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Labour Market Regulation, Productivity-Improving R&D and Endogenous Growth

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Labour Market Regulation, Productivity-Improving R&D and Endogenous Growth

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of Labor

Labour Market Regulation, Productivity-Improving R&D and Endogenous Growth

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ABSTRACT

Labour Market Regulation, Productivity-Improving R&D and Endogenous Growth

We present a growth model in which R&D increases productivity, union-firm bargaining determines the distribution of rents and the government can support unions by labour market regulation. We show that if unions are initially very strong, regulation increases only the workers' profit share and has no impact on employment and growth. Otherwise, regulation increases wages. Because firms try to escape this cost increase through the improvement of productivity by R&D, the economy grows faster. Regulation (deregulation) is desirable when the growth rate is below (above) some critical level.

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1 Introduction

The problem of high unemployment and low growth, a phenomenon called 'Eurosclerosis', is one of the most pressing economic problems in the European Union. Recently, the OECD Jobs Study took a stand on this problem by arguing that strengthening competitive forces in the economy would foster economic growth and reduce unemployment.[1] To examine this, I establish an endogenous-growth model in which unemployment is caused by efficiency wages and union-firm bargaining. Following Blanchard and Giavazzi (2001), we think of labour market regulation (deregulation) as increasing (decreasing) the bargaining power of the labour unions.

The review of the literature shows that the relationship between growth and labour market regulation can be highly institution-specific. Peretto (2000) examines the effects of regulation by a product-variety model in which labour is employed only in production and final goods can be directly used in $R\&D$. He also assumes that unions completely ignore that the increase of their wages affects productivity through $R\&D$. Peretto's main assertion is that a fall in union power promotes $R\&D$ and growth through a higher profit margin. In contrast, we assume that labour is used both in production and $R\&D$ and unions take into account also the effects through $R\&D$.

Palokangas (1996, 2000) introduces wage bargaining into Romer's (1990) product-variety model in which $R\&D$ employs labour only but final goods are produced from skilled labour, unskilled labour and intermediate products. He shows that higher relative union bargaining power leads to a higher growth rate as follows. Because $R\&D$ employs skilled labour and increases aggregate labour income, the union does not accept any agreement causing unemployment of skilled labour. With full employment of skilled labour, the increase in union power speeds up economic growth through a transfer of skilled labour from the production of final goods to $R\&D$. This conclusion results however from three specific assumptions. First, bargaining is carried out at the level of an industry or the economy rather than at the level of a single firm. Second, there are two separate labour inputs, skilled and un-

[1] Cf. OECD (1994), pp. 23 and 53: 'Establishing a competitive environment could, therefore, improve job prospects by both eliminating wage premia and encouraging output expansion.'

skilled labour, which are both organized in the same labour union. Third, there are no efficiency wages. In contrast, we assume union-firm bargaining, homogeneous labour and efficiency wages.

This paper is organized as follows. Labour market imperfections, which play a crucial role in the analysis, are presented in section 2. Sections 3 and 4 specify the behaviour of consumers and high-tech firms. Section 5 considers union-firm bargaining and section 6 optimal labour market regulation.

2 The labour market

The economy consists of two sectors that produce consumption goods. The *high-tech sector* contains a fixed number n of similar price-setting firms (indexed $i = 1, ..., n$), each of which manufactures one variety of the differentiated products, produces new knowledge and uses labour, knowledge and some non-traded factor as inputs. The *traditional sector* comprises competitive firms that produce unit of output from one labour unit. A high-tech firm and a firm-specific union bargain over the wage and the workers' profit share taking macroeconomic variables (e.g. the price level, aggregate consumption, the expected labour income elsewhere) as given. Labour market regulation determines relative union bargaining power.

We assume that labour supply N is fixed, for simplicity. Because the traditional sector is competitive, we obtain the equilibrium condition

$$L + \sum_{i=1}^{n} l_i = N, \tag{1}$$

where L is the employment of physical labour in the traditional sector and l_i is that in the ith high-tech firm (hereafter firm i). Firm i pays a share s_i of its profit π_i to its workers in proportion to employment. Since the profit share is non-negative for both parties, we obtain

$$0 \leq s_i \leq 1. \tag{2}$$

The total wage is then given by

$$v_i \doteq w_i + s_i \pi_i / l_i, \tag{3}$$

where w_i is the base wage and $s_i\pi_i/l_i$ the profit share per worker. Labour income U_i in firm i is equal to the total wage (3) times employment l_i:

$$U_i \doteq v_i l_i = w_i l_i + s_i \pi_i. \tag{4}$$

When a worker quits high-tech firm i, his expected income elsewhere in the economy, v_{-j}, is given by the probability-weighed average

$$v_{-i} \doteq \sum_{j \neq i} v_j \frac{l_j}{N - l_i} + \varpi \frac{L}{N - l_i} = \frac{1}{N - l_i} \Big[\sum_{j \neq i} v_j l_j + \varpi L \Big], \tag{5}$$

where v_i is the total wage in firm j, $l_j/(N-l_i)$ the probability of getting a job in firm j, ϖ the wage in the traditional sector and $L/(N-l_i)$ the probability of being employed by the traditional sector.

An employee in firm i works the harder, the higher his wage v_i relative to his prospective earnings elsewhere, v_{-i}. Consequently, a worker's effort in firm i, E_i, increases with the ratio v_i/v_{-i}:[2]

$$E_i = E(v_i/v_{-i}), \quad E' > 0, \quad E(1) = 0. \tag{6}$$

Efficient labour input in firm i is then given by

$$x_i = E_i l_i. \tag{7}$$

Because a worker would not make any effort if he earned the same income outside the firm, $E(1) = 0$, there must be $E_i > 0$ and $v_i > v_{-i}$.[3]

If firm i could alone choose its base wage w_i and profit share s_i, it would give up profit sharing, $s_i = 0$, and minimize the unit labour cost $v_i/E_i = v_i/E(v_i/v_{-i})$ by the wage $v_i = w_i$, given a worker's expected income elsewhere v_{-i}. This defines a non-union wage,

$$\tilde{v}_i = \arg\min_{v_i} [v_i/E(v_i/v_{-i})] = \epsilon v_{-i}, \text{ where } \epsilon > 1 \text{ and } \epsilon E'(\epsilon) = E(\epsilon). \tag{8}$$

Because a worker is willing to join a labour union only if this increases his income, the total wage for a member, v_i, must exceed the non-union wage

[2]This function is constructed in line with Solow (1979), Summers (1988) and Garino and Martin (2000). However, the results in this paper hold even if the effort per worker is wholly inflexible, $E' \equiv 0$, provided that there is unemployment in the equilibrium.

[3]This property simplifies the analysis by eliminating full employment in the model.

$\tilde{v}_i = \epsilon v_{-i}$. Given this and (8), a wage increase raises unit labour cost v_i/E_i:[4]

$$\frac{\partial}{\partial v_i}\Big[\frac{v_i}{E(v_i/v_{-i})}\Big] = \frac{1}{E}\Big[1 - \frac{E'}{E}\,\frac{v_i}{v_{-i}}\Big] > 0.$$

The agents act as players in the following extensive game. First, the government determines relative union bargaining power. Second, each union-firm pair bargains over the wage and the workers' profit share. Third, firms decide on output and $R\&D$. Fourth, consumers decide on spending and saving. The model is solved by backward induction in sections 3-6.

3 Consumers

Because all consumers are price takers, we can aggregate them into a single agent. This representative consumer's intertemporal utility is given by

$$\int_0^\infty \frac{1}{1-\sigma}[c^{1-\sigma} - 1]e^{-\rho t}dt \text{ with } \rho > 0,\ \sigma > 0 \text{ and } \sigma \neq 1, \tag{9}$$

where c is an index of composite consumption of high-tech goods, $1/\sigma$ the intertemporal elasticity of substitution, ρ the subjective discount rate and t time. The index c is produced from high-tech and traditional goods according to Cobb-Douglas technology. The elasticity of substitution between any two of the high-tech goods, $\mu > 1$, is constant. These assumptions imply

$$c = y^{\xi}L^{1-\xi}, \quad 0 < \xi < 1, \quad y = \Big[\frac{1}{n}\sum_{i=1}^{n} y_i^{1-1/\mu}\Big]^{\mu/(\mu-1)}, \quad \mu > 1, \tag{10}$$

where y_i represents the quantity of high-tech good i consumed, y the index of the high-tech goods, L the quantity of traditional goods consumed and parameter ξ the relative weight of high-tech goods in consumption.

The consumer decides on how to divide his spending over the goods. We choose the consumption price for the composite high-tech good y as the numeraire. Because the traditional sector produces one unit of output from

[4]This result is necessary for the uniqueness of the equilibrium. Otherwise, there could be two equilibria: one with a high wage v_i and high effort E_i, and the other with a low wage and low effort.

one labour unit, its output price is equal to its wage ϖ. Given the Cobb-Douglas function in (10), we then obtain

$$\varpi L/\xi = y/(1-\xi) = Pc, \quad P = \zeta \varpi^{1-\xi}, \tag{11}$$

where $\zeta > 0$ is a constant. Given the CES function in (10), we obtain the price p_i for high-tech good i as a function of the output of the good, y_i, and the index of high-tech output, y, with the following properties:

$$p_i(y_i, y) = \frac{\partial y}{\partial y_i} = \frac{1}{n}\Big(\frac{y}{y_i}\Big)^{1/\mu}_{,} \quad \sum_i p_i y_i = y, \quad \frac{\partial (p_i y_i)}{\partial y_i} = \Big(1 - \frac{1}{\mu}\Big) p_i. \tag{12}$$

The consumer takes the interest rate r, the consumption price P and his income I as given and maximizes utility (9) subject to the accumulation of wealth Ω over time, $\dot{\Omega} \doteq d\Omega/dt = r\Omega + I - Pc$, where c is consumption. In the steady state, this maximization yields

$$g \doteq \dot{c}/c = (r - \rho)/\sigma, \tag{13}$$

where g is the growth rate of consumption. Solving for the interest rate yields

$$r = \rho + \sigma g. \tag{14}$$

Because in the steady state the demand for labour in the traditional sector, L, is constant, conditions (11) and (13) imply

$$\frac{\dot{y}}{y} = \frac{\dot{\varpi}}{\varpi} = \frac{\dot{P}}{P} + \frac{\dot{c}}{c} = (1-\xi)\frac{\dot{\varpi}}{\varpi} + \frac{\dot{c}}{c} = (1-\xi)\frac{\dot{y}}{y} + g \text{ and } \frac{\dot{y}}{y} = \frac{g}{\xi}. \tag{15}$$

4 High-tech firms

The production and management of each product requires its own product-specific knowledge. Because a high-tech firm cannot directly apply techniques and procedures developed by other high-tech firms, these being tailored to the specific situation of others, product-specific knowledge can be accumulated only through product-specific $R\&D$ targeted at one product.[5] Firm i's productivity both in production and in $R\&D$ is in fixed proportion to its

[5]The process of innovation in the model is a minor modification of that in Smulders and Van der Klundert (1995) and Van Schaik and De Groot (1998).

stock of knowledge h_i, which is accumulated by $R\&D$. Its output y_i and the increase in its productivity, $\dot{h}_i$, are then given by

$$y_i = m_i h_i, \tag{16}$$

$$\dot{h}_i = z_i h_i, \tag{17}$$

where m_i and z_i are intermediate inputs in production and $R\&D$.

Firm i possesses a fixed amount of non-traded input and employs the amount x_i of efficient labour. Both m_i and z_i can be produced from these two inputs with constant returns to scale. On the assumptions that there is no factor intensity reversal and the increase in efficient labour x_i increases output, the increase in x_i must decrease $R\&D$ by Rybczynski's theorem. The resulting Rybczynski line can be expressed by two monotonous functions:

$$m_i = m(x_i), \quad m' > m_i/x_i > 0, \quad z_i = z(x_i), \quad z' < 0. \tag{18}$$

Given the inverse demand function in (12), we obtain profits

$$\pi_i = p_i(y_i, y)y_i - w_i l_i. \tag{19}$$

The firm chooses the employment of efficient labour, x_i, to maximize the present value of the flow of profits $\int_0^\infty \pi_i e^{-rt} dt$, where r is the interest rate, subject to the accumulation of knowledge (17), given the base wage w_i, the effort per worker, E_i, and aggregate demand y. Given (12), (16), (18) and (19), it is equivalent to maximize at each moment of time the Hamiltonian

$$\begin{aligned}\mathcal{H}_i &= \pi_i + q_i \dot{h}_i = p_i y_i - w_i l_i + q_i \dot{h}_i = p_i(y_i, y)y_i - (w_i/E_i)x_i + q_i z_i h_i \\ &= p_i(m(x_i)h_i, y)m(x_i)h_i - (w_i/E_i)x_i + q_i z(x_i)h_i \end{aligned} \tag{20}$$

by x_i, where the shadow price of knowledge, q_i, evolves according to

$$\dot{q}_i = rq_i - \frac{\partial \mathcal{H}_i}{\partial h_i} = (r - z_i)q_i - \frac{\partial(p_i y_i)}{\partial y_i} m_i, \quad \lim_{t\to\infty} q_i h_i e^{-\rho t} = 0.$$

To explain this equation, we write it as follows:

$$r - \frac{\dot{q}_i}{q_i} = z_i + \frac{\partial(p_i y_i)}{\partial y_i}\frac{m_i}{q_i}. \tag{21}$$

Assume that the firm increases its stock of knowledge h_i by one unit. Output then increases by m_i and, by multiplying this by the marginal revenue of

output (in terms of knowledge), $(1/q_i)[\partial(p_i y_i)/\partial y_i]$, we obtain the marginal revenue of knowledge in production, $(m_i/q_i)[\partial(p_i y_i)/\partial y_i]$. The marginal revenue of knowledge in $R\&D$ is given by $\partial \dot{h}_i/\partial h_i = z_i$. The sum of these must be equal to the marginal cost of knowledge, which (in terms of knowledge) consists of the interest rate r minus capital gains $\dot{q}_i/q_i$.

The maximization of the Hamiltonian (20) by z_i yields

$$\frac{w_i}{E_i} = \Big[\frac{\partial(p_i y_i)}{\partial y_i} m'(x_i) + q_i z'(x_i)\Big] h_i. \tag{22}$$

Because firm i has only one accumulating asset h_i, it is always in the steady state where $\dot{y}_i/y_i = \dot{h}_i/h_i$ holds and inputs m_i, z_i and x_i are constants. With the normalization of the consumption price at unity, the output price p_i and the shadow price q_i are constants. Given this, (14), (17) and (21), we obtain

$$\dot{y}_i/y_i = \dot{h}_i/h_i = z_i, \quad h_i(t) = h_i(0)e^{z_i t}, \quad \rho + \sigma g = r = z_i + \frac{\partial(p_i y_i)}{\partial y_i}\frac{m_i}{q_i}. \tag{23}$$

Solving for q_i from this yields

$$q_i = \frac{\partial(p_i y_i)}{\partial y_i}\,\frac{m_i}{\rho + \sigma g - z_i}.$$

Inserting this into (22) and noting (12) and (18), we obtain

$$\begin{aligned}\frac{w_i}{E_i p_i} = \Phi_i(x_i, g, h_i) &\doteq \left[m' + \frac{z' m_i}{\rho + \sigma g - z_i}\right]\frac{\partial(p_i y_i)}{\partial y_i}\frac{h_i}{p_i} \\ &= \Big(1 - \frac{1}{\mu}\Big)\left[m'(x_i) + \frac{z'(x_i)m(x_i)}{\rho + \sigma g - z(x_i)}\right] h_i. \end{aligned} \tag{24}$$

The dependence of $w_i/(E_i p_i)$ on x_i through (24) is ambiguous. We make the plausible assumption that given the stock of knowledge, h_i, and the growth rate g (or the interest rate $r = \rho + \sigma g$), an increase in real unit labour cost $w_i/(E_i p_i)$ decreases the employment of efficient labour, x_i:

$$\partial \Phi_i/\partial x_i < 0. \tag{25}$$

Given (7), (16), (18), (24) and (25), we define the ratio of base wages $w_i l_i$ to income as a function of employment x_i, and the growth rate g:

$$\begin{aligned}&\phi_i(x_i, g) \doteq \frac{w_i l_i}{p_i y_i} = \frac{w_i x_i}{E_i p_i m_i h_i} = \frac{\Phi_i(x_i, g, h_i) x_i}{m(x_i) h_i} \in (0, 1) \\ &\text{with } \frac{\partial \phi_i}{\partial x_i} = \frac{x_i}{m_i h_i}\frac{\partial \Phi_i}{\partial x_i} + \frac{\Phi_i}{h_i}\Big(\frac{1}{m_i} - \frac{x_i}{m_i^2} m'\Big) < 0. \end{aligned} \tag{26}$$

Given $\mu > 1$, (12), (16), (19), (24), (23) and (26), we obtain the present values for the flows of output, wages and profits for firm i, Y_i, W_i and P_i, as:

$$\begin{aligned}
Y_i(x_i, g, y) &\doteq \int_0^\infty p_i y_i e^{-rt} dt = \frac{y^{1/\mu}}{n} \int_0^\infty y_i^{1-1/\mu} e^{-rt} dt \\
&= \frac{y^{1/\mu}}{n} m_i^{1-1/\mu} \int_0^\infty h_i^{1-1/\mu} e^{-rt} dt \\
&= h_i(0)^{1-1/\mu} \frac{y^{1/\mu}}{n} m(x_i)^{1-1/\mu} \int_0^\infty \exp\Big\{ \Big[\Big(1 - \frac{1}{\mu}\Big) z_i - r \Big] t \Big\} dt \\
&= h_i(0)^{1-1/\mu} \frac{y^{1/\mu}}{n} m(x_i)^{1-1/\mu} \Big[r - \Big(1 - \frac{1}{\mu}\Big) z_i \Big]^{-1} \\
&= h_i(0)^{1-1/\mu} \frac{y^{1/\mu}}{n} m(x_i)^{1-1/\mu} \Big[\rho + \sigma g - \Big(1 - \frac{1}{\mu}\Big) z(x_i) \Big]^{-1}, \qquad (27)
\end{aligned}$$

$$W_i(x_i, g, y) \doteq \int_0^\infty w_i l_i e^{-rt} dt = \phi_i \int_0^\infty p_i y_i e^{-rt} dt = \phi_i(x_i, g) Y_i(x_i, g, y), \qquad (28)$$

$$\Pi_i(x_i, g, y) \doteq \int_0^\infty \pi_i e^{-rt} dt = Y_i(x_i, g, y) - W_i(x_i, g, y). \qquad (29)$$

5 Union-firm bargaining

Firm i and a firm-specific union bargain over the wage w_i and the workers' profit share s_i. We assume that in the case of a dispute there is no production, and consequently no labour income and no profits. The reference income is then zero for both the firm and the union. Some papers assume that the expected wage outside the firm is the union's reference point,[6] but this is not quite in line with the microfoundations of the alternating offers game. Binmore, Rubinstein and Wolinsky (1986) state (pp. 177, 185-6) that the the reference income should not be identified with the outside option point. Rather, despite the availability of these options, it remains appropriate to identify the reference income with the income streams accruing to the parties in the course of the dispute.[7] Accordingly, a worker's expected income elsewhere, v_{-i}, affects his effort in the workplace, E_i, but not the union's reference income.

[6] E.g. in Garino and Martin (2000).

[7] For example, if the dispute involves a strike, these income streams are the employee's income from temporary work, union strike funds, and similar sources, while the employer's income might derive from temporary arrangements that keeps the business running.

The union attempts to maximize the present value $\mathcal{U}_i$ of labour income U_i and the firm attempts to maximize the present value $\mathcal{P}_i$ of the owner's profit share $(1-s_i)\pi_i$. Given (4), (28) and (29), we obtain these targets as:

$$\mathcal{U}_i(s_i, x_i, g, y) = \int_0^\infty U_i e^{-rt} dt = W_i + s\Pi, \;\; \mathcal{P}_i(s_i, x_i, g, y) = (1-s_i)\Pi_i. \quad (30)$$

Because targets $\mathcal{U}_i$ and $\mathcal{P}_i$ are constants, the solution for the asymmetric Nash bargain is obtained through maximizing the Generalized Nash Product $\mathcal{U}_i^\alpha \mathcal{P}_i^{1-\alpha}$, where parameter $0 < \alpha < 1$ is the union's relative bargaining power, subject to constraints (2) by the wage w_i and the profit share s_i, taking aggregate demand y and the growth rate of consumption, g, as given.

Because there is a one-to-one correspondence between w_i and x_i through (6) and (24), we can replace w_i by x_i as the instrument of the maximization. Maximizing $\mathcal{U}_i^\alpha \mathcal{P}_i^{1-\alpha}$ by x_i and $s_i \in [0,1]$ and noting the symmetry throughout all i, we obtain (see Appendix A)

$$\xi z(x) = g(\alpha) \;\text{ with }\; \begin{cases} g' > 0 \text{ for } 0 < \alpha < \overline{\alpha}, \\ g' \equiv 0 \text{ for } \overline{\alpha} \leq \alpha \leq 1, \end{cases} \quad (31)$$

where $\overline{\alpha} \in (0,1]$ is a constant. This result can be rephrased as follows:

Proposition 1 *There exists a critical level of* $\overline{\alpha} \in (0,1]$ *of the relative union bargaining power* α *as follows:*

(i) *If unions are strong enough,* $\alpha \geq \overline{\alpha}$*, there is profit sharing and the the wage* w_i *is chosen to maximize the present value of output* (27)*. In such a case, labour market regulation has no effect on growth,* $dg/d\alpha = 0$*.*

(ii) *If unions are not too strong,* $\alpha < \overline{\alpha}$*, there is no profit sharing,* $s_i = 0$ *and* $v_i = w_i$ *for all* i*. In such a case, labour market regulation (i.e., the increase in* α*) promotes economic growth,* $dg/d\alpha > 0$*.*

If unions are strong enough (i.e., if α close enough to one), they can claim a share of profits on the top of the wages. In such a case, relative union bargaining power determines the workers' profit share but it is in the interests of both parties to choose the base wage w_i to maximize the discounted value of output. A change in relative union bargaining power has then no effect

on employment or economic growth. If unions are relatively weak (i.e., if α not too close to one), there is no profit sharing and employment and $R\&D$ decisions depend on relative union bargaining power α. Regulation (i.e., the increase in α) then increases the wage w_i relative to effort E_i. The increase in average labour cost w_i/E_i decreases employment and firms escape this cost increase by transferring resources from production to $R\&D$. A higher level of $R\&D$ will lead to a higher growth rate.

6 Welfare evaluation

Now we examine the optimal level of labour market regulation. Because, by proposition 1, regulation is totally ineffective for $\alpha \geq \overline{\alpha}$, we focus on the case $\alpha < \overline{\alpha}$ for which $s_i = 0$ and $v_i = w_i$. With perfect symmetry through all firm-union pairs $i = 1, ..., n$, we obtain $l_i = l$, $x_i = x$, $y_i = y$ and $v_i = w_i = w$. Given (18), the accumulation of knowledge in (23) takes then the form

$$\dot{h}/h = z(x), \tag{32}$$

and total consumption is determined by (see Appendix B)

$$c = h^{\xi}\varphi(x). \tag{33}$$

The government maximizes the welfare of the representative consumer (9) by labour market regulation/deregulation (i.e. by increasing/decreasing α) subject to the consumption function (32) and the accumulation of knowledge (33). Since there is one-to-one correspondence from α to x through (18) and (31), we can replace α by x as the instrument of the maximization. The Hamiltonian corresponding to the government's problem is then given by

$$\mathcal{F} = \frac{1}{1-\sigma}[c^{1-\sigma} - 1] + \lambda z(x)h = \frac{1}{1-\sigma}[\varphi(x)^{1-\sigma}h^{(1-\sigma)\xi} - 1] + \lambda z(x)h, \tag{34}$$

where the co-state variable λ evolves according to

$$\dot{\lambda} = \rho\lambda - \frac{\partial \mathcal{F}}{\partial h} = [\rho - z(x)]\lambda - \xi\varphi(x)^{1-\sigma}h^{(1-\sigma)\xi-1}, \quad \lim_{t\to\infty} \lambda h e^{-\rho t} = 0. \tag{35}$$

At each moment of time, the Hamiltonian (34) must be maximized. This produces the first-order condition $\partial\mathcal{F}/\partial x = \lambda h z' + \varphi^{-\sigma}h^{(1-\sigma)\xi}\varphi' = 0$ or

$$\lambda = -\varphi(x)^{-\sigma}h^{(1-\sigma)\xi-1}\varphi'(x)/z'(x). \tag{36}$$

Because the government has only one accumulating asset, it is always in the steady state where the level of employment, x, is constant. Equations (32) and (36) then yield $\dot{\lambda}/\lambda = [(1-\sigma)\xi - 1]\dot{h}/h = [(1-\sigma)\xi - 1]z$. Inserting this, (14), (36) and $g = \xi z$ from (31) into (35), we obtain

$$[(1-\sigma)\xi - 1]z = \dot{\lambda}/\lambda = \rho - z - \xi\varphi^{1-\sigma}h^{(1-\sigma)\xi-1}/\lambda = \rho - z + \xi z'\varphi/\varphi'$$

and

$$\xi z'\varphi/\varphi' = (1-\sigma)z\xi - \rho = (1-\sigma)g - \rho = g - r. \tag{37}$$

Because the integral (9) converges only if $\rho < (1-\sigma)\dot{c}/c = (1-\sigma)g$, from equations (33) and (37) it follows that consumption and employment are positively associated, $\varphi' > 0$ and $\partial c/\partial x > 0$. Noting this, (18), (31) and (33), we define the elasticity of the level of $R\&D$, z, with respect to consumption $c = \varphi h^{\xi}$ when the level of productivity, h, is kept constant, as:

$$\theta \doteq \left|\frac{\partial z}{\partial c}\frac{c}{z}\right| = \left|\frac{\partial z}{\partial x}\frac{\partial x}{\partial c}\frac{c}{z}\right| = \left|\frac{z'\varphi}{z\varphi'}\right| = -\frac{z'\varphi}{z\varphi'} = -\frac{\xi z'\varphi}{g\varphi'} > 0.$$

Inserting (37) into this definition, we obtain the growth rate maximizing the representative consumer's welfare, $g^* = r/(1+\theta)$. This, together with proposition 1, leads to the following policy rule:

Proposition 2 *The government should regulate (deregulate) the labour market as long as the growth rate g is below (above) $g^* \doteq r/(1+\theta)$.*

Inserting $r = \rho + \sigma g^*$ from (14) into $g^* = r/(1+\theta)$, we obtain $g^* = \rho/(1-\sigma+\theta)$ and the following corollary:

Proposition 3 *The lower the elasticity of $R\&D$ is with respect to consumption, θ, the more likely regulation increases welfare (i.e., the more likely $g < g^*$).*

Propositions 2 and 3 are explained in the final section.

7 Conclusions

In this paper, efficiency wages, union-firm bargaining and profit sharing were incorporated into a unified framework of endogenous growth. We were interested in how regulation (deregulation), which strengthens (weakens) unions in bargaining, affects economic growth. An employee works the harder, the more more the wage in the firm exceeds the expected labour income outside the firm. A firm accumulates knowledge and increases its productivity by doing $R\&D$. In this framework, we obtain the following results.

Provided that union power is not initially too high, labour market regulation decreases employment and current consumption but fosters economic growth. When union bargaining position is improved, wages increase relative to a worker's effort and firms try to escape this cost increase through improved productivity, by increasing its $R\&D$. With larger $R\&D$, the economy will grow at a faster rate. If unions are strong enough, they can claim a share of profits on the top of their wages. Unions and firms then share the profit in fixed proportion to their relative bargaining power and maximize the discounted value of total income by the wage, so that labour market regulation will not affect $R\&D$ and growth.

The desirability of regulation or deregulation depends on whether economic growth is too fast or too slow from the welfare point of view. If this is too fast, the labour market should be deregulated to slow down technological change. Overly slow growth can be eliminated by labour market regulation. The higher the elasticity of $R\&D$ with respect to consumption (given the interest rate), the more likely regulation increases welfare. Consumption and $R\&D$ are produced from the same resources. The more a decrease in current consumption by one unit increases future consumption through larger $R\&D$ and a higher growth rate, the higher is the welfare-maximizing growth rate and the more likely actual growth should be promoted by regulation.

While a great deal of caution should be exercised when a highly stylized mathematical model is used to draw conclusions about the effects of regulation on growth, the following judgement nevertheless seems to be justified. Since the institutional specification of the labour market is significant for the outcome of regulation, in contrast to the OECD Jobs Study, strengthening competitive forces in the labour market may slow down economic growth.

Appendix

A. The proof of result (31)

We deduce first two useful subresults. Given (27), we obtain

$$\frac{\partial^2 \log Y_i}{\partial x_i \partial y} = 0. \tag{38}$$

Because there is symmetry through all i, in the macroeconomic equilibrium there must be $z_i = z$, $x_i = x$, $l_i = l$, $y_i = y$ and $v_i = v$. Given this, (10), (15), (18) and (23), we obtain

$$g = \xi \frac{\dot{y}}{y} = \frac{\xi}{y} \sum_{k=1}^{n} \frac{\partial y}{\partial y_k} \dot{y}_k = \frac{\xi}{n} \sum_{k=1}^{n} \Big(\frac{y}{y_k} \Big)^{1/\mu - 1} z_k, \quad g\big|_{y_k = y} = \frac{\xi}{n} \sum_{k=1}^{n} z(x_k). \tag{39}$$

Given equations (4), (12), (16) and (28)-(30), we define a function

$$\begin{aligned}
&\Gamma_i(s_i, x_i, g, y, \alpha) \doteq \log[\mathcal{U}_i^{\alpha} \mathcal{P}_i^{1-\alpha}] = \alpha \log \mathcal{U}_i + (1-\alpha) \log \mathcal{P}_i \\
&= \alpha \log[W_i(x_i, g, y) + s_i \Pi_i(x_i, g, y)] + (1-\alpha)[\log \Pi_i(x_i, g, y) + \log(1 - s_i)] \\
&= \alpha \log[(1 - s_i) W_i + s_i Y_i] + (1-\alpha) \log(Y_i - W_i) + (1-\alpha) \log(1 - s_i) \\
&= \log Y(x_i, g, y) + \alpha \log[(1 - s_i)\phi_i(x_i, g) + s_i] + (1-\alpha) \log[1 - \phi_i(x_i, g)] \\
&\quad + (1-\alpha) \log(1 - s_i).
\end{aligned} \tag{40}$$

The outcome of bargaining is obtained through maximizing the logarithm of the Nash product (40) s.t. $0 \leq s_i \leq 1$ by x_i and s_i, keeping g and y constant. This is equivalent to the maximization of the Lagrangean

$$\mathcal{L}_i = \Gamma_i(s_i, x_i, g, y, \alpha) + \chi_1 s_i + \chi_2 (1 - s_i)$$

subject to Kuhn-Tucker conditions

$$\chi_1 s_i = 0, \;\; \chi_1 \geq 0, \;\; \chi_2 (1 - s_i) = 0, \;\; \chi_2 \geq 0. \tag{41}$$

Given (40), we obtain the first-order conditions for s_i and x_i as:

$$\begin{aligned}
&\frac{\partial \mathcal{L}_i}{\partial s_i} = \frac{\partial \Gamma_i}{\partial s_i} + \chi_1 - \chi_2 = \frac{\alpha(1 - \phi_i)}{(1 - s_i)\phi_i + s_i} - \frac{1 - \alpha}{1 - s_i} + \chi_1 - \chi_2 = 0, \\
&\partial \mathcal{L}_i / \partial x_i = \partial \Gamma_i / \partial x_i = 0.
\end{aligned} \tag{42}$$

Consider first the case where

$$\text{either} \quad \alpha = 1 \quad \text{or} \quad \frac{1-\alpha}{\alpha} = \frac{(1-s_i)(1-\phi_i)}{(1-s_i)\phi_i + s_i}. \tag{43}$$

If $\alpha = 1$, then (40), (41) and (42) produce

$$\chi_2 = \frac{1-\phi_i}{(1-s_i)\phi_i + s_i} + \chi_1 > \chi_1 \geq 0, \quad s = 1, \quad \Gamma_i = \log Y_i.$$

This means that the maximization of (40) by x_i is equivalent to the maximization of the present value of output, Y_i, by x_i:

$$x_i = \arg\max_{x_i} Y_i(x_i, g, y). \tag{44}$$

Next, assume $\alpha < 1$ and

$$\frac{1-\alpha}{\alpha} = \frac{(1-s_i)(1-\phi_i)}{(1-s_i)\phi_i + s_i}. \tag{45}$$

This, (29) and (40) yield $(1-s_i)\phi_i + s_i = \alpha$, $(1-s_i)(1-\phi_i) = 1-\alpha$ and

$$\Gamma_i = \log Y_i(z_i, g, y) + \text{constants}.$$

Again, the maximization of (40) by x_i is equivalent to the maximization of Y_i by x_i. We conclude that if (43) holds, then x_i is determined by (44). Noting this and the first-order condition for x_i, we can define a constant

$$\overline{\alpha} = \inf\{\alpha | \ \partial \mathcal{L}_i / \partial x_i = 0 \ \text{ and (43) holds}\} \leq 1. \tag{46}$$

Because in the model there is symmetry through all i, this yields

$$x_i = x = \arg\max_{x} Y_i(x, g, y) \ \text{ for } \alpha \geq \overline{\alpha}. \tag{47}$$

From (39) and (47) it follows that inputs x_i for all i and the growth rate g are independent of α for $\alpha \geq \overline{\alpha}$.

If $\alpha \to 0$, then given (41) and (42) we obtain

$$\chi_1 = (1-\alpha)/(1-s_i) + \chi_2 > \chi_2 \geq 0, \quad s_i = 0.$$

Hence, for sufficiently small values of α condition (43) cannot hold. Given this result and (46), there must be $\overline{\alpha} > 0$. Because condition (44) holds for $\overline{\alpha} \leq \alpha \leq 1$, the equilibrium of the system is independent of α and

$$dz/d\alpha = 0 \text{ for } \overline{\alpha} \leq \alpha \leq 1. \tag{48}$$

Finally, consider the case

$$0 < \alpha < \overline{\alpha}. \tag{49}$$

It follows that (43) does not hold and

$$\alpha < 1, \quad \frac{1-\alpha}{\alpha} \neq \frac{(1-s_i)(1-\phi_i)}{(1-s_i)\phi_i + s_i}. \tag{50}$$

holds. Because $s_i = 1$ is in contradiction with (50), $s_i < 1$ obtains. From $s_i < 1$, (41), (42) and (50) it follows

$$\chi_2 = 0, \quad \chi_1 = \frac{1-\alpha}{1-s_i} - \frac{\alpha(1-\phi_i)}{(1-s_i)\phi_i + s_i} > 0, \quad s_i = 0.$$

Given $s_i = 0$, the function (40) takes the form

$$\Gamma_i(0, x_i, g, \alpha, y) = \log Y(x_i, g, y) + \alpha \log \phi_i(x_i, g) + (1-\alpha)\log[1 - \phi_i(x_i, g)],$$

and the remaining first-order condition the form

$$\frac{\partial \Gamma_i}{\partial x_i} = \frac{\partial \log Y_i(x_i, g, y)}{\partial x_i} + \frac{\alpha/\phi_i(x_i, g) - 1}{1 - \phi_i(x_i, g)} \frac{\partial \phi_i(x_i, g)}{\partial x_i} = 0. \tag{51}$$

This, (26) and (38) yield

$$\frac{\partial^2 \Gamma_i}{\partial x_i \partial c} = \frac{\partial^2 \log Y_i}{\partial x_i \partial c} = 0, \quad \frac{\partial^2 \Gamma_i}{\partial x_i \partial \alpha} = \frac{1}{(1-\phi_i)\phi_i} \frac{\partial \phi_i}{\partial x_i} < 0. \tag{52}$$

Noting (26), (52) and the second-order condition $\partial^2 \Gamma_i / \partial x_i^2 < 0$, and differentiating the first-order condition (51) totally, we define the function

$$x_i = \Psi(\alpha, g) \text{ with } \frac{\partial \Psi}{\partial \alpha} = -\frac{\partial^2 \Gamma_i}{\partial x_i \partial \alpha} \Big/ \frac{\partial^2 \Gamma_i}{\partial x_i^2} < 0 \text{ for } 0 < \alpha < \overline{\alpha}. \tag{53}$$

Noting the symmetry over i and inserting the right-hand equation of (39) into the functions (53), we obtain a system of n equations

$$\Delta_i = x_i - \Psi(\alpha, g) = x_i - \Psi\Big(\alpha, \frac{\xi}{n} \sum_k z(x_k)\Big) = 0 \text{ for } j = 1, ..., n, \tag{54}$$

with endogenous variables $x_1, ..., x_n$. Differentiating the system (54), we obtain the coefficient matrix

$$\big(\partial \Delta_i / \partial x_k\big)_{n \times n}. \tag{55}$$

The reaction function for each sector i is given by (54). With perfect symmetry over all sectors i, the sufficient conditions for the stability of the equilibrium imply that the coefficient matrix (55) is subject to diagonal dominance.[8] Noting the symmetry over x_k for $k \neq i$ as well as equations (54), we obtain the diagonal dominance into the form

$$\begin{aligned} 0 < \frac{\partial \Delta_i}{\partial x_i} \pm \sum_{k \neq i} \frac{\partial \Delta_i}{\partial x_k} &= 1 - \frac{\xi}{n} \frac{\partial \Psi}{\partial g} z'(x_i) \pm \frac{\xi}{n} \sum_{k \neq i} \frac{\partial \Psi}{\partial g} z'(x_k) \\ &= 1 - \Big[\frac{1}{n} \pm \Big(1 - \frac{1}{n} \Big) \Big] \xi \frac{\partial \Psi}{\partial g} z' \ \text{ for } k \neq i. \end{aligned}$$

This implies $\xi\, z'\, \partial \Psi / \partial g < 1$. Noting the symmetry throughout all k, we obtain $x_k = x$ for all k and $z(x) = g/\xi$. Functions (53) can then be transformed into $\Psi(\alpha, g) = x = z^{-1}(g/\xi)$, where z^{-1} is the inverse function of $z(x)$. Differentiating this equation and noting (18) and (53) and $\xi\, z' \partial \Psi / \partial g < 1$, we obtain $\partial \Psi / \partial g > 1/(\xi\, z')$ and

$$\xi z = g(\alpha) \ \text{ with } \ g' \doteq \frac{dg}{d\alpha} = \frac{\partial \Psi}{\partial \alpha} \Big/ \Big(\frac{1}{\xi z'} - \frac{\partial \Psi}{\partial g} \Big) > 0 \ \text{ for } 0 < \alpha < \overline{\alpha}. \tag{56}$$

Results (48) and (56) can be summarized as (31).

B. The proof of result (33)

Noting symmetry $l_i = l$, $x_i = x$, $z_i = z$, $y_i = y$ and $v_i = w_i = w$ and using equations (11), (12) and (26), we obtain

$$p_i = 1/n, \quad \varpi L = \xi y/(1-\xi), \quad v = w = \phi_i y/(nl). \tag{57}$$

Given these and (18), equations (1), (5), (6), (7) and (31) take then the form

$$\begin{aligned} & L + nl = N, \quad l = x_i/E_i = x/E(v/v_{-i}), \quad g = \xi z, \\ & \frac{v_{-i}}{v} = \frac{1}{N-l} \Big[(n-1)l + \frac{\varpi}{v} L \Big] = \frac{1}{N-l} \Big[(n-1)l + \frac{\xi}{1-\xi} \frac{nl}{\phi_i(z,g)} \Big] \\ & \qquad = \frac{1}{N/l - 1} \Big[n - 1 + \frac{\xi}{1-\xi} \frac{n}{\phi_i(Z, \xi Z)} \Big]. \end{aligned} \tag{58}$$

In the system (58), there are four equations, four endogenous variables L, l, g and v/v_{-i} and one exogenous variable x. By the comparative statics of

[8] See, for example, Dixit (1986), p. 117. Here, the diagonal term 1 is positive, so that the inequality must be greater than zero.

this system, we can define L as a function of x. Equations (10), (16), (17) and (18) as well as the function $L(x)$ produce

$$c = y^{\xi}L^{1-\xi} = h^{\xi}m(x)^{\xi}L(x)^{1-\xi} = h^{\xi}\varphi(x) \text{ with } \varphi(x) \doteq m(x)^{\xi}L(x)^{1-\xi}.$$

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