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A Model of Power-Biased Technological Change*

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Abstract

New technologies have allowed firms to monitor low-skill workers more closely, thus reducing the power of these workers. We show that this 'power-biased change' may generate rising wage inequality and increases in the work intensity and unemployment of low-skill workers.

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Key words: power-biased technical change, skill bias, efficiency wage, inequality, work intensity.

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1 Introduction

Earnings inequality in the United States and other liberal market economies rose considerably from the late 1970s through the early 1990s. Explanations for this change include institutional change, increased openness to trade, and technological change. This paper is about how to understand the contribution of technological change, and in particular of new information and communications technologies (ICTs).

The contribution of new technology to earnings inequality has most often been explained in terms of skill-biased technological change (SBTC). An alternate hypothesis focuses on agency problems within the firm and the effects of ICTs on the ability of management to monitor the effort of low-skill workers (Guy and Skott, 2005). An increase in monitoring ability can be viewed as a reduction in the power of workers, and we refer to this alternate explanation as power-biased technological change (PBTC).

Consider truck drivers. Prior to the 1980s a driver's employer usually had only a vague idea of where the driver and truck were. Now the location of the truck, and even the behavior of its engine, are often tracked by satellite. The skills required of the driver have not changed, but his scope for taking advantage of possible slack in his schedule is diminished, and the employer has new information with which to remove slack from the schedule over time. Such pure cases are exceptional. Studies of the effect of ICTs in growing industries such as retailing, banking and telecommunications show that a widening of workplace power differences following the adoption of ICTs is quite common. Significant populations of lower-paid workers face increased monitoring, more precise task specification, and reduced opportunity for promotion, while managers face more consequential choices as a result of increased organizational flexibility. To the extent these studies deal with skill, however, skill differentials appear to be widening, too (Grimshaw et al., 2002; Hunter and Lafkas, 2003).

In this paper we focus on one end of this problem, the monitoring of low-paid workers. Using an efficiency-wage model, we show that PBTC can account for a simultaneous rise in the relative wage and the relative employment of high-skill workers, generally regarded as a key piece of evidence for the SBTC hypothesis. Unlike the SBTC hypothesis, it also explains increased intensity of work effort, evidence for which is reviewed by Green (2005).

2 The model

We consider an economy with two types of workers. There is no heterogeneity among workers of a given type and employed workers always hold jobs that match their type.[1]. All firms are identical and, disregarding non-labor inputs, output of the representative firm is given by

$$Y = F(e_H N_H, e_L N_L)$$

[1] Skott (2006) analyses earnings inequality when unemployed high-skill workers may accept low-skill jobs.

where e_i and N_i denote effort and employment of type i workers, $i = H, L$ (H =high power, L =low power). Our concern is with the effect of asymmetric changes in the ability of firms to monitor effort, and in order to focus on this aspect we assume symmetry between the two groups of workers in all other respects.

Workers' choice of effort is determined by the cost of job loss and the sensitivity of the risk of job loss to variations in effort. We assume that if a firm pays the wage w_i, the effort of its type-i workers is determined by the maximization of the objective function V^i,

$$V^i = p^i(e_i)[w_i - v(e_i) - h^i(\bar{w}_i, b, u_i)] \tag{1}$$

where $\bar{w}_{i,}u_i$ and b denote the average wage, the unemployment rate and the rate of unemployment benefits. As shown in the Appendix, an intertemporal optimization model reduces to a special case of problem (1).

The functions $v(e_i)$ and $p^i(e_i)$ describe the disutility associated with effort and the effect of effort on the expected remaining duration of the job, respectively. The symmetry assumption implies that the $v-$function is the same for both groups of workers, and $v' > 0, p^{i\prime} > 0$. The function $h^i(\bar{w}_i, b, u_i)$ represents the expected utility in case of job loss; the partial derivatives satisfy $h^i_{\bar{w}} > 0, h^i_b > 0$ and $h^i_u < 0$ under all standard assumptions.

The first order condition for the worker's maximization problem can be written

$$-p^i v' + (w_i - v - h^i)p^{i\prime} = 0 \tag{2}$$

and we may write the solution to the problem as

$$e_i = f^i(w_i, \bar{w}_i, b, u_i) \tag{3}$$

The sign of the partial f^i_w must be positive at any wage (above the minimum) chosen by a profit maximizing firm and, using the second order condition in combination with the partials for h^i, it is straightforward to show that $f^i_{\bar{w}} < 0, f^i_b < 0, f^i_u > 0$.

Technical changes that improve firms' ability to monitor effort will shift the p^i-function. The key property of this shift is that it affects the *sensitivity* of the firing rate to variations in effort. Thus, we assume that

$$\frac{p^{i\prime}}{p^i} = \lambda(e_i, \mu_i) \tag{4}$$

where the parameter μ_i describes monitoring ability and $\lambda_\mu > 0$. An improvement in firms' ability to monitor the efforts of individual workers makes the expected job duration of any individual worker more sensitive to changes in the worker's own effort. Equation (4) expresses this assumption.

The wage is set by the firm. The standard first order conditions imply that

$$\frac{e_{iw} w_i}{e_i} = 1 \tag{5}$$

and, using (3)-(5), the solutions for wage and effort can be expressed[2]

$$\begin{aligned} w_i &= w_i(\bar{w}_i, u_i; \mu_i) \\ e_i &= e_i(\bar{w}_i, u_i; \mu_i) \end{aligned}$$

In equilibrium, $w_i = \bar{w}_i$ and

$$w_i = w_i(u_i; \mu_i), \quad i = H, L \tag{6}$$

$$e_i = e_i(u_i; \mu_i), \quad i = H, L \tag{7}$$

Combining equations (6)-(7) with firms' first order conditions with respect to employment, we get

$$w_i = e_i F_i(e_L N_L, e_H N_H) \tag{8}$$

Using the definitional relations between unemployment u_i and employment N_i, equations (6)-(8) yield equilibrium solutions for the endogenous variables (w_i, e_i, N_i) as functions of the parameters μ_i that describe the technology.

Definite conclusions concerning the effects of a changes in power (changes in the parameters μ_i) can be obtained if functional forms for the $h-, p-$ and $v-$functions are introduced. We assume that the $p-$ and $v-$functions satisfy

$$\frac{p^{i\prime}}{p^i} = \lambda(e_i, \mu_i) = \frac{\mu_i}{e_i} \tag{9}$$

$$v(e_i) = e_i^{\gamma}, \gamma > 1 \tag{10}$$

The specification of the semi-elasticity of the p^i-function in (9) can be seen as a log-linear approximation of the p^i-function around the equilibrium solution for e_i. Equation (10) is standard, the parameter restriction $\gamma > 1$ implying that given the chosen scale of effort, the disutility of effort is strictly convex and that an equilibrium solution for w exists.

The specification (9)-(10) implies that (6)-(7) take the following form

$$e_i = \left[\frac{\mu_i}{\mu_i + \gamma} \frac{1}{\gamma - 1} h_i\right]^{1/\gamma} \tag{11}$$

$$w_i = \frac{\gamma}{\gamma - 1} h_i \tag{12}$$

With respect to the fallback position h^i, finally, we use the specific functional form obtained from the optimization model in the Appendix:

$$h^i = \frac{(r + \delta)u_i}{ru_i + \delta} b + \frac{\delta(1 - u_i)}{ru_i + \delta} (\bar{w}_i - v(\bar{e}_i)) \tag{13}$$

where $\bar{e}_i$ is determined by setting $w_i = \bar{w}_i$ in equation (3); r and δ are the discount rate and the rate of job separations, respectively.

[2] Unemployment benefits are assumed constant and are therefore omitted from the expressions.

Turning to the demand for labor, we assume a symmetric CES production function,

$$Y = A[0.5(e_L N_L)^{-\rho} + 0.5(e_H N_H)^{-\rho}]^{-1/\rho}$$

where $\sigma = 1/(1+\rho)$ is the elasticity of substitution. This specification implies that equation (8) can be written

$$w_i = 0.5^{-1/\rho} A e_i [1 + (\frac{e_j N_j}{e_i N_i})^{-\rho}]^{-(1+\rho)/\rho} \tag{14}$$

With symmetric and inelastic labor supplies (normalized at unity), finally, we have

$$u_i = 1 - N_i \tag{15}$$

The solutions for $(e_L, w_L, N_L, e_H, w_H, N_H)$ can be derived using (11)-(15). Not surprisingly, the fully symmetric case with $\mu_L = \mu_H$ produces a symmetric solution for effort, wages and employment: $(e_L, w_L, N_L) = (e_H, w_H, N_H)$.

The effects of a decline in the power of $L-$workers (a rise in μ_L) depend critically on the elasticity of substitution. It is readily seen that if the two types of workers are perfect substitutes ($\rho = -1$), both the wage w_L and employment N_L must increase following a rise in μ_L. But perfect substitution is an extreme case. We know of no attempts to estimate the elasticity of substitution between groups with different workplace power but power and skill are strongly correlated (Guy and Skott, 2005), and the estimates of the elasticity of substitution between different skill categories presented by Card, Kramarz and Lemieux (1999) are all very low. Thus, the empirically interesting case is likely to be one in which the elasticity of substitution is below unity, and the implications of changes in μ_L are explored in Table 1 for different, non-negative values of ρ.

Table 1a assumes a Cobb-Douglas production function ($\rho = 0$) while Tables 1b-1c introduce complementarity ($\rho = 1$ and $\rho = 10$). The variations in μ_L are within (what we consider) its plausible range. The intertemporal interpretation in the Appendix implies that $p = 1/(r+\delta)$ and hence that $p'/p = -\frac{1}{r+\delta}\frac{d\delta}{de} = -\frac{\delta}{r+\delta}\frac{1}{e}\frac{d\log\delta}{d\log e}$ where δ is the rate of job separations. Job separations happen for a range of reasons (including voluntary quits and plant closures), and it seems unlikely that $-\frac{d\log\delta}{d\log e}$ should exceed unity.[3] It follows that μ will be less than one. With respect to the other parameters of the model, we use a discount rate of $r = 0.05$ and a rate of separations of $\delta = 0.2$. Unemployment benefits are normalized at one, $b = 1$, the productivity parameter is $A = 10$, and the (inverse) indicator of the power of $H-$workers is $\mu_H = 0.1$. The parameter γ in the utility function, finally, must be greater then one (cf above), and the qualitative results appear to be insensitive to the precise value. The tables use $\gamma = 5$.

As indicated in Table 1, a decrease in the power of $L-$workers benefits the $H-$workers in terms of both wages and employment. Their effort also goes up but the net welfare effect

[3] This statement is meaningful, despite the ordinality of effort, since the chosen scale implies that productivity is proportional to effort.

can be calculated if one accepts the assumptions underlying the intertemporal optimization in the Appendix. Given these assumptions, the welfare of unemployed and employed workers can be measured by $h(= rU)$ and $x = (w - e^{\gamma})\frac{r}{r+\delta} + h\frac{\delta}{r+\delta}(= rV)$, and both h_H and x_H increase for all values of ρ.

$L-$workers also benefit from an erosion in their own power if the production function is Cobb-Douglas. They increase effort but employment and wages also improve, and the net benefits are unambiguously positive. The explanation is straightforward. Agency problems lead to outcomes that are Pareto suboptimal, and the increased ability of firms to monitor effort reduces the agency problem. Taking into account the derived effects on employment and wages, workers may therefore in some cases benefit from a decline in their own workplace power. Tables 1b-1c, however, show how the improvements in employment and wages are eroded as the degree of complementarity in production increases. With weak complementarity ($\rho = 1, \sigma = 0.5$) the wage as well as the utility variables h_L and x_L move non-monotonically as the power indicator μ_L changes. When $\rho = 10$, conditions deteriorate along all three dimensions, and the welfare measures h_L and x_L decline strongly when μ_L increases.

The model can yield outcomes that are broadly in line with US and UK experience. If $\rho = 1$, for instance, and there is an increase in μ_L from 0.5 to 1, the low-paid $L-$workers raise effort (=productivity) by about 10 percent, their real wage declines slightly, their relative wage falls by about 12 percent, and the relative unemployment rates remain roughly unchanged. One should not read too much into this broad congruence with empirical observations, and we certainly do not claim that the model (and PBTC, more generally) provides a complete explanation of the movements in wage inequality. The simulations show, however, that the effects of PBTC can be quantitatively important.

3 Conclusions

New technologies may change skill requirements but they also change the relative power of different employees; the fact that more skilled employees have seen an increase in relative pay does not demonstrate that it is the skill that is being compensated. Our model is limited to changes in monitoring, which is just one avenue by which ICTs can affect the workplace power of employees. Within this territory it demonstrates that the PBTC hypothesis can explain the simultaneous occurrence of lower wages, higher unemployment and higher work effort for the lower skilled.

4 Appendix

Consider an infinitely lived agent with instantaneous utility function

$$u(c, e) = c - v(e)$$

Assume that the interest rate r is equal to the discount rate. The time profile of consumption is then a matter of indifference to the agent, and we may assume that consumption matches current income. If U denotes the value function of an unemployed worker, a worker who is currently employed at a wage w faces an optimization problem that can be written

$$\max E[\int_0^T (w - v(e)) \exp(-rt)\ dt + \exp(-rT)\ U]$$

where the stochastic variable T denotes the time that the worker loses the job. Assuming a constant hazard rate, T is exponentially distributed. In a steady state, the objective function can be rewritten

$$E[\int_0^T (w - v(e)) \exp(-rt)\ dt + \exp(-rT)\ U] = (w - v(e) - h)p + U$$

where $h = rU$ and $p = E(1 - \exp(-rT))/r = (1 - \frac{\delta}{r+\delta})/r = \frac{1}{r+\delta}$ is an increasing function of the rate of separations δ.

The value function for an unemployed worker, and thus h, will depend on the average level of wages, the rate of unemployment benefits and the hiring rate. With a constant rate of unemployment, the hiring rate q is proportional to the average rate of separations

$$q = \bar{\delta}\frac{L}{N - L} = \bar{\delta}\frac{1 - u}{u}$$

where u is the unemployment rate and $\bar{\delta}$ is the average rate of separations. The risk of job loss gives an incentive for workers to provide effort. But an increased average firing rate does not help the firm unless it raises effort, and effort is determined by the semi-elasticity p'/p (see the first order condition (2)). Thus, the average firing rate in the economy need not be related to the average level of effort, and we assume that $\bar{\delta}$ is constant.

In equilibrium, $w = \bar{w}$ and in order to find the value of $h = h(\bar{w}, b, u)$ we note that

$$V - U = (w - h - v(e))p \tag{A1}$$

$$U - V = (b - rV)s = \{b - r[(w - h - v(e))p + \frac{h}{r}]\}s \tag{A2}$$

where $s = E(\frac{1-\exp(-rT_u)}{r})$ and the stochastic variable T_u denotes the remaining length of the spell of unemployment of a currently unemployed worker. With a constant rate of separations, random hiring and constant unemployment, the stochastic variable T_u follows an exponential distribution with expected value $ET_u = \frac{u}{1-u}ET$ where $ET = 1/\bar{\delta}$ is the average expected remaining duration of employment for an employed worker. Using (A1)-(A2) and the expressions for p and s ($p = 1/(r + \delta); s = 1/(r + \delta(1 - u)/u)$)), it follows that

$$h = (w - v(e))\frac{\delta(1 - u)}{ru + \delta} + b\frac{(r + \delta)u}{ru + \delta}.$$

References

[1] Card, D., F. Kramarz and T. Lemieux, 1999, Changes in the Relative Structure of Wages and Employment: A Comparison of the United States, Canada and France, Canadian Journal of Economics 32 (4), 843-877.

[2] Green, F., 2005, Why Has Work Effort Become More Intense?, Industrial Relations 43 (4), 709-741.

[3] Grimshaw, D., H. Beynon, J. Rubery and K.G. Ward, 2002, The Restructuring of Career Paths in Large Service Sector Organisations: 'Delayering', Upskilling and Polarisation, Sociological Review 50 (1), 89-116.

[4] Guy, F. and P. Skott, 2005, Power-Biased Technological Change and the Rise in Earnings Inequality, Working Paper 2005-17, Department of Economics, University of Massachusetts.

[5] Hunter, L.W and J.J. Lafkas, 2003, Opening the Box: Information Technology, Work Practices, and Wages, Industrial and Labor Relations Review 56 (2), 224-43.

[6] Skott, P., 2006, Wage Inequality and Overeducation in a Model with Efficiency Wages, Canadian Journal of Economics 39 (1), 94-123.

Table 1: Effects of a decline in the power of $L-$ workers on effort, wage and unemployment

1a: Cobb-Douglas, $\rho = 0$

μ_L	e_L	w_L	u_L	h_L	x_L	e_H	w_H	u_H	h_H	x_H
0.1	0.45	4.45	0.21	3.56	3.73	0.45	4.45	0.21	3.56	3.73
0.5	0.63	5.35	0.19	4.28	4.47	0.46	5.42	0.20	4.34	4.56
1.0	0.72	5.73	0.18	4.58	4.78	0.47	5.90	0.20	4.72	4.95

1b: Weak complementarity, $\rho = 1$

μ_L	e_L	w_L	u_L	h_L	x_L	e_H	w_H	u_H	h_H	x_H
0.1	0.45	4.45	0.21	3.56	3.73	0.45	4.45	0.21	3.56	3.73
0.5	0.61	4.65	0.20	3.72	3.89	0.47	6.00	0.20	4.80	5.03
1.0	0.69	4.63	0.19	3.70	3.86	0.48	6.73	0.19	5.38	5.65

1c: Strong complementarity, $\rho = 10$

μ_L	e_L	w_L	u_L	h_L	x_L	e_H	w_H	u_H	h_H	x_H
0.1	0.45	4.45	0.21	3.56	3.73	0.45	4.45	0.21	3.56	3.73
0.5	0.56	3.12	0.23	2.50	2.61	0.49	7.18	0.19	5.74	6.02
1.0	0.61	2.55	0.25	2.04	2.12	0.50	8.11	0.19	6.49	6.81