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by Mark Roberts

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January 2002

Central wage setting under multiple technological equilibria: A mechanism for equilibrium elimination.

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Abstract.

Instituting an initial round of centralized wage setting before an ultimate round of decentralized wage bargaining may raise actually raise employment. A general multi-equilibrium model is presented with strategic complementarities in the implementation of a new technology through aggregate demand spill-overs. Centralized wage setting in establishing an outside option wage, which is selectively binding on lo-tech firms, may achieve the "big push" to a hi-tech general equilibrium with higher employment, output, wages and profits.

JEL Nos: J30, J50

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Central bargaining, imperfect competition, strategic complementarity, multiple equilibria, minimum wage.

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I. Introduction.

In practice centralized wage bargaining generally constitutes the first stage of a multi-stage process, suggesting that it complements rather than substitutes decentralized bargaining.[2] Consequently, the benefits of centralization must be in establishing prior constraints on the subsequent local bargaining process rather than in internalizing local externalities.[3] [4] This paper presents a model of multiple technological equilibria to show that a centralized first stage of wage setting may switch an economy from low to high technology production, creating, not only higher wages, but also higher employment, output and profits.

An apparent rationale for centralization might be to provide a forum for coordination on a preferred equilibrium. However, this may not be sustainable in a multi-stage setting without some additional precommitment mechanism. Firms would otherwise resort to uncooperative Nash behaviour at the second stage where their technology choices are made. The role of centralization considered here is to establish a minimum wage in order to eliminate the low technology equilibrium.[5]

It is well established that a minimum wage may raise activity and welfare outside a first-best world. Although the classic case is of labour market monopsony, recent work has turned more towards the analysis of human capital formation. Many models consider the allocation of workers between dual labour markets, based on their educational attainment, where typically a minimum wage would be binding on a low wage secondary sector. For example, Cahuc and Michel (1996) show that a minimum wage will reduce the demand for unskilled labour and raise the endogenous growth rate through standard Romer-type productivity spill-overs.

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[2] Generally, the literature treats centralization and decentralization as substitutes rather than complements. This may be tenable only in the case of Austria according to the OECD empirical survey in 1994.

[3] Many of these issues are surveyed in Moene, Wallenstein and Hoel (1993) and in Calmfors (1993).

[4] Holden (1988) also shows that employment may be higher under a two stage system than under a single central stage, because firms are then allowed the scope to set employment before the local wage bargain.

[5] In a practical sense, it might be easier to commit to a quantitative variable like a wage level, than to a idiosyncratic qualitative variable like a technology.

By contrast, Agell and Lommerud (1997) consider a minimum wage imposed on a primary sector, since the secondary sector is informal, where employment is determined as a labour supply decision. The effect is to raise both the return to education and an educational entry hurdle, giving an uncertain employment response. The results can also go either way in Ravn and Sorensen (1999) in a single sector endogenous growth model, because while a minimum wage encourages pre-work schooling, as in Agell and Lommerud, it discourages on-the-job training as in Hashimoto (1982).

The contribution of this present paper is to consider the effect of a minimum central wage on the technology decisions of firms. Multiple equilibria emerge, because they face both implementation costs and strategic complementarities. The antecedents to this kind of model are reviewed in Cooper and John (1988) and Murphy, Schleifer and Vishny (1989). In the terminology of the Murphy *et al*, we show how a central wage might achieve the "big push" from a low to a high technology (henceforth, from "lo-" to "hi-tech") general equilibrium.[6]

The analysis focuses on the elimination of the lo-tech general equilibrium. A minimum central wage may be effective, if it is set to be selectively binding on any remaining lo-tech firms but not on any firms defecting from the lo-tech general equilibrium. This causes a *relative labour cost* effect against which there is a countervailing effect from the reduced outputs of lo-tech firms diminishing aggregate demand and the scale of profits for all firms and, hence, the gross profits gain from implementation. For certain parameterizations, the *relative labour cost* exceeds this adverse *aggregate demand effect*, so that a central wage may effectively switch the economy to hi-tech production with higher wages, employment, output and profits.[7]

It may be useful at the outset to underscore three conceptual features of the model. First, the model *in equilibrium* is, properly, single-sector. The property of strategic complementarity generates equilibria where firms all make common choices of technology. These are also assumed to be the only salient outcomes. The co-existence

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[6] Hammour (1991) and Cooper (1994) provide a dynamic analyses with these considerations.

of hi- with lo-tech firms is only an *out-of-equilibrium* potential for Nash-acting firms contemplating defection from a lo-tech general equilibrium to hi-tech production.

Secondly, as in Roberts, Staehr and Tranaes (2000), the model precludes any conflict at the initial central stage. The assumptions of wage-employment bargaining, as in McDonald and Solow (1981), and of all round risk-neutrality imply that second stage bargaining is effectively only over shares of a joint, locally efficient surplus. Thus, there is a first stage consensus over the level at which the central wage should be set in order to maximize this joint surplus. Consequently, the paper refers to central wage *setting* rather than bargaining.

Thirdly, the central wage is specified as an outside pay-off, which is guaranteed to union members who cannot secure a higher wage but continue to work without penalizing the firm.[8] It is not a reservation, which would be received when bargaining breaks down whether not there is a working-to- rule provision.[9]

The paper is organized as follows. Section 2 presents a model of imperfectly competitive firms which produce differentiated consumption goods and bargain locally with unions over wages and employment. Section 3 considers the equilibrium outcomes in the absence of a binding central wage constraint. Section 4 looks at the various general equilibrium possibilities. Section 5 investigates the conditions under which a binding central wage will eliminate a lo-tech general equilibrium. Section 6 extends the discussion beyond the immediate model and Section 7 offers a brief summary of the analysis.

II. The Model.

Overview of the sequential structure.

The economy works in the following sequence. At the first stage there is a first round of centralized wage setting by firms and unions coming together as federations. The second stage is a local one where firms unilaterally choose a technology. The final

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7 Booth (1995) suggests that higher wages (through union effects) may end X-inefficiencies by removing the cushion of surplus profits.

8 See Binmore, Rubinstein and Wolinsky (1986).

9 As in Holden (1988).

third stage is also local with decentralized wage bargaining between firms and unions.

The first stage of centralized wage setting.

Firms and unions come together as federations to determine a central wage. Specifically, this is defined as a guaranteed minimum to union members who work, but it is paid out only if it exceeds any subsequently locally bargained wage. Defining w_i* as the unconstrained bargained wage of firm i and $\tilde{w}$ as the central wage, $w_i = \max[w_i*, \tilde{w}]$ where w_i is the actual wage paid out in firm i.

It is not a reservation wage, which would be paid out either as strike pay when local bargaining breaks down or as a payment to unemployed members, which fits with the assumption that strikes are allowed under local bargaining. Moene, Wallerstein and Hoel (1988) show that the central wage has no effect on the ultimately bargained wage, if the central wage is not paid out where local bargaining breaks down in the strikes-allowed case. Alternatively, Holden (1988) assumes that workers work-to-rule in the event of a breakdown in local negotiations and receive the central wage.

The assumption of risk-neutral, utilitarian unions who bargain efficiently with risk-neutral firms at the second stage implies that the conflict will only be over shares of a joint and efficient surplus. [10] At the first stage both parties have the same incentive to maximize the size of this joint efficient surplus, which gives the same consensus in the multiple equilibrium case as in Roberts, Staehr and Tranaes (2000). It is a misnomer to speak of central *bargaining* rather than *setting* in the present context.

The second stage of technology choice.

Firms locally and unilaterally choose their technologies after the first centralized stage, so that their choices are conditioned on a prior and collective commitment to a central wage. There is some significance to the fact that the technology choice precedes decentralized bargaining, reflecting a hold-up as in Grout (1984), which is discussed in Section 6, but it is crucial to the analysis that it follows the first stage.

[10] The local efficient contract curves are vertical in wage-employment space.

Firms would otherwise be able to coordinate on a generally profitable technology, which would here negate any need for central wage setting.

The third stage of local wage bargaining.

The firm and union Nash bargain locally over wages and employment as in McDonald and Solow (1981).[11] They effectively maximize a geometrically weighted surplus of profits and union utility. We now solve the model backwards, starting with local bargaining. Each of these is now determined: first, profits from the structures for households' demands and firms' outputs; then, union utilities from households' indirect utilities.

The structure of product demand.

Each individual, z, has Dixit-Stiglitz (1977) preferences over a continuum on the unit measure of differentiated consumption goods and a disutility of effort, e, from a discrete unit of labour supply, if employed:

$$V_Z = \left(\int_0^1 y_{iZ}{}^{\mu} f(i)di\right)^{\frac{1}{\mu}} - e_Z \qquad \int_0^1 f(i)di = 1, \quad 0 < \mu < 1$$

$$e_Z = e > 0\text{, if employed;} \qquad e_Z = 0\text{, if unemployed.} \tag{1}$$

where y_{iZ} is the ith good consumed by individual z and $f(i)$ is its relative weighting in consumption, which by assumption is common to all individuals. The elasticity of substitution between any two goods is $(1-\mu)^{-1}$.

The individual and aggregated budget constraints are

$$P^{-1}\int_0^1 P_i y_{iZ} f(i)di = y_Z\ , \qquad P^{-1}\int_0^1 P_i y_i f(i)di = y$$

$$y_Z = w_Z + \pi\text{, if employed;} \quad y_Z = \pi\text{, if unemployed} \tag{2}$$

where P_i is the absolute price of good i and P is an aggregate price deflator. Real income of individual z is y_Z and aggregated real incomes are y. The individual employed by firm j receives the wage income w_j plus a profit income, π, from

[11] This is assumed only for analytical convenience. The same basic analysis goes through in an earlier paper [Roberts (1997)] where employment is on the demand curve and where the wage is pushed up to ensure that just a subset of insiders are employed.

holding a portfolio of shares in all the firms of the economy. An unemployed individual only receives the same share of aggregate profits, π.

The property of homotheticity:

$$y_{iZ} = \left(P_i / P_j\right)^{\frac{-1}{1-\mu}} y_{jZ} \qquad \forall i, j \qquad , \qquad \forall z \tag{3}$$

with homogeneity across consumers ensures that the relative demand for any consumption good does not depend on the distribution of income between wages and profits or on the distribution of individuals between work and unemployment. The form of (3) suggests that for an appropriate definition of the general price level, P,

$$P \equiv \left(\int_0^1 P_i^{\frac{-\mu}{1-\mu}} f(i) di \right)^{\frac{-(1-\mu)}{\mu}} ,$$

the individual and aggregated demands for each consumption good, i, are

$$y_{iZ} = \left(P_i / P\right)^{\frac{-1}{1-\mu}} y_Z \quad \forall i, z \, ; \qquad y_i = \left(P_i / P\right)^{\frac{-1}{1-\mu}} y \quad \forall i \tag{4}$$

The indirect utility function of an individual z is then solved as

$$V_Z \equiv \left(\int_0^1 \left(P_i / P\right)^{\mu} f(i) di \right)^{\frac{1}{\mu}} y_Z - e_Z$$

In a symmetric equilibrium for consumption, $P_i = P \quad \forall i$, the respective indirect utilities of employed and unemployed individuals are:

$$V_{jZ}^E \equiv w_j + \pi - e, \quad \text{if employed in } j; \qquad V_Z^U \equiv \pi, \quad \text{if unemployed} \tag{5}$$

The structure of output.

The firm operates under decreasing returns to scale, $\theta < 1$, using labour, L_i, as the only input:

$$y_i = A_i L_i^{\theta}, \qquad A_i = A_L, A_H (> A_L) \quad ^{12} \tag{6}$$

Production also depends on the firm's choice of A_i, a multiplicative technology parameter.

Profits and the firm's bargaining surplus.

Real profit, net of the implementation cost, is given by:

[12] This is gross output if the implementation cost is interpreted a production loss.

$$\pi_i = (P_i / P)y_i - w_i L_i - f - c_i, \qquad c_i = c\text{, if } A_i = A_H;\ \ c_i = 0\text{, if } A_i = A_L \qquad (7)$$

where w_i is the real wage, f is a fixed production cost. The implementation cost, c, is incurred whether or not an agreement is reached where $A_i = A_H$ and is never incurred where $A_i = A_L$.

Using the demand and production functions in (4) and (6) gives net profits as:

$$\pi_i = y^{1-\mu} A_i^{\mu} L_i^{\theta\mu} - w_i L_i - f - c_i, \qquad c_i = c\text{, if } A_i = A_H; \quad c_i = 0\text{, if } A_i = A_L \qquad (8)$$

We note that the prices have been solved out of the profit function, so any induced variations in the relative prices are now incorporated in the analysis.

In the event of an agreement, net profits are given by (8); in the event of a disagreement, net profits are -c, if $A_i = A_H$ and zero if $A_i = A_L$. The firm's bargaining surplus is $y^{1-\mu} A_i^{\mu} L_i^{\theta\mu} - w_i L_i - f$ for both technology choices, $A_i = A_L, A_H$. Unlike the implementation cost, the fixed output cost, f, appears because it is incurred only if production goes ahead because an agreement is reached.

Union preferences.

Unions are utilitarian and have an exogenous number of M_i members. A union attached to firm i would want to maximize:

$$D_i = (w_i + \pi - e)L_i + \pi(M_i - L_i) \qquad \text{where} \quad L_i < M_i \qquad (9)$$

which incorporates equations (5) for the indirect utilities of its employed and unemployed members.

If negotiations break down, utility is πM_i. The difference, the union bargaining surplus, is $(w_i - e)L_i$. The Nash product combines the two bargaining surpluses:

$$N_i = (y^{1-\mu} A_i^{\mu} L_i^{\theta\mu} - w_i L_i - f)^{1-\sigma}\left((w_i - e)L_i\right)^{\sigma} \qquad (10)$$

where σ is the relative weight of union bargaining power.

Technology choice.

After the first stage where a central wage, $\widetilde{w}$, is set, the second stage follows where firms locally and unilaterally choose the production technology. If a firm adopts the new technology in A_H, it must incur a implementation cost, c. This may be interpreted either as a fixed output loss, which is independent of labour input, in adopting the new technology or as the disutility of the extra effort incurred by an owner-manager in making the changeover.

As technology is the only source of heterogeneity across firms, outputs can be indexed with respect to the technology choice, so that $y_L \equiv y_i | A_i = A_L$ and $y_H \equiv y_i | A_i = A_H$. The proportion of firms choosing hi-tech production is λ. The binomial distribution with the constant elasticity demand formulation gives aggregate real output as

$$y = \left(\lambda y_H{}^{\mu} + (1-\lambda) y_L{}^{\mu}\right)^{\frac{1}{\mu}} \tag{11}$$

which has been solved by aggregating nominal revenues, using the demand equation in (4), then deflating by the price level. As the firm level output variables are also determined partially by aggregate output, the simultaneous solution of aggregate and local variables is presented below.

III. Solutions without a Binding Central Wage Constraint.

The first case considered is where the central wage, $\widetilde{w}$, is not binding on any local labour market: $w_i = w_i{}^* = \max[w_i{}^*, \widetilde{w}] \quad \forall i$. This is where central wage setting is either absent or redundant. We also assume that there is unemployment in each firm, $L_i < M_i$, $\forall i$.

Partial equilibrium solutions.

Bargaining over both wages and employment gives two first-order conditions

$$[(1-\sigma)\theta\mu + \sigma] A_L{}^{\mu} y^{1-\mu} L_i{}^{\theta\mu} - w_i{}^* L_i - \sigma f = 0 \tag{12.1}$$

$$\theta\mu A_L{}^{\mu} y^{1-\mu} L_i{}^{\theta\mu-1} = e \tag{12.2}$$

subject to

$$w_i > \widetilde{w} \tag{12.3}$$

Equation (12.2) gives employment as

$$L_i = (\theta\mu / e)^{\frac{1}{1-\theta\mu}} A_i^{\frac{\mu}{1-\theta\mu}} y^{\frac{1-\mu}{1-\theta\mu}} \tag{13.1}$$

The assumption of a risk-neutral utilitarian union leads conveniently to a vertical contract curve in wage-employment space. The production function in (6) with (13.1) gives output as:

$$y_i = (\theta\mu / e)^{\frac{\theta}{1-\theta\mu}} A_i^{\frac{1}{1-\theta\mu}} y^{\frac{\theta(1-\mu)}{1-\theta\mu}} \tag{13.2}$$

Gross trading profits are solved as:

$$\pi_i = (1-\sigma)\left[(1-\theta\mu)(\theta\mu / e)^{\frac{\theta\mu}{1-\theta\mu}} A_i^{\frac{\mu}{1-\theta\mu}} y^{\frac{1-\mu}{1-\theta\mu}} - f\right] \tag{13.3}$$

Conditions (12.1) and (12.2) give the wage as:

$$w_i{}^* = \Omega - \sigma f (e / \theta\mu)^{\frac{1}{1-\theta\mu}} A_i^{-\frac{\mu}{1-\theta\mu}} y^{-\frac{1-\mu}{1-\theta\mu}} \quad \text{where} \quad \Omega \equiv [\sigma + (1-\sigma)\theta\mu](e / \theta\mu) \tag{13.4}$$

We note that the bargained wage is decreasing in the fixed production cost, f, because this reduces profits and the total surplus. Given the constant elasticity of labour demand and utilitarian union preferences, the technology parameter, A_i, raises the wage only through reducing the effect of, f.[13] Finally, union utility is solved as:

$$v_i = \sigma\left[(1-\theta\mu)(\theta\mu / e)^{\frac{\theta\mu}{1-\theta\mu}} A_i^{\frac{\mu}{1-\theta\mu}} y^{\frac{1-\mu}{1-\theta\mu}} - f\right] \tag{13.5}$$

Proposition 1. *Switching to the higher technology, for a given aggregate output level, raises the firm's employment, output, gross profits, the wage and union utility in partial equilibrium.*

From inspection of equations (13), $\partial x_i / \partial A_i > 0$ for $x_i = L_i, y_i, \pi_i, w_i, v_i$.

[13] This specification was made for the convenience of obtaining an open-form solution for a model where technology affects both the wage and employment.

Furthermore, the firm's own variables are increasing in aggregate output to the extent that its demand curve is downward-sloping, $\mu < 1$.

Aggregate output is obtained from equations (11) and (13.2):

$$y = (\theta\mu / e)^{\frac{\theta}{1-\theta}} \left[\lambda A_H^{\frac{\mu}{1-\theta\mu}} + (1-\lambda) A_L^{\frac{\mu}{1-\theta\mu}} \right]^{\frac{1-\theta\mu}{\mu(1-\theta)}} \tag{14}$$

The full general equilibrium solution is determined by substituting equation (14) back into into equations (13).

The gain in gross profits from adopting the new technology in terms of each value of λ is obtained by subtracting gross profits where $A_i = A_L$ from the same where $A_i = A_H$ and by substituting in equation (14):

$$g(\lambda) = (1-\sigma)(1-\theta\mu)(\theta\mu / e)^{\frac{\theta}{1-\theta}} \left[\lambda A_H^{\frac{\mu}{1-\theta\mu}} + (1-\lambda) A_L^{\frac{\mu}{1-\theta\mu}} \right]^{\frac{1-\mu}{\mu(1-\theta)}} \left[A_H^{\frac{\mu}{1-\theta\mu}} - A_L^{\frac{\mu}{1-\theta\mu}} \right] > 0 \tag{15}$$

Proposition 2. *There is a strategic complementarity in the new technology, if* $\mu < 1$.

This follows from the derivative of the gross gain function in equation (15):

$$\frac{\partial g(\lambda)}{\partial \lambda} = (1-\sigma)(1-\theta\mu)\left(\frac{1-\mu}{\mu(1-\theta)} \right)\left(\frac{\theta\mu}{e} \right)^{\frac{\theta}{1-\theta}} \left[\lambda A_H^{\frac{\mu}{1-\theta\mu}} + (1-\lambda) A_L^{\frac{\mu}{1-\theta\mu}} \right]^{\frac{1-\mu}{\mu(1-\theta)}-1} \left[A_H^{\frac{\mu}{1-\theta\mu}} - A_L^{\frac{\mu}{1-\theta\mu}} \right] > 0$$

The gain to adopting the new technology is increasing in the proportion of firms which adopt the new technology, because of aggregate demand spill-overs where $\mu < 1$. Equation (15) shows that the gross gain for any firm from switching is greater at the hi- than the lo-tech general equilibrium by the factor, $g(1)/g(0) = (A_H / A_L)^{\frac{1-\mu}{(1-\mu\theta)(1-\theta)}}$.

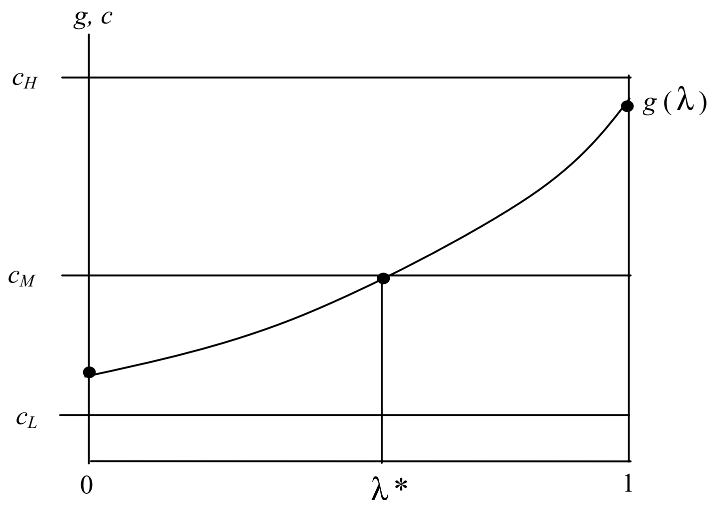
The property of strategic complementarity depends partly on an employment response. If, however, employment is fixed in both firms, as in Roberts (1997), the gross gain is still rising in λ, but the effect is dampened. If employment is fixed only in the hi-tech firms, there is an asymmetry with greater wage increases and lower profit increases in the hi-tech firms. This invites the question, whether the property of strategic complementarity still remains? The answer is yes for this particular model (shown in the Appendix), since rises in λ still generate sufficiently expansionary aggregate demand effects on the gross gain.

IV. General Equilibrium Solutions.

Equilibrium possibilities.

There are three possible of numbers of equilibria depending on the magnitude and the distribution of implementation costs. Abstracting from the latter, we assume common implementation costs. The gain function in (15) is plotted in the Figure below for three magnitudes of the implementation cost - low, intermediate and high.

Figure One.



(i) Low implementation costs give a unique hi-tech general equilibrium at $\lambda = 1$ since $g(\lambda) > c_L \ \forall\lambda$. Here, central wage setting is redundant in this model.

(ii) Intermediate implementation costs give three self-fulfilling Nash general equilibria at $\lambda = 0$, $\lambda*$ and 1, where respectively, $g(0) < c_M$, $g(\lambda*) = c_M$ and $g(1) > c_M$. The three Nash equilibria are ranked in order of λ for individual utilities, union utilities and profits.[14] We abstract from the mixed equilibrium at $\lambda*$ for the following reasons. An integer value for λ is probably the least likely as a focal point for coordination. There is also an assignment problem of which firms are allocated to the lo-and which to the hi-tech technology.[15] The focus is on the choice between the two exterior cases at $\lambda = 0$ and $\lambda = 1$.

(*iii*) High implementation costs, $g(\lambda) < c_H \quad \forall\lambda$, generate a unique general equilibrium at giving $\lambda = 0$. Firms would have no incentive to accede to central wage setting.

We are concerned with the multiple equilibria case of intermediate implementation costs and the two outer integer equilibria. The configurations for $\lambda = 0$ where $A_i = A_L$, $\forall i$, and $\lambda = 1$ where $A_i = A_H$, $\forall i$, are:

$$L_i(\lambda) = (\theta\mu / e)^{\frac{1}{1-\theta}} A_i^{\frac{1}{1-\theta}} \tag{16.1}$$

$$y_i(\lambda) = (\theta\mu / e)^{\frac{\theta}{1-\theta}} A_i^{\frac{1}{1-\theta}} \tag{16.2}$$

$$\pi_i(\lambda) = (1-\sigma)\left[(1-\theta\mu)(\theta\mu / e)^{\frac{\theta}{1-\theta}} A_i^{\frac{1}{1-\theta}} - f\right] \tag{16.3}$$

$$w_i(\lambda)^* = \Omega - \sigma f (e / \theta\mu)^{\frac{1}{1-\theta}} A_i^{-\frac{1}{1-\theta}} \tag{16.4}$$

Proposition 3. *The wage level is higher in the hi-tech general equilibrium than in the lo-tech general equilibrium.*

From inspection of equation (16.4).

This suggests that a central wage may penalize firms in lo-tech production.

V. Eliminating the Lo-tech General Equilibrium?

We focus on the multiple equilibria case from intermediate implementation costs where the economy is trapped at the lo-tech equilibrium, $\lambda = 0$. The analysis concerns its possible elimination by raising the gross implementation gain. To achieve this it is necessary that the central wage is set at a level which is high enough

[14] Employment, wages, union utility and gross profits are all increasing in aggregate output [equations (13)], which is itself increasing in the proportion of hi-tech firms from [equation (15)].

[15] The mixed equilibrium is also upwardly-unstable, because once the cost is made, it is sunk, so it is never worthwhile to revert to being lo-tech.

to be binding on remaining lo-tech firms but not on any firm potentially defecting from $\lambda = 0$.

The condition for a selective binding central wage from equation (16.4) at $\lambda = 0$ is:

$$\Omega - \sigma f \left(e/\theta\mu\right)^{\frac{1}{1-\theta}} A_L^{-\frac{1}{1-\theta}} < \tilde{w} \leq \Omega - \sigma f \left(e/\theta\mu\right)^{\frac{1}{1-\theta}} A_H^{-\frac{1}{1-\theta}} \qquad (17)$$

This condition ensures the existence of a full relative labour cost effect. However, there is still the possibility that the implementation gain could even be lowered by the adverse and indirect aggregate demand effect. Thus, it may generally be counter-productive to raise the central wage all the way to its hi-tech level.

The partial equilibrium relative labour cost effect.

If condition (17) holds, the wage in the lo-tech firm is constrained at the central wage level. It is assumed that the lo-tech firm and union continue to bargain over the employment level[16]. Maximizing the Nash surplus in (10) for $A_i = A_L$ gives the single first-order condition (12.1):

$$\left[(1-\sigma)\theta\mu + \sigma\right] A_L^{\ \mu} y^{1-\mu} \tilde{L}_L^{\ \theta\mu} - \tilde{w}\tilde{L}_L - \sigma f = 0 \qquad (18.1)$$

$$w_L = \tilde{w} \qquad (18.2)$$

Henceforth, we use *tildes* to denote the variables constrained by the central wage.

Applying the production function in (6) shows that the output of the lo-tech firm is now an implicit function of aggregate output and the central wage:

$$\left[(1-\sigma)\theta\mu + \sigma\right] y^{1-\mu} \tilde{y}_L^{\ \mu} - \tilde{w}\left(\tilde{y}_L / A_L\right) - \sigma f = 0 \qquad \text{or} \qquad \tilde{y}_L = \tilde{y}_L(\tilde{w}, y) \qquad (19)$$

Equations (6), (8) and (19) give:

$$\pi_L = (1-\sigma)[(1-\theta\mu) y^{1-\mu} \tilde{y}_L^{\ \mu} - f] \qquad (20)$$

Proposition 4. *The minimum wage constraint will reduce employment, output and profits in the lo-tech-firm in partial equilibrium (where aggregate demand, y, is held constant).*

This follows because $\partial\tilde{x}/\partial\tilde{w} < 0$, where $\tilde{x} = \tilde{L}_L, \tilde{y}_L, \tilde{\pi}_L$ from equations (18)-(20).

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[16] To assume otherwise would introduce an additional asymmetry concerning bargaining.

The general equilibrium aggregate demand effect.

The constrained solution for lo-tech output in (19) with the unconstrained solution for hi-tech output in (13.2) into (11) gives aggregate output as an implicit function of the central wage:

$$y = \left(\lambda(\theta\mu / e)^{\frac{\mu\theta}{1-\mu\theta}} A_H{}^{\frac{\mu}{1-\theta\mu}} . \, y^{\frac{\mu\theta(1-\mu)}{1-\theta\mu}} + (1-\lambda)(\tilde{y}_L(\tilde{w}, y))^{\mu} \right)^{\frac{1}{\mu}} = y(\tilde{w}, \lambda) \qquad (21)$$

Proposition 5. *A rise in the central wage, binding on lo-tech firms, will reduce profits in all firms wherever lo-tech firms are present,* $\lambda < 1$.

This follows from sign of the derivative of (21),

$$\frac{\partial y}{\partial \tilde{w}} = \frac{(1-\lambda)\,\partial \tilde{y}_L / \partial \tilde{w}}{(\tilde{y}_L / y)^{1-\mu} - \left(\lambda(\theta(1-\mu)/1-\theta\mu)\left(\tilde{y}_L{}^{1-\mu} y_H{}^{\mu} / y\right) + (1-\lambda)\,\partial \tilde{y}_L / \partial y\right)} \leq 0 \qquad (22)$$

with equations (13.3) and (20).

Propositions 4 and 5 constitute, respectively, the relative labour cost and the adverse aggregate demand effects of a binding central wage. Unfortunately, the latter is strongest at the equilibrium of concern, $\lambda = 0$, where lo-tech firms have the greatest weight.

The combined effect on the gross profits gain.

The central wage setters at stage one try to raise the gross implementation gain at $\lambda = 0$ for the possibility of eliminating the lo-tech general equilibrium. Lo-tech profits at $\lambda = 0$ where $y = \tilde{y}_L$ from equation (20) are:

$\pi_L = (1-\sigma)[(1-\theta\mu)y - f]$

Hi-tech gross profits are still given by (13.3) and the difference, the gross gain, becomes

$$\tilde{g}(0) = (1-\sigma)(1-\theta\mu)\left[(\theta\mu / e)^{\frac{\theta}{1-\theta}} A_H{}^{\frac{\mu}{1-\theta\mu}} y(\tilde{w},0)^{\frac{1-\mu}{1-\theta\mu}} - y(\tilde{w},0) \right] \qquad (23)$$

This is the unilateral gain to switching where all other firms remain with lo-tech production.

Proposition 6. *If the elasticity of substitution (or μ) is sufficiently high, a binding central wage will raise the gross gain from innovation at the lo-tech general equilibrium.*

The derivative of equation (23) is:

$$\frac{\partial \tilde{g}(0)}{\partial \tilde{w}} = (1-\sigma)(1-\theta\mu)\left[\left(\frac{1-\mu}{1-\theta\mu}\right)(\theta\mu/e)^{\frac{\theta}{1-\theta}} A_H^{\frac{\mu}{1-\theta\mu}} y(\tilde{w},0)^{\frac{-\mu(1-\theta)}{1-\theta\mu}} - 1\right]\frac{\partial y(\tilde{w},0)}{\partial \tilde{w}} \tag{24}$$

A positive sign for (24) is required. Inequality (22) and decreasing returns to scale, $\theta < 1$, imply that for this to be positive, it must be so where $y(\tilde{w},0)$ is greatest, where the central wage constraint just begins to bite at $y(\tilde{w},0) = y_L*$. Substituting in the value from equation (16.2) where $A_i = A_L$ gives the parameter condition as

$$((1-\mu)/(1-\theta\mu))(\theta\mu/e)^{\frac{\theta(1-\mu)}{(1-\theta)(1-\theta\mu)}}(A_H/A_L)^{\frac{\mu}{1-\theta\mu}} < 1 \tag{25}$$

It is required that the adverse aggregate demand effect is relatively weak in order for the gross gain to rise with the central wage. This is clearly demonstrated to be the case in the limit of an infinite elasticity of substitution, $\mu \to 1$, where there are no aggregate demand spill-overs at all, so the left-hand side term of (25) drops out, for $\theta < 1$. However, it is also necessary that $\mu < 1$ for the existence spill-overs and multiple equilibria [See Proposition 2]. So, the model works - in the present constant elasticity of substitution form - where μ is at an intermediate level.[17]

Provided this condition is satisfied, there may be either an interior maximum or a corner solution, where the second weak inequality in (17) holds, respectively, as a strong inequality and as an equality. These depend again on the elasticity of demand. If it is not satisfied, the centralization will only entrench the lo-tech equilibrium but with higher wages and lower profits.

Proposition 6 is necessary but not sufficient to eliminating the lo-tech equilibrium, since the gain may increase but not enough to exceed the cost. If the gross gain is

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[17] For example, where $\mu = 3/4$ and $\theta = 2/3$, condition (25) reduces to $(A_H/A_L)^{3/2} < 4e$.
An alternative specification where the elasticity of demand is decreasing in quantity would be favourable to the analysis.

large enough, the economy then moves to another general equilibrium with higher employment, output, wages and profits [from equations (16)]. Thus, a first stage of wage setting may raise the ultimate wage level, but at the gross gain - not the cost - of employment.

VI. Further Discussion.

The effect of the hold-up problem.

The fact that the technology decision precedes decentralized wage bargaining stage represents a hold-up, where the firm incurs all of the implementation cost. This has two basic implications. First, the lo-tech outcome is always less likely, because firms are unable to bargain away any share of the implementation cost on to the unions. Firms face the lower net gain of $g-c$ instead of $g-(1-\sigma)c$, which is significant where local unions are strong and their relative bargaining weight, σ, is large. Secondly, the unions will always prefer the hi-tech production as they do not share its cost. Alternatively, without a hold-up, the union payoff will merely be a proportion, $\sigma/(1-\sigma)$, of the firm's payoff. This implies that firms and unions will always agree on the choice of technology.

Creating a hi-tech equilibrium in the unique equilibrium case?

A lo-tech equilibrium can be eliminated in the multiple equilibria case, but can a hi-tech equilibrium be created in the unique lo-tech equilibrium case? The answer is yes in a technical sense, but problematic in terms of firms' incentives. First, at $\lambda=1$, there is no adverse aggregate demand effect to counter the beneficial relative cost effect, as no constrained lo-tech firms are present. However, firms would always be better-off at any remaining lo-tech general equilibrium and never agree to centralized wage setting in the unique equilibrium case. And, if the lo-tech equilibrium still remains alongside a newly created hi-tech equilibrium, there is still the coordination problem which has been assumed.

Coordination.

We now relax the maintained assumption that coordination is not possible. This effectively allows an collective choice of λ and a new condition for switching from the lo- to the hi-tech equilibrium in $\pi_H(1)-c>\pi_L(0)$. This is less stringent than the existence condition for a hi-tech Nash equilibrium in $\pi_H(1)-c>\pi_L(1)$ as $\pi_L(1)>\pi_L(0)$. The main implication is that coordination makes central wage setting redundant. Firms will have no incentive to agree to set a minimum wage.

A central or a statutory minimum wage?

It has been shown that central wage setting may in certain circumstances promote hi-tech production and the term, "central wage", has been used interchangeably with "minimum wage". This suggests that a statutory and a central minimum are at times perfect substitutes.[18]

In practice, the option of a central or a statutory minimum wage probably often comes down to political preferences concerning delegated decision making. Toft (1995) remarks that unemployment insurance in Denmark and Sweden has traditionally been administered through the labour unions, while in the UK and Germany it has been instituted by the state independently of the labour unions [Toft (1995)].[19] Governments may choose to work either independently from or alongside collective institutions. In Canada, US and UK, representatives of an "Anglo-Saxon model", there is little evident sympathy for labour market centralization and statutory minimum wage policies have been in operation. In Germany and Denmark, countries with a recent social democratic past, minimum wages effectively arise from a central bargaining process.[20]

The circumstances where firms would never agree to a minimum wage imply that a statutory minimum wage may at times achieve what centralization cannot. Assume that firms *can* but never choose to coordinate on the hi-tech equilibrium, because $\pi_H(1)-c<\pi_L(0)$. Now suppose the policy-maker imposes a statutory minimum wage which lowers $\tilde{\pi}_L(0)$ sufficiently below $\pi_L(0)$, so that $\pi_H(1)-c>\tilde{\pi}_L(0)$.

[18] It is arguable that there may be informational asymmetries, not here considered, which may favour centralization as a forum for information revelation and pooling.

[19] Toft (1995) suggests it is this circumstance which has led to the persistently high level of unionization in these Scandinavian countries.

[20] Somewhere between, the southern European approach is to give statutory clout to a mimimum wage bargained within labour market institutions.

Firms are now better-off by coordinating on the hi-tech equilibrium with the policy but are even better-off without the policy.[21] The same applies where coordination is not possible with a starting position where $\pi_H(0) - c < \pi_L(0)$ but with $\tilde{\pi}_H(0) - c > \tilde{\pi}_L(0)$ after the policy.

There are two common assumptions made about policy-maker preferences. One is that policy-makers prefer higher employment and output and, hence, the hi-tech equilibrium. Another is that the desire for re-election might lead to pursuing median voter preferences. We assume that the median voter is a union member. The hold-up now has interesting implications.

In the absence of binding local wage contracts, union preferences will coincide with both cases of government preferences, since policy-makers like union members do not incur any part of implementation costs. They would always agree on higher output and on the expediency of statutory minimum wages to achieve this aim. Union members might then favour interventionist governments, which institute statutory minimum wages.

In the presence of binding local wage contacts, however, where the implementation cost is shared, firms and unions, in this model, are always in agreement over the technology choice and, so, on whether a binding central wage should be set. Union members would in this case be favour hands-off governments, which free the reins for delegated decision-making. Policy-makers would concur only with median voter preferences. Thus, the so-called "social-democratic" outcome of centralization arises in this model through the existence of binding local wage contracts and finds governmental support where there is a primary desire for re-election.

Alternative models.

There are possibly alternative externalities, which will generate similar results. In an input-output structure firms may pass on productivity improvements from technology

[21] This works because there is scope for coordination. It would be better for firms to precommit against coordination, so there is no government incentive to set a mininum wage. However, the government also has an incentive to precommit to a minimum wage in order to make coordination the best (time-consistent) response by firms.

innovation to other firms as lower output prices (cheaper input prices for other firms) and as higher input demands (greater output demands elsewhere). There might also be other forms of labour market behaviour. The basic results are replicated in Roberts (1997) where labour is on its demand curve and employment is fixed at an insider level. The only general requirement is that wages are increasing in technology, so that central wage policy can discriminate against potential lo-tech firms.

Increasing the dimension of heterogeneity.

The only potential source of heterogeneity is from the binomial choice of technology, while strategic complementarity generates equilibria where all firms choose the same. Firms with idiosynchratic difference may have other incentives for central wage setting within the alternative framework of Cournot product market competition. More profitable firms may want to drive out less profitable rivals by the imposition of higher wage costs.[22] The minimum central wage may then decrease employment and output without giving any incentive for investment in new technology through worsening product market concentration. Less productive firms would then be reluctant to agree to centralized wage setting.[23]

VII. Summary.

A case for central wage setting, where it is complementary rather than substitutable with decentralized bargaining, has been presented in honour of what seems to be the general empirical case. There are both partial equilibrium advantages to introducing a new technology in higher employment, output, wages and profits (Proposition1) and external benefits in strategic complementarities (Proposition 2). Implementation costs may generate multiple equilibria where the economy becomes stuck in a low technology trap. The fact that wages will be higher in the hi-tech general equilibrium (Proposition 3) suggests that a binding central wage might selectively penalize lo-tech firms. This works through a favourable relative cost effect (Proposition 4), but there is also an offsetting aggregate demand effect (Proposition 5). The combined effect is favourable, if the elasticity of demand is not too low (Proposition 6). Then, for a sufficiently large increase in the gross gain of switching, a first round of central wage

[22] Profitability differences may derive from idiosynchratic differences in productivity, efficiency, access to cheaper inputs and union strength.

setting may actually raise employment, output and profits as well as the ultimate wage level.

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[23] This feature is found in the dual labour market model of Roberts, Staehr and Tranaes (2000).

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Appendix.

We prove that if hi-tech firms alone hit full employment, so that a rising λ does not increase their profits through rising employment, the property of strategic complementarity still remains despite this unfavourable asymmetry. The profit of the lo-tech firm for which $L_L < M_L$ remains as in equation (13.3). In the hi-tech firm, where $L_H = M$, the firm and union bargaining only over the wage which gives profits as

$$\pi_H = (1-\sigma)\left[A_H.^{\mu} M^{\theta\mu} y^{1-\mu} - e - f\right] \tag{A1}$$

The difference, the gross gain is

$$g = (1-\sigma)\left[A_H{}^{\mu} M^{\theta\mu} y^{1-\mu} - e - (1-\theta\mu)(\theta\mu/e)^{\frac{\theta\mu}{1-\theta\mu}} A_i{}^{\frac{\mu}{1-\theta\mu}} y^{\frac{1-\mu}{1-\theta\mu}}\right] \tag{A2}$$

Strategic complementarity remains, if $\partial g/\partial\lambda > 0$. This requires the inequality condition,

$$y^{-\mu\theta\left(\frac{1-\mu}{1-\theta\mu}\right)} A_H.^{\mu} M.^{\theta\mu} > (\theta\mu/e)^{\frac{\theta\mu}{1-\theta\mu}} A_L.^{\frac{\mu}{1-\theta\mu}} \tag{A3}$$

The least favourable case is where y is highest at the general equilibrium $\lambda = 1$, where $y(\lambda = 1) = A_H M.^{\theta}$ Substituting this back gives the revised condition, $A_H M^{\theta} > (\theta\mu/e)^{\frac{\theta}{1-\theta}} A_L.^{\frac{1}{1-\theta}}$ The fact that $M \geq L_H$ with equation (16.1) implies $M \geq (\theta\mu/e)^{\frac{1}{1-\theta}} A_H.^{\frac{1}{1-\theta}}$ and, so, $A_H M^{\theta} \geq (\theta\mu/e)^{\frac{\theta}{1-\theta}} A_H.^{\frac{1}{1-\theta}}$. As $A_H > A_L$, condition (A3) always holds for all values of λ. The reason is that there are still significantly high hi-tech profits rises from the aggregate demand spill-overs as λ increases.