Pasi Holm* - Seppo Honkapohja** - Erkki Koskela***
Bank of Finland Research Department
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A MONOPOLY UNION MODEL OF WAGE DETERMINATION WITH TAXES AND ENDOGENOUS CAPITAL STOCK: AN EMPIRICAL APPLICATION TO THE FINNISH MANUFACTURING INDUSTRY****

* University of Helsinki
** Academy of Finland
*** Bank of Finland
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ABSTRACT

The paper formulates a model of wage determination in accordance with the notion of a monopoly union determining wages after which the firm decides on employment. The novelty is to incorporate investment and capital decisions by firms. In the theoretical part the subgame-perfect Nash equilibrium and its comparative statics for wages, capital stock and employment are characterized in various cases.

In the empirical part the model is estimated by using the annual data from the Finnish manufacturing industry over the period 1960 - 1987. The dynamic system of equations describing the determination of capital stock, wages and hours of work performs reasonably well; there are no obvious signs of misspecifications, coefficient estimates and other properties of the models are correct from the point of view of our theoretical reasoning. Finally, and importantly, diagnostics and various non-nested test procedures indicate that the conditional hours of work specification - where hours of work are determined recursively after the wage-capital stock game - outperforms alternative specifications implied by the conventional theory of the demand for factors of production.

Keywords: monopoly union, Nash equilibrium, wage, capital stock and employment determination.

CONTENTS

1 INTRODUCTION

There has been a rapidly growing literature on labour unions in the past years (see e.g. Oswald (1985), Farber (1986) and Holmlund et al (1989) part I, for recent surveys). Most of the economic research on the behaviour of unions has focused on the determination of wages and employment. In this context, three alternative models have been used. According to the first model, the monopoly union model which comes from Dunlop (1944), wages are determined by the process in which the trade union maximizes its objective function given the labour demand curve. The second is the efficient bargain model, where the employer and the trade union negotiate over both wages and employment. This approach is usually associated with the work of Leontief (1946) and has been elaborated e.g. in McDonald and Solow (1981). Finally, there is the so-called right-to-manage model due to Nickell and Andrews (1983) according to which the employer and the trade union negotiate over wages, but it is the employer who decides on the level of employment. Contrary to the monopoly union and efficient bargain models the right-to-manage model has not been subjected to direct empirical testing.

Tests designed to discriminate between the efficient bargain and monopoly union models have given mixed results (see Brown and Ashenfelter (1986) on the one hand and MaCurdy and Pencavel (1986) on the other). In addition it has been argued that the efficient bargain model does not lie in conformity with how the labour market functions; the employers seem to have retained the right to set employment unilaterally. This is the assumption we stick to in what follows.

The role of taxes has been studied in some models of wage and employment determination (see e.g. Hersoug et al (1986), Padoa Schioppa (1990), Pencavel and Holmlund (1988) and Tyrväinen (1988)). A notable feature in these and the other studies mentioned earlier is the lack of analysis of the effect of the trade union on the firms' choice of other factors of production, in particular, on the choice of capital stock. This omission may be serious if the presence of a trade union affects the firm's choice of capital stock and if investment behaviour depends on how wages are determined.

Incorporating the capital stock determination into the model provides a new strategic variable in the game between the employer and the trade union. In fact, some such theoretical analyses have recently been presented in the literature. Grout (1984) has analyzed the effects of the lack of binding contracts on input use and profits of firms, while van der Ploeg (1987) explored the implications of long-term wage contracts and investment in capital on non-cooperative wage bargaining between the employer and the trade union within an infinite horizon model. Hoel (1990) has compared the local versus central wage bargaining with endogenous investments. Finally, Anderson and Devereux (1988) have modified a variant of the monopoly trade union model by incorporating into it the extra dimension of the firm's choice of the capital stock. They have showed how this set-up can be interpreted as a simple non-cooperative game between the firm and the trade union and analyzed the Nash equilibrium, the trade union leadership and the employer leadership cases.

The purpose of this paper is to develop an extension of the framework used by Anderson and Devereux (1988) in order to analyze the interaction between the employer and the trade union in determining employment, wages and the capital stock. Since investment decisions often bring about into the analysis difficult - and from empirical viewpoint intractable - elements of dynamic games, it is best at this stage to use a simplest possible approach, which seems to be amenable to empirical analysis. We incorporate various taxes into the framework, develop the comparative statics and estimate the model by using the annual data from the Finnish manufacturing industry over the period 1960 - 1987. To our knowledge this is the first application of the trade union model with endogenous capital stock, which has been subjected to an empirical analysis.

To anticipate results, our specification of employment, wage and capital stock determination works reasonably well; there are no obvious signs of misspecification, coefficient estimates are generally of right sign in terms of the predictions of the game theoretic model. Finally, the employment equation - where employment is determined recursively after the wage-capital stock game - clearly outperforms the employment equations implied by the conventional theory of the demand factors of production.

The paper is organized as follows. In section 2 the model is presented and the equilibrium is defined while comparative static predictions are developed in section 3. Section 4 is devoted to empirical results. Finally, there is a brief concluding section. Some of the derivations are delegated into the appendix.

2 THE MODEL AND THE NASH EQUILIBRIUM

In this section we formulate a model of wage determination in accordance with the notion of monopoly union determining wages, after which the firm decides on employment. This is one of the standard frameworks in the recent literature on trade unions and wage formation. The novelty here is to incorporate into the model investment and capital decisions by firms. They obviously provide a new stage strategic variable in the game between the firm and the union. As we noticed earlier, a few such analyses have been presented before, see e.g. Grout (1984), van der Ploeg (1987), Anderson and Devereux (1988), and Hoel (1990). Since investment and capital often bring about into the analysis difficult elements of dynamic games which are hard to deal with in empirical work, we will develop an extension of the framework of Anderson and Devereux (1988). Their model seems to be amenable to econometric estimation.

The basic elements of the model are as follows. The game is played in two stages. First, the union and the firm decide on wages and the capital stock, respectively. In the second stage, the firm determines the level of employment, given wages and capital stock. The equilibrium concept is the subgame-perfect Nash equilibrium.[1)]

Moving to the model, the profits of the firm are given by

$$\Pi = P[zf(K,L)]f(K,L) - rK - (1+s)wL, \tag{1}$$

where $Q = P^{-1}(p)z^{-1} \equiv D(p)Z$ is a downward-sloping demand curve of the separable form introduced by Nickell (1978, p. 21). $Z = z^{-1}$ is a parameter describing the position of the demand curve faced by the firm. For brevity it is convenient to formulate the theoretical analysis in terms of the variable z.[2)] Perfect competition is obviously the special case with $z = 1$ and $P(Q) = p$. $f(K,L)$ is a standard two-factor production function depending on the capital stock K and labor L. $r = (1+u)\bar{r}$ is the cost of capital after corporate taxes paid by the firm, with $\bar{r}$ the corresponding before-tax cost and u the tax rate. w is the wage rate, and s is the rate of payroll taxes.

The objectives of the union is taken to be the usual one, according to which its utility is an expected utility of the after-tax wage and unemployment benefits, the probability weights being given by employment and unemployment, respectively:

$$W = U[(1-t)w]L + U(b)(\bar{L}-L). \tag{2}$$

In (2) t is the income tax rate, assumed constant for simplicity, b denotes the benefit from unemployment insurance, while $\bar{L}$ is the total labor force or union membership which is assumed to be exogenous. For simplicity, we have written the union's utility function in terms of monetary variables. This amounts to the simplifying assumption that the product prices of the sector under study carry only a very small weight in the deflator for the real wage and UI benefit variables that the union is concerned with.

We solve the model in the standard way of backward induction starting with the last period. So the firm optimizes employment given (w,K). The first-order condition is

$$MR(p)f_L(K,L) - (1+s)w = 0 \text{ for } L < \bar{L},$$
$$\geq 0 \text{ for } L = \bar{L}$$

Here the term $MR(p) \equiv P'zf(K,L) + P$ is the marginal revenue from producing an extra unit of output. Clearly, MR is only a function of p under the assumed separability of the demand function, see Nickell (1978, p. 21). Note that in this case $MR(p) = p[1+1/\varepsilon(p)]$, where $\varepsilon(p) = (dQ/Q)/(dp/p)$ denotes the elasticity of demand. If the elasticity is constant with $\varepsilon < -1$, then the marginal revenue is increasing in p, which we assume is more generally the case. This gives rise to a conditional labour demand function

$$L = g[(1+s)w,z,K]. \tag{3}$$

The partial derivatives of g are now given by:

$$g_1 = (MR'P'zf_L^2 + MRf_{LL})^{-1} < 0,$$
$$g_2 = -[MR'P'f(K,L)f_L]/(MR'P'zf_L^2 + MRf_{LL}) < 0,$$
$$g_3 = -[(MR'P'zf_K + MRf_{LK})f_L]/(MR'P'zf_L^2 + MRf_{LL}).$$

The signs follow from the assumptions on the production function and $MR' > 0$, $P' < 0$. Note that the shift variable $z = Z^{-1}$, where Z is the usual scale variable of the separable demand curve. This explains the puzzling-looking sign for g_2: an increase in z shifts the demand curve to the left. The sign of g_3 is not theoretically determinate, due to conflicting effects in the numerator. In what follows we assume $g_3 > 0$ which holds, for example, in the case of a Cobb-Douglas production function and constant-elasticity demand curve (see appendix).

For the perfectly competitive model we have $MR' = P' = 0$, implying $g_1 = (Pf_{LL})^{-1}$, $g_2 = 0$, $g_3 = -f_{LK}/f_{LL}$. The conditional demand for labor depends then on the real labor cost $(1+s)w/p$, as is well-known. In fact, assuming constant returns to scale we have $f_L(K,L) = f_L(1,L/K)$, so that inverting the marginal condition gives a particular form for the conditional labor demand function:

$$L = \hat{g}[(1+s)w/p,\ K] = h[(1+s)/p]K, \qquad (3')$$

where $h(.) = [f_L(1,L/K)]^{-1}$.

We now move to the first stage of the game in which the firm and the union decide on the capital stock K and the wage w, respectively, taking the other player's decision variable as given. Using (3) as a constraint in these optimizations provides for the requirement of the subgame perfection of the equilibrium. The firm's decision problem is to maximize with respect to K the profits

$$P\{zf[g((1+s)w,z,K),K]\}f[g((1+s)w,z,K),K] - rK - (1+s)wg[(1+s)w,z,K],$$

taking w as given. This gives, using (3) as the envelope condition,

$$MR(p)f_K(K,L) - r = 0. \qquad (4)$$

In (4) we know that $p = P[zf(L,K)]$, with $L = g((1+s)w,z,K)$, so we may write it in general form as

$$H(w,\ K,\ z,\ r,\ s,\ t,\ b) = 0. \qquad (5)$$

In (5) we have included as arguments all the exogenous variables eventhough t and b are not present at all in (4). In the case of perfect competition in the product market we use (3') as a constraint in the optimization and get the solution in general form as

$$\hat{H}(w,\ K,\ p,\ r,\ s,\ t,\ b) = 0. \qquad (5')$$

In the Nash equilibrium the union solves the problem

$$\text{Max } U[(1-t)w]g[(1+s)w,z,K] + U(b)(\bar{L} - g[(1+s)w,z,K]),$$

taking K as exogenously given. The first-order condition is

$$\frac{(1-t)U'(.)}{(1+s)[U(.) - \bar{U}]} + g_1(.)/g(.) = 0, \tag{6}$$

for the firm with imperfect competition in the product market, and

$$\frac{p(1-t)U'(.)}{(1+s)[U(.) - \bar{U}]} + \hat{g}_1(.)/\hat{g}(.) = 0, \tag{6'}$$

for the firm facing perfect competition in the product market. Note that in (6) and (6') we have used the notation $\bar{U} = U(b)$. Taking into account the nature of the functions U(.) and g(.) we write these conditions in the general form as equations

$$G(w, K, z, s, t, b, r) = 0, \tag{7}$$

or

$$\hat{G}(w, K, p, s, t, b, r) = 0 \tag{7'}$$

in the two cases under consideration. It should be noted that again we have included as arguments in (7) and (7') all the relevant variables. Clearly, the cost of capital r is not present in (6). More importantly, it may also be proved that in some special cases, e.g. constant elasticity of demand and Cobb-Douglas production function, the expression $g_1(.)/g(.)$ in (6) and the competitive model under constant returns to scale the expression $\hat{g}_1(.)/\hat{g}(.)$ in (6') is in fact independent of K (see appendix).

The Nash equilibrium is then the solution to the two equations (5) and (7), or (5') and (7'), depending on the competitive situation in the product market. Once the equilibrium values of w and K are solved, the resulting employment level is then given by (3) or (3'), respectively.

3 COMPARATIVE STATICS OF THE NASH EQUILIBRIUM

The remaining step in the theoretical part of the analysis is the derivation of the comparative-static properties of the equilibrium. Since the reaction functions of the firm and the union are given in implicit form by (5) and (7) [or (5') and (7'), respectively] we start by determining the partial derivatives of H(.) and G(.) with respect to the strategy variables K and w. Differentiating (4) with respect to K and w gives

$$H_K = MR'P'z(f_K + f_L g_3)f_K + MR(f_{KK} + f_{KL} g_3),$$

$$H_w = MR'P'zf_L f_K(1+s)g_1 + MRf_{KL}(1+s)g_1.$$

In the imperfectly competitive case the signs of H_K and H_w are in general not determinate. $H_K < 0$ nevertheless follows as the 2nd order condition for maximum. For the perfectly competitive case the corresponding expressions are both negative. In what follows we assume that also in the imperfectly competitive model $H_w < 0$. (The modifications to the analysis for $H_w > 0$ would be straightforward.)

In differentiating (6) we note $G_w < 0$ as a result of the second order condition for the union's optimum. Regarding G_K we recall that $G_K = 0$ always in the competitive case and at least in some imperfectly competitive situations (see appendix). For simplicity, $G_K = 0$ is thus assumed in the theoretical analysis. However, we note that in general the sign of G_K is not determinate. In fact, G_K is proportional to the derivative of wage elasticity of employment with respect to capital, and its magnitude depends in a complicated way on both the production function and the demand curve for output of the firm. The (empirically relevant) case $G_K > 0$ would only imply obvious minor modifications to the comparative-static results.

Next, we determine the dependence of H(.) and G(.) [respectively H(.) and $\hat{G}$(.)] on the exogenous variables s, t, b, r, z and p. Tedious calculations give

$$H_s < 0,\ H_r < 0,\ H_t = 0,\ H_b = 0,\ H_z < ?0,$$

where ? is the last inequality means that the sign is in general ambiguous but assumed to be negative in what follows. The same restrictions are obtained for $\hat{H}(.)$ in the competitive case, with the result that $\hat{H}_p > 0$ in place of the dependence on the shift parameter z. Again it should be recalled that z is the inverse of the usual shift variable of the demand function which explains the different signs of H_z and $\hat{H}_p$.

For the reaction function of the trade union it is straightforward to obtain the following dependence on the exogenous variables:

$G_s < 0,\ G_b > 0,\ G_r = 0.$

The signs G_z and G_t are theoretically indeterminate. In the competitive case the same dependences hold, with $\hat{G}_p$ replacing G_z, and the sign of $\hat{G}_p$ is theoretically unclear. The sign of G_t depends essentially on the degree of relative risk-aversion of the union. It is positive under the reasonable assumption that relative risk-aversion is constant and greater than one (see appendix for further details).[3)]

After these considerations the effects of exogenous variables s, t, p, z (resp. p), and r on wages, capital and employment may be conveniently summarized geometrically. In figure 1 we have drawn in the (K,w)-space the reaction functions of the firm and the trade union. The former is downward-sloping and the latter is horizontal (assuming $G_K = 0$). Their intersection gives the Nash equilibrium. The dashed curves in the diagram represent shifting of the reaction functions due to a change in some exogenous variables. Various possible equilibria after a shift have been marked in the diagram by letters A - H. In table 1 below the diagram we indicate first the various possibilities, given some sign restrictions. In the most right-hand panel of table 1 we show the qualitative results of a shift in the exogenous variable on wages, capital and employment.

DIAGRAM 1. Comparative-Statics of Nash Equilibrium

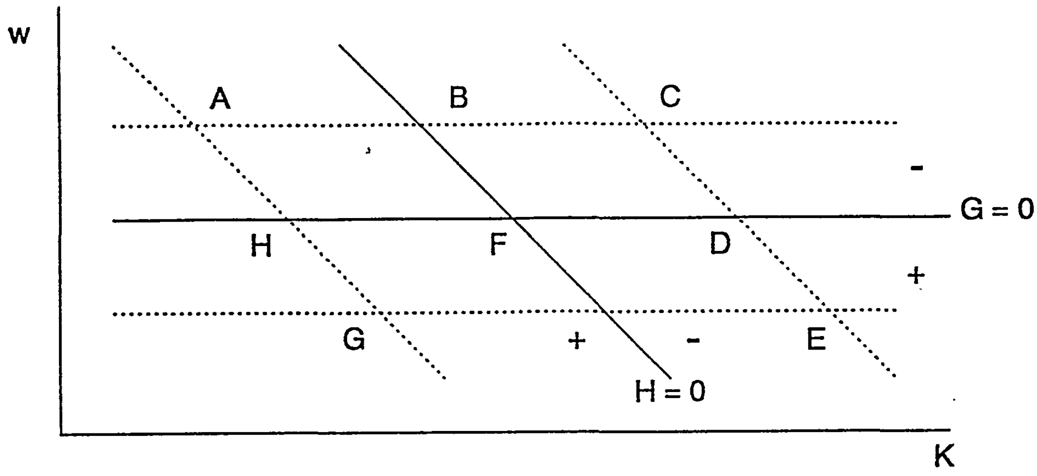

TABLE 1. Comparative-Statics of Nash Equilibrium

Type of shift	Effect on reaction function		New eq. point at	Effect on wages, capital and employm.		
$\Delta s > 0$	$H_s < 0$	$G_s < 0$	G	$\Delta w < 0$	ΔK?	ΔL?
$\Delta t > 0$	$H_t = 0$	$G_t > 0$ $G_t < 0$	B F	$\Delta w > 0$ $\Delta w < 0$	$\Delta K < 0$ $\Delta K > 0$	$\Delta L < 0$ $\Delta L > 0$
$\Delta b > 0$	$H_b = 0$	$G_b > 0$	B	$\Delta w > 0$	$\Delta K < 0$	$\Delta L < 0$
$\Delta z > 0$	$H_z < 0$	$G_z > 0$ $G_z < 0$	A G	$\Delta w < 0$ $\Delta w > 0$	ΔK? $\Delta K < 0$	ΔL? $\Delta L < 0$
$\Delta p > 0$	$\hat{H}_p > 0$	$\hat{G}_p > 0$ $\hat{G}_p < 0$	C E	$\Delta w > 0$ $\Delta w < 0$	ΔK? $\Delta K > 0$	ΔL? $\Delta L > 0$
$\Delta r > 0$	$H_r < 0$	$G_r = 0$	H	$\Delta w = 0$	$\Delta K < 0$	$\Delta L < 0$

According to the comparative statics, the unemployment benefit affects wages positively and employment and capital stock negatively, while e.g. a rise in the user cost of capital will decrease the employment and capital stock with no effect on wages. Moreover, under reasonable assumptions the income tax rate will have a negative effect on employment and capital stock, but a positive effect on wages. As for the other variables, the results are not fully determinate and depend in a complicated way on the production function and the demand curve for the output of the firm. So e.g. a rise in the payroll tax rate will decrease wages, but the employment and capital stock effects remain ambiguous. As for the demand shift variable in the imperfect competition case and the producer price in the perfect competition case respectively, their signs are not determinate, though the sign of the wage effect seems to eliminate certain configurations.

4 AN EMPIRICAL APPLICATION TO THE FINNISH MANUFACTURING INDUSTRY

We now move to the empirical part of the paper, which is organized as follows: We start by specifying the capital stock, wage and employment equations with associated dynamics to be estimated and describe the data and variables to be used in estimation. Next we present estimation results for the system of equations concerning the determination of the capital stock, wages and employment in the Finnish manufacturing industry over the period 1960 - 1987. In the final section we contrast our employment equation, where employment depends recursively on the wage-capital stock game, with the employment equations implied by the conventional theory of the demand for factors of production.

4.1 On the Specification of Econometric Models and the Data

In what follows we use the theoretical framework-presented and elaborated in sections 2 - 3 - as giving potentially relevant variables and their a priori signs in the determination of capital stock, wages and employment. We assume the log-linear functional form so that we have the following equilibrium system of equations

$$\log(K^*) = \alpha_0 + \alpha_1 \log[w^*(1+s)/q] + \alpha_2 \log(c/q) + \alpha_3 \log(Z) \tag{8a}$$

$$\log(w^*) = \beta_0 + \beta_1 \log[(1+s)/q] + \beta_2 \log[(1-t)/p] + \beta_3 \log(K^*) + \beta_4 \log(Z) + \beta_5 \log(b/p) \tag{8b}$$

$$\log(L^*) = \gamma_0 + \gamma_1 \log[w^*(1+s)/q] + \gamma_2 \log(K^*) + \gamma_3 \log(Z) \tag{8c}$$

where q is the producer price, p the consumer price, c the after-tax user cost of capital while other variables are as before. The system of equations (8a - 8c) differs from that in the theoretical section in some respects. First, the price variable has been introduced and decomposed into the producer and consumer prices. Though the producer price is endogenous with a downward-sloping demand curve, the separable form of the demand function enables us to write the marginal revenue function in the form $MR(q) = q(1 + 1/\varepsilon(q))$ (see Nickell (1978), p. 21 - 22). Second, in the theoretical section the union's utility function was specified in terms of monetary variables for simplicity. This amounted to the simplifying assumption that the producer price carry only such a small weight in the deflator for the real wage and UI benefit variables that it can omitted. Postulating the union's utility function (2) in terms of w/p and b/p, where the consumer price is exogenous, brings about the consumer price into the analysis. The first-order condition for the maximization of the union's utility function implies the restrictions log((1+s)/q) and log ((1-t)/p) for the wage equation (8c).

The equilibrium systems of equations (8a-c) needs to be complemented by the specification of dynamics for the estimation purposes. According to the time structure of the model wages and capital stock are determined simultaneously by (8a-b), and conditional on the wage-capital stock game employment is determined recursively by (8c). Therefore, it is appropriate to discuss dynamics separately for wages and capital stock on the one hand and for employment on the other hand.

As for the adjustment process for wages and capital stock we follow - in the lack of better alternative[4] - formulations used in the stability analysis of oligopoly equilibria, in particular Dixit (1986) and postulate the myopic rule for the firm and union according to which they increase capital stock and wages respectively if they perceive positive marginal profit and utility from doing so. Taking the linear approximations around the equilibrium (logK*, logw*) we get following dynamic system

$$D\log(K) = \lambda_{11}[\log(K_{-1}) - \log(K^*)] + \lambda_{12}[\log(w_{-1}) - \log(w^*)] \tag{9a}$$

$$D\log(w) = \lambda_{21}[\log(K_{-1}) - \log(K^*)] + \lambda_{22}[\log(w_{-1}) - \log(w^*)] \tag{9b}$$

where D is the difference operator. For the system the stability conditions are that the eigenvalues of the

$$I + \begin{pmatrix} \lambda_{11} & \lambda_{12} \\ \lambda_{21} & \lambda_{22} \end{pmatrix} \equiv I + \Lambda \tag{10}$$

are inside the unit circle (here I is the unit matrix).

As for the determination of employment there are good reasons to think that increasing marginal costs (of hiring and firing) will surely set in at some stage. These strictly convex adjustment costs lead to a partial adjustment process for employment. Using aggregate data raises at least two aggregation issues which must be considered, namely aggregation across firms and aggregation across different types of labour. It can be shown that allowing for differences in the adjustment costs between firms and/or for different types of labour with different adjustment costs have the effect of introducing additional lag(s) to the dependent variable[5] (see Nickell (1986) for further details). Because there is no particular reason for either firms or labour to be homogenous we specify the following second-order process for employment

$$D\log(L) = \lambda_{33}[\log(L_{-1}) - \log(L^*)] + \lambda_{34}[\log(L_{-2}) - \log(L^*)] \qquad (9c)$$

As for the stability of this second-order difference equation the roots of the characteristic equation $b^2 - (1+\lambda_{33})b - \lambda_{34} = 0$ must be less than unity in absolute value. The stability region is a triangle defined by

$$-\lambda_{33} - \lambda_{34} > 0 \qquad (10c)$$

$$1 + \lambda_{34} > 0 \qquad (10d)$$

$$2 + \lambda_{33} - \lambda_{34} > 0 \qquad (10e)$$

According to the equation 8a (8b) the firm's (union's) actions depend on the union's (firm's) reaction function. This kind of interdependence is problematic in the sense that if the equations 8a and 8b describe the simultaneous move game, then capital stock and wage equations cannot be identified in the dynamic system (9a - 9b). In order to avoid this identification problem the variables $\log(w^*)$ and $\log(K^*)$ in 9a and 9b are replaced by forecasts $\log(w^f)$ and $\log(K^f)$, which are made at time t-1 for the Nash equilibrium prevailing at time t.

The equations (9a - 9c) are estimated for the Finnish manufacturing industry using annual data over the period 1960 - 1987. Most of the data comes from the BOF4 Quarterly Model of the Finnish Economy of the Bank of Finland. Before going into the estimation results it is worthwhile to explain the construction of some variables.

First, the rental price of the capital stock - the after-tax user cost of capital - was calculated in the following way[6)]

$$c_t = g_t(i_t + \delta_t + \pi_t^e)(1 - u_t\Psi_t)/(1 - u_t), \qquad (11)$$

where g is the price of investment goods, i is the nominal interest rate, δ is the capital depreciation coefficient, π^e is the expected rate of change in g, u is corporate income tax rate, and $\Psi = \psi/(\psi+i)$ describes the present value of the tax depreciation associated with one unit of capital stock. ψ is the tax depreciation coefficient of the capital stock. We assumed that expected rate of change in g (π^e) is formed according to error learning formula

$$\pi^e = (1-\tau)\pi^e_{-1} + \tau\pi_{-1}. \qquad (12)$$

The estimation of the adaptation parameter (τ) (the value τ is fixed to be 0.4) is shown in the authors' paper (Holm et al 1990).

Second, the capital stock forecast K^f was calculated as follows: The capital depreciation formula implies that a capital forecast is a function of a investment forecast such that

$$K^f - K_{-1} = I^f + \delta K_{-1}. \qquad (13)$$

The manufacturing firms' investment plan made in previous spring (I^{ps}) was used as the proxy for I^f (see Pyyhtiä (1990)).

Third, the variable $w^{cd} = w^c(1+w^d)$, where w^c is the contract wage and w^d is the forecast of wage drift calculated assuming a first order autoregressive process in the wage drift series, was used as the proxy for w^f.

Finally, the real gross national product was used as a proxy describing the shift variable of the demand curve. The UI benefit variable (b) had to be left out from estimation because the uniform series was not available after 1984.

4.2 Estimation Results

The basic set of dynamic equations (9a - 9c) jointly with the equilibrium equations (8a - 8c) contain parameter restrictions which may not hold. Therefore, it is appropriate to estimate them in an unrestricted form and test for parameter restrictions right at the outset. Before the preliminary estimations, however, we modified the system of equations a bit. First, we introduced the time trend into the hours of work equation[7)] to account for labour-saving technical progress. Second, we did not try to estimate the depreciation coefficient of the capital stock separately, but imposed the restriction $\log(K^f) - \log(K_{-1}) = \log(I^{ps}) - \log(\delta K_{-1})$. Finally, in order to account for the potential simultaneity between log(w) and log(K) implied by our theoretical reasoning, we substituted log(w) and log(K) by $\log(\hat{w})$ and $\log(\hat{K})$, which are fits from auxiliary regressions, where log(w) and log(K) were regressed on all the exogenous variables included into the system. After these steps the unrestricted system of equations could be written as

$$\log(K) = \alpha_0 + \alpha_1\log(\hat{w}/q) + \alpha_2\log(1+s) + \alpha_3\log(c/q) + \alpha_4\log(Z) + \alpha_5\log(K_{-1}) + \alpha_6\log(w^{cd}) + \alpha_7\log(w_{-1}) + u_t \tag{14a}$$

$$\log(w) = \beta_0 + \beta_1\log(1+s) + \beta_2\log(q) + \beta_3\log(1-t) + \beta_4\log(p) + \beta_5\log(\hat{K}) + \beta_6\log(Z) + \beta_7\log(I^{ps}) + \beta_8\log(\delta K_{-1}) + v_t \tag{14b}$$

$$\log(L) = \gamma_0 + \gamma_1\log(w/q) + \gamma_2\log(1+s) + \gamma_3\log(K) + \gamma_4\log(Z) + \gamma_5 trend + \gamma_6\log(L_{-1}) + \gamma_7\log(L_{-2}) + \varepsilon_t \tag{14c}$$

where u_t, v_t and ε_t refer to the error terms of the equations.

The simultaneous structure of (14a - 14c) was tested by carrying out Hausman's exogeneity test on the equation by equation basis (see e.g. Harvey (1990, p. 311)). In accordance with our theoretical reasoning we could not reject the hypothesis that wages and capital stock are exogenous variables in the hours of work equation and we could reject the hypothesis that wages are an exogenous variable in the capital stock equation. Contrary to our theoretical reasoning, however, we could not reject the hypothesis that capital stock is an exogenous variable in the wage equation.[8)] Despite of this minor departure from the theoretical structure of the model we proceed to test for parameter restrictions in the equations system, where wages and capital are determined simultaneously and hours of work recursively conditional on the wage-capital stock game.

The generalized adjustment mechanism (9a - 9b) imposes the following restrictions ($\alpha_6 = -\alpha_7$ and $\beta_7 = -\beta_8$) to the system of equations (14a - 14b). The χ^2 test statistic for the joint restriction turned out to be 12.01, which exceeds the critical value 7.25 with 3 degrees of freedom at the 5 per cent significance level. The value of the test statistic is, however, too high because the w^{cd}-variable has been partly obtained from the fit of an auxiliary regression (see section 4.1). Therefore, we decided to impose the restrictions shown in (9a - 9b).

The SURE estimation results of the system of equations (9a - 9c), where the equilibrium values are determined according to (8a - 8c) are presented in Table 2.[9)]

TABLE 2. The SURE Estimation Results of the System of Equations

variable	Equation log(K)		log(w)		log(L)	
log[w(1+s)/q]	.117	(2.91)			-.202	(3.09)
log(c/q)	-.009	(2.68)				
log(Z)	.135	(3.21)	.368	(7.57)	.825	(7.61)
$\log(K_{-1})$	.712	(16.3)	-.033	(4.49)		
$\log(w^{cd})$	.179	(2.56)				
$\log(w_{-1})$	-.179	(2.56)	.388	(9.02)		
log[(1+s)/q]			-.139	(2.88)		
log[(1-t)/p]			-.327	(4.12)		
log(K)			.352	(7.51)	.504	(4.26)
$\log(I^{ps})$			.033	(4.49)		
$\log(\delta)$			-.033	(4.49)		
trend					-.040	(9.40)
$\log(L_{-1})$					.466	(3.80)
$\log(L_{-2})$					-.364	(3.02)
constant	1.741	(3.06)	-8.85	(20.3)	-10.3	(7.45)
R^2	.9991		.9999		.9570	
SSE	.0013		.0017		.0028	
DW	1.58		1.72		1.45	

R^2 is the adjusted multiple correlation coefficient, DW is the Durbin-Watson statistic for the first-order serial correlation, SSE is the standard error of the estimate and t-ratios are in parentheses. Note that the log(w) and log(K) - variables in the capital stock and wage equations respectively are fits from auxiliary regressions.

The estimation results can be briefly summarized as follows: First, since the system has been estimated in the level form, the adjusted multiple correlation coefficients R^2 are naturally relatively high. The DW statistics do not, however, show any first-order serial correlation. Second, the parameter estimates are reasonably precisely estimated and of expected sign from the point of view of our theoretical reasoning. More specifically, a rise in the cost of labour will decrease employment and increase capital stock, while the user cost of capital affects capital stock negatively. The shift variable of the demand curve is highly significant and seems to have a positive effect on capital stock, wages and employment, which lies in conformity with the new equilibrium point A of Table 1 and Diagram 1. Moreover, a rise in w^f - a forecast made at time t-1 for the Nash equilibrium w^* prevailing at time t - will (in conformity with the new equilibrium point G of Table 1 and Diagram 1) increase capital stock. As for the wage equation, the real payroll tax rate will have a negative effect and the real income tax rate a positive effect on wages, while the capital stock and investment plans affect positively. Finally, turning to the hours of labour equation, the parameter estimates indicate that the labour cost will have a negative, but the capital stock and demand variable a positive effect, which are complemented by the second-order dynamics.

We next move on to tests parameter restrictions associated with the dynamic structure of the system. Because the system has been estimated in the level form, the stability conditions (10a - 10e) can now be expressed as stationarity conditions:

(a) eigenvalues of $I + \Lambda$ are inside the unit circle

(b) absolute values of roots (b_1 and b_2) of characteristic equation:

$$b^2 - \log(L_{-1}):3 \cdot b - \log(L_{-2}):3 = 0 \qquad (15)$$

are inside the unit circle.

where variables refer to parameters and where e.g. the first part of $\log(L_{-1}):3$ refers to the variable $\log(L_{-1})$ and second part to the employment equation. The capital stock and wage equations are here denoted by 1 and 2 respectively.

The eigenvalues of $I+\Lambda$ are given by

$$\frac{1.100 \pm .361}{2}$$

These are clearly less than one in absolute value.

The roots of the characteristic equation associated with the second-order difference equation for hours of work are

$$b_1, b_2 = \frac{.47 \pm \sqrt{(.47)^2 - 4\cdot(.36)}}{2}$$

Since $\sqrt{.36} < 1$, the difference equation is stable and because $(.47)^2 - 4\cdot(.36) < 0$, the roots are conjugate complex.

This shows that the dynamic structure of the system - reported in Table 2 - is stable. In order to evaluate the performance of the equations a bit more, we finally turn to compare the hours of work equation - suggested by our theoretical reasoning with two alternative specifications, which can be derived from the conventional theory of the demand for factors of production.

4.3 Testing for Alternative Specifications of Hours of Work Equations

In order to shed further light on the performance of the conditional hours of work equation, which is determined recursively after the wage-capital stock game we have compared it with two alternative specifications of the hours of work equation. The alternative specifications differ in terms of what they assume about the working of output market. Depending on whether firms face a downward-sloping demand curve (DSDC) or a binding demand constraint (BDC) in the output market we have the following three specifications for the determination of the desired hours of work

(CLD): $\log(L^*) = \gamma_0 + \gamma_1 \log[w(1+s)/q] + \gamma_2 \log(K) + \gamma_3 \log(Z)$ (16a)

(DSDC): $\log(L^*) = \gamma_0 + \gamma_1 \log[w(1+s)/q] + \gamma_2 \log(c/q) + \gamma_3 \log(Z)$ (16b)

(BDC): $\log(L^*) = \gamma_0 + \gamma_1 \log[w(1+s)/c] + \gamma_3 \log(Q)$ (16c)

The specifications differ in two ways. In equation (16c) the demand variable is output (Q), whereas in other cases (Z) - proxied by the real GNP - describes the position of the demand curve. In the conditional hours of work equation the capital stock appears in the right hand side, while in the conventional equations this is replaced by the rental price of the capital stock, c.

The OLS estimation results of these three alternative specifications - complemented with the second-order dynamics and abstracted from interrelated aspects of factor demands - are presented in Table 3. The goodness-of-fit statistics, other diagnostics of models and signs and precision of parameter estimates all suggest that the conditional hours of work equation (CLD) performs best; the CLD passes all the tests with the exception of the Chow-test, whereas the other specifications suffer from serial correlation as well.[10)]

Finally, we made some further comparisons by using two types of non-nested tests, namely the J-test suggested by Davidson and McKinnon (1981) and the encompassing test suggested by Mizon and Richard (1986). The J-test was carried our in the following way:

TABLE 3. The OLS Estimation Results of Alternative Hours of Work Equations

variable	CLD		DSDC		BCD	
$\log(L_{-1})$	.436	(3.00)	.613	(3.40)	.604	(3.70)
$\log(L_{-2})$	-.349	(2.40)	-.072	(0.40)	-.055	(0.30)
$\log[w(1+s)/q]$	-.202	(2.60)	.013	(0.20)	.002	(0.30)
$\log(c/q)$			.002	(0.30)	-.002	(0.30)
$\log(K)$	.506	(3.60)				
$\log(Q)$					.440	(5.87)
$\log(Z)$	.843	(6.60)	.925	(5.10)		
trend	-.040	(8.00)	-.034	(4.80)	-.020	(5.98)
constant	-9.43	(6.40)	-7.63	(3.50)	-1.36	(1.36)
R^2	.943		.901		.918	
DW	1.38		0.78		0.94	
BPG	8.74 (6)		6.35 (6)		2.99 (5)	
CHOW	8.29 (6,5)		13.3 (6,5)		42.3 (6,7)	
AR(1)	1.76		4.08		4.26	
AR(2)	1.32		2.10		0.21	
AR(3)	1.02		0.15		0.01	
AR(4)	1.06		1.21		0.67	

(Column group header: Equation)

R^2 is the adjusted multiple correlation coefficient, DW is the Durbin-Watson statistic for the first-order serial correlation, BPG is the Breusch-Pagan-Godfrey heteroscedasticity test statistic, its 5 % critical value being 12.50 (with 6 degrees of freedom), CHOW is the stability test statistic, its 5 % critical value being 3.12 (with (6,5) degrees of freedom). Finally, the statistics AR(i), where i refers to the degree of autocorrelation, are the LM-statistics for the i:th order autocorrelation. t-ratios are in parentheses.

All models were first estimated by OLS and the fits of the CLD, DSDC and BDC (called CLD, DSDC and BDC, respectively) models were saved. Then the models were re-estimated by including the fit of other model as an additional explanatory variable. If the t-ratio of the fit is statistically significant, the regressors of that model are "important" and the maintained hypothesis is rejected.

The results of the J-tests are reported in Table 4:

TABLE 4. The J-test a lâ Davidson-McKinnon (1981)

Model	Fit	Estimate of fit	t-ratio of fit
1:CLD:	DSDC	3.99	1.33
	BDC	0.79	1.97
2:DSDC:	CLD	1.09	3.92
3:BDC:	CLD	0.87	3.66

Clearly CLD model rejects other specifications, but vice versa is not the case at the significance level which is high enough. Hence, CLD slightly dominates the other specifications according to the J-test.

The encompassing test was carried out in the following way. The joint model - including all explanatory variables from all models -

$$\begin{aligned}\log(L) = {} & \gamma_0 + \gamma_1 \log(L_{-1}) + \gamma_2 \log(L_{-2}) + \gamma_3 \log[w(1+s)/q] \\ & + \gamma_4 \log(c/q) + \gamma_5 \log(K) + \gamma_6 \log(Q) + \gamma_7 \log(Z) \\ & + \gamma_8 \mathrm{trend}\end{aligned} \qquad (17)$$

were first estimated. Then the restrictions implied by the alternative specifications were tested by means of F-test statistics.

TABLE 5. The Encompassing Test a lâ Mizon-Richard (1986)

group 1: restrictions: $\gamma_4 = \gamma_6 = 0$;	$F = 2.10$ $F_{.05}(2,16) = 3.63$
group 2: restrictions: $\gamma_5 = \gamma_6 = 0$;	$F = 9.41$ $F_{.05}(2,16) = 3.63$
group 3: restrictions: $\gamma_5 = \gamma_7 = 0$ & $\gamma_2 = -\gamma_3$;	$F = 7.02$ $F_{.05}(3,16) = 3.24$

Results are reported in Table 5 together with the F-statistics for the restrictions and their critical values at the 5 per cent significance level. According to the results only the first set of restrictions cannot be rejected so that CLD model again dominates other specifications.

5 CONCLUDING REMARKS

In this paper we have formulated a model of wage determination in accordance with the notion of a monopoly union determining wages after which the firm decides on employment. The novelty has been to incorporate into the model investment and capital decisions by firms in a way that is amenable to econometric estimation. This extension obviously provide a new strategic variable in the game between the firm and the union.

In the theoretical part we assume that the game between the firm and the union is played in two stages. First, the firm and union decide on capital stock and wages, respectively. In the second stage, the firm determines the level of employment, given wages and capital stock. The equilibrium concept is thus the subgame-perfect Nash equilibrium. After characterizing the Nash equilibrium in various cases we develop the comparative-static predictions of the model for wages, capital stock and employment.

In the empirical part the model is estimated by using the annual data from the Finnish manufacturing industry over the period 1960 - 1987. According to the estimation results the system of equations describing the determination of capital stock, wages and hours of work performs reasonably well; there are no obvious signs of misspesification, coefficient estimates and other properties of the models are correct from the point of view of our theoretical reasoning. Finally, and importantly, diagnostics and various non-nested test procedures indicate that the conditional hours of work specification - where hours of work are determined recursively after the wage-capital stock game - outperforms alternative specifications implied by the conventional theory of the demand for factors of production.

Although results are encouraging, some limitations should be pointed out. First, the specifications, while generally rather satisfactory, do not always obey the restrictions predicted by the theoretical structure. Clearly, there remains some scope for improvement in this respect. In particular, we should stress that the treatment of dynamics is at the moment rather ad hoc and some further theoretical and empirical research in this direction would probably pay off. Second, both theoretical arguments and empirical evidence suggest that labour can only be adjusted rather slowly in practice. If labour adjustment takes longer time to complete that the period of wage settlements, it could be argued that firms have to choose the level of their employment before wages are set. Thus there is also a need to consider and test for alternative models of the time structure of decisions in the game between the firms and the unions.

FOOTNOTES

1) However, under one set of assumptions, which makes the union's reaction function independent of the strategy variable of the firm, Stackelberg leaderships either by the firm or the union are identical to the Nash equilibrium.

2) In the empirical part we revert back to using empirical proxies for Z, since this is customary in empirical work.

3) There seems to be no concensus on how the relative risk aversion varies so that the constant relative risk aversion might be regarded as a good benchmark case. As for the size of the relative risk aversion, the estimates - while varying widely - generally come up with the conclusion that it is well above one (see Machina (1983) for further details).

4) Though the Nash equilibrium describes the simultaneous move game between the firm and the union, in practice one does not expect conflicting agents to move instantaneously to an equilibrium. But how the final equilibrium is achieved via "disequilibrium dynamics" is far from clear and remains largely an unexplored territory. See, however, MacLeod (1985) for a preliminary analysis of "disequilibrium dynamics" based on the existence of adjustment costs.

5) There are other ways of justifying two lags on the dependent variable. E.g. Sargent (1978) justifies the second lag as arising from a serially correlated unobservable shock to technology! Distinguishing between these hypotheses lies beyond the scope of this paper.

6) For a definition of the user cost of capital and some of the issues involved, see Nickell (1978), chapter 9 or Koskenkylä (1985)).

7) We used the hours of work as a proxy for employment, and did not try to distinguish between them. For an attempt to do this with the Swedish data, see Pencavel and Holmlund (1988).

8) A complete set of results is available from the authors upon request.

9) We also estimated the system of equations by OLS thus ignoring the potential contemporaneous correlation of error terms. The likelihood ratio test for the maintained hypothesis of diagonal covariance matrix of error terms got the value 5.89, which is slightly below the critical value 7.81 at the 5 per cent significance level. Thus the OLS estimation can be defended. The OLS estimation results were rather similar to those reported in Table 2. Due to the slightly lower efficiency of estimation some of the parameters were less precisely estimated, but the diagnostics showed no signs of misspecification. E.g. the value of the Durbin-Watson statistic was 1.80 for the wage equation and 1.55 for the capital stock equation. In addition, the

Breusch-Pagan-Godfrey heteroscedasticity test statistic was 5.75 (with 8 degrees of freedom) for the wage equation and 10.94 (with 7 degrees of freedom) for the capital stock equation. As for the hours of work equation, see Table 3. A complete set of results is available from the authours upon request.

10) Pehkonen (1990), p. 118 - 122, has recently estimated employment equations by using the annual data on the Finnish manufacturing and mining sector, which includes many, but not all the explanatory variables which occur in our conditional hours of work specification. He does not, however, justify his employment equation by relying on the time structure of the game between the firm and the union.

APPENDIX

(I) we prove the assertion that for the conditional labor demand g(.) the expression $g_1(.)/g(.)$ is independent of the capital stock under constant returns to scale and perfect competition in the product market: In this case the marginal product $f_L(.)$ is homogenous of degree 0, so in the perfectly competitive case we may write (4) in the form

$$f_L(L/K) = (1+s)w/p. \qquad \text{(A-1)}$$

Inverting (A-1) gives

$$L = f_L^{-1}[(1+s)w/p]K \equiv h(.)K,$$

so that g_1/g will be independent of K. In fact, the same result holds for some specifications with imperfect competition in the product market. Take a Cobb-Douglas production function f(K,L) = $K^{\alpha}L^{1-\alpha}$ and constant-elasticity demand curve $Q = z^{-1}p^{\beta}$. Then it is easy to show that the conditional labor demand (3) takes the form

$$L = [(1+s)w\beta/(1+\beta)]^{\beta/[1-\alpha(\beta+1)]}z^{-1/[1-\alpha(\beta+1)]}K^{-\alpha(\beta+1)/[1-\alpha(\beta+1)]} \qquad \text{(A-2)}$$

so that g_1/g will be independent of K. Note also that in this case $g_3 > 0$ since $\beta < -1$.

(II) Next, we consider the influence of union's risk aversion on the effects of variations in income tax rate:

Differentiating (6) with respect to t gives

$$\frac{(1+s)(U-\bar{U})[-U'-(1-t)wU'']+(1-t)U'(1+s)U'w}{[(1+s)(U-\bar{U})]^2} \qquad \text{(A-3)}$$

since the term g_1/g is independent of t. The expression inside the square brackets in the first term of the numerator can be written in the form $(-U')\{1-R[(1-t)w)\}$, where $R = -w(1-t)U''/U'$ is the

Arrow-Pratt measure of relative risk aversion. Assuming the unemployment benefit level be such that $U > \bar{U}$ it follows that $G_t > 0$ when $R > 1$.

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