaining power of the firms is equal to one minus the union's bargaining power as described above.

[6]The test that costs do not affect the labour contract is identical to the test that the union strike costs are zero i.e. all coefficients in the term representing relative

variables are sensitive to the bargaining framework and the technological assumptions and their standard errors are often large. In the efficient contracting model, the firms' relative strike costs are negatively and significantly affected by interest rates and capital utilization ratios. Effects of inventory levels and labour market conditions depend on the technology assumptions. Part of the problem of large standard errors is caused by the considerable amount of multicollinearity which is present among these variables. Attempts to find better data failed as other variables which were used did not provide additional information. Also, attempts to estimate separately the strike costs of the firm and the union were not successful.

When output is treated as exogenous, the likelihood value increases and the prediction of employment improves considerably but the resulting labour coefficient (the labour cost share) is implausibly low. In the efficient contracting model this implies a small marginal revenue product of labour. Part of the problem is caused by the large amount of correlation between employment and output. This results in a large standard error on the employment coefficient. However, even when using the upper bound of a confidence interval, the labour coefficient estimate in the cooperative model is very small. Otherwise, the

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strike costs are set to zero.

technological parameters (e.g. demand elasticities) seem reasonable and they are comparable to previous estimates.

Consistently throughout the estimation, the efficient contracting model performs better in the sense of generating a higher likelihood value. However, the parameter estimates seem to be more sensitive to technological assumptions than to the bargaining framework used. This has serious implications for the interpretation of results in wage-employment determination studies where the technology is not modelled rigorously.

Overall, the bargaining game by Rubinstein proves to be tractable and amenable to empirical research. In general, the estimation yields reasonable technological parameters and many of the results concerning the union utility are comparable to previous findings. Furthermore, new insights are provided on bargaining powers and the measurement of strike costs.

This thesis is organized as follows. A review of the literature is provided in the next chapter. This is followed in Chapter 3 by a description of the bargaining game and its application to contract negotiations. The modelling of the union and firms' objectives is also discussed in Chapter 3. Chapter 4 is composed of two parts: first, the models to be estimated are derived based on the assumptions given in the previous chapter, and secondly, a short discussion of the data is provided. Estimation results are presented in Chapter 5 and finally, concluding remarks are made in Chapter 6. Details concerning data sources and manipulations are provided in Appendix A.

Chapter 2

Review of the Literature

In this section, an overview of the literature in relevant areas is presented. Since my work touches upon several areas of research, this is by no means an exhaustive review. There are basically two major literatures involved: wage-employment determination models and noncooperative bargaining games. I will start by discussing the first as it will serve to motivate the choice of a bargaining model. Other topics which will be mentioned include: models of union behaviour, cooperative bargaining games and strike theory.

In wage-employment determination (W-E) models, micro data on wage-employment contracts between a union and a particular industry are studied. Contrary to Phillips' curve models of wage determination, these studies are based on rigorous models of union objectives and firm technologies. It is also recognized that negotiated agreements are the result of firm-union bargaining and consequently, factors affecting either party (e.g. the firm's product market conditions and the union's preferences) can influence the outcome.

Wage-employment models have three components each of which is an area of research in itself. They are: the modelling of union goals, firm objectives and constraints, and the bargaining framework. Firms are usually assumed to maximize profits. The representation of the technology varies a lot across studies. Examples will be given later on in this chapter.

The modelling of union behaviour has been a controversial issue in industrial relations ever since the 1940's. The question is: can we model union objectives by a common well-behaved utility function or is the union's decision-making too complex to be even approximated by such a formulation?

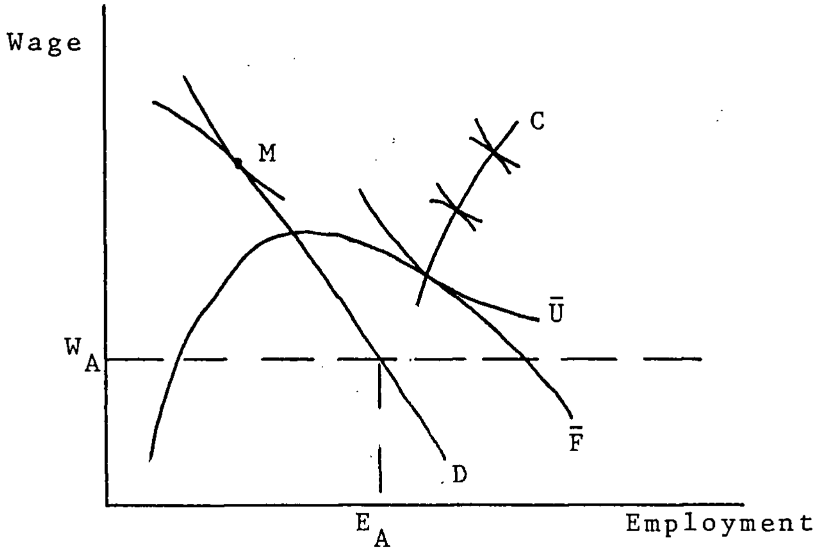
In most cases, economists have assumed the existence of a well-defined utility function without specifying the underlying process generating it. Two exceptions are Oswald (1982) and Blair and Crawford (1984) who investigate the implications on union preferences of various assumptions concerning workers' preferences and the political process under which the union operates. To date, the results have been discouraging in the sense that only in very special cases is it possible to generate a well-behaved union utility function from the underlying workers' preferences. For example, a rent maximizing utility function can be generated by a union who maximizes a representative worker's expected utility if this expected utility is equal to the worker's expected income and if all workers in the union's fixed membership have an equal chance of being employed. In this study, I assume the existence of a well-behaved union utility function, but I believe there is a lot of important work to be done in this area. (See Farber (1986) for a discussion of the issues involved).

Two different bargaining set-ups have been considered in W-E studies. In the first one, it is assumed that the union and the firm bargain over wages only, the employment level being chosen by the firm. This implies that the contract will be located on the labour demand curve. In the second framework both wages and employment levels are negotiated. Efficient bargaining then yields outcomes situated on a contract curve (the Pareto frontier) which is defined by the locus of tangency points between the union's indifference curves and the firm's iso-profit curves. This contract curve will in general be to the right of the labour demand curve in wage-employment space. This is easily seen from Figure 1 (following page).

In Figure 1, D is a labour demand, $\bar{F}$ is an iso-profit curve, $\bar{U}$ is a union indifference curve, and C is the contract curve. Iso-profit curves are horizontal at the point of intersection with the labour demand and they are negatively sloped to the right of the demand. Unless the union indifference curves are horizontal (in which case the union does not care about the employment level), their tangency points with iso-profit curves will be to the right of the labour demand.

Figure 1

Bargaining Frameworks



In the case of a rent maximizing union (i.e. the union utility takes the form $E \cdot (W-W_A)$ where W_A is the alternative wage), the contract curve is vertical. The employment level is determined by equating the marginal revenue product of labour with the alternative wage (see point E_A in Figure 1). This level of employment maximizes total rents and is independent of the negotiated wage. The contract wage serves to divide the rents between the union and the firm. Note that under the assumptions of rent maximization and bargaining over both wages and employment, the resulting contracts will be efficient in the sense that the employment level is also the competitive employment level. This property is called "strong efficiency" by Brown and Ashenfelter (1986).

Note that in either the labour demand or the contract curve models, no particular outcome on the relevant curve is predicted unless one agent is free to impose his choice. Usually, in the studies based on a labour demand model, the union is assumed to choose the wage. The point M in Figure 1 is an example of a predicted contract under such an assumption. This framework is called the monopoly model. In the studies based on the contract curve model (also called cooperative model), the wage is not explained. Econometrically, either the wage is treated as exogenous (e.g. Martinello (1984)), or the endogeneity of the wage is recognized by the use of instrumental variables but, there is no underlying model explaining the choice of the instruments (e.g. MaCurdy and Pencavel (1986)). Unless a monopoly model of unions is assumed, the prediction of a particular contract requires the specification of a bargaining model. None of the wage-employment determination studies include such a model.

Once union preferences and the firm's profit function have been specified, wage and employment equations are derived and estimated. The estimation results are used to make inferences about union objectives, and possibly the firm's technology and product market. In some W-E studies, estimation results are used to evaluate bargaining frameworks i.e. whether the data is better explained by locating the outcomes on a contract curve, a labour demand curve, or at the union's preferred wage level on the labour demand curve.

The first data set used for such studies involved the United Mine Workers and the bituminous coal industry in the U.S. Farber (1978) assumes the monopoly model holds and that the union acts as if it maximizes the expected utility of the median aged member. His central result is that the workers are quite risk averse which suggests that the union places substantial weight on employment.

Carruth and Oswald (1983) develop and estimate a model of the wage policy of the National Union of Mineworkers in Great Britain. As in Farber (1978), it is assumed that the union can choose wages subject to a labour demand constraint. In their modelling of the labour demand however, they allow for partial adjustment of labour over time due to the presence of adjustment costs. The workers are identical with constant relative risk aversion utility functions and the union behaves as if it adopted a utilitarian rule. Again the workers are found to be risk averse but less so than their U.S. counterparts.

The International Typographical Union (ITU) locals in a number of American cities have been the subject of several wage-employment determination studies. Dertouzos and Pencavel (1981), Pencavel (1984a), and Pencavel (1984b) all assume the monopoly model of bargaining. The major difference in the models is in the specification of the union locals' objectives. These are found to vary across locals. Popular forms of union preferences such as the maximization of the wage bill and of economic rents are often rejected. The results suggest that in most cases, relatively high weights are placed on employment.

In the next two studies, nested tests are performed to evaluate the applicability of efficient contract or cooperative models to the data. Brown and Ashenfelter (1986) assume the ITU maximizes rents and test whether employment is determined by the alternative wage (efficiency) or the contract wage (the contract is on the labour demand curve). They find that both wages affect employment which suggests that the contracts in this industry are inefficient. However, it could also mean rent maximization is not a good description of the ITU's behaviour. MaCurdy and Pencavel's (1986) test is based on the observation that a profit maximizing firm that is free to choose its input levels will set input price ratios equal to the ratio of the same input's marginal revenue product. If employment is chosen by efficient contracting, an extra term appears in the wage equation in the form of the union's marginal rate of substitution between wages and employment, A quite general functional form is assumed for the MRS and the extra term is found to be important in the estimation.

They conclude that an outcome on the labour demand constraint is unlikely in the ITU negotiations.

Martinello (1984) studies the behaviour of the International Woodworkers of America, in particular the locals of the IWA bargaining with the British Columbia wood products industry. The union is assumed to have a utility function which is quadratic in labour and compensation. Non-nested tests suggest that the efficient contracting model performs better than the monopoly model. The union is concerned with both wage and employment levels and the alternative wage. Both wage bill and rent maximization are tested and rejected. The study by Martinello involves a more rigorous modelling of the firm's technology. In particular, it is assumed that the firm adjusts other input levels to the labour contract rather than fixing them exogenously. Also, general functional forms are adopted to represent the firms' technology. Unfortunately, his estimates do not support the curvature properties associated with profit maximizing behaviour and his choice of functional forms.

The study by Card (1986) involves airline mechanics in seven airlines in the U.S. Several unions are involved but they are all assumed to behave identically, in particular, to maximize rents. This framework, which is similar to that in Brown and Ashenfelter (1986), is extended to allow for an additional effect of the alternative wage on the level of employment. More specifically, Card assumes that the firm faces adjustment costs in its labour input so that the profit maximizing level of employment is a function of past employment and future wage rates. Moreover, expectations of future wage rates are functions of current alternative wages which implies that even if the labour demand curve is a binding constraint, employment contracts will be functions of the alternative wage. However, he finds that an unrestrictive function for employment where neither the monopoly model (with the dynamic labour demand) nor the rent maximizing contract curve are imposed performs better.

The last wage-employment determination study to be reviewed is by Eberts and Stone (1986) and involves public school teachers. Eberts and Stone (1986) reject the hypothesis that outcomes are located on a labour demand curve after finding a positive relationship between wage compensation and employment protection clauses such as limits on class sizes. By contrast, they find the expected negative effect on salary of changes in non-employment job attributes such as fringe benefits and leave provisions.

A different approach is taken in Abowd (1987) who uses the behaviour of stock values in response to the signing of collective agreements to test whether the data supports an efficient bargaining model or a framework where the firm unilaterally chooses employment. That data consists of contracts signed from 1976 to 1982 involving U.S.

manufacturing and non-manufacturing firms with publicly traded stocks. All unions are assumed to be rent maximizers. Abowd finds that the collective agreements serve to distribute the firms' rents to workers and shareholders but do not seem to provide information to stockholders concerning the unions' (possibly private) information on future labour costs. This is consistent with the hypothesis of a common information set for the unions and the firms bargaining together. In Abowd's model the efficient and inefficient contracting frameworks have different implications for the relationship between unexpected changes in union members' wealth and stockholders' wealth. The empirical results support the predictions of the efficient contracting model.

There are various possible extensions to empirical models of wage-employment determination some of which would involve more explicit modelling of the effects of uncertainty and private information.

Another important extension is the incorporation of a bargaining model. Not only can a bargaining model be used to identify the influence of additional exogenous factors but it may shed new light on the way previously used determinants affect wage-employment contracts. As an example, with the use of a bargaining game, we could take into account effects of the alternative wage or labour market conditions on the contract wage by its influence on the relative bargaining strengths of the agents.

In most of the W-E studies, the importance of explicit modelling of the bargaining process is mentioned. The problem has been the lack of appropriate models. Historically, bargaining models have been of two types. The first type consists of axiomatic models (or cooperative games) in which a particular outcome is chosen on the basis of its characteristics (e.g. symmetry). Unless one relies on focal-point type arguments, these models prescribe what the solution ought to look like rather than what it is observed to be. In that sense they are more appropriate for the study of arbitration decisions than negotiated outcomes. In any case, the fact that these models contain no description of the process by which agents arrive at the solution makes them difficult to use in empirical studies of non-experimental bargaining settings.[7]

The best-known axiomatic bargaining model is the one first proposed by J. Nash. The Nash bargaining solution satisfies the four axioms of symmetry, Pareto optimality, Independence of irrelevant alternatives and Invariance to linear transformations. It can be written as the solution

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[7]See Roth (1979) and Riddell (1981) for discussions of various solution concepts. There is a substantial literature on experimental bargaining studies in which various bargaining solutions are tested. For example, see Coursey (1982) and Roth and Schoumaker (1983).

to the maximization of the product of the two players' utility increments over their threat points. If symmetry is relaxed, different weights can be attached to the players' utilities. Examples of the use of this solution in empirical research are de Menil (1971), Hamermesh (1973), and Svejnar (1980, 1986). de Menil (1971) assumes a Nash bargaining solution in his study of U.S. manufacturing wages while Hamermesh and Svejnar attempt to test whether the (symmetric) Nash bargaining solution holds.

In his latest study, Svejnar (1986) looks at wage and employment contracts in several U.S. industries with sample periods varying across industries. Unions are assumed to be rent maximizers but risk aversion is allowed in the form of a constant relative risk aversion coefficient. An asymmetric Nash bargaining solution is assumed with the weights on the two players' utilities being functions of exogenously determined bargaining powers. Results suggest that the relative bargaining powers are highly variable across industries and the symmetric Nash bargaining solution is often rejected. Unfortunately, estimates of risk aversion parameters of the workers are very imprecise, possibly because of very small sample sizes. In some of the empirical work, the bargaining powers are allowed to vary over time and the results show that the union bargaining power increased with the presence of COLA clauses and inflation and decreased during periods of price controls and high unemployment.

In the second type of bargaining model, the negotiation process is described. But, until very recently, such models relied on ad hoc and unsatisfactory assumptions about the rationality of the agents and information transmission. Examples are the models by J. Cross and Zeuthen-Harsanyi in which players make systematic errors about their opponent's and even their own future behaviour.[8] It is only in the past decade that bargaining has been modelled as a non-cooperative game between rational (Bayesian-Nash) players. This is the type of model I use in my empirical work.

Before proceeding to examine the literature on non-cooperative bargaining games, I want to mention a related area of work namely, the implicit contract literature. The issue of whether firms and unions engage in implicit contracting arises in this framework due to the fact that we do not observe firm-union contracts in which the employment level is specified. We do observe contracts with manning requirements and seniority provisions, and the evidence presented above also suggests that unions are concerned with employment levels, so why not explicitly contract for employment? Several possible reasons have been provided; these involve imperfect information, monitoring costs and

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[8]See Foley and Maunders (1979) for a good description of this type of model.

transaction costs. This does not mean than the resulting contracts will be inefficient. We can have contracts in which nothing is said about the employment level but which include some kind of compensation scheme that will ensure efficiency.[9] Also, implicit contracting over and above the negotiated agreement could ensure efficiency. Efficiency and incentive compatibility imply structure on the form of these contracts; however, the results so far are model specific and very little is known about their empirical relevancy.[10]

The literature on non-cooperative bargaining games is fairly recent.[11] A lot of the work is set in a buyer-seller game where these players bargain over the price of the one good that will (or will not) be traded. Chatterjee and Samuelson (1983) present a one period buyer-seller game in which the players submit sealed offers. There is two-sided uncertainty about the opponent's valuation of the good and inefficient (no-trade) outcomes can occur in equilibrium.

Fudenberg and Tirole (1983), Sobel and Takahashi (1983) and Fudenberg, Levine and Tirole (1983) extend the game to a multi-stage one. In imperfect information environments

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[9]See Hall and Lilien (1979) for examples of this.

[10]See Azariadis (1981) for a survey.

[11]See McLennan (1982) for a general definition of the bargaining problem in a game theoretic framework.

learning will occur. In choosing their strategies, the players have to take into account the effect their observable behaviour will have on their opponents' beliefs. It is also fundamental to these models that there is discounting so that players have incentives to agree early in the game. Fudenberg and Tirole; (1983) look at a two-period game with two-sided uncertainty while Sobel and Takahashi (1983) extend the model to an infinite-horizon game for the one-sided uncertainty case. Fudenberg, Levine and Tirole (1983) generalize the infinite-horizon one-sided imperfect information results.

In the preceding games (with the exception of Chatterjee and Samuelson (1983)), only the seller makes offers. The buyer's strategy consists in accepting or rejecting them. Also, the uncertainty always involves the opponent's valuation of the good. In the next set of games, two players bargain over the splitting of a fixed pie, Again there are costs of delay so that the pie shrinks over time, but the players now alternate in making offers and where there is uncertainty, this uncertainty concerns the opponent's delay costs rather than the initial bargaining set. This game was first presented in Rubinstein (1982) for the certainty case. He extends his results for the one-sided uncertainty case in Rubinstein (1985).

Considerable extensions of these models were provided in Cramton (1984) (see also Cramton (1985)). In his thesis, Cramton looks at a game between a buyer and a seller. The equilibrium are characterized for finite and infinite horizon cases, for one-sided, two-sided, and no uncertainty (the uncertainty always involves the opponent's valuation of the good), for games with alternating offers as well as one-sided offers, and finally for continuous time models where there is no first mover advantage.

An important feature of the above models is that the agents have cardinal objective functions with identical units of measure (dollars in one case and pie share in the other). In a firm-union context, if we assume that employment is also being determined, this amounts to requiring that the union maximize rents or a linear function thereof, a very restrictive assumption in view of the empirical evidence reviewed earlier. This feature is relaxed in some of the examples in Binmore (1987C) and in McLennan (1982). They also write the solution to the Rubinstein game as an asymmetric Nash bargaining solution for some classes of models. As will be seen later, this turns out to be important for my work. Another common feature of these models is the use of discounting as time costs. Discount factors are easy to manipulate and they also have a stationarity characteristic that Rubinstein (1982) found crucial in his model.

The bargaining games mentioned above have two characteristics that are desirable for applied work on firm-union contracts: (i) the set of equilibria is small (the equilibrium is often unique) (ii) there is a lot of flexibility in the offers the agents can make initially, and throughout the game.[12] This is especially important when studying a particular union and industry because a lot of the information contained in the data is found in the distribution of the surplus rather than in the strike lengths (if only because of the relative numbers of observations). It is often the case that bargaining models involving asymmetric information and hence the possibility of inefficient outcomes or strikes as equilibria also include severe restrictions on the offers the players are allowed to make. This is due to reasons of tractability. In this study however, the focus is on the contracts rather than strikes and therefore, it is important that the offers be determined endogenously rather than heavily restricted by outside influence. (Of course when one can observe exogenous restrictions on the possible offers such as wage controls then the model should reflect this).

Many recent developments have been made in non-cooperative bargaining games especially in the area of games with imperfect information and mechanism design under imperfect information. Players engage in sophisticated reputation building strategies and implications of the

[12] Not all bargaining games have these characteristics e.g. Osborne (1985) and Crawford (1981).

structure of the contract on the equilibrium outcomes are studied. However, empirical application of these more sophisticated games is very difficult because the equilibria become very complex and would require better, more detailed data on the bargaining process and the information structure.[13]

Empirical work based on an explicitly formulated bargaining game is practically non-existent. To my knowledge the only empirical study using a bargaining game framework is Fudenberg, Levine, and Rudd (1985). In their paper, a union and a firm bargain over the absolute size of the increase in the real wage. Only the union makes offers, the firm either accepts (the contract is signed) or rejects (there is a strike). Strikes occur in equilibrium because there is imperfect information, the union being uncertain about the value of the offered wage increment to the firm. The equilibrium strategy for the union takes the form of a wage concession schedule. This schedule reflects the union's prior beliefs and how these beliefs are updated over time as the union observes the firm's actions (acceptance or rejection). Because of the special form of the uncertainty (the beliefs), the wage concession schedule can be written as a function sufficiently simple to estimate.

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[13]See Roth (1985) for a recent survey.

Concession schedules have been used in the study of strikes in the work of Ashenfelter and Johnson (1967) and Farber (1978). The setting is quite different in those papers in that it involves a political model of union behaviour. More specifically the union leaders are not always acting in the workers' best interest since they have different goals (e.g. re-election). In such a framework, it is difficult to evaluate the estimated parameters. In Fudenberg, Levine and Rudd, these have an economic interpretation. Their reasonableness (or lack thereof) provides some information on the applicability of the model, in particular of the stringent rationality requirements. However, as in previous work, in the Fudenberg, Levine and Rudd paper, strikes are always to the disadvantage of the worker (the concession schedule is downward sloping).[14] This is due to the information structure, the rules of the game, and the fact that the game involves negotiation of one contract only i.e. the workers are not able to learn from previous contract negotiations. To allow for strategies involving more than one contract negotiation, a supergame would be required.

The work by Gul and Sonnenschein (1985) indicates what seems to be a basic flaw in the Fudenberg, Levine and Rudd

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[14]See Eaton (1978) for an interesting variant of the Ashenfelter and Johnson model in which it is the workers who benefit from strikes.

model. Fudenberg, Levine and Rudd assume continuous time while results by Gul and Sonnenschein suggest that inefficient outcomes (i.e. strikes) can only be generated as equilibrium points in discrete time games. Concerning the empirical aspect of their work, the model adopted by Fudenberg, Levine and Rudd has the following weaknesses:

(i) All inputs including employment (and therefore output levels) are fixed exogenously, independently of the wage. This conflicts with empirical evidence from wage-employment determination models.

(ii) The model is estimated using data on many different unions and industries with no allowance for variance in union preferences or firm technology parameters.

(iii) Once signed, the contract is assumed to last forever. This means that the expected value of the contract will be overstated.

(iv) The information structure is very simple and does not allow for uncertainty regarding strike costs. Also the firm is assumed to know everything about the union.

For my empirical work, I use a model based on the Rubinstein game. There are two main reasons for this. First, it is possible to use more general formulations of the union's and firm's objective functions without complicating the analysis too much. Secondly, it is clear that in practice, both negotiating parties do make offers.

As mentioned above, a fundamental characteristic of the Rubinstein's game and other non-cooperative bargaining models is the presence of delay costs which provide incentives to the players to agree early in the game. In the industry which is studied here, delays lead to strikes and costs of delay are measured by strike costs. The last area of research which will be discussed in this chapter and to which I now turn is the empirical work on strike costs.

Most of the empirical studies on strikes have focused on the estimation of two types of relationships. Firstly, the effects of variations in strike costs on length and/or frequency of strikes are modelled. More recently, the level of uncertainty in the economic environment of the two negotiating parties is related to the occurrence of strikes. Although these studies generally did not include a model of bargaining and hence of strikes, these relationships were justified by the arguments that, ceteris paribus, increases in strike costs will make parties less willing to strike. Also highly uncertain environments will increase the amount of asymmetric information between the players and lead to a higher probability of strikes. Examples of these studies are Kennan (1980) and Reder and Newmann (1980) (strike costs); Siebert and Addison (1981), Mauro (1982), and

Lacroix (1983) (uncertainty), and Tracy (1986) (both strike costs and uncertainty).

The main determinants of strike costs that have been considered are measures of borrowing costs for the firm (interest rates, levels of inventories), measures of opportunity costs of the workers (unemployment), and measures of cyclical variations. Industry specific variables are also used such as capital intensity and variations in shipments (which indicate the ability of the firm to keep its market share during work stoppages), as well as measures of union power such as the level of unionization in the industry. Since a single industry is studied here, the latter type of effect is not considered. Tracy (1986) also considers the size of the rents as an explanatory factor of strikes. In this study, the determinants of strike costs are used to measure variations in the proportion of rents which is lost per time period during strikes (i.e. one minus the discount factors of the players). The absolute level of rents lost due to strikes will be affected by the total rents available as well as the discount factors of the players.

Chapter 3

The Model

The study of negotiated wage and employment contracts involves the modelling of the 3 components of collective bargaining: the union objectives and constraints, the firm goals and technology, and the bargaining relationship. Each of these will be studied in turn but first I address the question of the negotiation of the level of employment. Specifically, is employment unilaterally chosen by the firm, in which case the contract is on the labour demand curve, or do the parties negotiate the level of employment thereby attaining an efficient contract (a point on the contract curve)? It was seen in Chapter 2 that if the union cares at all about the employment level, a Pareto optimal contract, i.e. a contract which corresponds to a tangency point between the union's and the firm's indifference curves will lie to the right of the labour demand curve. The resulting employment level will be greater than the firm would like in the sense that the marginal revenue product at that employment level will be smaller than the wage.

Although the collective agreements under study do not specify the level of employment, they do contain provisions directly affecting employment (e.g. job security provisions). Moreover, there are other instruments which could be used to obtain an efficient level of employment (e.g. non-linear compensation schemes). A priori, the efficient contracting model is more attractive unless there is some indication of a constraint which prohibits the two players from reaching a Pareto optimal point. Such a constraint could be due to imperfect information, monitoring costs or transaction costs. However, these constraints can be used to argue against the labour demand model as well. In general, this argument is not helpful in choosing between the two models. Turning to specific models of implicit contracting, we find that notions of efficiency and incentive compatibility do impose structure on the forms of the contracts but the results have been very model specific and little is known about their empirical relevancy.

In this paper, both the labour demand and the efficient contract or cooperative model are estimated. Their performance can be evaluated by the use of a non-nested test.

3.1 The Bargaining Game

This first section contains a description of the bargaining model and draws heavily from the work by Binmore (1987C). It is followed in section 3.2 by a discussion of the empirical application of the game to firm-union contract negotiations.

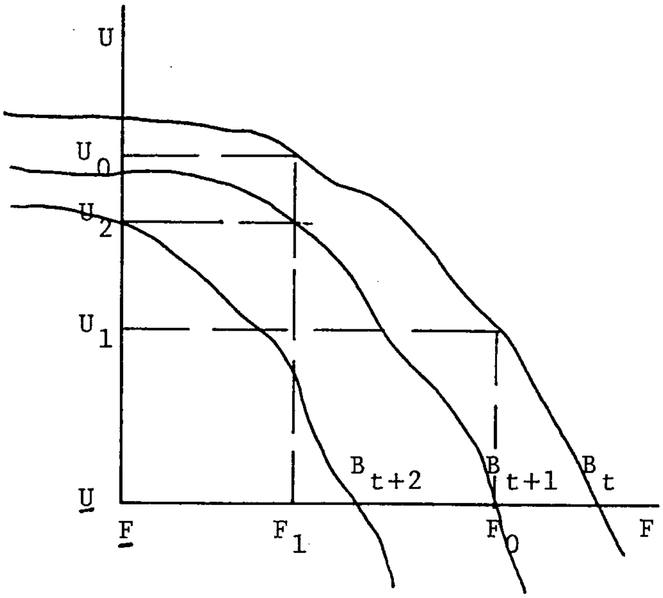
The bargaining is of the type first presented in game theoretic form in Rubinstein (1982). Two players are bargaining over the division of a pie. In the original paper, the size of the pie was fixed (i.e. the frontier of the bargaining set at the start of the negotiations was linear with slope -1). This amounts to assigning identical units of utility to the two players. More specifically, this forces the union to be rent maximizing, a hypothesis which is most often rejected in empirical studies. Binmore (1980) showed that this restriction could be relaxed without too much complication. In this study, I use the Binmore result and allow the union utility function to take a more general form. Rent maximization will be tested as a special case. Other than this, I follow the rules of the game and adopt the restrictions on the players' preferences as specified in Rubinstein [1982].

The two players alternate in making proposals. After hearing his opponent's offer, each player has to accept or reject it. If he accepts, the game ends and the proposal is implemented. If he rejects, he can make a new proposal. Any feasible agreement is preferred by both players to the no-agreement outcome. Moreover, each player incurs costs by delaying agreement so that for any time t, an agreement signed at time t is preferred to the same agreement signed at any time after t.

Both players are rational; i.e., they care only about the final agreement and not how it is reached. Also, they do not believe idle threats made by their opponent (idle threats are such that it would in fact not be in the player's best interest to carry them out). In the face of such rationality, any equilibrium to the game will have to be sub-game perfect as defined by Selton. The assumptions of rationality and of time costs are powerful ones. Figure 2 is used to illustrate this point.

Figure 2

Perfect Equilibria with Alternating Offers and Costs of Delay



In Figure 2, the present value objective functions or the present value utilities of the two players are measured along the axes. The point (F, U) is the no-agreement point, and B_i is the Pareto frontier of the bargaining set (the set of feasible agreements) at time i. The frontier B_i of the bargaining set shifts in over time because of delay costs. Suppose player F is the one to make a proposal at time t + 1. He anticipates B_{t+2}, and he knows that if no agreement is reached in period t + 1, the most his opponent can get is U_2 because U_2 is the maximum payoff of player U for the game starting at time t + 2. Player F knows that for any proposal he makes at t + 1 giving U a payoff greater than U_2, he could make himself better off by offering slightly less to U such that the proposed payoff to U would still exceed U_2. Furthermore, U would accept it. Therefore the set of perfect equilibrium points at time t + 1 will not include any point giving U more than U2.

We can use the same type of reasoning to find a lower bound to the perfect equilibrium payoffs to player U at time t + 1. Player U will not accept any payoff less than $\underline{U}$ since this is the minimum he can receive for the game starting at t + 2. Using the set B_{t+2} and the rationality of the players, we have limited the set of possible perfect equilibrium points to $[(F,U) : \underline{U} \leq U \leq U_2, F_1 \leq F \leq F_o]$ which I call PE_{t+1}.

We now move back one period. U is deciding what proposal he should make at time t. He knows that the relevant part of the bargaining set at time t + 1 is PE_{t+1} since he also anticipates B_{t+2} and he knows F is a rational player. Using the same type of reasoning as above, we can limit the set of possible perfect equilibria at time t to $[(F,U) : U_1 \leq U \leq U_o, F_1 \leq F \leq F_o]$ which is denoted PE_t.

If we were to go back to time t + 2 and limit the relevant bargaining set at t + 2 by using B_{t+3}, we could expect to limit PE_{t+1} and PE_t even more. It is interesting to look at the case where the bargaining set shrinks to a single point, the disagreement point. Suppose this occurs in finite time, more specifically assume that in Figure 2, the set B_{t+3} is the point ($\underline{F}$, $\underline{U}$). It is clear that in Figure 2, the PE sets will consist of one point only, in particular the unique PE possible at time t is (F_1, U_0). If the game is infinite, we can't work our way back from the disagreement point; however, with proper restrictions on the time costs the equilibrium to the limiting infinite bargaining game is unique. This result is all the more surprising given the large number of equilibria usually encountered in infinitely-repeated games.

The structure which is imposed on the time costs is that of stationarity and its implication is essentially to make the game homogeneous across time periods. This is well illustrated by a generalization of the argument used in Shaked and Sutton (1984).[15] Suppose the delay costs take the form of discounting and d_u,d_f are the respective discount factors for the players U and F, with $0 \leq d_i \leq 1$ for i = u,f. Let the Pareto frontier in current values

[15]Shaked and Sutton consider the case of the splitting of a fixed pie of size one i.e. the bargaining frontier in current values U and F is the unit simplex.

(i.e. time 0 values) be $U = \overset{*}{U}(F)$ and in general at time t: $U/d_u{}^t = \overset{*}{U}(F/d_f{}^t)$. Also, assume $\overset{*}{U}$ is invertible so that $F = \overset{*}{U}^{-1}(U)$ at $t = 0$.

Let player U be the first mover. If U_2 denotes the maximum utility level for U in the set PE_2 (i.e. in the set of perfect equilibrium points for the game starting at $t = 2$ rather than $t = 0$) then he will surely accept any offer giving him more than U_2 which implies that F will never offer him more than U_2 at time $t = 1$. By defining a maximum level of utility for player U at time 1, U_2 also defines a minimum level of utility for player F at time 1 which we can retrieve by using $\overset{*}{U}$: $F_1 = d_f \times \overset{*}{U}^{-1}(U_2/d_u)$ (remember that U_2 and F_1 are in present values). Since player F can guarantee himself F_1 for the game starting at $t = 1$, this limits the maximum payoff to player U at $t = 0$ to $U_o = \overset{*}{U}(F_1) = \overset{*}{U}\,[d_f \times \overset{*}{U}^{-1}(U_2/d_u)]$ which can be rewritten as:

$$\frac{\overset{*}{U}^{-1}(U_o)}{d_f} = \overset{*}{U}^{-1}\ (U_2/d_u). \tag{1}$$

Notice that the game starting at time $t = 2$ is exactly the same as the game starting at time $t = 0$ except that the two players' utility functions are scaled down by a fixed factor $d_i{}^2$ with $i = u$ for player U and $i = f$ for player F. Given the nature of the equilibrium as a series of optimization problems, the maximum payoff to player U for the game starting at t = 2 is the scaled down maximum payoff for the game starting at t = 0, or $U_2 = d_u{}^2 U_o$.

Substituting in (1) yields:

$$\frac{\overset{*}{U}^{-1}(U_o)}{d_f} = \overset{*}{U}^{-1}\ (d_u U_o). \qquad (2)$$

The concept of perfect equilibria and the homogeneity of the game have allowed us to solve for the maximum payoff to player U at time 0. Note that we can do the same for the minimum payoff to player U. In fact, if $\overset{*}{U}$ is concave, equation (2) is satisfied at one point only and therefore the equilibrium is unique.

As mentioned previously, Rubinstein solved this game by imposing structure on the preferences of the players with respect to the costs of delay. Specifically, these costs are assumed to be stationary over time and increasing with the value of the contract. Let $\hat{U}_i(C,t)$ be the utility player i receives from the bargain (or contract) C signed at time t. It is assumed that for i=u,f, and for all $t_1, t_2, t \in \{0,1,2,...\}$.

(A-1) $\hat{U}_i\ (C,t_1) > \hat{U}_i(C,t_2)$ if $t_1 < t_2$.

(A-2) $\dfrac{\partial \hat{U}_i\ (C,t)}{\partial C} > 0.$

(A-3) $\dfrac{\partial[\hat{U}_i(C,t) - \hat{U}_i(C,t-1)]}{\partial C} < 0.$

(A-4) $\hat{U}_i(C,t_1) \geq \hat{U}_i(C,\ t_1+1)$ iff $\hat{U}_i(C,t_2) \geq \hat{U}_i(C,t_2+1)$

Assumption (A-1) implies that time is costly, (A-2) that the contract is measured in units which are valuable to i, (A-3) that time costs are increasing in the contract units and (A-4) that time costs are stationary. The last assumption can be expressed differently as follows:

(A-4)' if $\hat{U}_i(C,t) = \hat{U}_i(C + e_i, t+1)$

then e_i is independent of t.

This says that the improvement in the contract necessary to compensate a player for waiting an extra time period is the same at all times. (Note that (A-3) implies that e will be increasing in the value of the contract). Assumption (A-4) is very restrictive. Binmore (1987a) shows that with some strengthening of (A-4), there are only two forms of time costs permitted: discounting and fixed costs per time period, i.e.

$$\hat{U}_i(C,t) = U_i(C)\, d_i^t \quad \text{or} \quad \hat{U}_i(C,T) = U_i(C) - D_i t.$$

In order to give examples of fixed and discounting costs, let delays be strikes and suppose that the two parties are negotiating a 2-year contract worth V in total value. An example of fixed costs would be the loss to each party of a fixed proportion of V in each period of the strike; e.g., a strike of six months would mean losing 1/4 of V, a strike of one year, the loss of 1/2 of V, etc. Now suppose that if there is a strike, the contract is pushed forward in time and that V is still the value of the contract signed after the strike. During the strike, the two parties might have to borrow money or deplete savings, but in any case, they are incurring the opportunity cost of receiving the value of the contract later in time. In this last example, delay costs take the form of discounting. In reality, both types of costs seem plausible. When strikes are short, it is possible that the potential contract value (V) is completely recovered after the agreement is signed through higher than average production levels. For longer strikes, the recovery of the potential contract value becomes more implausible and fixed costs are probably encurred as well.

In Rubinstein (1982) the set of Perfect Equilibria is fully characterized for the game with perfect information and a fixed pie. In the case of discount costs, the equilibrium is unique, it occurs at time 0, and it gives to the first mover, say player i, a share of the pie $S_i = (1-d_j)/(1-d_i d_j)$. (Note that the equilibrium share S_i is easily derived from equation (2) and the fixed pie bargaining frontier: $\overset{*}{U}(F_o) = 1-F_o$). In the case of fixed costs, if $D_u \neq D_f$, the equilibrium is unique and occurs at time 0, but if $D_u = D_f$, there are multiple equilibria some of which could occur later in the game.

Rubinstein (1985) generalizes his results for the game with one-sided imperfect information concerning the opponent's time costs. Further results on Rubinstein bargaining with imperfect information are derived in Crampton (1984a) and (1984b). Not surprisingly, the set of equilibrium points is very sensitive to the information structure. In the absence of asymmetries in the information, there is nothing to gain from a delay and we expect the agreement to be signed at the beginning of the game.[16] With asymmetric information, delays can play a role in providing information; however, even for very simple models the equilibria are quite complex. Furthermore, the equilibria depend crucially on aspects of the information structure such as prior beliefs for which no data are available.

It is important to note that in the results described above, there is an advantage in being the first mover in the negotiations. For example, the share of the pie S_i going to the first mover in the game with discounting and perfect information is greater than one half when $d_i = d_j$. (From above, $S_i = (1-d)/(1-d^2)$ where $d = d_i = d_j$ and $0 < d < 1$). Unless there are institutional factors determining the first

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[16] I do not think the equilibria involving delay which can occur in the case of equal fixed costs under perfect information are good models of delays in bargaining since, in such a framework, there is nothing to be gained by delaying the agreement. Rather, they indicate a need for some strengthening of the equilibrium concept in that case.

mover, we would expect the players to bargain over who goes first. In this sense, the game is incomplete.

One way to deal with this feature is to allow the time interval between proposals to become small. In the continuous time game there is no advantage in being the first mover. Note that this continuous time game is the limit of the discrete time game when time intervals between offers tend to zero. It can be interpreted as a game where at each instant, a player can either make a (new) offer or accept the most recent proposal by his opponent. However, it is important that the order of the moves be respected; each offer has to be rejected or accepted before another offer is made. In other words, simultaneous offers are not allowed.

There is another reason why the continuous time model is appealing. For the game with discounting and perfect information, Binmore (1987b) showed that as the time interval between moves approaches to zero, the two perfect equilibrium points corresponding to the two possible first movers approach each other and at the limit, the resulting unique solution is a generalized Nash bargaining (GNB) solution with weights being functions of the discount rates only.[17] The GNB solution can be written as the solution to:

$$\max_{U_u, U_f} \quad (U_u - T_u)^{a_u} (U_f - T_f)^{a_f} \qquad \text{s.t} \quad (U_u, U_f) \in B \qquad (3)$$

where

U_i is the utility of player i, i = u,f

T_i is the utility of player i at the disagreement point

a_i is the weight given to the utility of player i (often interpreted as the bargaining power of player i)

B is the bargaining set.

Note that any point on the Pareto frontier of the convex bargaining set can be written as a generalized Nash bargaining solution with the choice of appropriate weights. Therefore, since it is efficient, the perfect equilibrium to the Rubinstein game (with perfect information) is also a GNB solution. In general, however, the appropriate weights will be functions of all the parameters of the game, i.e. the functions representing delay costs, the first mover, and the parameters of the time 0 bargaining set. The Binmore results is that the unique perfect equilibrium for the

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[17]The Nash bargaining solution is a cooperative game solution concept which satisfies the four following axioms: independence of irrelevant alternatives, symmetry, Pareto efficiency, invariance to (increasing) afine transformation. It can be written as the solution to the optimization problem (3) with $a_1 = a_2 = .5$. A generalized Nash bargaining solution is a Nash bargaining solution without the symmetry requirement.

continuous time game with discounting can be written as a GNB solution with a zero threat point and with the following weights:

$$a_u = \frac{\ln d_f}{\ln d_u + \ln d_f} \qquad a_f = \frac{\ln d_u}{\ln d_u + \ln d_f}$$

where d_i is the discount factor of player i.

(Note that if the threat point were positive, it would be reached in finite time and the game would no longer have an infinite horizon.)

Binmore's result is important for the empirical application of the game because writing the equilibrium as an optimization problem makes it possible to derive estimating wage and employment equations under general specifications of the utility functions. In comparison, for the discrete time game with discounting costs, one is practically forced to assume the union is a rent maximizer in order to derive the estimating model unless approximations are used. To see this let the frontier of the bargaining set at time 0 be: $U_u(C) = \overset{*}{U}(U_f(C))$ where C denotes the wage and employment contract. The equilibrium contract for the discrete time game, $\overset{*}{C}$, will be the solution to the following equation:

$$d_u U_u(C) = \overset{*}{U}[\overset{*}{U}^{-1}(U_u(C))/d_f].$$

Rent maximization causes $\overset{*}{U}$ to be linear and the above equation is then easily solved.

3.2 Application of the Bargaining Game to Firm-Union Contract Negotiations

There are several crucial elements in the Rubinstein bargaining game. In this section, these assumptions are discussed in the context of firm-union contract negotiations.

First, the players must alternate in making offers and once an offer has been made, it must be accepted or rejected before another offer is made. For example, the union offers a wage-employment contract to the firm, the firm then accepts or rejects this contract. If it accepts, a collective agreement is signed; if it rejects, bargaining moves on to the next round and the firm makes a counter offer to the union. This framework is preferable to the bargaining models where one side only can make offers since, in the case of collective bargaining, both firms and unions do make offers. Also, during negotiations, a move by a party is generally expected to elicit a response from the other party (see Craig (1986), Chapter 7).

Secondly, both the firm and the union incur costs if the agreement is delayed. In the bargaining process under study, negotiations on a new contract start several months before the end of the existing contract, negotiating teams are composed of permanent employees of the two parties, and disputes are settled by work stoppages (strikes or lockouts) rather than arbitration. It is assumed that the bargaining game begins at the time of expiry of the previous contract (time 0). At this time either an agreement is signed (the first offer is accepted) in which case no costs of delay are incurred, or there is a strike/lockout and both parties bear costs. The strike/lockout will continue and the costs increase until an offer is accepted and the contract is signed. Note that the costs of maintaining the negotiating teams are not included in the costs of delay but are rather embedded in the utility functions of the parties. Also, the players are not allowed to use threats other than work stoppage (e.g. work slowdown or simply continued working without a contract). This would complicate the model considerably as the kind of threat used and the timing of the punishment would be part of the strategy of the players.[18] Furthermore, empirical application would require data on the various threats and their associated costs.

The third major element in Rubinstein bargaining is the infinite bargaining horizon. There are no exogenous factors forcing the players to stop bargaining while there are still gains from trade. For example, budget constraints such as requiring that the union cannot survive a strike after the

[18]See Hart (1986) for a step in this direction.

depletion of its strike fund are precluded. Rather, it is assumed that the union could borrow money to sustain itself indefinitely during a strike. The alternative is a finite game in which the equilibrium would depend crucially on the total time available to the players. In the absence of data on the length of negotiation rounds and on the number of possible rounds before a final breakdown in bargaining, it would be impossible to distinguish between various equilibria.

Finally, the two bargaining partners are extremely rational in the sense described in section 3.1 (i.e. they care only about the final agreement and its associated utility and they do not believe idle threats). This is a major improvement over past models of the negotiation process in which the equilibrium depended on some form of irrationality of the players. The models by Cross and Zeuthen-Harsanyi are well-known examples of bargaining in which parties make systematic mistakes about their opponent's behaviour or even their own future behaviour. (See Foley and Maunders (1979) for a description of these models.)

Although these are the fundamental assumptions underlying Rubinstein bargaining, the particular game which is chosen will depend on the maintained assumptions regarding the information structure and the modelling of time as a discrete or continuous variable.

It was mentioned in the previous section that allowing asymmetric information will in general imply that some of the equilibrium points are contracts signed after a strike or lockout. However, the equilibrium is substantially more complex even when very simplifying assumptions are made on the information structure (e.g. one-sided imperfect information with only two possible types of opponent). Furthermore, the equilibrium is very sensitive to certain behavior such as forming prior beliefs and updating beliefs outside equilibrium paths for which no data is available. A study of strikes will involve dealing with these problems, but for the purposes of this research, the complications introduced by allowing for strikes are just too great and I assume perfect information.

The question then arises as to the applicability of such a strong information assumption to the data set under study. The IWA and the employer association representing the industry have been bargaining together for a long time and discussions with a union negotiator suggest that they have a good knowledge of the firms' technology and markets (or at least they believe they do). A further indication of the mature relationship between the union and the firm is the incidence of strikes. Over the period under study (1963-83) only 3 strikes involving at least 10% of the employees occurred due to contract negotiations.

The choice of whether to model time as a discrete or continuous variable should depend on the ability of the players to commit themselves to their offers. For example, if the union has a way of convincing the firm that it will not consider a new offer before the next month, then its present offer will stand for a long time. Unfortunately, I have no data on this and when choosing the appropriate model, other considerations come into play. A discrete time model has the characteristic that the player with the first move has an advantage even with equal time costs and similar utility functions. In practice, it is generally the case that the union is the first mover. However, if there are large benefits to being first mover, one would expect the two players to bargain over the privilege of going first. The absence of such disputes suggests that the time periods are small, i.e. the first mover advantage is not important. Furthermore, as mentioned in the previous section, Binmore has shown that the equilibrium to the continuous time game can sometimes be written as a Nash bargaining solution. This means that a more general specification of the players' objectives can be used while keeping the estimating model tractable. With these considerations in mind, I adopt a continuous time specification of the game.

The use of continuous time is not sufficient to allow me to use the Binmore result; it is also necessary to assume that the delay costs take the form of discount factors.

Although this might seem unduly restrictive, in fact, if I am to use Rubinstein bargaining, I have very little flexibility in the specification of the time costs. The choice is practically limited to fixed costs, discounting costs or combinations of the form:

$$\hat{U}_i(C,t) = [U_i(C) - D_i t]\, d_i^t \tag{4}$$

When choosing among these possibilities, an important consideration is the implied threat point. The threat point is formed by the utility levels that the two players can guarantee themselves no matter what strategy their opponent plays. Fixed costs have the disadvantage that the implied threat point is $(-\infty,-\infty)$ i.e. the players believe that their opponent can keep on negotiating even with extremely large losses or negative utilities. With discounting costs and an infinite horizon, it is assumed that the threat point is (0,0).

It is not uncommon to specify a zero disagreement point for the firm although in the presence of fixed costs, this will overestimate the guaranteed profit level at least in the short run. Specifying a zero threat point for the union is more unusual. Generally, a measure of the alternative income has been used as a disagreement point. However, a constraint on the contract wage such as an alternative wage is not inconsistent with the assumption of a zero threat point. For example, suppose that any contract giving the workers less than the alternative wage is unacceptable to the union. Also, during a strike, the workers do not earn the alternative wage, they earn a strike pay which is less than the best alternative income. To be consistent with a zero threat point, the utility function of the union would be normalized to equal zero at the point of zero employment and an income level equal to the strike pay. Furthermore, the equilibrium contract in this model would have to satisfy the constraint that the wage be greater or equal to the alternative wage.[19]

Utility functions of the form of equation (4) above with both fixed and discounting time costs will approach the following threat point as the strike length becomes infinite:

$$\left(\frac{D_u}{\ln d_u}, \frac{D_f}{\ln d_f} \right).$$

Although this specification is less restrictive, the resulting estimating model is substantially more complex and it requires better data on strike costs, in particular, on

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[19]The equilibrium of the bargaining game in this example can be written as the solution to:

$$\max_{U_u, U_f} U_u^{A_u} U_f^{A_f} \quad \text{s.t. } (U_u, U_f) \in \tilde{B},\ U_u \geq 0,\ U_f \geq 0$$

where $\tilde{B}$ is the set formed by the utility pairs corresponding to all possible contracts giving the union at least the alternative wage, and U_u takes the form $\tilde{U}_u(W,E,)-U_s$ with U_s representing the utility received from the strike pay.

exogenous factors which enable one to discriminate between the D_i's and d_i's.

Unfortunately, the literature on strike costs is not very helpful in choosing among these specifications. Also, the available data is fairly limited. Consequently, in this paper, the simplest formulation is chosen and discounting costs are assumed (fixed costs are set equal to zero). Note that the discount factors can be different for the firm and the union.

Two final remarks should be made concerning the bargaining game:

(i) Although it is not necessary for existence of equilibria, convexity of the bargaining set does ensure uniqueness. In general, standard restrictions on the objective functions of the players are not sufficient to guarantee a convex set. The usual practice of convexifying the bargaining set by allowing the players to randomize causes problems in empirical applications because the observed contract is the ex post contract. If the ex ante or expected contract is random, our observation will contain an error which will generally be correlated with the parameters and the exogenous factors of the game. I assume the set is convex and this assumption will be checked at each data point.

(ii) The game models one contract negotiation only and previous contracts can affect the present negotiations only through the exogenous factors. A complex reputation building strategy covering several contracts is not allowed. This would require a Supergame where each time period is itself a bargaining game.

3.3 The Firm's Technology and Objectives

In this section we characterize the time independent portion of the firm's utility function ($U_f(C)$ in the above notation). The firm produces output Q_1 using 3 inputs: labour (E), materials and supplies (Q_2), and capital services (Q_3). It is assumed that the production process can be represented by a Cobb-Douglas function. Two different frameworks are estimated. These two models correspond to different sets of assumptions concerning the sensitivity of inputs and output to the labour contract C.

In the first model, it is assumed that both output and materials and supplies are adjusted to the labour contract while capital is exogenously determined. The profit function restricted with respect to labour and capital and dual to the Cobb-Douglas production function is written as:

$$\pi_R \,(T, P_1, P_2, Q_3, E) = R0 \times T^{R1} \times P_1^{(1-R2)} \times P_2^{R2} \times Q_3^{R3} \times E^{Re}$$

where P_1 is the price of output, P_2 is the price of materials and supplies, Q_3 is the quantity of capital services, T is a time index, and the R's are functions of the underlying production function parameters. R3 is the profit elasticity of capital and Re is the profit elasticity of labour. R2 is the ratio of revenues to restricted profits while (1-R2) is the ratio of material costs to restricted profits. (Restricted profits are gross of labour and capital costs). R1 measures shifts in the production process over time while R0 is a scaling factor. It is expected that R3, Re, R0>0, R2<0, and Re<1.

To this restricted profit function correspond the demand for materials and supplies:

$$Q_2 = -R2 \times R0 \times T^{R1} \times P_1^{(1-R2)} \times P_2^{(R2-1)} \times Q_3^{Re} \times E^{Re}$$

and the supply curve:

$$Q_1 = (1-R2) \times R0 \times T^{R1} \times P_1^{-R2} \times P_2^{R2} \times Q_3^{R3} \times E^{Re}$$

In the second model, output is considered as exogenous to the bargaining process. Although this is a restrictive assumption, it is commonly made in estimations of production processes. In the labour demand literature as well as in other areas of work, researchers find it difficult to explain the behaviour of input and output quantities by the use of prices only. Martinello (1984) who also studied the B.C. wood products industry but with a more flexible functional form than the one used here had similar difficulties when treating output as endogenous. As will be seen later, assuming that output is an exogenous variable does improve the prediction of employment in this study; however, it also creates new problems.

The restricted profit function in the second model is written as:

$$\pi_B(T, P_1, P_2, P_3, Q_1, E) = P_1 Q_1 - B0 \times T^{B1} \times P_2^{(1-B3)} \times P_3^{B3} \times Q_1^{B2} \times E^{Be}$$

where P_i is the price of input i, for i = 2,3, T is a time index and the B's are functions of the underlying production function parameters. B3 is the cost share of capital and (1-B3) is the cost share of materials and supplies. B2 is the cost elasticity of output and Be is the cost elasticity of labour. Note that Be will equal the labour cost share only if the labour contract is situated on the labour demand. Otherwise (e.g. in the cooperative model), the wage will not equal the shadow price of labour. B0 is a scaling parameter and B1 measures shifts in the production process over time. It is expected that $B2 > 0$, $Be < 0$, and $B3 > 0$.

To the restricted profit function π_B correspond the demand for materials and supplies:

$$Q_2 = (1-B3) \times B0 \times T^{B1} \times P_2^{-B3} \times P_3^{B3} \times Q_1^{B2} \times E^{Be}$$

and the demand for capital services:

$$Q_3 = B3 \times B0 \times T^{B1} \times P_2^{(1-B3)} \times P_3^{(B3-1)} \times Q_1^{B2} \times E^{Be}.$$

It is assumed that all prices except the wage are exogenous, i.e. that the input and output markets are competitive. This does not seem unreasonable for the output price since most of the output is sold in highly competitive international markets. However, the competitive market assumption may be restrictive in the case of the materials price since some of the lumber mills in this data set are owned by companies who also engage in logging. (See Chapter 4, section 4.2 for a more detailed description of the industry)

In its bargaining with the union, the firm is assumed to maximize profits. Its utility function can then be written as:

$$U_f^R\,(W,E) = \pi_R\,(T,\ P_1,P_2,Q_3,E) - P_3 \times Q_3 - W \times E$$

for the case in which capital is exogenous, and

$$U_f^B\,(W,E) = \pi_B\,(T,\ P_1,Q_2,P_3,P\ ,E) - W \times E$$

when output is exogenous. W is the wage and exogenous variables other than (W,E) are subsumed on the left-hand side of the equations for simplicity.

Under standard convexity assumptions, both of these utility functions will have the following properties:

$$\frac{\partial U_f^i}{\partial E} = \frac{\partial \pi_i}{\partial E} - W \begin{cases} = 0 & \text{on the labour demand curve} \\ < 0 & \text{to the right of the labour demand curve} \end{cases}$$

$$\frac{\partial^2 U_f^i}{\partial E^2} < 0 \; ; \quad \frac{\partial U_f^i}{\partial W} = -E < 0 \; ; \quad \frac{\partial^2 U_f^i}{\partial W \partial E} = -1 \; ; \quad \frac{\partial^2 U_f^i}{\partial W^2} = 0 \; ;$$

where i = R,B.

3.4 Union Objectives

The modelling of union objectives has been a contentious issue for several decades. As mentioned in Chapter 2, attempts to justify a union objective function by the individual union members' preferences and by a representation process such as majority voting or utilitarianism have yielded few general results. As is common in this literature, I assume the existence of a well-behaved concave utility function defined over wages, employment, and the alternative wage (W_A). This function is assumed to take the CES form:

$$U_u(C) = (\delta E^{-\rho} + (1-\delta)\,(W-W_A)^{-\rho}\,)^{-1/\rho} \qquad (5)$$

Special cases of this formulation include:

$\rho = -1$, the linear utility function: $\delta E + (1-\delta)(W-W_A)$

$\rho = 0$, the Cobb Douglas: $E^{\delta}(W-W_A)^{(1-\delta)}$

$\rho = 0$ and $\delta = .5$, rent maximization: $E(W-W_A)$.

Some economists are of the opinion that a rent maximizing utility function should be imposed a priori. (See for example, Brown and Ashenfelter (1986).) This claim is based on the assumption that the union maximizes the average worker's expected utility which is usually assumed to be equal to this worker's expected income:

$$\frac{E}{\bar{E}} \times W + \left(1-\frac{E}{\bar{E}}\right) W_A \ .$$

where E is employment and $\bar{E}$ is the union membership. I do not know of any empirical evidence which supports this assumption and furthermore, when it is tested in empirical studies of unions, the rent maximization hypothesis is virtually always rejected. Therefore, I choose to use a more general form of the utility function of the union which includes rent maximization as a special case.

Note that the alternative wage has been incorporated in the utility function of the union rather than imposed as a constraint on the bargaining set. At the threat point (where $U_u(C)=0$), the employment level will be zero and the wage will equal the alternative wage. This implies that during strikes, the workers are earning their best alternative income. This strong assumption can be avoided by modifying the definition of the union utility as follows:

$$U_u(C) = \begin{cases} 0 \text{ for } W < W_A \\ (\delta E^{-\rho} + (1-\delta)(W-W_A)^{-\rho})^{-1/\rho} & \text{for } W \geq W_A \end{cases}$$

and by adding the constraint $W \geq W_A$ to the set of possible equilibrium contracts.

This formulation allows for the possibility of a strike pay less than the alternative wage. However, to simplify the estimation, the constraint on the contract wage is not imposed but it will be checked at each data point.

Chapter 4

The Data and the Empirical Specification of the Model

As described in the previous chapter, this study involves the estimation of four different models: the cooperative and the labour demand bargaining models are estimated for each of the two possible firm profit functions. For purposes of comparison and also to avoid any confusion, I am devoting a separate section (4.1), to the derivation and presentation of the four estimation models. This is followed in section 4.2 by a brief discussion of the data. A detailed description of the data sources and calculations is provided in Appendix A.

4.1 The Estimation Models

In Chapter 3, the objective functions of the two negotiating parties were specified. The union utility is a function of the labour contract C=(W,E) and the time at which the contract is signed. Assumptions (A-1) to (A-4) from chapter 3 are imposed on the preferences of the two players engaged in a Rubinstein bargaining game. These assumptions imply that each player's objective function is separable with respect to the time at which the agreement is reached. We can then consider the time independent utility function of the union which is specified as:

$$U_u(W,E) = (\delta E^{-\rho} + (1-\delta)(W-W_A)^{-\rho})^{-1/\rho} \tag{1}$$

Similarly, we can consider the time independent portion of the firm's objective function which is assumed to equal the profits achieved under the labour contract C=(W,E). Two different frameworks are studied. Firstly, the level of output is exogenous to the bargaining in which case the firm's utility is:

$$U_f^B(W,E) = P_1 x\ Q_1 - B0\ x\ T^{B1}\ x\ P_2^{(1-B3)}\ x\ P_3^{B3}\ x\ Q_1^{B2}\ x\ E^{Be} - W\ x\ E$$

$$= \pi_B\ (T,\ P_1,Q_1,P_2,P_3,E) - W\ x\ E$$

and, secondly, the capital input is treated as exogenous:

$$U_f^R(W,E) = R0\ x\ T^{R1}\ x\ P_1^{(1-R2)}\ x\ P_2^{R2}\ x\ Q_3^{R3}\ x\ E^{Re} - P_3 x\ Q_3 - W\ x\ E$$

$$= \pi_R\ (T,\ P_1,P_2,Q_3,E) - P_3\ x\ Q_3 - W\ x\ E$$

where the vectors of B's and R's are vectors of coefficients, T is a time trend, P_i and Q_i are the price and quantity indices of input/output i with i=1 for output, i=2 for materials and supplies and i=3 for capital services.

A problem with the above specifications is the possible discrepancy between the employment level affecting the two parties utilities. More precisely, the union utility will depend on the employment of union members while the firm's profit will vary according to total employment. As is the case for most unionized industries, the industry under study here has unionized production workers and non-unionized administrative and sales personnel. Theoretically, the obvious solution to this problem is to treat non-production workers as a separate input in the production process. Empirically, at least for this data set, the addition of this new input does not provide more information because of the large correlation between production and non-production employment. (See Appendix A for details.) In order to include them in the profit calculations, non-production labour costs are considered as a fixed fraction of production labour costs. This fraction is measured by the average ratio of non-production to production labour costs over the sample and is equal to 15%. The firm's two possible utility functions expressed in terms of the employment of production workers only become:

$$U_f^B(W,E) = 1.15 \times [\ \frac{P_1 Q_1}{1.15} - BxT^{B1} \times P_2^{(1-B3)} \times P_3^{B3} \times Q_1^{B2} \times E^{Be} - WxE] \qquad (2)$$

$$= \pi_B\ (T,\ P_1,\ Q_1,\ P_2,\ P_3,\ E) - 1.15 \times W \times E$$

and

$$U_f^R(W,E) = 1.15 \times [RxT^{R1} \times P_1^{(1-R2)} \times P_2^{R2} \times Q_3^{R3} \times E^{Re} - \frac{P_3 Q_3}{1.15} - WxE] \qquad (3)$$

$$= \pi_R(T,\ P_1, P_2, Q_3, E) - 1.15 \times W \times E$$

where $B = \frac{B0}{1.15}$ and $R = \frac{R0}{1.15}$.

Given the assumptions of continuous time, discounting costs, and perfect information, I can use Binmore's result (see Chapter 3) and write the labour contract for the cooperative model as the solution to the following:

$$\max_{W,E} U_u(W,E)^{\frac{\ln df}{\ln du+\ln df}} U_f^i(W,E)^{\frac{\ln du}{\ln du+\ln df}} \tag{4}$$

with F.O.C.: $$\frac{\partial \ln U_u(W,E)}{\partial W} \times \frac{\ln df}{\ln du} = - \frac{\partial \ln U_f^i(W,E)}{\partial W}$$

$$\frac{\partial \ln U_u(W,E)}{\partial E} \times \frac{\ln df}{\ln du} = - \frac{\partial \ln U_f^i(W,E)}{\partial E}$$

where du is the union's discount factor, df is the firm's discount factor and i = B or R.

The first-order conditions are used to generate wage and employment estimating equations. Instead of checking second order conditions for the problem as written in (4), I will verify that for each data point:

i) The firm's iso-profit curves are less convex than the union indifference curves. This ensures that the point on the contract curve in (W,E) space is a tangency point of the iso-utility curves.

ii) The bargaining frontier in (U_u, U_f) space is concave to the origin. This frontier is derived from the solution to:

$$\max_{W,E} U_u(W,E) \quad \text{s.t.} \quad U_f^i(W,E) \geq \bar{U}_f$$

where i = R or B and $\bar{U}_f$ is a given level of utility for the firm.

Solving for (W,E) and substituting in U_u, we have a relationship between U_u and $\bar{U}_f$: $\bar{U}_u\ (\bar{U}_f)$, the bargaining frontier.

The conditions (i) and (ii) are stronger than is necessary but they are more intuitive and easier to check.

In the labour demand model where the firm unilaterally chooses employment, the equilibrium to the bargaining game can be generated as the solution to:

$$\max_{W} U_u\ (W,E)^{\frac{\ln df}{\ln du+\ln df}}\ U_f^i(W,E)^{\frac{\ln du}{\ln du+\ln df}} \qquad (5)$$

subject to $\frac{\partial U_f^i\ (W,E)}{\partial E} = 0$ (the firm chooses employment to maximize profits.)

with F.O.C.: $\frac{\partial \ln U_u\ (W,E)}{\partial W}\ [1 + \text{MRS} \times \frac{\partial \bar{E}(W)}{\partial W}] \times \frac{\ln df}{\ln du} = -\frac{\partial \ln U_f^i\ (W,E)}{\partial W}$

where $\bar{E}(W)$ is the labour demand function which solves the constraint, i = R or B, and MRS is the marginal rate of substitution for the union;

i.e. $$\text{MRS} = \left(\frac{\delta}{1-\delta}\right) \times \left(\frac{W-W_A}{E}\right)^{\rho+1}$$

For the labour demand model, the frontier of the bargaining set is the labour demand curve expressed in utilities. Condition (ii) above will also be checked at each data point for this model. The bargaining frontier is derived from an optimization problem similar to that in (ii) but with the added constraint that the (W,E) combination lie on the labour demand curve.[20]

The formulation of the labour demand and the cooperative models in terms of the optimization problems (4) and (5) can be somewhat misleading. Specifically, the labour demand model can be written as the solution to the optimization problem (4) with the added constraint that the wage-employment contract be located on the labour demand

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[20]For the cooperative model, the first derivative of the bargaining frontier is

$$\bar{U}'_u\ (\bar{U}^i_f) = -\ U_{uW}\ \ /E < 0$$

where U_{uW} is the partial of U_u w.r.t. the wage. The second derivative has the sign of the following expression:

$$U^i_{fEE}/E - (1/E - U_{uEW}/U_{uW})^2 \times (U_{uW}/U_{uWW}) + U_{uEE}/U_W$$

In particular, in this model, a sufficient (but not necessary) condition for concavity of the bargaining set is that the contract curve be positively sloped.

For the labour demand model, the first derivative of the bargaining frontier is the slope of the labour demand curve which is negative. Concavity of the labour demand curve would ensure convexity of the bargaining set but in general, the second derivative of the frontier will have the sign of the following expression:

$$U_{uWW} \times (U^i_{fEE})^2 + U_{uEE} + U_{uWE} \times U^i_{fEE} - U_{uW} \times U^i_{fEE}/E$$
$$+ (1/E + U_{fEE}/U^i_{fEE}) \times U_{uE}/(E \times U^i_{fEE}).$$

curve. In other words, the bargaining set in the space of utilities for the labour demand model is a subset of the bargaining set for the cooperative model. (The two frontiers are identical if and only if the union does not care about employment.) It may seem as if the labour demand model is nested in the cooperative model. However, this is not the case. The set of possible solutions to (4) is the frontier of the cooperative model bargaining set. These solutions do not include (as a subset) the set of solutions to (5) which is composed of the points along the frontier of the labour demand bargaining set. In other words, there are no parameter restrictions which, if imposed on the cooperative model, will yield solutions inside the cooperative bargaining set such as the solutions to the labour demand model.[21]

The system of estimating equations for both the cooperative and the labour demand models are given under the assumption of exogenous output in Table I and under the assumption of exogenous capital in Table II. The ϕ's are error terms and γ has been substituted for the expression

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[21]There are two exceptions to this corresponding to the two trivial models in which the union does not care about employment and the firms have complete bargaining power. In the latter case, the competitive solution holds in the labour market.

Table I

Estimation Models Under the Assumption of an Exogenous Output Profit Function

I **Utility Functions** (at the beginning of negotiations)

Union: $U_u(W_t,E_t) = (\delta E_t^{-\rho} + (1-\delta)(W_t - W_{At})^{-\rho})^{-1/\rho}$

Firms: $U_f^B(W_t,E_t) = \frac{P_{1t}Q_{1t}}{1.15} - BT_t^{B1} P_{2t}^{(1-B3)} P_{3t}^{B3} Q_{1t}^{B2} E_t^{Be} - 1.15 W_t E_t$

II **Cooperative Model**

$$\phi_{1t}^{cB} = W_t - \frac{P_{1t}Q_{1t}}{1.15E_t} + BT_t^{B1}\, E_t^{(Be-1)}\, Q_{1t}^{B2}\, P_{2t}^{(1-B3)}\, P_{3t}^{B3}$$

$$+ \left(\frac{\ln du}{\ln df}\right)_t \gamma \left(\frac{W_t - W_{At}}{E_t}\right)^{\rho+1} E_t + \left(\frac{\ln du}{\ln df}\right)_t (W_t - W_{At})$$

$$\phi_{2t}^{cB} = W + (Be)\, BT_t^{B1}\, E_t^{(Be-1)}\, Q_{1t}^{B2}\, P_{2t}^{(1-B3)}\, P_{3t}^{B3} - \gamma \left(\frac{W_t - W_{At}}{E_t}\right)^{\rho+1} E_t$$

$$\phi_{3t}^{cB} = Q_{2t} - (1-B3) BT_t^{B1} E_t^{Be} P_{2t}^{-B3} P_{3t}^{B3} Q_{1t}^{B2}$$

$$\phi_{4t}^{cB} = Q_{3t} - (B3) BT_t^{B1} E_t^{Be} P_{2t}^{(1-B3)} P_{3t}^{(B3-1)} Q_{1t}^{B2}$$

Table I - Continued

III. Labour Demand Model

$$\phi^{mB}_{1t} = W_t - \frac{P_{1t}Q_{1t}}{1.15E_t} \quad 1 + \frac{1}{(Be-1)W_t}\gamma \quad \frac{W_t - W_{At}}{E_t}^{\rho+1} \quad E_t + \left(\frac{lndu}{lndf}\right)_t (W_t - W_{At})$$

$$+ BT_t^{B1} E_t^{(Be-1)} P_{2t}^{(1-B3)} P_{3t}^{B3} Q_{1t}^{B2} + \left[\frac{1}{Be} + \left(\frac{lndu}{lndf}\right)_t\right] \gamma \left(\frac{W_t - W_{At}}{E_t}\right)^{\rho+1} \quad E_t$$

$$\phi^{mB}_{2t} = W_t + (Be)\ BT_t^{B1} E_t^{(Be-1)} Q_{1t}^{B2} P_{2t}^{(1-B3)} P_{3t}^{B3}$$

$$\phi^{mB}_{3t} = Q_{2t} - (1-B3) BT_t^{B1} E_t^{Be} P_{3t}^{P3} Q_{1t}^{B2} P_{2t}^{-B3}$$

$$\phi^{mB}_{4t} = Q_{3t} - (B3)\ BT_t^{B1} E_t^{Be} P_{2t}^{(1-B3)} P_{3t}^{(B3-1)} Q_{1t}^{B2}$$

where $\left(\frac{lndu}{lndf}\right)_t = (F0 + F1 \times Z_t + F2 \times INV_t + F3 \times CU_t + U0 \times UN_t$

$+ U1 \times UIC_t + U2 \times DEM_t)^2$

and

ϕ^{kB}_{jt} = error term for equation j, observation t, model kB;

j=1,...,4; t=1,...,84; k=cooperative (c) or labour demand (m);

B = exogenous output profit function.

IV. Predicted Signs (for both models):

$B > 0$	$\gamma = \frac{\delta}{1-\delta} > 0$	$F0$?	$U0 > 0$
$B1$?		$F1 < 0$	$U1 < 0$
$B2 > 0$	$\rho \geq -1$	$F2 > 0$	$U2 < 0$
$B3 > 0$		$F3$?	
$Be < 0$			

Table II

Estimation Models Under the Assumption of an Exogenous Capital Profit Function

I Utility Functions (at the beginning of negotiations)

Union: $U_u(W_t,E_t) = (\delta E_t^{-\rho} + (1-\delta)(W_t-W_{At})^{-\rho})^{-1/\rho}$

Firms: $U_f^R(W_t,E_t) = RT_t^{R1} P_{2t}^{R2} P_{1t}^{(1-R2)} Q_{3t}^{R3} E_t^{Re} - \frac{P_{3t}Q_{3t}}{1.15} - 1.15\ W_tE_t$

II Cooperative Model

$$\phi_{1t}^{cR} = W_t - RT_t^{R1} P_{2t}^{R2} P_{1t}^{(1-R2)} Q_{3t}^{R3} E_t^{(Re-1)} + \frac{P_{3t}Q_{3t}}{1.15\ E_t}$$

$$+ \left(\frac{lndu}{lndf}\right)_t \gamma \left(\frac{W_t-W_{At}}{E_t}\right)^{\rho+1} E_t + \left(\frac{lndu}{lndf}\right)_t (W_t-W_{At})$$

$$\phi_{2t}^{cR} = W_t - (Re)\ RT_t^{R1}\ E_t^{(Re-1)} P_{2t}^{R2}\ P_{1t}^{(1-R2)}\ Q_{3t}^{R3} - \gamma\left(\frac{W_t-W_{At}}{E_t}\right)^{\rho+1} E_t$$

$$\phi_{3t}^{cR} = Q_{2t} + (R2)\ RT_t^{R1} E_t^{Re} P_{2t}^{(R2-1)} P_{1t}^{(1-R2)} Q_{3t}^{R3}$$

$$\phi_{4t}^{cR} = Q_{1t} - (1-R2)\ RT_t^{R1} E_t^{Re} P_{2t}^{R2} P_{1t}^{-R2} Q_{3t}^{R3}$$

Table II - Continued

III. Labour Demand Model

$$\phi_{1t}^{mR} = W_t + \frac{P_{3t}Q_{3t}}{1.15E_t} \quad 1 + \frac{1}{(Re-1)W_t} \gamma \left(\frac{W_t - W_{At}}{E_t}\right)^{\rho+1} E_t + \left(\frac{lndu}{lndf}\right)_t (W_t - W_{At})$$

$$- RT_t^{R1} R_{2t}^{R2} P_{1t}^{(1-R2)} Q_{3t}^{R3} E_t^{(Re-1)} + \left[\frac{1}{Re} + \left(\frac{lndu}{lndf}\right)_t\right] \gamma \left(\frac{W_t - W_{At}}{E_t}\right)^{\rho+1} E_t$$

$$\phi_{2t}^{mR} = W_t - (Re)\ RT_t^{R1} E_t^{(Re-1)} P_{2t}^{R2} P_{1t}^{(1-R2)} Q_{3t}^{R3}$$

$$\phi_{3t}^{mR} = Q_{2t} + (R2) RT_t^{R1} E_t^{Re} P_{2t}^{(R2-1)} P_{1t}^{(1-R2)} Q_{3t}^{B3}$$

$$\phi_{4t}^{mR} = Q_{1t} - (1-R2)\ RT_t^{R1} E_t^{Re} P_{2t}^{R2} P_{1t}^{-R2} Q_{3t}^{B3}$$

where $\left(\frac{lndu}{lndf}\right)_t = (F0 + F1 \times Z_t + F2 \times INV_t + F3 \times CU_t + U0 \times UN_t$

$+ U1 \times UIC_t + U2 \times DEM_t)^2$

and

ϕ_{jt}^{kR} = error term for equation j, observation t, model kR;

j=1,...,4; t=1,...,84; k=cooperative (c) or labour demand (m);

R = exogenous capital profit function.

IV. Predicted Signs (for both models):

$R > 0$	$\gamma = \frac{\delta}{1-\delta} > 0$	F0 ?	$U0 > 0$
R1 ?		$F1 < 0$	$U1 < 0$
$R2 < 0$	$\rho \geq -1$	$F2 > 0$	$U2 < 0$
$R3 > 0$		F3 ?	
$Re > 0$			

$\delta/(1-\delta)$. Unless explicitly stated otherwise, the following description applies to both profit functions (i.e. for i=R and B). For the cooperative models, the first two equations ϕ_{1t}^{ci} and ϕ_{2t}^{ci} are derived from the first order equations to (4) and represent the negotiated wage and employment equations. For the labour demand models, the first equation is the first order condition to (5), and the second equation is the constraint, i.e. the labour demand equation. In both the cooperative and the labour demand models, two extra equations appear. For the exogenous output profit function, they represent the input demand functions for materials and supplies (ϕ_{3t}^{cB} and ϕ_{3t}^{mB}) and for capital services (ϕ_{4t}^{cB} and ϕ_{4t}^{mB}) derived from the restricted profit function $\pi_B(T, P_1, Q_1, P_2, P_3, E)$. For the exogenous capital profit function, they represent the input demand for materials and supplies (ϕ_{3t}^{cR} and ϕ_{3t}^{mR}) and the output supply function (ϕ_{4t}^{cR} and ϕ_{4t}^{mR}) derived from the restricted profit function $\pi_R(T, P_1, P_2, P_3, Q_3, E)$. It is assumed that the endogenous inputs and output will adjust to the negotiated level of employment as well as prices and the exogenous input or output quantities.

It is important to note that even with the simple functional forms adopted here, it is not possible to solve the first order conditions to the cooperative models in order to get reduced forms for W and E. We are forced to estimate structural equations.[22] The question then arises as to the particular representations of the first order conditions which should be used for estimation. Two considerations are important: the degree of nonlinearity in the equations, and the intuitive explanation for the location of the error term. ϕ^{ci}_{2t} is an error which is made on the location of the bargaining frontiers. For both i = R and B, the right hand side (RHS) of this equation will equal zero for wage-employment pairs located on the contract curve. Specifically, the RHS of ϕ^{ci}_{2t} is the difference between the marginal rates of substitution of the two players multiplied by employment. ϕ^{ci}_{1t} measures the error made on the location of the equilibrium along the bargaining frontiers. For both i=R and B, the RHS of this equation is simply the inverse of the first order condition to (4) with respect to W. ϕ^{cB}_{3t}, ϕ^{cB}_{4t} and ϕ^{cR}_{3t} are additive errors made to the input quantity decisions in the profit maximization problem while ϕ^{cR}_{4t} is an additive error made to the output quantity. For purposes of comparison, the labour demand model is given the same structure, i.e. for both i=R and B, the RHS of ϕ^{mi}_{2t} is the bargaining frontier which is the labour demand equation in this case, and the RHS of ϕ^{mi}_{1t} is derived directly from the first order condition to (5).

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[22]The problem is that both the levels and the gradients of the utility functions appear in the first order conditions, and there is a necessary linearity imposed in the profit functions by the term -WE.

It is interesting to note the differences between the cooperative and labour demand models. As has been mentioned by several authors in the past the difference between the two bargaining frontiers (between ϕ_{2t}^{ci} and ϕ_{2t}^{mi}) is simply the addition in the cooperative model case of a term representing the marginal rate of substitution of the union.[23] With Rubinstein bargaining, the difference in the two <u>first</u> equations ϕ_{1t}^{ci} and ϕ_{1t}^{mi} is also the addition of a term, this time to the labour demand model. This term equals

$$\frac{\partial \ln U_u}{\partial E} \times \frac{\partial \bar{E}(W)}{\partial W} .$$

When choosing the optimal wage through negotiations in the labour demand model, the players will take into account the indirect effect of the wage on the union utility through its effect on the employment level.

4.2 The Data

Table III presents a list of the variables used in the estimation along with descriptive statistics. The following discussion will include only brief descriptions of data sources and construction as details are given in the form of a data appendix, Appendix A.

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[23] This was used in McCurdy and Pencavel (1986) to test which of the two models performed better.

Table III

Descriptive Statistics of Variables

	Description	Var.	Mean	Min.	Max.	Standard Deviation
1.	Real compensation paid per hour of employment	W	4.5209	2.7233	5.9169	0.95098
2.	Hours of employment (in 10 M's)	E	2.3132	0.8324	3.7705	0.72052
3.	Quantity of output (shipments) (in 10M's)	Q_1	38.4844	15.1218	96.0790	17.6237
4.	Quantity of materials and supplies (in 10M's)	Q_2	23.8612	6.6975	63.7650	11.8151
5.	Quantity of capital services (in 10M's)	Q_3	2.4203	0.6656	8.0661	1.7983
6.	Real price of output index	P_1	1.2085	0.7626	2.4285	0.3574
7.	Real price of materials and supplies index	P_2	1.1305	0.4909	2.4053	0.3750
8.	Real price of capital services index	P_3	0.9255	0.3545	1.6422	0.2630
9.	Real alternative wage in B.C. (Employment weighted average of the manufacturing and service industries in B.C.)	W_A	3.4165	2.4554	3.9879	0.4748
10.	Rate of interest (McLeod, Young, Weir 10 industrial bond rate)	Z	9.5876	5.3700	16.3201	2.9958
11.	Avg. change in the value of inventories over the previous 5 years (in 0,000's of dollars)	INV	0.7925	-1.5592	8.1721	1.6409
12.	Utilization rate in the wood products industry in Canada	CU	9.0158	7.0150	9.8150	0.7308
13.	Unemployment rate in B.C.	UN	0.07285	0.04198	0.13823	0.0228
14.	Measure of the generosity of the unemployment insurance	UIC	0.3964	0.1203	0.6676	0.2258
15.	Proportion of total females and males under 25 in total labour force in B.C.	DEM	0.4929	0.4169	0.5415	0.0395

4.2.1 The Institutional Setting

The data involves the International Woodworkers of America and the wood products industry in British Columbia over the period 1963-1983. The wood products industry is part of the dominant industrial sector in B.C., the forestry sector. The manufacturing industries of the forestry sector (wood products and paper and allied industries) account for almost one-half of total manufacturing activity in the province. The wood products industry is composed of sawmills, shingle and shake mills and plywood and veneer mills. The B.C. mills are responsible for a large part of the total Canadian output as they produce about two thirds of Canada's softwood lumber, virtually all of the cedar shingles and shakes, and the bulk of the national softwood plywood output.

The wood products industry is more concentrated in B.C. than elsewhere in Canada. Most of the top 15 lumber producers in Canada are based in B.C. (See Industry, Trade, and Commerce (1978), pg.32.) Furthermore, the level of concentration in B.C. is increasing. In the past 20 years, the trend has been toward the construction of larger, more centralized mills, especially in the B.C. interior where most of the rapid growth of the 1960's and 1970's took place. Major factors responsible for this trend include technological change and a movement toward more capital-intensive operations. B.C. interior sawmills and plywood mills which are believed to be very efficient by world standards, have adopted new technologies better capable of processing small dimension logs. Also, they have increased productivity through larger automation (thereby reducing labour content), installation of facilities for the recovery of by-products and an increase in the quality control. New environmental standards have increased the capital content of the production process as well.

The B.C. lumber industry is highly export oriented. B.C. sawmills export almost 80% of their output. The largest single market for B.C. lumber is the United States due to proximity and ease of markets. Lumber grades, sizes and grading procedures have been standardized throughout North America, customs documentation is minimal, and over the sample period, there was virtually unrestricted free trade of lumber between Canada and the U.S. The province's share of total U.S. consumption of softwood lumber was 20.4% in 1978. (See Percy (1986), pg.5.) The province's lumber industry is consequently very dependent on U.S. demand and U.S. domestic output, on exchange rates and trade barriers, and on the transportation costs to the U.S. of the high bulk, low value commodity.

While sawmills sell most of their product in highly competitive international markets, plywood mills in B.C. sell close to 80% of their output inside Canada. This is due to the fact that many of Canada's major trading partners in forest products provide varying degrees of protection for their domestic plywood producers through tariffs. For example, in the late 70's, the U.S. tariff on plywood was about 20%. In fact, the U.S. emerged as a major competitor in the Canadian softwood plywood market in the 1970's with U.S. imports representing almost 23% of domestic consumption in 1975. Imports have somewhat declined since then; however, it is believed that the United States will continue to be a competitive factor in the domestic market. (See Industry, Trade, and Commerce (1978), pg. 40.)

The major input market of the wood products industry, that of logs, is largely affected by government policy. Direct government intervention takes the form of provincial restrictions on the export of unprocessed logs which constrain the forestry industry to provide wood inputs for the wood products and paper and allied products industries. For example, an average of 0.9% per year of the total provincial timber harvest was exported as logs between 1972 and 1979 (see Percy (1986), pg.4). Indirect government intervention takes the form of stumpage fees and tax rates. In particular, effective tax rates are higher in the logging sector than for manufacturing industries and the stumpage fee is calculated as a function of the price of logs. Both these policies give incentives to the vertically integrated firms to pass on timber rents to their wood products operations in the form of a low price for logs.

That there are rents in the forestry industry not captured by government has been argued by several observers including Copithorne (1979), Haley (1980), and Percy (1986). Haley (1980) compares B.C. stumpage fees with those set in the Pacific Northwest and finds the U.S. fees much larger. Until recent changes, U.S. stumpage fees were set by winning bid, and they were not allowed to vary with changes in end-product prices occurring during the contract. U.S. softwood lumber producers have also argued that lower stumpage rates in B.C. constitute an implicit subsidy for Canadian producers.

Copithorne (1979) argues that higher wages in sawmilling and logging in B.C. relative to corresponding industries in Ontario is indicative of a leakage of rents into wage levels. He acknowledges however, that there could be other explanations for higher wages; for example, more instability in employment, and higher efficiency.[24] Evidence of larger than average wages in the B.C. forestry sector is also provided in Allen (1985). Percy (1986) estimates that in 1979, 58.8% of total rents available in the forestry sector (including logging, wood products and paper and allied industries) were not captured by the B.C. government.

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[24]The hypothesis of higher efficiency is supported by results of a study of regional productivity done by Denny et al. (1981).

Expected future growth prospects for the B.C. wood products industry are bleak. There have been concerns in recent years that the volume of timber harvested in the province may decline significantly in the future due to lower timber volumes from second-growth stands and from significant reductions in the forest base for non-timber use. This would cause a corresponding contraction of the wood products industry. Expected increased competition from traditional markets and U.S. restrictions on lumber imports will adversely affect output markets. For coastal plywood mills, the prospects are worse. It is believed that the viability of the generally high-cost coastal mills depends largely on a modernization program undertaken in the late 1970's (see Industry, Trade, and Commerce (1978), pg.43).

The institutional setting described above has several implications for the modelling of the industry. First, the distinction between interior and coastal sawmills is important and if more data were available, it would be preferable to distinguish between interior and coastal plywood mills as well. Secondly, the assumption of an exogenous output price is not unreasonable given that, except for plywood mills, the firms sell most of their output in highly competitive international markets. There are also indications that plywood mills face stiff competition in their output markets. These are: an increase in plywood imports from the United States, and the extensive modernization program undertaken in the late 1970's which is believed to be crucial for the viability of the coastal plywood mills.

Thirdly, there is evidence that a substantial portion of the timber rents are not captured by government. Moreover, firms have incentives to pass on these rents to their wood products operations in the form of low materials prices. This implies that the price of materials is not determined through competition. Nevertheless, the assumption of an exogenously determined price of materials is maintained in this study in order to avoid modelling the whole forestry sector in B.C.

I now turn to the collective bargaining setting. It is claimed by the International Woodworkers of America (IWA) that 95-99% of the output in the B.C. wood products industry is produced by IWA members (see Martinello (1984), pg.23). The IWA is a large, well organized union which has succeeded in keeping the wood products industry virtually completely unionized over the period under study. Bargaining is provincially centralized. According to Martinello (1984), p.23:

> "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."

Centralized bargaining can be to the advantage of either the union or the firms. A general work stoppage will be industry-wide and will impose large strike costs on all firms. On the other hand, the fact that all firms are experiencing the work stoppage implies that each individual firm is maintaining its market share relative to the other firms in the industry. Individual strike data for the industry shows that the IWA has engaged in both industry-wide strikes and work stoppages affecting a small number of firms.

During the sample period, most of the contracts were 2 years in length, the remaining ones being either 1 or 3 years long. The timing of contracts is an important issue which is not addressed in this study but which is left for future research.

4.2.2 Industry Price and Quantity Data

The raw data on input and output quantity and prices was cumulated and analyzed by Martinello (1984). I also adopted some of his methodology in the treatment of the raw data. The major differences between the data set used here and that in Martinello's work are: in this study, the non-production workers are taken into account in the calculation of firms' profits; the capital services input quantity and price are generated by a different procedure and are based on more detailed data (which was not available at the time of Martinello's study); the arbitrary input cost shares chosen by Martinello are not adopted here (the natural shares given by the data are used); finally, I extend the sample period to include 1980-1983. The data consists of annual observations on wages, employment, other inputs and output in the wood products industry in British Columbia. The firms in the industry are divided into 4 groups: the coastal sawmills, the interior sawmills, the shingle and shake mills and the plywood and veneer mills. The data cover 21 years 1963-1983 for a total of 84 observations.

There are several reasons why the IWA is a good candidate for the present study. As mentioned in the previous section, evidence shows that the natural resources industry in B.C. offers substantial rents and that, at least in the wood products industry, B.C. unions have succeeded in capturing some of these rents.

Another advantage of this data lies in the input and output data. The technology parameters included in the wage and employment bargaining equations will be constrained to be consistent with the input and output quantities and prices. Finally, the modelling of the bargaining setting is straight-forward since it involves only 2 agents; the IWA representing virtually all workers in the industry, and the

Forest Industrial Relations Association representing all firms in the industry.

One of the drawbacks of this data stems from the pooled cross-section time-series nature of the observations. Since the focus of this study is on wage and employment contracts, the modelling of the production process is kept simple and hence restrictive. Specifically, the technology parameters are assumed to be constant across groups of firms.

The observations are annual rather than per contract. The dates of signature of the contracts are available so that the data could be converted to a contract basis, however, since contracts were on average 2 years in length, this would reduce my sample size by one half. Note that explicit modelling of uncertainty and risk sharing requires contract data rather than annual observations. For reasons of simplicity and data requirements, these issues are not explicitly modelled in this research. However, I do consider them interesting aspects of collective bargaining and possible extensions to the present study.

Another disadvantage of this data concerns the wage data. The wage variable is actually compensation per paid person-hour. This includes overtime payments, bonuses, paid vacations and other payments for work not performed. To the extent that these fringe benefits increased over the period, this variable will overstate the variations in the wage.[25]

The quantity of labour is measured by the number of person-hours paid. The choice of units for the measurement of labour is an important issue in wage-employment determination studies. It can be argued that the union cares about the number of workers (i.e. the number of union members) and, possibly, about the hours of work per worker as well. The firms will be concerned with the total number of hours worked, or, if hours and the number of workers are not perfect substitutes in the firm's production process, then the firm will care about both the hours per worker and the number of workers. If the hours per worker are fixed, then it makes no difference which unit is used; however, if the hours per worker are variable, then the correct procedure is to treat the number of workers and the hours per worker as two separate bargaining variables. Hours per worker were calculated over the sample and are provided in Appendix A. In fact, the dispersion around the mean is not very important, and in order to avoid the complications which would arise from adding a third bargaining variable, it is assumed that, at least at the time of negotiation, the parties intend to keep hours per worker fixed.

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[25]Martinello (1984) corrected the data for increases in vacations and holidays and found his estimates virtually unchanged (see Martinello (1984), pg.24).

Most of the input and output variables were constructed using data from the census of manufacturing. Detailed data on the quantities and values of items included in each of materials and supplies, fuels and electricity, and shipments were used to construct chained Fisher ideal price indices and corresponding implicit quantity indices for each of the input and output groups.

Unfortunately, data on capital stocks is available separately only for the fourth group of firms (veneer and plywood mills). The other 3 groups of firms (sawmills and shingle and shake mills) are aggregated. A disaggregate measure of capital services is constructed using the aggregate capital stock, the disaggregated fuels and electricity quantity and price indices and a constructed user cost of capital index. The price of capital services is implicit in the formulation and can be calculated directly (see Appendix A for details).

4.2.3 The Alternative Wage

The alternative wage measure is based on the expected real hourly earnings (including pay for time not worked) assuming the worker is faced with the following options:

i) to work in the service or manufacturing industries in B.C. and to earn the employment weighted average hourly earnings in these industries. This will occur with probability $\bar{p}$ = (employment in these sectors/total labour force)

ii) to collect unemployment insurance (UI) equal to the average hourly UI payment in B.C. adjusted by a scaling factor which takes into account changes in the taxation of UI benefits.[26] This event will occur with probability $(1-\bar{p})$ times the probability of getting UI. The latter is calculated as the number of weeks of UI paid in B.C. divided by the total number of weeks of unemployment in B.C.

This is a similar alternative wage measure to the one constructed by Martinello (1984), the difference being that he used the total B.C. industrial composite earnings for the alternative rather than earnings in services and manufacturing. The CPI is used to convert the alternative wage to (constant) 1971 dollars.

When comparing this real alternative wage (WA) to the union wage (W) I found that for one group of firms, the interior sawmills, $W_A > W$ in 1964 and 1965. This violates my definition of W_A as a constraint on the negotiated contract. However, surveys conducted in the 1960's on wages in several blue collar occupations in B.C. show that wages in the interior were below the provincial average while the

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[26]The resulting UI payment is a pre-tax payment. This is consistent with the measures of alternative earnings and of the revenues of the firm.

southern coastal areas offered wages for these same occupations which were consistently above the average. Later surveys show very little differences in the regional wages. Results of these surveys were used to construct interior and coastal weights which were applied to the provincial W_A describe above. The resulting wages were used as alternative wages for the interior and coastal sawmills respectively. These weights reach 1 in the mid-70's and are maintained there for the rest of the sample period. The minimum weight for the interior is .91 and the maximum weight for the coast is 1.045. (See the Appendix for more details on the regional wages and weights.)

4.2.4 Strike Costs

In this study, time costs or the ability of players to withstand a strike/lockout measure the bargaining power of the players and affect the equilibrium contract even in the absence of strikes. In the empirical models given in Table I and Table II, the relative strike costs are measured by the term (lndu/lndf).

A large proportion of the empirical studies on strikes have focused on the estimation of relationships between determinants of strike costs and the frequency or length of strikes. Although these studies did not include a bargaining model and hence a model of strikes, the relationship was justified by the argument that (ceteris paribus) higher strike costs will make bargaining parties less willing to strike. Examples of this type of work are Kennan (1980) and Reder and Neumann (1980).

Unfortunately, the modelling of the technology of strike costs has been limited to the ad hoc identification of variables believed to have some impact and to the prediction of the sign of the impact in a (often linear) regression equation. It is an area where research could be very fruitful. In the absence of a rigorous model of strike costs, I have adopted the following simple formulation:[27]

$$\left(\frac{\text{lndu}}{\text{lndf}}\right)_t = (F0 + F1 \times INT_t + F2 \times INV_t + F3 \times CU_t + U0 \times UN_t + U1 \times UIC_t + U \times DEM_t)^2$$

where F0 is a constant, and t denotes the observation, t=1, ... 84.

The first 3 variables measure variations in the firms' strike costs over time. They are:

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[27]A linear form for (lndu/lndf) was also estimated with very little difference in the estimates for the cooperative models (except for the strike cost parameters which were correspondingly larger). For the monopoly models, the linear form yielded some values for (lndu/lndf) which were negative. Forcing the term to be greater than zero by squaring improved the likelihood of the monopoly models from the estimation of the linear form constrained to be greater than zero. All models were also estimated with an added exogenous variable in the specification of the strike costs representing wage and price controls. A dummy variable taking the value of 1 in 1976, 1977, and 1978 was added but had very little effect on the estimates. More detail is given on this in Chapter 5.

INT_t = The nominal rate of interest. F1 < 0 is expected reflecting the fact that an increase in borrowing costs of the firm will increase relative strike costs of the firm.

INV_t = The change in the value of inventories averaged over the last 5 years. F2 > 0 is expected since a firm building up its inventories will be reducing its strike costs. The average over the past 5 years was used to smooth out the very large yearly variations in this variable.[28]

The last 3 variables measure changes in the opportunity cost of labour through changes in labour market conditions. Following Riddell and Smith (1982), tightness of the labour market is measured by the difference between the unemployment rate (UN) and the natural rate of unemployment. The latter will vary according to changes in unemployment insurance (UIC) and changes in the composition of the labour force (DEM). More precisely, let the natural rate of unemployment at time t equal $\mu + \mu_1 UIC_t + \mu_2 DEM_t$. Labour market tightness will be measured by $UN_t - \mu - \mu_1 UIC_t - \mu_2 DEM_t$. In the formulation of (lndu/lndf) above, U0 measures the effect of labour market tightness, $U1 = U0 \times \mu_1$, $U2 = U0 \times \mu_2$ and the term $U0 \times \mu$ is

[28]The estimation results deteriorated slightly when the change in inventories over the last year was used instead of the average over the last 5 years.

included in the constant FO. The variables are measured as follows:

UN_t = The unemployment rate in B.C. U0 > 0 is expected since the term $(UN_t - \mu - \mu_1 UIC_t - \mu_2 DEM_t)$ is inversely related to labour market tightness and as labour market tightness falls, the opportunity cost of labour also decreases thereby increasing the relative strike costs of the union.

UIC_t = A measure of the generosity of the unemployment insurance program. It is constructed as follows: the proportion of the labour force covered by unemployment insurance in Canada times the ratio of unemployment insurance benefits to the average wage in B.C. times a scaling factor which takes into account the taxation of unemployment benefits. (The proportion of the labour force covered by UI was not available for B.C.) U1 < 0 is expected since the natural rate of unemployment will increase with UIC_t (i.e. $\mu_1 > 0$).

DEM_t = The proportion of women of all ages and men under 25 years of age in the total labour force in B.C. Again U2 < 0 is expected since the natural rate of unemployment and DEM will be positively related.

Some of the models were also estimated using additional measures of borrowing costs such as mortgage rates for the workers and demand loan rates for the firm. However, the estimates were not greatly affected and they are not reported here. Also, all attempts at distinguishing between du and df failed. Given the limited data available on strike costs, it was impossible to estimate separately the two elements of the ratio $\frac{\ln du}{\ln df}$.

Chapter 5

Estimation Results

Each of the four systems of 4 simultaneous, nonlinear, structural equations presented in Tables I and II was estimated using FIML. No restrictions are imposed on the variance-covariance matrix of the errors across equations. The contemporaneous errors across the 4 groups of firms are assumed to be i.i.d. but first order autocorrelation is allowed. Specifically, if ϕ^{kj}_{iyf} is the error for equation i, model kj, year y, and group of firms f, then

$$\phi^{kj}_{iyf} = r^{kj}_{i}\phi^{kj}_{i(y-1)f} + \nu^{kj}_{iyf}$$

where: ν^{kj}_{iyf} is i.i.d. $N(\bar{\nu}^{kj}_{i}, \Sigma^{kj}_{4x4})$ for i=1,...,4;

y = 1964,...,1983;

k = c (cooperative), m (labour demand);

j = B (exogenous output profit function), R (exogenous capital profit function);

f = 1 (coastal sawmills), 2 (interior sawmills), 3 (shingle mills), 4 (plywood and veneer mills).

The serial correlation coefficient r^{kj}_{i} is allowed to vary across equations but not across groups of firms nor across time periods. Although no constant term is predicted by the models (see Tables I and II), consistent errors were found and the introduction of constant terms ($\bar{v}_i^{kj}$) improved the estimation.[29]

The four groups of firms are treated as identical except for the inclusion in all four estimation models of a dummy variable which takes the value of one for interior sawmills. Attempts were made to estimate models where the constant term or the scaling factors B and R differed across the four groups of firms. These models proved very difficult to estimate and no convergence was reached. It seems as though more extensive data sets are required on each group of firms to model adequately the differences that might exist in their technologies. (Note that to allow for separate constant terms across all groups of firms, I have to add 8 new parameters to the estimation which is described here.) Interior sawmills proved to be different in terms of the sample error means and the addition of a separate constant terms for these firms improved the likelihood value. The reported coefficients on this dummy variable should be added to the constant terms to get the appropriate constant terms for interior sawmills.

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[29]To generate the constant terms as part of the model requires more general specifications of the technology. However, this would also result in more complicated bargaining equations. In particular, the first equations of the systems given in Tables I and II would be substantially more complex. This is left for future research.

Estimation results under the assumption of exogenous output are presented in the next section. The results for the case of exogenous capital are given in section 5.2.

5.1 Exogenous Output Model

Table IV presents estimated coefficients for the case where output is treated as exogenous in the bargaining process. For comparison, the results for both the cooperative (from now on COOP) and the labour demand (from now on LDEM) bargaining models are given in this table.[30]

5.1.1 The Firms' Technology

For both the cooperative and labour demand models, the technology coefficients are significant with the exception of the exponent on the time trend B1 and the labour exponent for the COOP model. Time has no significant effect in either model on the location of the production function. For both models, labour has the expected negative effect on restricted costs but this effect is more important in the LDEM model and, for the COOP model, the labour coefficient is not only very small, it is also imprecise.

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[30]From Table XI in the Appendix, we can see that the size of the shingle and shake mills in terms of costs and revenues is smaller than the other three groups of firms by a factor of the order of 10. To simplify the estimation, all quantity data concerning shingle mills was multiplied by 10. The implications of this is that the estimated B, R, and γ should be multiplied by $10^{B2+Be-1}$, $10^{R2+Re-1}$, and $10^{-\rho}$ respectively in order to get the appropriate parameters for shingle mills.

Table IV

Exogenous Output Estimation Results

(asymptotic t's in parenthesis)

Cooperative Model

I. Union Utility		
γ	2.43168	(12.345)*
implied $\delta = \frac{\gamma}{1+\gamma}$	.7086	
ρ	0.04670	(1.323)
II. Technology		
B	0.36868	(6.228)*
B1	0.00353	(0.155)
B2	1.09337	(28.211)*
B3	0.03008	(4.296)*
Be	-0.01260	(-0.787)
III. Strike Costs		
F0	1.99872	(1.602)
F1	-0.28815	(-10.948)*
F2	0.05858	(3.141)*
F3	-0.26947	(-5.243)*
U0	-4.4653	(-1.569)
U1	2.85672	(5.445)*
U2	5.08272	(1.600)
IV. First Order Serial Correlation Coefficients		
eq.1	0.62005	(11.340)*
eq.2	0.17802	(2.209)*
eq.3	0.18805	(2.310)*
eq.4	0.12803	(1.172)

Labour Demand Model

I. Union Utility		
γ	5.88248	(8.142)*
implied $\delta = \frac{\gamma}{1+\gamma}$	.8547	
ρ	-0.04792	(-1.637)
II. Technology		
B	2.21139	(4.221)*
B1	0.00826	(0.717)
B2	0.81466	(15.825)*
B3	0.01572	(3.939)*
Be	-0.18179	(-14.386)*
III. Strike Costs		
F0	-6.69166	(-3.343)*
F1	-0.01315	(-0.375)
F2	-0.15232	(-8.251)*
F3	0.13628	(1.419)
U0	-2.52046	(-1.047)
U1	-1.12130	(-1.717)
U2	13.20971	(2.534)
IV. First Order Serial Correlation		
eq.1	0.23388	(3.809)*
eq.2	0.25721	(4.206)*
eq.3	0.29529	(3.639)*
eq.4	0.17485	(1.700)

Table IV Continued

	Cooperative Model		Labour Demand Model	
V. Constants				
eq.1	1.79659	(6.137)*	8.52566	(2.680)*
eq.2	-1.69284	(-7.032)*	-1.05901	(-3.500)*
eq.3	-3.67800	(-6.376)*	12.71037	(5.979)*
eq.4	-0.87202	(-3.926)*	-0.84391	(-3.677)*
Interior Sawmills Dummy				
eq.1	1.71361	(5.580)*	2.09485	(0.878)
eq.2	-0.36749	(-2.956)*	-0.71870	(-2.719)*
eq.3	-3.30972	(-4.132)*	-0.40284	(-0.511)
eq.4	-3.10524	(-12.140)*	-3.28161	(-12.726)*
Value of the ln likelihood	-3286.8887		-3315.1120	
Number of observations	84		84	
R^2 between predicted and actual	(1)			
-W	0.6415		0.7334	
-E	0.2896		0.3367	
$-Q_2$	0.9481		0.9574	
$-Q_3$	0.6341		0.5978	
R^2 between predicted and actual in reduced sample 1964 - 1979				
-W	0.9244		0.8861	
-E	0.3527		0.1732	
$-Q_2$	0.9454		0.9418	
$-Q_3$	0.6954		0.7151	

* significant at 5% in 2-tailed tests

Note: (1) For the cooperative model, one observation, shingle mills in 1982, was deleted in the R^2 calculation.

For comparison it is perhaps more useful to express the input coefficients in terms of cost shares of the underlying unrestricted cost function:

$$C_{UN}(Q_1,P_2,P_3,\tilde{W}) = \text{Constant} \times T^{(\frac{-B1}{Be-1})} Q_1^{(\frac{-B2}{Be-1})} P_2^{(\frac{-(1-B3)}{Be-1})} P_3^{(\frac{-B3}{Be-1})} \tilde{W}^{(\frac{Be}{Be-1})}$$

Note that $\tilde{W}$, the shadow price of labour, is equal to the (predicted) actual wage in the LDEM model but $\tilde{W} \leq W$ in the COOP model since in that case, the contract can be located to the right of the labour demand curve. The cost shares for C_{UN} are:

Cost Shares

Input	COOP Model	LDEM Model	Reference Shares in the Literature*	Actual Average Cost Shares Over Sample**
Labour	.0124	.1538	.23	.31
Materials and Supplies	.9579	.8329	.55	.63
Capital	.0297	.0133	.21	.06

*see Martinello (1984), pg.31.
**see Appendix A

The estimation with exogenous output yields much smaller labour shares than are commonly reported due to the small values of the labour exponents. This is not surprising for the COOP model since the level of employment could be located far to the right of the labour demand curve, but, ignoring econometric issues, the LDEM model is equivalent to standard cost function estimations with the exception that the wage is now chosen through bargaining rather than by competitive forces. The small labour shares are compensated by very large shares for materials and supplies. The capital shares seem extremely small when compared to general estimates but they are not so surprising when they are compared to actual average cost shares over the sample.

In order to look at scale effects, I take advantage of my simple Cobb-Douglas specification and derive the underlying production function parameters:

$$\text{COOP:} \quad Q_1 = \text{Constant} \times T^{-.0032} \times Q_2^{.8871} \times Q_3^{.0275} \times E^{.0155}$$

$$\text{LDEM:} \quad Q_1 = \text{Constant} \times T^{-.0101} \times Q_2^{1.2082} \times Q_3^{.0193} \times E^{.2231}$$

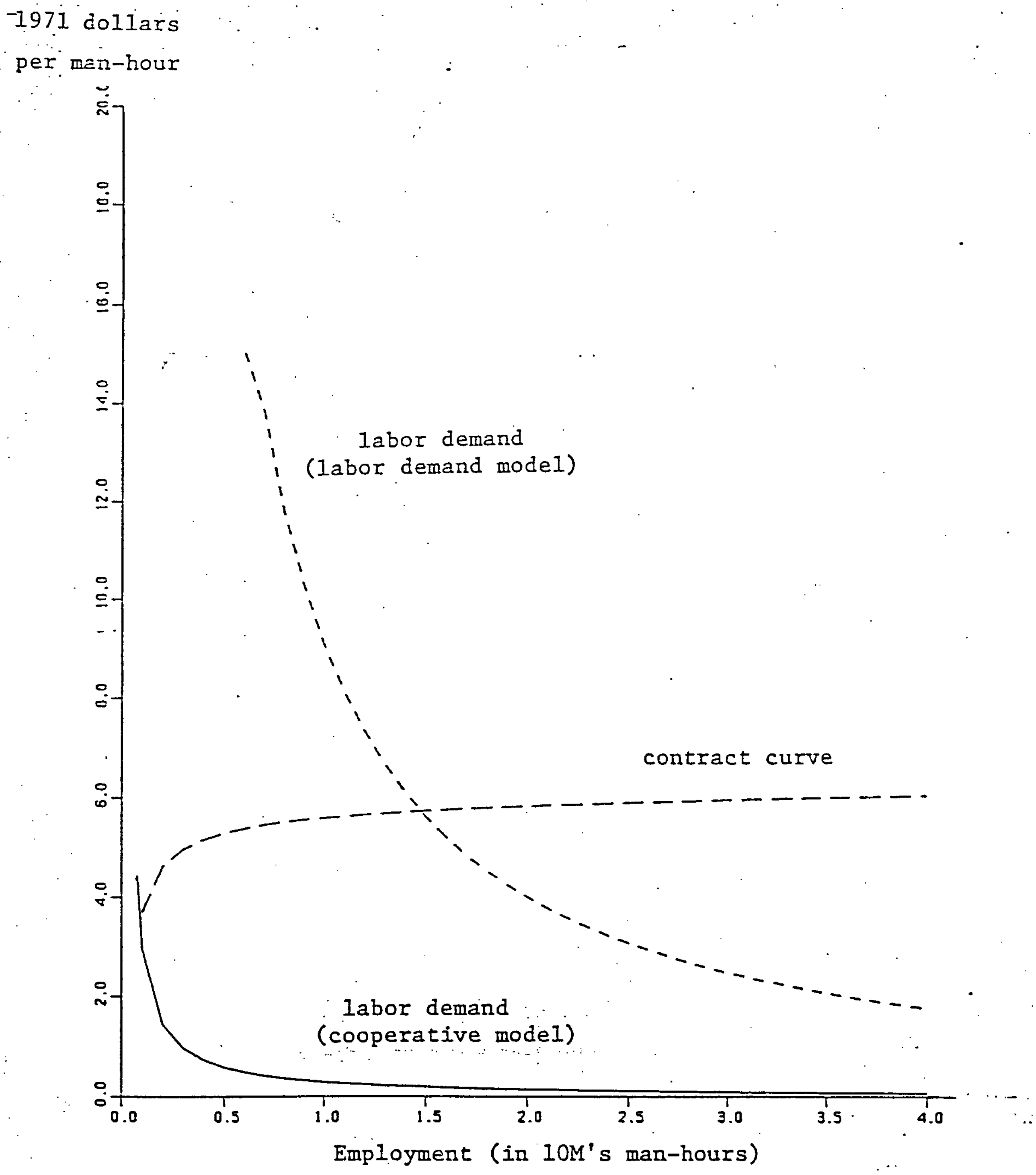
In the COOP model, the technology exhibits decreasing returns to scale while the reverse is true for the LDEM model. Again, a higher coefficient on labour is expected in the LDEM model since that model forces the marginal revenue product of labour to closely resemble the wage. What is perhaps surprising is that the output elasticity of materials is also larger in the LDEM model.

In the LDEM model, the wage is forced to reflect the marginal revenue product of labour. This is not the case for the COOP model. The results for the exogenous output technology indicate that for the COOP model, the wage is considerably larger than the marginal revenue product of labour. The average marginal revenue product of labour over the sample in the LDEM model is 3.3432 which is somewhat lower than the average wage over the sample (4.5). In the COOP model, the average marginal revenue product of labour is only 0.12. It is true that the estimate for the COOP model is imprecise, but even when a 95% confidence interval is calculated for the labour coefficient and the upper bound (in absolute values) is used for Be, the average marginal revenue product of labour is less than one. The two estimated labour demand curves evaluated at the mean of the data are illustrated in Figure 3.[31] (These estimated relationships do not take into account the structure of the error i.e. constant terms and serial correlation are not included in the calculations.) As will be seen later in this chapter, when output is treated as endogenous, the estimated marginal revenue products of labour are larger, especially for the COOP model (see Figure 5). One possible explanation is that the inclusion of output quantity as an exogenous variable introduces multicollinearity in the data and increases the inaccuracy of the estimates of labour

[31]The labour demand calculations for the COOP model exclude the observation for shingle mills, 1982. To obtain predicted values for wages and employment, a system of 2 non-linear equations must be solved for each data point. This system could not be solved with any reasonable degree of accuracy for this observation.

Figure 3

Labour Demand Curves and the Contract Curve. Exogenous Output Estimation.



productivity. (The correlation coefficient between output and employment over the sample is .7371).

Studies using a special case of the LDEM model, the case where the union unilaterally chooses the wage (the monopoly model), have yielded large price elasticities for the labour demand curve. Examples are Martinello (1984) who finds the elasticity (in absolute value) to equal 1.5 for the IWA, and Dertouzos and Pencavel (1981) who find a value of 1.23 at the mean of the data for the International Typographical Union (ITU). These should be compared with general estimates of elasticities smaller than .5 in the literature where union impacts are ignored. In this study, the elasticities lie somewhere in between these values; they are .9876 for the COOP model and .8462 for the LDEM model. Furthermore, this remains true when all bargaining powers are given to the union i.e. when (lndu/lndf) is fixed at zero. In that case the estimated elasticities are 1.033 for COOP and .8405 for LDEM.

5.1.2 Union Preferences[32]

For both the LDEM and the COOP model, results suggests that the union puts more weight on employment than on wages ($\delta > .5$). The difference in the weights is greater for the LDEM than the COOP model but in both cases, the test of equality of weights (i.e. the test that $\gamma=1$) is rejected at the 1% level of significance. This result is consistent with previous findings involving the ITU as well as the IWA. Again for both the COOP and the LDEM models, the parameter ρ is not significantly different from 0. This implies that we cannot reject the hypothesis that the union preferences take the form of a Cobb-Douglas function. The resulting elasticity of substitution ($\simeq 1$) is larger than that found by Martinello (1984) ($\simeq .7$) and by Dertouzos and Pencavel (1981) for the ITU (.7). Rent maximization ($\rho=0$ and $\gamma=1$) is rejected for both models, a result which was also found by Dertouzos and Pencavel (1981) and Martinello (1984).

It is reassuring that the union preferences are so similar in the two models given the difference in the technology coefficients. However, some differences do exist. The elasticity of substitution for the COOP model (.9554) is lower than for the LDEM model (1.0503) which

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[32]Taking into account the scaling of the data for shingle mills, the union utility parameters γ for those firms is 2.18376 for the COOP model and 6.5687 for the LDEM model. None of the qualitative results described in this section are affected when considering these adjusted parameters for shingle mills.

means that the indifference curves are more convex in the COOP model. At the mean of the data, it would take a 0.44% increase in the wage (above the alternative wage) to compensate the union for a loss of 1% in the number of workers in the COOP model. This same measure equals 1.32% in the LDEM model. It takes a much larger increase in the wage to compensate the union for the loss of one worker in the LDEM model. These estimates are comparable to that found in Martinello (1984) (.67%).

5.1.3 The Contract Curve and the Bargaining Sets

The contract curve for the COOP model evaluated at the mean of the data has also been plotted in Figure 3. It is very flat i.e. the contracts move quickly away from the labour demand curve. The average elasticity of the contract curve over the sample is 3.44%.

For 4 of the data points in the COOP model and 2 of the data points in the LDEM model, the predicted wage was lower than the alternative wage. This occurred during the 1980's recession, specifically, for the COOP model, $W<W_A$ for the sawmills from 1980 to 1983 and for the LDEM model, the same is true for interior sawmills and for shingle mills in 1982. This finding is not consistent with the assumption of a zero threat point which is maintained in this study. However, it can be explained by the presence of fixed costs of delay which cause the threat point to be less than zero. The possibility of a negative threat point sounds plausible in

the short run but it is unlikely that the players can survive prolonged periods of negative utility.

Excluding the observations mentioned above plus shingle mills in 1982 for the COOP model (see footnote 31), I find that the bargaining sets in utility space for both the COOP and LDEM models are convex everywhere. This ensures that the equilibrium to the bargaining game is unique. Also, for the COOP model, the iso-profit curves are everywhere less convex than the union indifference curves. This ensures that the contract curve is defined by tangency points of the iso-utility curves. (Note that this is not an issue in the LDEM model since in that case, the labour demand curve is the contract curve.)

5.1.4 Bargaining Powers[33]

The determinants of the firms' strike costs are all significant and have the expected signs in the COOP model.

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[33]All models were also estimated with the addition of a dummy variable representing the effects of wage and price controls on the relative strike costs. This dummy variable takes the value of one in 1976, 1977, and 1978. In all cases, the coefficients on this variable are small and not significantly different from zero. The other parameters are practically unaffected by the addition of this term. The likelihood is slightly improved. Under the assumption of exogenous output, the log likelihood value for the cooperative model is -3285.9340 and for the labour demand model, -3315.0744. The same values under the assumption of exogenous capital are -3466.6705 and -3479.1330 respectively. The coefficients on the dummy variable are: for the exogenous output framework, -0.099 for COOP and 0.025 for LDEM, for the exogenous capital model, 0.018 for COOP and -0.078 for LDEM.

An increase in the interest rate will cause a rise in the relative strike costs of the firms while an increase in inventory levels over the past 5 years will be accompanied by a fall in the firm's relative strike costs during the following year. The capital utilization rate is negatively related to firms' relative strike costs. Tracy (1986) found a positive effect of business cycles on the firms' strike costs. In that study, business cycles were meant to measure cyclical variations in rents and hence in the absolute level of strike costs. Here, the coefficient on the capital utilization ratio measures business cycle effects on strike costs over and above the cyclical variations in rents. In the LDEM model, only the inventory level has a significant coefficient and it has the opposite sign to that in COOP. The interest rate and capital utilization rate have smaller and insignificant effects.

The union strike costs varied over time according to labour market tightness as measured by the term:

$$U0[UN_t - \frac{U1}{U0} \times UIC_t - \frac{U2}{U0} \times DEM_t].$$

Note that unemployment also enters the alternative wage measure and, through W_A, directly affects the constraint on the union's utility. The effect of unemployment on strike costs is over and above the direct effects on W_A (e.g. effects on spouse's income). For both the COOP model and the LDEM model, U0 has the wrong sign which implies that relative union strike costs increase (and hence union bargaining power falls) when the labour market becomes tighter. However, these effects are imprecise as standard errors are large. The UIC and DEM variables in the COOP model have the predicted (positive) effects on the natural rate of unemployment but only the UIC coefficient is significant. In the LDEM model, the coefficient on DEM has the predicted sign and is significant while the UIC coefficient has the wrong sign but is insignificant.

The term (lndu/lndf) is bounded below by 0, the case where the union has all the bargaining power, and is unbounded above as it approaches ∞ when the firms' time costs go to 0. The average value of the relative strike costs (lndu/lndf) over the sample is .1943 in the COOP model and .1222 in the LDEM model. The union has relatively less power when contracts are assumed to be efficient. Log likelihood tests were performed on the following hypothesis: (lndu/lndf)=0 (the union has all the bargaining power) and (lndu/lndf)=1 (equal bargaining power; i.e., F0=1 and all other coefficients equal to 0). Both hypotheses were rejected for both models. The estimates do not support the monopoly model of unions nor a symmetric Nash bargaining solution.

The fact that the value of (lndu/lndf) is very low implies that the union discount rate du is much larger than the discount factor of the firms df. In order to have a better idea of the relative bargaining powers implied by the value of (lndu/lndf), I calculated the weights on the two parties' utilities in the Nash bargaining solution (see equations (4) and (5) in Chapter 4). These weights are easier to interpret as they are bounded below by zero, bounded above by 1, and they sum to one. The weight on the union utility is given by:

$$a_u = \frac{\mathrm{lndf}}{\mathrm{lndu} + \mathrm{lndf}} = \frac{1}{1 + (\mathrm{lndu}/\mathrm{lndf})}.$$

The weight on the firms' profits is:

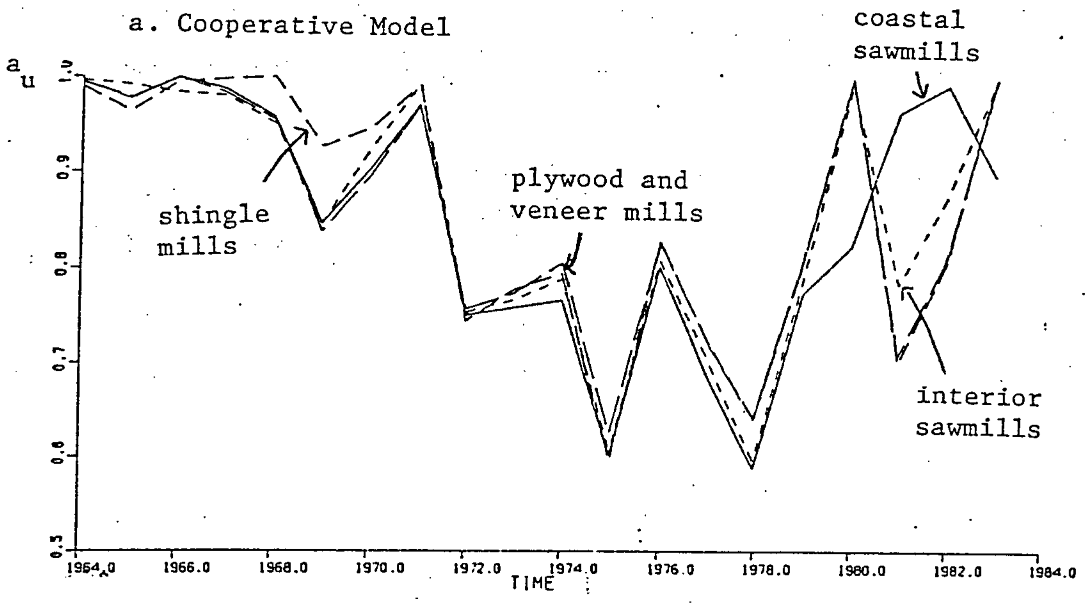
$$a_f = \frac{\mathrm{lndu}}{\mathrm{lndu} + \mathrm{lndf}} = \frac{(\mathrm{lndu}/\mathrm{lndf})}{1 + (\mathrm{lndu}/\mathrm{lndf})} = 1 - a_u .$$

The bargaining power of the union (as measured by the term a_u) is plotted for all four groups of firms and for both the COOP and LDEM models in Figure 4. The first thing to note is how large the bargaining power of the union is in the exogenous output model. The average union utility weight in the COOP model is .8375 and in the LDEM model .8913. For both models, the bargaining power of the union decreases in the 70's but rises again in the 80's to reach its 1960's level again by 1982 or 1983. For the COOP model, the decrease started in the early '70's but for the LDEM model, the bargaining power remained at its high level until 1976. Furthermore, this fall in the 70's is not caused

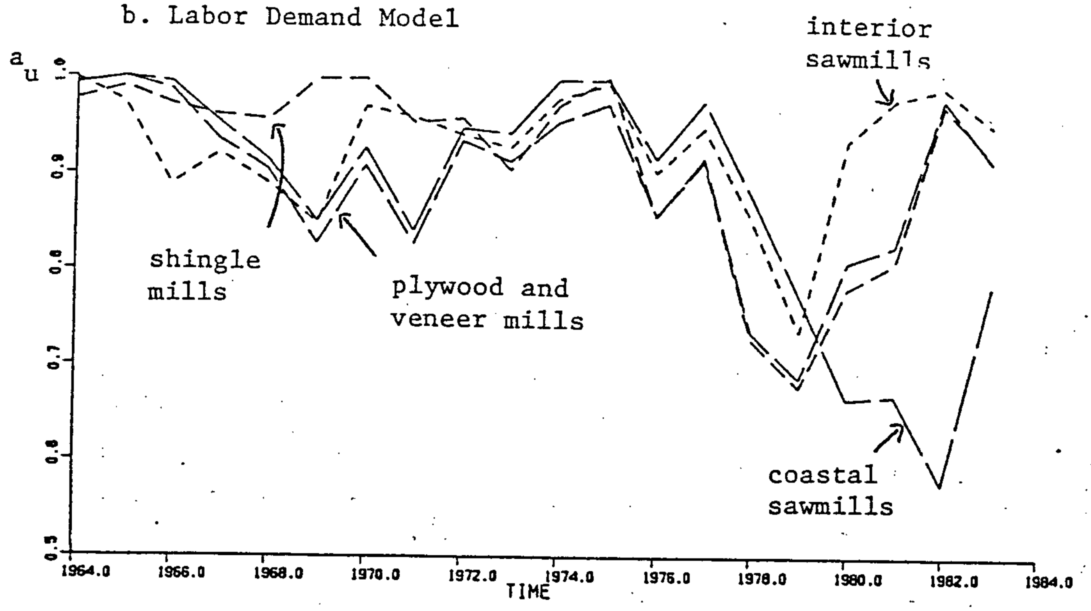
Figure 4

Union Bargaining Power. Exogenous Output Estimation.

a. Cooperative Model



b. Labor Demand Model



solely by the perverse coefficient on the unemployment rate. The union bargaining power calculated as above with U0, U1 and U2 set at zero still shows a slight downward trend in the '70's with a sharp fall around 1981 and a subsequent increase in the last 2 years of the sample.

It is surprising to see the estimated union bargaining power decreasing in the late '70's when the provincial economy was booming and labour markets were very tight. However, it should be kept in mind that a decrease in a_u does not imply a decrease in the union utility function, in fact, the union utility was increasing over this period. What it indicates is that the firms' profits were increasing faster than the utility of the union. This is perhaps more easily shown by looking at the estimated proportions of total rents captured by the firm which are listed in Table V for the COOP model.

The proportions given in Table V are calculated as the ratio of estimated profits of the firms divided by profits evaluated at the alternative wage and at the corresponding employment level on the labour demand curve. I find that the firms succeeded in capturing slightly over 40% of rents on average over the period. Also, the proportion of rents captured by the firm was larger on average in the 1970's, especially in the latter half of the decade.

Table V

Proportion of Total Rents Captured by the Firm.

Cooperative Model with Exogenous Output

Year	Coastal Sawmills	Interior Sawmills	Shingle Mills	Plywood & Veneer Mills
1964	.31113	.59166	.39781	.46465
1965	.33218	.57967	.43755	.44462
1966	.35079	.58601	.43599	.43327
1967	.42393	.57622	.42172	.46698
1968	.36535	.55831	.38423	.43616
1969	.28265	.43007	.20909	.45712
1970	.29588	.50572	.24876	.47370
1971	.32846	.56994	.34617	.48529
1972	.43833	.55050	.38960	.47539
1973	.44509	.49261	.36297	.43178
1974	.18168	.39963	.29614	.36443
1975	.45291	.60943	.54350	.52181
1976	.41620	.56498	.43655	.44838
1977	.44037	.51496	.39039	.41167
1978	.51582	.55352	.47949	.54334
1979	.45093	.45831	.44947	.38503
1980	.17879	.45267	.34229	.22093
1981	.29232	.55320	.39730	.20498
1982	.27218	.63340	- (1)	.17610
1983	.33905	.65908	.40259	.22517

Grand Avg. = .4223

Note: (1) Predicted values for wages and employment could not be calculated for this observation (see footnote 31).

It is interesting to note the difference in the proportion of rents captured by the union (which is less than 60% on average) and the union bargaining power as measured by a_u (which is greater than 80% on average). The proportion of rents is a poor indicator of union bargaining power because it is based on the vertical distance (in W,E space) between the iso-profit curve corresponding to the estimated profit level and the iso-profit curve corresponding to a zero profit. The correct value of union bargaining power is based on the distance measured along the contract curve. These two measures are the same only if the union is rent maximizing and if the contract is efficient.

For the LDEM model, estimated profits and rents are negative for most data points due to the large scaling factor B (2.21). As mentioned earlier, the marginal revenue product (MRP) of labour is much larger in the LDEM model than in the COOP model because it is forced to reflect the wage. This higher MRP of labour is achieved in part by a larger coefficient on labour (Be). However, and this was evident from the labour cost share, this labour coefficient is still small and a substantial part of the difference in the MRP's is due to the larger scaling factor B. This, in turn, causes the estimated costs of materials and capital to be big and the estimated profits are, in general, negative.

5.1.5 Comparing the COOP and LDEM Models

In Table IV, we see that the efficient contract model performs better in the sense that its likelihood value is larger.[34] This has been true throughout my whole research with this data set. It is interesting to compare the correlation coefficients between predicted and actual values of the endogenous variables. For wages and employment, the R^2's are actually larger in the LDEM model. The list of prediction errors showed that the COOP model was very poor at predicting wages and employment in the 1980's. This is clear from the R^2's calculated without the years 1980 to 1983 which are also reported in Table IV.

This suggests the interesting hypothesis that while the efficient contract model performs better in general, the LDEM model is more appropriate during severe recessions. The large changes which occurred in the economic environment of the two players due to the severe recession in the 1980's could have made bargaining over employment very costly in terms of transactions and monitoring (enforcement) costs. This could be tested by a switching regime type model or a general model nesting the two bargaining models. A larger data set would probably be required as well.

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[34]Since both models have the same number of parameters, the comparison of the likelihood values is equivalent to using the Akaike Information Criterion with both models being considered as nested in a more general model which could take the form of a convex combination of the two.

5.2 Exogenous Capital Model

Table VI presents coefficients for both bargaining models and for the case where capital services are treated as exogenous to the bargaining process. Output is now chosen optimally given the negotiated labour contract.

5.2.1 The Firms' Technology

For both the COOP and the LDEM models, all technology coefficients are significantly different from zero. It is surprising how similar the coefficients are in the two bargaining models. That was not the case in the exogenous output estimation. The time trend has coefficients which are significantly less than zero implying that the production function in both bargaining models is shifting in over time. The effects are quite small however.

As for the exogenous output estimation, I derive the input cost shares based on the underlying unrestricted cost function:

$$C_{UN}(Q_1, P_2, \tilde{P}_3, \tilde{W}) = \text{Constant} \times T^{C1} \times Q_1^{C2} \times P_2^{1-C3-Ce} \times \tilde{P}_3^{C3} \times \tilde{W}^{Ce}$$

where the exponents are functions of the vector of estimated R coefficients. Note that since capital is assumed to be exogenous, the shadow price of capital $\tilde{P}_3$ will in general differ from the actual price of capital P_3. Also, $\tilde{W}$, the

Table VI

Exogenous Capital Estimation Results
(asymptotic t's in parentheses)

Cooperative Model

I.	**Union Utility**		
	γ	1.05352	(7.315)*
	implied $\delta = \frac{\gamma}{1+\gamma}$	.51303	
	ρ	0.14051	(2.786)*
II.	**Technology**		
	R	17.98817	(7.436)*
	R1	-0.21048	(-7.461)*
	R2	-0.53964	(-9.294)*
	R3	0.59467	(9.753)*
	Re	0.19463	(6.873)*
III.	**Strike Costs**		
	F0	4.66183	(4.548)*
	F1	-0.07521	(-4.041)*
	F2	-0.02315	(-2.064)*
	F3	-0.20538	(-4.869)*
	U0	-7.99731	(-5.357)*
	U1	0.67511	(2.044)*
	U2	-0.62665	(-0.276)
IV.	**First Order Serial Correlation Coefficients**		
	eq.1	0.26175	(3.599)*
	eq.2	0.45682	(6.606)*
	eq.3	0.08056	(1.228)
	eq.4	0.27959	(4.234)

Labour Demand Model

I.	**Union Utility**		
	γ	1.49223	(5.619)*
	implied $\delta = \frac{\gamma}{1+\gamma}$	.59875	
	ρ	0.16808	(2.781)*
II.	**Technology**		
	R	16.74362	(5.854)*
	R1	-0.11640	(-3.772)*
	R2	-0.53247	(-6.970)*
	R3	0.44378	(6.063)*
	Re	0.29027	(9.971)*
III.	**Strike Costs**		
	F0	-4.49366	(-4.073)*
	F1	0.05896	(2.300)*
	F2	0.02169	(1.296)
	F3	0.22046	(3.891)*
	U0	9.08620	(2.647)*
	U1	-0.21710	(-0.707)
	U2	0.86142	(0.329)
IV.	**First Order Serial Correlation**		
	eq.1	0.32974	(4.739)*
	eq.2	0.38440	(6.227)*
	eq.3	0.04105	(0.592)
	eq.4	0.17203	(2.716)*

Table IV Continued

	Cooperative Model		Labour Demand Model	
V. Constants				
eq.1	1.02308	(0.703)	-0.10978	(-0.069)
eq.2	-1.33659	(-8.483)*	-0.97044	(-3.102)*
eq.3	-9.26692	(-6.687)*	-7.89717	(-4.253)*
eq.4	-4.99822	(-1.825)	-1.12594	(-0.307)
Interior Sawmills Dummy				
eq.1	2.74521	(2.863)*	2.52769	(1.908)
eq.2	0.39170	(2.039)*	0.44520	(1.242)
eq.3	-3.91362	(-1.386)	-5.25611	(-1.324)
eq.4	4.14343	(0.997)	0.58108	(0.099)
Value of the ln likelihood	-3466.7148		-3479.5348	
Number of observations	84		84	
R^2 between predicted and actual				
-W	0.6823		0.7020	
-E	-0.0817		0.0055	
$-Q_2$	0.5829		0.5314	
$-Q_1$	0.5466		0.5591	
R^2 between predicted and actual in reduced sample 1964 - 1979				
-W	0.9346		0.9390	
-E	-0.0589		-0.2929	
$-Q_2$	0.5024		0.4264	
$-Q_1$	0.3829		0.3729	

*significant at 5% in 2-tailed tests

shadow price of labour will in general be less than the actual wage in the COOP model since employment will be located to the right of the labour demand curve. The cost shares for the exogenous capital estimation are:

Cost Shares

Input	COOP Model	LDEM Model	Reference Shares in the Literature (see Martinello (1984), pg.31)	Actual Average Cost Shares over Sample (see Appendix A)
Labour	.1465	.2291	.23	.31
Materials and Supplies	.4061	.3504	.55	.63
Capital	.4475	.4204	.21	.06

The labour share which is substantially larger than in the exogenous output estimation is comparable to the shares reported in the literature. Also, the difference in the labour shares in the two bargaining models is smaller than in the exogenous output estimation.

Assuming capital is exogenous yields large cost shares for this input, about twice the size of the reference share and seven times the size of the actual share calculated over the sample. This suggests that in this estimation, the shadow price of capital is larger than the actual price. The firms would increase their usage of capital if the adjustments were costless.

The underlying production function parameters are derived from the vector of technological coefficients:

COOP: $Q_1 = \text{Constant} \times T^{-.1367} \times Q_2^{.3505} \times Q_3^{.3862} \times E^{.1264}$

LDEM: $Q_1 = \text{Constant} \times T^{-.0760} \times Q_2^{.3475} \times Q_3^{.2896} \times E^{.1894}$

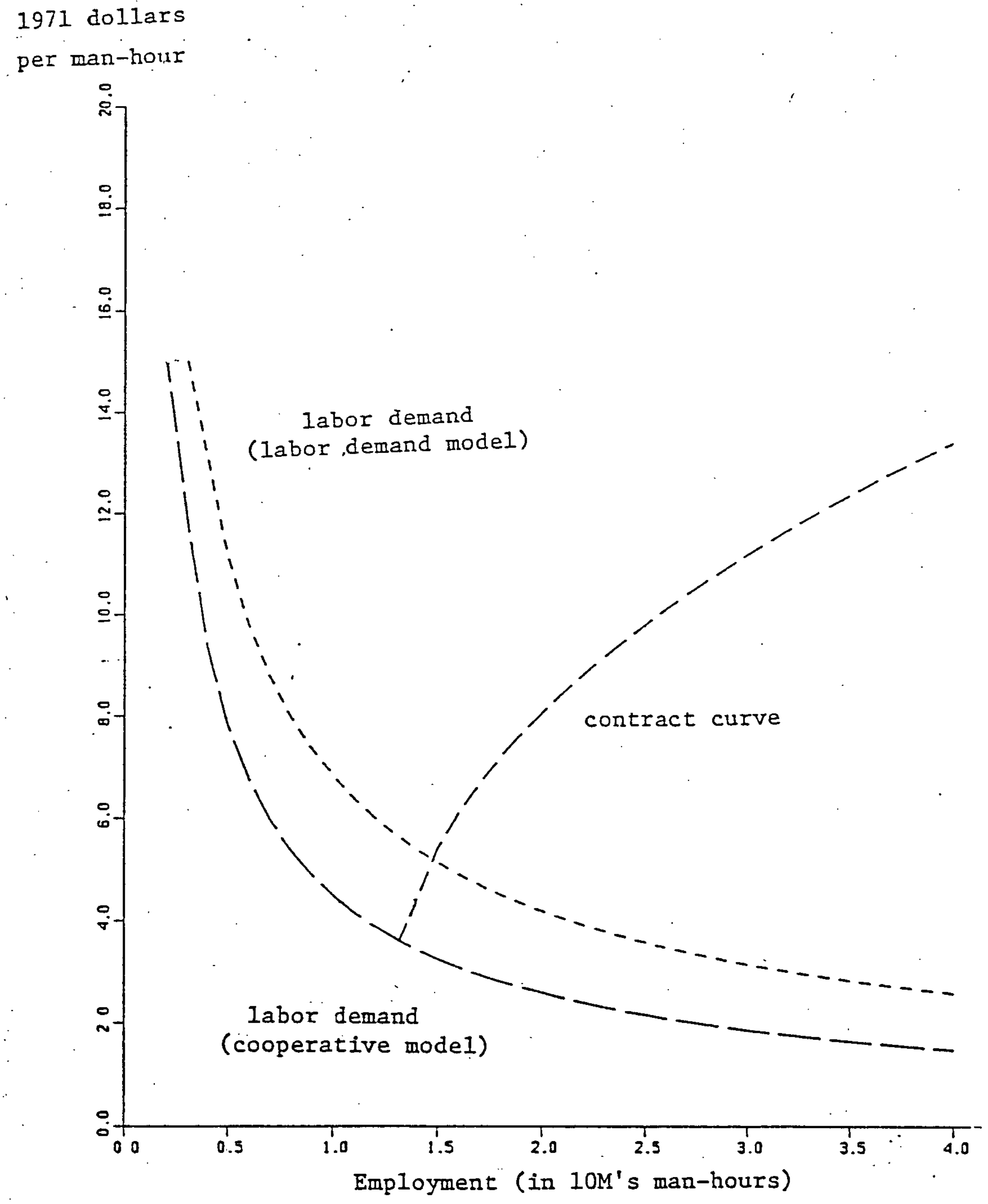
Both production function estimates exhibit decreasing returns to scale. This was also the case in the exogenous output COOP model but the LDEM model with exogenous output yielded increasing returns due to a very high coefficient on materials and supplies.

The average marginal revenue product (MRP) of labour over the sample is 2.1803 for the COOP model and 3.6234 for the LDEM model. (Notice that the average MRP in the LDEM model is lower than the average wage of 4.52 because it does not take into account the structure of the error term.) The two estimated labour demand curves evaluated at the mean of the data are illustrated in Figure 5. The labour demand for the LDEM model is somewhat flatter but otherwise quite similar to its counterpart in the exogenous output model. This is expected since in both cases, the marginal revenue product of labour is forced to reflect the wage. The COOP model labour demand in Figure 5 is much higher than the COOP model labour demand in Figure 3 due to a larger coefficient on labour (Re). When contracts are assumed to be efficient, the estimated marginal revenue product of labour is on average \$1.50 per hour (measured in 1971 dollars) less than the LDEM value. In the exogenous output estimation, this

Figure 5

Labour Demand Curves and the Contract Curve.

Exogenous Capital Estimation.



same difference is $2.20 per hour reflecting the greater similarity between efficient and inefficient bargaining model labour demands in the exogenous capital estimation.

The labour demand elasticities are .7708 for the LDEM model and .8535 for the COOP model. Both of them are slightly lower than the elasticities estimated under the assumption of exogenous output (.8462 for LDEM and .9876 for COOP). These estimates still lie below the ones found by Martinello (1984) for the IWA (1.5) and by Dertouzos and Pencavel (1981) for the ITU (1.23). As for the exogenous output estimates, I verify whether my smaller labour demand elasticities are due to different assumptions on the union's ability to set the wage. For the two results mentioned above, it was assumed that the union could unilaterally choose the wage. I re-estimated the exogenous capital model with (lndu/lndf) set at zero. The resulting labour demand elasticities are 1.1644 for the COOP model and 0.778 for the LDEM model. Letting the union have all bargaining power does increase the labour demand elasticities especially for the efficient contracting model, however, the resulting elasticities are still smaller than those reported by Martinello and Dertouzos and Pencavel.

5.2.2 Union Preferences

In the previous discussion, it was seen that the estimates of the firms' technology were very different depending on whether output or capital was treated as exogenous to the bargaining process. This is consistent with Martinello's findings.[35] In that study however, the union utility parameters were found to be very similar in the two scenarios. Although there are some similarities in my utility parameter estimates with the exogenous output estimates, I also find important differences.

As for the technology coefficients, I find that the utility parameter estimates are very similar in the COOP and LDEM models, more so than in the exogenous output case. The elasticity of substitution in the efficient contracting model is .8768, and for the LDEM model, it is .8561. The hypothesis that the elasticity of substitution equals 1 which could not be rejected in the exogenous output model, is now rejected at the 1% level of significance for both bargaining models. The weight on employment in the union utility function is now just slightly greater than the coefficient on the wage term. For the COOP model, the employment coefficient is .513 with a corresponding wage coefficient of .487. For the LDEM model, these coefficients are .599 and .401 respectively. (These should be compared to employment coefficients of .71 for the COOP and .85 for the LDEM models in the exogenous output estimation.) The

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[35]Martinello (1984) assumed all inputs and the output to be endogenous in his profit function estimation and he assumed an exogenous output in his cost function estimation.

hypothesis of equal weights on employment and $(W-W_A)$ is now accepted at the 5% level of significance for both bargaining models.

The marginal rate of substitution between the number of workers and wages above the alternative wage expressed in percentage terms and calculated at the mean of the data is .15 for the COOP model and .20 for the LDEM model. As for the exogenous output estimation, it takes a larger increase in the wage in the LDEM model to compensate the union for a 1% fall in the number of workers. However, with exogenous capital, the difference in the MRS's in the two bargaining model is very small. Finally, rent maximization ($\rho=1$ and $\gamma=1$) is rejected for both the COOP and LDEM models. This was also true in the exogenous output estimation.

5.2.3 The Contract Curve and the Bargaining Sets

The contract curve for the COOP model evaluated at the mean of the data has been plotted in Figure 5. It is much steeper than the average contract curve estimated under the assumption of exogenous output. Also, for that case, the contract curve at the mean of the data was a good representation of the contract curves over the sample as the slopes were positive and small at all data points. When capital is treated as exogenous however, some of the contract curves have large positive slopes while slopes are negative and large in absolute value at other data points.

Over the sample, the slope varies from -671.8 for interior sawmills in 1973 to 106.9 for shingle mills in 1968. In general, the contract curve is more likely to be backward bending if the MRS is small.[36] With an MRS equal to zero, the contract curve would be identical to the labour demand curve. Also, ceteris paribus, the contract curve will be flatter the smaller is the coefficient on labour (Re).

In the exogenous output estimation, the predicted wage was less than the alternative wage for a few of the data points corresponding to the recession years of the early '80's. This is also the case under the assumption of exogenous capital. Specifically, the predicted wage is less than the alternative wage for interior sawmills in 1980, 1981 and 1983 for both bargaining models. Ignoring these observations, the bargaining sets are concave everywhere for both the COOP and the LDEM models and, for the COOP model, the iso-profit curves are everywhere less convex than the union indifference curves. This ensures that second order conditions to the maximization problem describing the Nash bargaining solution are satisfied and that the equilibrium is unique.

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[36]More specifically, in this model, the contract curve will have a negative slope if

$$(\rho+1)\gamma\left(\frac{W_t - W_{At}}{E_t}\right)^{\rho+1} < 1.$$

5.2.4 Bargaining Powers[37]

Contrary to the technology and union utility parameters, the coefficients on the strike costs determinants are very different in the two bargaining models. There are more similarities between the coefficients of the same bargaining model estimated under different technological assumptions.

For the COOP model, the results concerning the firm strike costs are the same as for the exogenous output estimation except that the inventory variable now has the opposite sign implying that an increase in average inventory holdings will increase the firm's relative strike costs. The results concerning the union's strike costs determinants are also qualitatively the same as in the exogenous output estimation with the exception of the demographics variable coefficient which has a perverse but insignificant sign. The coefficients in the LDEM model are more different from their counterparts in the exogenous output estimation; however, given the large standard errors on these coefficients in both estimations, their variability is not so surprising.

The average value of the term measuring relative strike costs (lndu/lndf) is .8949 for the LDEM model and 2.1061 for the COOP model. As was the case for the exogenous output

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[37]See footnote 33.

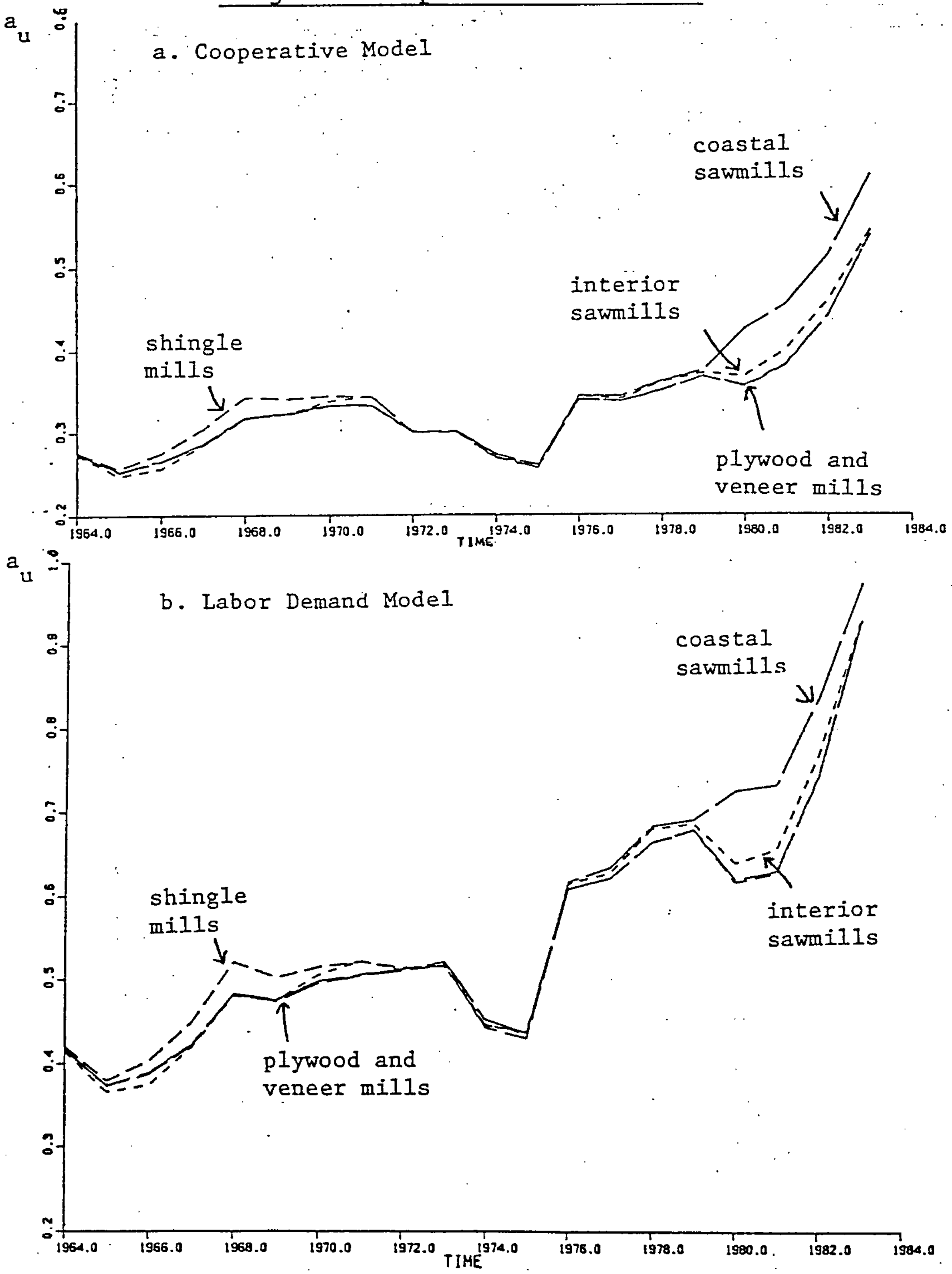
estimation, the union has relatively less power when contracts are assumed to be efficient. Tests of the monopoly model (lndu/lndf)=0 and the symmetric Nash bargaining solution (lndu/lndf)=1 are performed and these hypothesis are rejected for both bargaining models.

The exogenous capital estimation yields larger discount factors for the firm relative to the union. The weights on the utility functions of the firm and the union in the Nash bargaining solution (as described in section 5.1) were also calculated for the exogenous capital model. They are plotted for both bargaining models in Figure 6. Despite the different coefficients on the exogenous variables affecting the strike costs, the profile of the union's relative bargaining power over time is very similar in the COOP and LDEM model. The union bargaining power in the labour demand model is everywhere larger than the COOP model estimate, the difference averaging .2. In both cases the union power rises slowly in the late 1960's and 1970's followed by a rapid increase in the early 1980's. The union achieves almost complete control over wages in 1984 according to the LDEM model while the relative union power at its maximum is closer to 2/3 in the COOP model. The average union utility weight over the sample is .5277 for the LDEM model and .3220 for the COOP model. These should be compared to .8913 and .8375 respectively for the exogenous output estimation.

Figure 6

Union Bargaining Power.

Exogenous Capital Estimation.



It is interesting to compare the bargaining powers of the union and firm as measured above with the division of rents between the two of them. In the exogenous output estimation, it was seen that the bargaining power of the union was underestimated when measured by the proportion of rents it succeeded to capture. This is still true for the estimation under exogenous capital. The proportion of rents captured by the firm is given in Table VII for the efficient contract model and in Table VIII for the labour demand curve.

On average, firms captured 77% of rents in the COOP model and 83% in the LDEM model. The bargaining power of the firm as measured by the weight on its utility in the Nash bargaining solution is 68% in the COOP model and 47% in the LDEM model. The gentle rise in union bargaining power over the 1970's is not evident in Tables VII and VIII. However, with the exception of interior sawmills, the proportion of rents captured by the firm fell substantially during the recession years of the 1980's and this is consistent with the rapid increase in union bargaining power during those years (see Figure 6).

5.2.5 Comparing the COOP and LDEM Models

As was the case for the exogenous output estimation, the efficient contract model performs better than the LDEM model in the sense that it generates a higher likelihood value. When output is no longer used as an explanatory

Table VII

Proportion of Total Rents Captured by the Firm

Cooperative Model with Exogenous Capital

Year	Coastal Sawmills	Interior Sawmills	Shingle Mills	Plywood & Veneer
1964	.74880	.82466	.78684	.65592
1965	.80234	.88400	.82541	.74559
1966	.81928	.89641	.83191	.76808
1967	.81880	.88980	.81860	.77545
1968	.80743	.87658	.80092	.75927
1969	.79035	.84419	.77868	.77011
1970	.78127	.87310	.75429	.77290
1971	.80159	.88317	.80895	.80389
1972	.83279	.88068	.81736	.82067
1973	.83166	.86472	.80659	.81259
1974	.82508	.87030	.81825	.82484
1975	.83462	.90171	.81784	.84606
1976	.78420	.86755	.76305	.80948
1977	.80739	.86251	.78170	.79832
1978	.79446	.85348	.77085	.80681
1979	.78648	.83982	.75432	.77218
1980	.73643	.91261	.78749	.78223
1981	.72202	.98679	.77092	.74739
1982	.68826	.90225	.72923	.66790
1983	.60260	1.01554	.62893	.65400
Average	.78079	.8865	.78411	.76968

Overall Average = .76692

Table VIII

Proportion of Total Rents Captured by the Firm

Labour Demand Model with Exogenous Capital

Year	Coastal Sawmills	Interior Sawmills	Shingle Mills	Plywood & Veneer
1964	.83630	.86966	.86711	.79415
1965	.85970	.89976	.91029	.82874
1966	.87056	.90588	.88378	.84198
1967	.87158	.89942	.88096	.85160
1968	.87050	.89194	.87339	.85086
1969	.86362	.86426	.85733	.86414
1970	.85637	.88969	.85336	.86553
1971	.86852	.90226	.87547	.88099
1972	.87147	.88892	.86671	.87625
1973	.86502	.87651	.85630	.87016
1974	.86398	.88497	.86081	.87816
1975	.87227	.90417	.87496	.88412
1976	.85015	.87767	.83377	.86731
1977	.85565	.86819	.83897	.86286
1978	.84673	.85904	.83387	.85828
1979	.84156	.85597	.82865	.85061
1980	.84015	1.10236	.85337	.86201
1981	.84198	1.10372	.85113	.85419
1982	.82862	.94375	.83383	.83032
1983	.81952	1.07388	.80887	.84253
Average	.85471	.91810	.85711	.85574

Overall Average = .82992

variable, the prediction of employment worsens considerably. Although there is still some indication that the LDEM model is better at predicting the behavior in wages and employment during the 1980's recession, the evidence is not as strong as in the exogenous output estimation.

5.3 Summary of Results

With one exception, the technology coefficients in all 4 estimation models were significant and had the predicted sign. The exception is the coefficient on labour which was very small with a large standard error in the estimation of the COOP model under the assumption of exogenous output. Using output as an explanatory variable did increase the predictive powers of the model especially with respect to labour; however, it also yielded implausibly low values for the labour coefficients. The result was the very small labour cost shares reported in section 5.1.1.

The small marginal revenue product of labour was accompanied by a large marginal rate of substitution for the union compared to the exogenous capital estimates. This yielded a flat contract curve with an average elasticity of less than 5%. This contract curve evaluated at the mean of the data is drawn in Figure 3 and it should be compared to its counterpart in the endogenous output - exogenous capital estimation which is illustrated in Figure 5.

The closeness and similarity of the labour demand curves in Figure 5 is an indication of the similarity in the technological parameters in the two bargaining models when output is treated as endogenous. In general, the estimated parameters have been more sensitive to the imposition of exogenous output than to the imposition of a different bargaining framework. This is also true of the union utility parameters.

Many of the qualitative results concerning the union utility function were consistent across models. In all cases, the union cares about both wages and employment with a larger weight being placed on employment. The difference between weights placed on employment and wages is quite large and significant in the exogenous output estimation but when output is endogenous and capital exogenous, the equality of the weights cannot be rejected for either bargaining models. In all models, the union has convex indifference curves with the elasticity of substitution ranging from .86 to 1.05. When output is treated as exogenous, the hypothesis of a Cobb-Douglas specification cannot be rejected. Rent maximization is always rejected.

The data supports the bargaining model in the sense that the introduction of the bargaining variables improved the likelihood; i.e., (lndu/lndf)=0 is rejected in all models. Also, in the efficient contract model, with few exceptions, the contract curve was well-defined as the locus of tangency points between the iso-profit and union indifference curves and the bargaining frontier in the space of utilities was concave. The latter condition ensures uniqueness of the equilibrium. The exceptions all involved observations in the 1980's and they were inconsistent with the maintained assumption of a zero threat point for the union (i.e. the predicted wage was less than the alternative wage). Similar results were found in the LDEM model with endogenous output but with exogenous output, this model frequently yielded negative predicted profits due to the low coefficient on labour.

The proportion of rents captured by the firm, a measure which is often used as an indicator of the firm bargaining power overestimated the bargaining power of the firms as defined by the weight on the profit function in the Nash bargaining solution. Although the rapid increase in the union bargaining power during the recession years of the early 1980's was reflected in the proportion of rents captured by the firm (interior sawmills excepted), in general, no monotone relationship between the two measures was detected. The exogenous output estimation yielded large estimates for the union bargaining power and a downward trend was indicated over the 1970's. The endogenous output, exogenous capital estimation yielded measures of union bargaining power closer to the firms' power although the hypothesis of equal bargaining powers was rejected for both bargaining models. There was also some evidence of an upward trend during the 1970's.

It is worth noting that although the magnitudes of the bargaining powers and their time profiles over the 1960's and 1970's varied across models, the indication of an increase in union power during the 1980's recession is found in all cases. One possible reason for this result is that the severe recession of the early 1980's placed firms in a precarious position financially, and greatly increased the probability of bankruptcy. Another possibility is that the firms and the union are risk sharing. If the severity of the 1980's recession was unanticipated and if the union is relatively more risk averse, risk sharing would imply a worsening of the firms' bargaining position relative to the union. A model where uncertainty and risk aversion are explicitly formulated could be used to test this second hypothesis.

The coefficients on the exogenous variables affecting the relative strike costs (and hence the bargaining powers) are seen to vary across models and they often have very high standard errors. In the efficient contracting model, the interest rate has a significant positive effect on the relative strike costs of the firm. The same is true of the capital utilization ratio. The effect of inventory build-up depends on the technology assumptions. Note that although a negative sign on the inventory coefficient was predicted, a positive relationship is also plausible in the case of unanticipated increases in inventory holdings. If they are unanticipated, changes in inventories can indicate financial hardship for the firms rather than a strong (low strike cost) bargaining position.

In the labour demand model the coefficients of the strike cost variables are highly variable with large standard errors. One problem with these variables is the large amount of multicollinearity especially among the determinants of the workers' strike costs. Some other variables were used but they did not contribute additional information. Also, attempts were made to estimate the discount factors of the firms and workers separately but none were successful.

Throughout this study, the efficient model performed better than the labour demand model in the sense of generating a larger likelihood value. Finally there was some indication especially in the exogenous output estimation that although the COOP model performed better overall, the labour demand model was a better predictor during the recession years of the 1980's.

Chapter 6

Conclusion

In this study, a version of the Rubinstein bargaining model is used to study union-firm negotiations. Specifically, the equilibrium of the game is used to generate wage and employment estimating equations. One of the characteristics of the resulting model is that the wage and employment contracts are affected by the relative strike costs of the negotiating parties even in the absence of strikes.

The data involves the B.C. wood products industry and the IWA, a powerful union believed to have been successful at capturing rents. The data includes input and output quantities and prices and equations representing input demands and output supply are estimated simultaneously with the negotiated wage and employment equations. In the literature on wage and employment determination in unionized sectors, two polar cases have been assumed: in one instance the firm can unilaterally choose employment and the resulting contract is on the labour demand curve, in the second case the level of employment is negotiated and the frontier of the bargaining set is the contract curve. Both scenarios are modelled and estimated in this paper. Also, each bargaining framework is estimated under two sets of technological assumptions. In one case, all inputs are chosen optimally as functions of the labour contract while the level of output is exogenous to the bargaining process. In the second case, output is endogenous and capital is treated as fixed during negotiations.

Since none of the previous empirical union contract studies had included a bargaining game, the empirical model estimated here is quite novel and it is reassuring that the estimated technology coefficients and union utility parameters are generally reasonable and comparable to previous estimates. For example, it is a standard result in this literature that the union cares about both wages and employment but with a larger weight on employment. The same thing is found in the study. The union indifference curves are convex with estimates of the elasticity of substitution ranging from .86 to 1.05. In all models, rent maximization is rejected as an appropriate representation of union behaviour.

The new results concern the bargaining powers of the firms and the union measured as functions of their relative strike costs. In all models, the term representing strike costs significantly affects the estimates. However, individual coefficients on strike cost variables are sensitive to both the bargaining framework and the technology assumptions. In all cases the hypothesis of equal bargaining powers (the Nash bargaining solution) is rejected as well as the monopoly model of unions (in which the union has complete bargaining power). Also, results suggest that the 1980's recession caused a rapid deterioration in the firms' relative bargaining power. According to my estimate, the efficient contracting model performs better than the labour demand model in which labour is chosen by the firm. Again, this is consistent with previous studies. However, the parameter estimates seem to be more sensitive to the technological assumptions than to the bargaining framework. This has serious implications for the interpretation of the results of wage-employment determination studies in which the technology is not modelled rigorously. Finally, although the cooperative model performs better overall, there is some indication (especially in the exogenous output estimation) that the labour demand model is better at predicting wages and employment during the recession years of the early 1980's.

Extensions to this study are possible in several different directions. Since this was a first attempt at the application of noncooperative bargaining models to empirical studies of wage and employment contracts, the game was kept very simple at the cost of restrictive assumptions especially concerning the information structure. In particular, the assumption of symmetric information could be relaxed. Also, uncertainty and behaviour towards risk could be explicitly formulated. This would allow for risk sharing and strikes as equilibrium outcomes.

Secondly, the application of this particular game has emphasized the need for better modelling and measuring of strike costs for both unions and firms. In particular, I believe that through the modelling of strike costs, it will be possible to discriminate empirically between different versions of the Rubinstein bargaining game and possibly other types of bargaining games as well.

Thirdly, this study suffers from problems which have been characteristic of the empirical wage-employment determination literature. In particular, data is available on wages and employment only, and other dimensions of the contracts such as fringe benefits are not taken into account. Also, this study does not include a general bargaining framework nesting the two polar cases of labour demand models and efficient contracting models.

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Appendix A
Data Sources and Construction

The appendix provides a detailed description of data sources and manipulation. For a broader discussion of the data set including comments on its advantages and drawbacks, the reader is referred to Chapter 5 of the text.

A.1 Price and Quantity Indices[38]

In this section, the B.C. wood products industry data namely the input and output quantities and prices are described. Unless otherwise specified, this data is collected through Statistics Canada's census of manufacturing. Industry costs and hence inputs are of three types: labour, materials and supplies, and fuels and electricity. The latter is used in conjunction with capital stock data to form a capital services input. This data is provided separately for the following 4 groups of firms: coastal sawmills, interior sawmills, shingle mills, and plywood and veneer mills. Most of the data is published in Statistics Canada catalogues 35-204 and 35-206 with the exception of the breakdown on output and materials and supplies for plywood and veneer mills and the breakdown on materials and supplies for shingle mills which are

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[38] I would like to thank F. Martinello for providing me with unpublished industry data.

unpublished. Also, the details on fuel and electricity costs are published in catalogue 57-208. With some exceptions, the methodology used in Martinello (1984) to construct price and quantity indices was also used here. The differences in the industry data between this study and Martinello (1984) are in the construction of the capital services input, the inclusion of non-production workers and the scaling of the data which was arbitrary in Martinello (1984). Also, the sample period has been extended to include the years 1980-1983.

A.1.1 Output

Data on the quantity and value of the different types of shipments is used to construct a chained Fisher ideal price index for each group of firms for 1963-83. The implicit quantity index is then derived by Fisher's weak factor reversal test. Finally, the price index was converted to 1971 constant dollars using the CPI. (Justification for the use of the Fisher direct price index and implicit quantity index can be found in Allen and Diewert (1981))

For shingle mills, the quantity and value of "further processed" shingles was not available in 1983 and the 1982 amounts were used. Similarly the quantity and value of shingles and shakes in coastal sawmills were not available for 1982 and 1983 and the 1981 amounts were assumed to remain constant. Also, for this same type of output in coastal sawmills, the 1980 figures were aggregated for Quebec and B.C. and the breakdown between these 2 provinces in 1981 was used to estimate separate provincial amounts for 1980.

A.1.2 Materials and Supplies

The procedure described above was used to generate price and quantity indices for the materials and supplies input. One problem was encountered, for 1981 and 1982, the quantity and value of shingle and shakes used for further processing in shingle mills were not available. The corresponding amounts for 1980 and 1983 were interpolated linearly to estimate the missing values.

A.1.3 Fuels and Electricity

Price and quantity indices were calculated using the following data breakdown: gasoline, fuel oils (kerosene, diesel, light and heavy fuel oils), liquified petroleum gases, natural gas, and electricity. Several problems were encountered. In 1982 and 1983, kerosene was included in the category other for which only value is available. The value for kerosene was assumed to constitute the same proportion of this category in 1982 and 1983 as it did on average in 1980 and 1981. To estimate the quantity of kerosene in 1982 and 1983, the price averaged over 1980 and 1981 was divided into the estimated 1982 and 1983 values respectively. (Averages over the two previous years were used instead of the last year's value because of the small numbers involved)

Although the total costs of fuel and electricity was available for coastal and interior sawmills separately for 1980 onwards, each component's quantity and value was given for the aggregated sawmills only. The aggregate values were divided into the two groups by using the relative contributions of these two groups in 1979 and by adjusting these proportions over time according to the changes in the corresponding proportions calculated with the total costs figures. The aggregate quantity was divided into the two groups of sawmills by using the estimated values described above and by assuming a common price for the two groups, this price being equal to the total (aggregate) value divided by the aggregate quantity. For example, the costs of electricity for interior sawmills in 1981 would be calculated as follows:

$$\frac{EC_{I}^{79}}{EC_{IC}^{79}} \times \left(\frac{TC_{I}^{81}}{TC_{IC}^{81}} \Big/ \frac{TC_{I}^{79}}{TC_{IC}^{79}} \right) \times EC_{IC}^{81} = EC_{I}^{81}$$

where EC = electricity costs

TC = total fuels and electricity costs

I = interior sawmills

IC = all sawmills i.e. interior plus coastal and where the superscript denotes the year. The quantity of electricity used by interior sawmills in 1981 would be calculated as follows:

$$EC_{I}^{81} \div \left(\frac{EC_{IC}^{81}}{EQ_{IC}^{81}} \right) = EQ_{I}^{81}$$

where EQ = quantity of electricity consumed

Finally, as noted by Martinello (1984) (see, pg.32), the cost of fuel for small establishments was included in the costs of materials and supplies, also, any power generated by the firms for their own use from wood waste or other sources was not included. Nothing could be done about these omissions.

A.1.4 Labour

The quantity of labour is measured by the number of man-hours paid which includes time paid but not worked such as vacations and statutory holidays. Also, these are hours worked by production workers only. The wage is calculated as total compensation paid to production workers divided by the number of man-hours paid to production workers. Total compensation includes all wages before deductions, overtime payments, bonuses, paid vacations and other payments for work not performed. The wage is then converted to constant 1971 dollars using the CPI.

An interesting issue concerns the choice of the unit of measure for the labour input. It can be argued that the firm will care about the hours of work inputed into its production process while the union is concerned with the number of workers since this reflects more closely the membership of the union. If the hours per worker are constant then it makes no difference which unit is chosen. If the number of workers is negotiated separately then the labour contract will have three dimensions, the wage, the hours per worker, and the number of workers. The bargaining would then be conducted with respect to these three variables. This would obviously complicate the analysis substantially. The hours per worker were calculated for each group of firms from 1963 to 1983. They are presented in Table IX. It is surprising how close these numbers are to the mean of 1,963 hours per worker per year. The only substantial deviations occur during recessions. These could be due to work sharing or to the elimination of overtime. In order to keep the analysis tractable, it is assumed that at the time of bargaining, the hours of work per worker is treated as a constant.

Another important issue concerns the treatment of non-production labour. For the wood products industry in B.C., this is composed mostly of administrative and office staff, the remainder being workers employed in sales and distribution. Since these workers are not part of the IWA,

Table IX

Hours per Worker per Year

in the B.C. Wood Products Industry

Year	Coastal Sawmills	Interior Sawmills	Shingle Sawmills	Plywood & Veneer Mills
1963	2054	1960	1891	2005
1964	2074	2026	1683	1991
1965	2047	2022	1959	1972
1966	2059	2006	1925	1894
1967	2067	2003	1944	1968
1968	2056	2040	1917	1963
1969	2050	2025	1921	1912
1970	2006	2003	1931	1893
1971	2022	2026	1952	1993
1972	1952	2017	1866	1951
1973	1992	1992	1888	1968
1974	1980	2074	1951	1903
1975	1940	2022	1926	1753
1976	2038	2035	1957	1751
1977	2046	1992	1988	1982
1978	2040	1992	2068	1954
1979	2038	2054	2063	1908
1980	2058	2056	1901	1977
1981	1845	1909	1918	1842
1982	1831	1836	1829	1599
1983	1943	1968	1879	1953

Overall Average = 1963

they should not be included in the employment and wage figures entering the union utility function. However, they are an additional input in the production process of the firm and the non-production labour costs should be included in the profit calculations. Non-production labour costs are a small proportion of total labour costs and more importantly, the number and the salaries of non-production labour are highly correlated with the number and the wages of production labour, respectively. I decided to account for non-production labour by increasing production labour costs by a factor of 1.15, the average inverse proportion of production workers' wages in total salaries and wages. Data on the relative magnitude of production labour in the total labour input is provided in Table IX.

A.1.5 Capital Services

Martinello (1984) adopted the following procedure in order to calculate the quantity and price of the capital input used by the mills. It is assumed that each mill uses its capital stock in conjunction with energy to form units of capital services which are then used as inputs in the production process. More specifically, it is assumed that the mills' production function is separable in the capital stock and the quantity of fuels and electricity consumed, i.e. the output of the group of mills i at time t, Q_{it} can be written as:

Table X

Share of Production Workers in Overall Labour in the B.C. Wood Products Industry

Year	Proportion of Production Workers in Total Employment in %				Proportion of Production Workers' Wages in Total Salaries and Wages in %			
	Coastal Sawmills	Interior Sawmills	Shingle Sawmills	Plywood &Veneer	Coastal Sawmills	Interior Sawmills	Shingle Sawmills	Plywood &Veneer
1963	91	92	93	90	88	88	91	87
1964	90	86	93	90	87	82	91	87
1965	90	88	93	90	87	85	92	87
1966	90	88	93	91	87	85	92	87
1967	91	89	93	92	88	85	91	89
1968	91	89	93	92	88	85	92	90
1969	90	90	93	92	87	87	91	89
1970	87	87	94	91	83	85	93	87
1971	87	87	94	91	84	84	93	89
1972	87	88	94	90	83	85	91	88
1973	87	89	93	91	84	85	90	88
1974	85	86	93	90	82	85	91	86
1975	82	87	93	90	78	85	91	85
1976	86	89	93	90	83	88	91	87
1977	86	89	92	90	84	87	91	88
1978	87	88	94	90	85	86	80	88
1979	87	87	93	91	84	85	91	88
1980	85	87	93	89	83	85	91	86
1981	85	86	92	88	81	82	91	84
1982	85	85	91	89	80	82	86	84
1983	86	86	93	90	82	84	86	87

overall average = 86.6%

$$Q_{it} = F_{it}(E_{it}, M_{it}, \tilde{K}(S_{it}, Y_{it}))$$

where F is the production function

E is the labour input

M is the quantity of materials and supplies

S is the capital stock (the constant 1971 dollar mid-year net capital stock measure calculated by Statistics Canada)

Y is the quantity of fuels and electricity

$\tilde{K}$ is the (common) aggregator function which has as its image K_{it}, the quantity of capital services used as input.

The aggregator function $\tilde{K}$ is assumed to take the form of a CES:

$$K_{it} = (\alpha Y_{it}^{-\beta} + (1-\alpha) S_{it}^{-\beta})^{-1/\beta}$$

Firms are assumed to minimize costs which, given the separability assumption, can be represented by a two-stage optimization problem. The first stage consists in solving the following:

$$(1) \quad \min_{Y_{it}, S_{it}} \; p_{it}^{Y} Y_{it} + p_{it}^{S} S_{it} \quad \text{subject to } K_{it} \geq \bar{K}$$

where $\bar{K}$ is a fixed level of capital services

p_{it}^{Y} is the price of fuels and electricity

p_{it}^{S} is the user cost of capital (to be described in detail later in this section)

From the first order conditions, the following relationship is derived:

$$\frac{p_{it}^{Y}}{p_{it}^{s}} = \frac{\alpha}{(1-\alpha)} \; \frac{S_{it}}{Y_{it}}^{\beta+1}$$

where the RHS is the marginal rate of technical substitution of the aggregator function $\tilde{K}$. This equation can be rewritten as:

$$(2) \qquad S_{it} = Y_{it}\left[\left(\frac{1-\alpha}{\alpha}\right)\left(\frac{p_{it}^{Y}}{p_{it}^{s}}\right)\right]^{\frac{1}{\beta+1}}$$

Data on capital stocks and energy consumption can be used to estimate the coefficients α and β. The quantity and price of energy were calculated for each year and each group of firms as described previously. The price of energy was converted to 1971 dollars using the CPI. Data on capital stocks by industry compiled by Statistics Canada are used to construct the quantity and value of the capital stock, S and p^{s}. This data is available for Canada in catalogue 13-211 while the provincial figures are unpublished. Unfortunately data on capital stocks is not available for the four groups of firms separately. The methodology used by Martinello (1984) consisted in using the energy costs and estimates of α and β to breakdown the aggregate capital stocks figures and obtain separate capital services estimates for each of the four groups of firms. At the time of Martinello's research, the only available data on capital stocks in B.C.'s wood product industry was an aggregate of all four groups of mills. Since then, separate data has become available on plywood and veneer mills. Following Martinello's procedure, I used this new data to estimate the system of equations given below:

$$(3)\quad \ln S_{4t} = \frac{1}{\beta+1} \ln\left(\frac{(1-\alpha)}{\alpha}\right) + \ln Y_{4t} + \frac{1}{\beta+1} \ln\left(\frac{p^{Y}_{4t}}{p^{s}_{4t}}\right) + u_{1t}$$

$$(4)\quad \ln (\sum_i S_{it}) = \frac{1}{\beta+1} \ln \frac{(1-\alpha)}{\alpha} + \ln \sum_i \left[Y_{it} x \left(\frac{p^{Y}_{it}}{p^{s}_{it}}\right)^{\frac{1}{\beta+1}} \right] + u_{2t}$$

where the subscript 4 denotes plywood and veneer mills;

$\sum_i$ denotes the sum over coastal and interior sawmills and shingle mills;

u_{jt} is the error term for equation j and year t;

t = 1963 to 1983.

However, the results of the estimation were unsatisfactory in the sense that the constant term

$$\frac{1}{\beta+1} \ln \left(\frac{1-\alpha}{\alpha}\right)$$

had a large standard error and the resulting estimates for α were extremely variable. Various estimates of the constant term and the implied α are reported below according to different assumptions concerning the degree of serial correlation in the error term u_{jt}.

Assumed serial correlation in U_{jt}	Estimated Constant Term	Asymptotic t ratio	Implied α	Value of the ln likelihood function
first order	258.65	0.17695	0	50.11805
second order	-2.5587	-0.12787	.9839	51.2876
third order	-5.5745	-2.0458	.9998	51.5514
fourth order	-226.42	-0.1285	1	53.9046

Not that if α is 0, energy plays no role in the calculation of the capital services input while the same is true of the capital stock if α is 1. In order to avoid the arbitrary choice of a reasonable α, I used a different, simpler approach. I assume that the relative input shares for energy and the capital stock are constant across the three groups of firms coastal sawmills, interior sawmills and shingle mills. This (constant) ratio denoted by G is then calculated as:

$$G_t = \sum_i S_{it} p^S_{it} \; / \; \sum_i Y_{it} p^Y_{it}$$

where the notation is the same as that used in equations (3) and (4) above. Note that R_t is allowed to differ across time periods. The aggregate capital stock measure for sawmills and shingle mills is then broken down into the capital stock measures for each of the 3 groups of firms according to:

$$S_{it} = G_{it} \times Y_{it} \times p^{Y}_{it} / p^{S}_{it}$$

where $G_{it} = G_t$ for i = coastal and interior sawmills and shingle mills.

A ratio G_{4t} can also be calculated for plywood and veneer mills for which a separate capital stock measure S_{4t} is available.

This procedure is consistent with the assumption of an aggregator function $\tilde{K}$ (S_{it}, Y_{it}) which takes the form of a Cobb-Douglas. Furthermore, if it is assumed that this function exhibits constant returns to scale then the coefficients on S_{it} and Y_{it} can be recovered from G_{it}. Specifically, I assume:

$$(5) \qquad K_{it} = Y_{it}^{\lambda_{it}} S_{it}^{(1-\lambda_{it})}$$

and cost minimizing behaviour. This implies:

$$\lambda_{it} = \frac{1}{1+G_{it}} \quad \text{for } i=1,2,3,4; \text{ and } t=1963,\ldots,1983.$$

The dual unit cost function is:

$$(6) \quad P^{k}_{it} = (p^{Y}_{it})^{\lambda_{it}} (p^{S}_{it})^{(1-\lambda_{it})} (\lambda_{it})^{-\lambda_{it}} (1-\lambda_{it})^{-(1-\lambda_{it})}$$

Quantity and price indices for capital services were calculated from equations (5) and (6) for each of the four groups of mills and each year. Note that by allowing δ_{it} to vary across time, I am not calculating predicted capital stocks (and hence K_{it}) net of some unexplained random error as was done in Martinello (1984). I think this is preferable because of the poor explanatory powers of regressions such as (3) and (4).

A second serious difference between the calculation of capital services in Martinello (1984) and here is found in the measure of the user cost of capital p^S_{it}. In Martinello (1984), this is calculated as:

$$\tilde{p}^S_{it} = (r_t + dep_t) \times p^I_t$$

where r is the interest rate measured by the McLeod, Young, Weir 10 industrial bond yield in Canada. This is available in the Bank of Canada Review.

dep is the depreciation rate which is calculated as the ratio of the capital consumption allowance to the mid-year gross capital stock. Both these series are unpublished. The capital consumption allowance was not available separately for plywood and veneer mills due to confidentiality and hence was calculated for the total B.C. woods product industry. It is assumed to be equal across the four groups of firms.

p^I is the price in 1971$ for capital expenditures on plant and equipment for the wood products industry in Canada published in 13-211.

The difference between $\tilde{p}^s_{it}$ and the user cost in this study p^s_{it} are two-fold. Firstly, expected capital gains are measured by the proportional change in the CPI and subtracted from the sum of interest and depreciation costs. Secondly, the price index of investment goods which I used is the index used by Statistic's Canada to inflate the constant value capital stock to current value capital stock. In theory, this index will be different for each of the groups of firms due to a different mix of investment. However, due to the aggregation of interior and coastal sawmills and shingle mills in capital stock measures, I have to assume this price index is equal for those three groups of firms. The user cost of capital which I calculate is then:

$$p^s_{it} = \frac{\text{current value } S_{it}}{\text{constant value } S_{it}} \times \left(r + dep - \frac{CPI_{t+1} - CPI_t}{CPI_t}\right)$$

for i = interior and coastal sawmills and shingle mills;

or i = plywood and veneer mills,

and t = 1963,...,1983.

A.1.6 Input Cost Shares and Profits

In this section, I examine the value of profits and the cost shares of inputs. This is interesting especially because of the capital services input which was constructed.

First, I would like to point out a difference between the final input-output data used in this study and that used in Martinello (1984). Martinello (1984) adopted an ad hoc scaling rule for the input and output price and quantity indices which ensured that profits were positive for most observations and which yielded input cost shares of 0.15 for capital, 0.25 for labour, and 0.59 for materials.

The shares were found comparable to an Industry, Trade and Commerce report which gives a materials share of one half to two thirds. Also, calculations from principal statistics of the industry shows that the share of materials divided by the share of labour averages 2.44.

In this study, I recover the natural units of the indices by using their bases. For example, the capital services input quantity and price indices will also have units equal to the (common) base which was used for the fuel and electricity and capital stock quantity and price indices, respectively. It is simple to recover the dollar value represented by the product of the capital services price and quantity indices by using this base.

In Table XI, the value of profits net of the capital services input are presented along with average input cost shares.

It is seen from Table XI that with no arbitrary scaling of the data, the resulting profits are positive for all but 6 out of the 84 observations. Profits were negative for all 4 groups of firms in 1982, for coastal sawmills in 1981 and for interior sawmills in 1970. One important remark is in order. The price and quantity indices for fuel and electricity, materials and supplies, and shipments were constructed from data on the various components of these costs and revenues. This detailed data does not yield the same totals as the total costs and revenues reported in the principal statistics for the industry. The reason for this is the omission of various data in the detailed data, for example, small establishments are omitted in the breakdown of fuel and electricity costs. The price and quantity indices in this study were generated to reflect variations in total costs and revenues reported in the principal statistics. It was assumed that the omitted data had the same breakdown proportionally and the same prices as the detailed data which was available. Therefore, the product of the price and quantity indices for the inputs/output will equal the total real costs/revenue for that input/output as reported in principal statistics divided by the base.

With respect to input cost shares, we find that the share of capital services used in this study which is on

Table XI

a. Profits Net of Capital Services and Input Cost Shares in the B.C. Wood Products Industry

Year	Coastal Sawmills	Interior Sawmills	Shingle Mills	Plywood and Veneer Mills
1963	5.0814	5.3954	0.4839	2.1561
1964	4.6299	5.9050	0.1917	2.0707
1965	4.4464	5.5079	0.0798	2.2390
1966	3.9038	5.1897	0.1598	1.8437
1967	5.0662	4.2921	0.2146	2.7318
1968	9.9539	9.7280	0.7732	2.7873
1969	7.3163	6.8809	0.3570	3.1189
1970	2.7140	-0.7919	0.0146	0.5368
1971	4.3482	4.3150	0.4380	2.2939
1972	6.8280	14.9517	0.9887	4.3251
1973	17.8310	22.2486	0.9518	4.9872
1974	7.7459	6.3443	0.2522	2.3548
1975	2.7964	3.7848	0.6186	2.4648
1976	5.9445	12.4591	0.9955	4.1137
1977	10.9838	20.2602	1.0770	3.0932
1978	13.7170	27.5161	1.1051	6.2824
1979	14.1214	24.6231	0.4968	3.5657
1980	4.4582	9.9658	0.6999	1.8470
1981	-0.6781	0.9772	0.2111	2.0271
1982	-2.6144	-7.4137	-0.1204	-1.2103
1983	2.8261	6.6433	0.0292	0.7207
Average	6.2581	8.9896	0.4770	2.5881

Overall Average = 4.5782

b. Average Input Shares of Total Costs Over the Sample Period

	Labour	Materials & Supplies	Capital Services
Coastal Sawmills	0.25611	0.70713	0.03676
Interior Sawmills	0.29382	0.61477	0.09140
Shingle Sawmills	0.36352	0.59451	0.04196
Plywood and Veneer Mills	0.32653	0.61847	0.05500
Average	0.31000	0.63372	0.05628

average 6% is much lower than that used by Martinello [15]. This is made up by increases in both the labour share (31% on average) and the materials and supplies share (63%). It is interesting to compare coastal and interior sawmills in this respect. We find that the capital services share is larger for interior sawmills while the opposite is true of the materials and suppliers share. The respective price and quantity indices show that while the price of capital services is comparable for the two groups of sawmills, interior sawmills are more capital intensive. Also, there is a noticeable difference in the price of materials and supplies in the two areas with the interior sawmills benefiting from the lower price. This is consistent with the hypothesis that timber prices are higher on the coast due to the large amount of harvesting and hence low yield of the forest lands.

In conclusion, I would like to mention two important flaws in the industry data as compiled for this study.

i) There is no accounting of corporate taxes and their impact on profits as a whole and on the user cost of capital.

ii) The assumption of exogeneity of the input prices can be very restrictive especially in the case of materials and supplies since some of the mills are owned by companies which also engage in logging.

A.2 The Alternative Wage

The alternative wage W_A is calculated as follows:

$$W_A = (\bar{p}_E \times HE_{s+m} + (1-\bar{p}_E) \times \bar{p}_{UI} \times UI) / CPI$$

where $\bar{p}_E$ is the probability of finding a job in either the service or the manufacturing sectors in B.C. This is measured by the ratio of total employment in these two sectors divided by the total provincial labour force.

HE_{s+m} is the employment weighted average hourly earnings in services and manufacturing in B.C. Similarly to the wage measure in the wood products industry, this alternative income includes pay for time not worked such as vacations and holidays.

$\bar{p}_{UI}$ is the probability of collecting unemployment insurance benefits given that the worker is unemployed. This is calculated as the number of weeks of unemployment insurance in B.C. divided by the total number of weeks of unemployment in B.C. The total number of weeks of unemployment in B.C. is calculated as (B.C. labour force - B.C. employment) * 52.

UI is the average hourly payment of unemployment insurance in B.C. adjusted for tax treatment.

(For the calculation of the tax factor, see Riddell and Smith [1982]. Note that the resulting UI payment is pre-tax. Also, this adjustment factor was available only up to 1979 and was assumed constant for 1979 to 1983.)

CPI is the Consumer Price Index which converts WA to the base of a CPI bundle of goods in 1971.

Both HE_{s+m} and UI were reported as weekly figures. They were converted to hourly numbers with the use of the average weekly hours of work in B.C. manufacturing. The manufacturing figure was used because of very poor coverage in other industries.

Surprisingly, the alternative wage turned out to be greater than the real wage in interior sawmills in 1964 and 1965. This is inconsistent with the interpretation of the alternative wage as the minimum acceptable wage to the union. Arguably, the occurrences of this inconsistency are few and the magnitudes are very small. (The differences between the actual wage in interior sawmills and the alternative wage are 0.01$ in 1964 and 0.03$ in 1965). However, this finding prompted me to look for data on the distribution of wages across the province in the '60's and '70's.

Three sources of data were found:

i) The Annual Salary and Wage Rate Survey conducted by the B.C. Bureau of Economics and Statistics over the period 1957-1966. Wages were given for selected occupations along with the number of employees surveyed. Office and professional occupations were not considered and that left 7 blue collar occupations. The wages were for full-time employees only and did not include overtime or special bonuses.

ii) The B.C. Survey of Salary and Wage Rates conducted by Labour Canada over the period 1971-1973. The data is similar to that in (i) except for a more limited number of occupations and fewer geographical centres.

iii) Statistics Canada Average Weekly Earnings for all employees and all industries are available for 4 different regions of B.C. from 1967 to 1984.

Descriptive Statistics for these three sets of data are provided in Table XII. It can be seen that during the '60's there was a gap between wages in the interior and the coast with the interior being consistently below the provincial average. This gap was almost gone by the early '70's. This is consistent with the behaviour of the real wage in the interior sawmills compared to the coastal saw mills except that a gap remains through the whole sample in that case. The differences in the wages across areas could be due to

Table XII

Wage Distribution Across B.C.

a. Government of B.C. Annual Wage Rate Survey. Employment weighted averages over 7 blue collar occupations.[1] Sample period 1957-1966.

1957 - 1966	Metro. Vancouver	Metro. Victoria	Southern Interior[2]	Northern Centres[3]	Provincial Average	Int. Weight Col.3/Col.5	Coastal Weight Cols.1+2/Col.5
Average	2.21	2.24	1.89	2.12	2.11	.8953	1.0521
Minimum	1.84	1.89	1.67	1.86	1.85	.8685	1.0049
Maximum	2.62	2.63	2.25	2.53	2.51	.9177	1.0720

Notes:

[1]Occupations: Labourer, Labour foreman, Carpenter, Automobile mechanic, Equipment operator (Heavy), Light truck driver, Medium truck driver.

[2]Southern Interior Centres: Kamloops, Kelowna, Penticton, and Vernon.

[3]Northern Centres: Prince Rupert, Prince George, Terrace, Quesnel and Smithers.

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b. Labour Canada, B.C. Survey of Wage Rates. Employment weighted averages over 3 blue collar occupations.[1] Sample period 1971-73.

1971 - 1973	Vancouver	Victoria	Kamloops	Prince George	Provincial Average	Int. Weight Col.3/Col.5	Coastal Weight Cols.1+2/Col.5
Average	4.16	3.99	3.93	4.01	4.02	.9796	1.0128
Minimum	3.73	3.59	3.56	3.68	3.64	.9410	1.0049
Maximum	4.63	4.35	4.13	4.38	4.37	1.0198	1.0281

Notes:

[1]Occupations: Light and heavy truck driver, Industrial truck driver, Labourer.

Table XII (Continued)

c. Statistics Canada, Average Weekly Earning. All employees. Industrial Composite. Sample period 1967-1984. Cat. 72-002.

	Vancouver	Victoria	Kamloops	Prince George	Provincial Average	Int. Weight Col.3/Col.5	Coastal Weight Cols.1+2/Col.5
1967-70							
Average	121.27	107.60	107.05	127.15	115.77	.9237	.9888
Minimum	109.69	97.49	93.40	115.36	103.99	.8982	.9807
Maximum	113.91	17.31	18.44	139.26	127.23	.9424	.9962
1971-73							
Average	161.48	137.99	149.96	165.22	165.66	.9755	.9751
Minimum	148.86	128.39	133.38	143.10	138.43	.9635	.9549
Maximum	174.47	148.75	162.11	181.82	166.79	.9912	1.0014
1974-84							
Average	302.38	334.16	322.46	282.39	310.35	.9613	.9699
Minimum	194.41	167.38	180.67	205.66	187.03	.9423	.9569
Maximum	420.31	461.97	432.58	382.13	412.59	1.0187	.9856

imperfect labour mobility or differences in the cost of living for example. We also find in Table XII that this gap is larger in the data on selected blue collar occupations than in the total employees earnings data. That there is a difference is not surprising given the differences in the mix of occupations that can exist between the various centres.

Although I did not want to place to much importance on any individual observation, I did want to take into account this trend of equalization of the wages across B.C. I constructed weights for the interior and the coastal areas by linear interpolation of the two average weights in the blue collar occupations. Also, once these weights reached 1, they were fixed there for the rest of the sample. These weights are presented in Table XIII. The interior weight was multiplied by the alternative wage to yield the alternative wage faced by interior sawmill workers and similarly for the coastal weight and coastal sawmill workers. The resulting alternative wages for the 4 groups of firms are also given in Table A-6.

A.3 Strike Costs

A discussion of the choice of variables affecting strike costs can be found in the text. In this section, data sources and calculations are given. The following

Table XIII

Interior and Coastal Weights, and Alternative Wages

Year	Weights		Alternative Wages		
	Interior	Coastal	Coastal Sawmills	Interior Sawmills	Shingle, Plywood & Veneer Mills
1963	0.9102	1.0449	2.81883	2.45545	2.69771
1964	0.9179	1.0414	2.86624	2.52633	2.75229
1965	0.9256	1.0378	2.97213	2.65080	2.86387
1966	0.9334	1.0343	3.01436	2.72030	2.91440
1967	0.9411	1.0307	2.92198	2.66797	2.83494
1968	0.9488	1.0272	2.97409	2.74710	2.89523
1969	0.9566	1.0236	3.09719	2.89446	3.02578
1970	0.9643	1.0201	3.17544	3.00174	3.11287
1971	0.9720	1.0165	3.37840	3.23050	3.32356
1972	0.9798	1.0130	3.48673	3.37246	3.44199
1973	0.9875	1.0094	3.55525	3.47811	3.52214
1974	0.9952	1.0059	3.67669	3.63758	3.65512
1975	1.0000	1.0023	3.87980	3.87090	3.87090
1976	1.0000	1.0000	3.89204	3.89204	3.89204
1977	1.0000	1.0000	3.98790	3.98790	3.98790
1978	1.0000	1.0000	3.85113	3.85113	3.85113
1979	1.0000	1.0000	3.78325	3.78325	3.78325
1980	1.0000	1.0000	3.87554	3.87554	3.87554
1981	1.0000	1.0000	3.90708	3.90708	3.90708
1982	1.0000	1.0000	3.92880	3.92880	3.92880
1983	1.0000	1.0000	3.79753	3.79753	3.79753

variables were used to measure variations in relative strike costs over time:

INT = The nominal rate of interest in percent as measured by the McLeod Young, Weir industrial bond yield average weighted long-term. It is available in the Bank of Canada Review.

INV = The change in the value of inventories averaged over the past 5 years This is calculated from the Principle Statistics of the wood products industry in BC (Statistics Canada cat. 35-204 and 35-206) The change in inventories is equal to value added plus costs of fuel and electricity plus costs of materials and supplies minus the value of shipments INV is expressed in terms of '0,000's of current dollars

CU = The Bank of Canada capacity utilization rate available from the Bank of Canada review. The rate was multiplied by 10 for estimation purposes

UN = The unemployment rate in BC. (Statistics Canada catalogue 71-201).

UIC = A measure of the generosity of the unemployment insurance program. It is equal to the proportion of the labour force covered by unemployment insurance in Canada times the ratio of unemployment insurance benefits to the average wage in BC times a factor which takes into account the tax treatment of unemployment benefits. The tax factor is the same as the one used in the alternative wage measure. Unemployment insurance data is given in Statistics Canada catalogue 73-001. Unfortunately, the data on coverage was available only for Canada The average wage is measured by the average weekly wage for BC's industrial composite, larger firm data, available from Statistics Canada catalogue 72-002.

DEM = The proportion of women of all ages and men under 25 in the total labour force in BC. This data is available from Statistics Canada's Labour Force Survey with the exception of the number of males under 25 in BC's labour force from 1966 to 1974 which is unpublished. Also, the number of males under 25 was not available from 1963 - 1965 and it was assumed that their proportion in BC's total labour force was constant from 1963 to 1966. Finally the data for males under 25 was not adjusted from 1966 to 1974 for the major changes which occurred in the Labour Force Survey in 1974. This caused a noticeable break in the series. To correct for this the following procedure was adopted:

$$m_t^{BC} = \left(\frac{m_{t+1}^{BC}}{LF_{t+1}^{BC}}\right) \times LF_t^{BC} \times \left(\frac{m_t^{C}}{LF_t^{C}}\right) \Big/ \left(\frac{m_{t+1}^{C}}{LF_{t+1}^{C}}\right)$$

where m_t^k = males under 25 years of age in the labour force in area K in year t

LF_t^k = total labour force in area k in year t

BC = British Columbia

C = Canada

t = 1963 to 1974.