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TECHNOLOGICAL PROGRESS AND UNEMPLOYMENT

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Technological Progress and Unemployment.

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Abstract

This paper presents a model where the form of innovations is endogenous. It is shown that, with labour market imperfections, that raise the wage above the shadow price of labour, firms overinvest in innovations cutting labour costs and underinvest in increasing quality. As a result, the market outcome features lower long run growth, higher unemployment and lower welfare than the social optimum. It is further shown that firms' incentives to cut labour costs are increased as wages rise, as the industry becomes more competitive and as the industry's growth rate falls behind the economy wide growth rate.

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This paper introduces a model with two types of innovations. One innovation type is a product innovation, in the sense that it increases product quality. The other type is a process innovation that reduces firms' fixed labour costs. The focus on these two innovation types is justified below.

It is shown that with labour union bargaining or efficiency wage imperfections in the labour market, firms overinvest in cutting fixed labour costs and underinvest in increasing quality. Hence the first result of the paper is normative: the market outcome features lower long run growth, higher unemployment and lower welfare than the social optimum. The second (positive) result of the paper is that firms' incentives to cut labour costs are increased as wages rise, as the industry becomes more competitive and as the industry starts to decline, in the sense that its growth rate falls behind the economy wide growth rate.

The main motivation for this paper stems from the observation that in the 1980s and 90s firms invested heavily in downsizing. Recent examples are National Westminster bank, AT&T and IBM. As documented by Audretsch (1995: 27) and Sampson (1995), the mass firings that followed from this downsizing involved to a great extent middle managers. In the popular press there were doubts about the welfare consequences of firing people while unemployment was in fact quite high already. But the firms claimed these lay offs were necessary to increase efficiency.

This paper takes a general equilibrium point of view and shows that firms were right in that firing employees improves efficiency. Moreover these workers can be allocated to other sectors in the economy. In other words, there is nothing wrong with downsizing as such. However, it is also shown that firms tend to overinvest in improving efficiency in this way, thereby increasing unemployment and reducing welfare. The intuition is that with an efficiency wage or labour union bargaining imperfection in the labour market, the wage rate exceeds the shadow price of labour. A firm's gain from firing an employee is the wage rate, while a social planner's gain is only the shadow price of labour. So indeed there are welfare losses associated with firing middle managers in times of unemployment.

The second motivation for this paper is to capture the notions 'defensive' and 'enterprise' investments. As discussed below, defensive investments cut costs but leave output unchanged. While entrepreneurial investments lead to product improvements that expand output. The explanation Eltis (1996) and Kitson and Michie (1996) give for Britain's dismal performance in manufacturing since 1960 is a bias towards defensive investments in the UK. This paper shows that this bias may be due to the institutional setting in the UK where the bargaining power of labour unions has been high. Moreover, I show that this bias is indeed welfare reducing, as claimed by Eltis, Kitson and Michie.

This paper adds two new points to the endogenous growth literature on unemployment, which is discussed below. First, the normative question of technological progress has not been analysed before. The literature has concentrated on the positive question of the correlation between growth and unemployment. Second, where previous papers have considered the relation between unemployment and the speed of technological progress, here the *form* of technological progress is endogenous.

In particular, innovations have two dimensions: a quality dimension and a fixed cost dimension. Human capital in the research and development (R&D) sector can be used to increase the quality of the next innovation or to reduce the fixed cost component of the production technology for the next innovation. In the production process of final goods there is only one input, labour. Whereas the first dimension affects the quality of the final output, the fixed labour component can be interpreted as the organisational overhead of the production process.

There are three arguments to motivate the analysis of this two dimensional innovation process. First, as noted above, downsizing involves to a great extent middle management, which is part of a firm's organisational overhead. Since the number of managers is not directly related to a firm's output level, it is better modelled as a fixed than as a variable labour cost. Thus downsizing is modelled as a reduction in fixed labour costs.

Second, as long as the firm's demand function is sufficiently elastic, marginal cost reductions as such cannot explain firing of employees at the firm level. As an illustration, consider a monopolist facing an inverse demand function of the form $p(x) = x^{-(1-\alpha)}$, where x is the output level and $0 < \alpha < 1$. Assume this firm produces one unit of output using c units of labour at a wage w. Then the firm chooses output level $x(c) = \text{argmax}_{x\geq 0} \{x^{-(1-\alpha)}x - cwx\}$. It is routine to verify that total employment cx(c) increases as c falls, $\partial[cx(c)]/\partial c < 0$. That is adopting a labour saving innovation, in the form of lowering marginal costs c, *increases* employment instead of causing unemployment. The intuition is, of course, that a reduction in marginal costs c leads to a fall in the firm's price level. This fall in price level leads again to such a rise in demand that output and employment rise. However, an innovation that reduces the fixed labour cost leads unambiguously to employees being fired.

Finally, this framework gives a formalisation of the distinction between enterprise and defensive investments used by economic historians, as for instance Eltis (1996: 184,186). Enterprise investments increase a firm's output and employment level by increasing the product range or by improving the quality of a firm's products. Defensive investments, on the other hand, cut costs and employment but leave product range and quality unchanged. In the framework here, enterprise investments are related to the quality improvements of final output, while defensive investments correspond to innovations reducing fixed costs. Kitson and Michie (1996: 198) make a similar distinction when they observe that in the UK 'manufacturing productivity grew in the 1980s ... largely due to job cuts rather than increased output and these jobs were not being lost in a period of full employment when the labour would be taken up productively elsewhere'. This paper argues that such job cuts, which do not raise output, increase unemployment and reduce welfare.

The theoretical literature has focussed on the positive question of the relation between growth and unemployment. As claimed by Bean and Pissarides (1993), empirically there is no clear correlation between these two phenomena, not over time nor in cross sections over countries. The theoretical literature reflects this lack of clear empirical evidence by showing that the effect of growth on unemployment is ambiguous. Finally, the models used have one dimensional innovations that reduce marginal costs or equivalently increase quality.

Aghion and Howitt (1994) start with an exogenously given growth rate and a search and matching imperfection in the labour market. They show that higher growth has two opposite effects on unemployment. On the one hand, there is the capitalization effect of higher growth which leads to lower unemployment. That is, higher growth makes it more attractive to start a firm and post vacancies, thereby reducing unemployment. On the other hand, there is the creative destruction effect of higher growth which causes firms to replace one another at higher speed. This leads to higher labour turnover and hence increases unemployment. Further, the higher speed of creative destruction, reduces the value of starting a new firm. Thus it becomes less attractive to start a new firm and post vacancies. These (direct and indirect) creative destruction effects cause a positive relation between growth and unemployment. With a similar set up, Mortensen and Pissarides (1995) show that the capitalization effect is likely to dominate in industries where the costs of implementing a new technology in an old plant are low. The creative destruction effects dominate in industries with high implementation costs. Since implementation costs are likely to vary widely over industries, there is no reason to expect a clear positive or negative association between growth and unemployment at the country level. The same conclusion follows from Bean and Pissarides (1993), who link growth to savings and model unemployment through a search and matching imperfection in the labour market. They show that depending on the exogenous parameters that differ over time or between countries the relation between growth and unemployment can be positive or negative.

Finally, Groot and Van Schaik (1997) and Daveri and Tabellini (1997) find a clear negative association between growth and unemployment. In Groot and Van Schaik, there is a dual labour market with wait unemployment. Then a rise in unemployment benefits raises wait unemployment. This reduces the profitability of producing high-tech goods. Hence R&D and the rate of growth are reduced. Daveri and Tabellini examine the effects of high taxes on labour. They claim that in countries with strong decentralised labour unions, high taxes on labour translate into high wage costs for firms. This in turn reduces labour demand and creates unemployment. Further, as firms' capital-labour ratio rises, the marginal product of capital falls which reduces savings and growth. The extent to which the rise in labour taxes passes through into higher wages, depends on how strong and how decentralised the unions are. Controlling for such differences between countries, they find a negative relation between growth and unemployment in their data. They suggest that the lack of correlation found by Bean and Pissarides (1993) is caused by their omission to condition on the different ways in which labour unions are organised in countries.

The rest of this paper is organised as follows. Section 1 presents the model. Section 2 solves for the private outcome. Section 3 compares the private outcome to the social optimum and section 4 concludes the paper.

1. The model.

Consider an economy with two sectors. The output level of sector 1 is denoted by x_l and the output level of sector r by x_r. The analysis focuses on the innovation choices of sector 1 and sector r is interpreted as the rest of the economy aggregated into one sector producing a composite commodity. The CES utility function at time t of the infinitely lived consumers is given by $u(x_l,x_r,t) = (q_t x_l^{\alpha} + r_t x_r^{\alpha})^{1/\alpha}$ with $0 < \alpha < 1$, where q_t denotes the quality of good 1 and r_t the aggregate quality of good r at time t. The time paths of q_t and r_t are considered below. It is assumed that sector 1 is small compared to the rest of the economy, which can be represented here as $r_t > q_t$ for each t. As shown below, a low value of the ratio q_t/r_t translates into a small share of sector 1 in the total revenue of the economy.

Consumers maximise lifetime utility $\Sigma_{t\geq0}\ \delta^t\ \ln[u(x_{lt},x_{rt},t)]$ subject to an intertemporal budget constraint, where δ is the discount factor. In each period, I choose total expenditure as numeraire. It is routine to verify that the consumers' maximisation problem at time t with expenditure in each period normalised to 1, that is

$$\max_{x_1,x_r}\left\{\left(q_t x_1^{\alpha}+r_t x_r^{\alpha}\right)^{\frac{1}{\alpha}} \middle| p_{1t}x_1+p_{rt}x_r=1\right\}.$$

leads to inverse demand functions at time t of the form $p_{1t}(x_1) = q_t A_t x_1^{-(1-\alpha)}$ and $p_{rt}(x_r) = r_t A_t x_r^{-(1-\alpha)}$ where

$$A_t=\frac{1}{\left(q_t^{\frac{1}{1-\alpha}}p_{1t}^{\frac{-\alpha}{1-\alpha}}+r_t^{\frac{1}{1-\alpha}}p_{rt}^{\frac{-\alpha}{1-\alpha}}\right)^{1-\alpha}}. \tag{1}$$

As usual, I assume that firms choose output levels to maximise profits, taking A_t as given. In both sectors firms produce with constant marginal costs equal to 1. As discussed below, in order to keep the maths simple I assume that innovations are always drastic. Hence the firm in sector 1 with the patent on q_t chooses x_{1t} to solve $\max_x \{q_t A_t x^{-(1-\alpha)}x - w_t x\}$, where w_t denotes the wage rate at time t. The firms in the other sectors of the economy choose their output levels in a similar way. Due to the well known aggregation property[†] of CES utility functions, this means that x_{rt} equals the solution to $\max_x \{r_t A_t x^{-(1-\alpha)}x - w_t x\}$. It follows that

$$x_{1t}=\left(\frac{\alpha q_t A_t}{w_t}\right)^{\frac{1}{1-\alpha}} \text{ and } p_{1t}=\frac{w_t}{\alpha} \tag{2}$$

$$x_{rt}=\left(\frac{\alpha r_t A_t}{w_t}\right)^{\frac{1}{1-\alpha}} \text{ and } p_{rt}=\frac{w_t}{\alpha}. \tag{3}$$

Substituting the expressions for p_{1t} and p_{rt} in equation (1) yields

$$A_t=\left(\frac{w_t}{\alpha}\right)^{\alpha}\frac{1}{\left(q_t^{\frac{1}{1-\alpha}}+r_t^{\frac{1}{1-\alpha}}\right)^{1-\alpha}}. \tag{4}$$

For reference below, define s_{1t} as sector 1's share in revenue at time t. $s_{1t} \equiv \frac{p_{1t}x_{1t}}{p_{1t}x_{1t}+p_{rt}x_{rt}}$.

Because $p_{1t} = p_{rt} = w_t/\alpha$, it follows that $s_{1t} = \frac{x_{1t}}{x_{1t}+x_{rt}}$. Then equations (2)-(4) imply

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[†] This property is proved in the note for the referee.

$$s_{lt} = \frac{q_t^{\frac{1}{1-\alpha}}}{q_t^{\frac{1}{1-\alpha}} + r_t^{\frac{1}{1-\alpha}}}. \quad (5)$$

Notice that the price cost margin in each sector equals $(p_{it} - w_t)/p_{it} = 1 - \alpha$, with $i = 1, r$. Thus a fall in α leads to a rise in the price cost margin. Therefore, as in Aghion and Howitt (1992), a fall in α is interpreted as a rise in market power, and conversely high α industries are called competitive. Finally, with equations (2)-(4) utility at time t can be written as

$$u(x_{lt}, x_{rt}, t) = \frac{\alpha}{w_t}\left(q_t^{\frac{1}{1-\alpha}} + r_t^{\frac{1}{1-\alpha}}\right)^{\frac{1-\alpha}{\alpha}} \quad (6)$$

and total variable labour demand equals

$$x_{lt} + x_{rt} = \frac{\alpha}{w_t}. \quad (7)$$

The wage w_t is determined by labour market equilibrium. The agents' inelastic supply of labour is normalised at 1. In order to introduce unemployment, I assume that the labour market features efficiency wages or labour union bargaining which are modelled here as follows. The wage level depends negatively on the unemployment level $w_t = b(1-\lambda_t^d)$, with $b'(.) < 0$ and λ_t^d total labour demand at time t.

The idea of $b'(.) < 0$ with labour union bargaining is that high unemployment weakens the labour union's bargaining position, thereby leading to lower wage levels. In the Shapiro and Stiglitz (1984) efficiency wage model, a firm offers a high wage to an employee to stop him from shirking. If the employee is found shirking he is fired. When unemployment is high, it will take a fired employee long to find a new job. This is an incentive for the employee not to shirk and hence the firm can offer him a lower wage that still induces the employee to work. Thus both imperfections are captured by the negative relation between wages and unemployment, $w_t = b(1-\lambda_t^d)$, above.

In the model here, labour demand at time t equals $\lambda_t^d = x_{1t} + x_{2t} + f_t$, where f_t is the fixed labour cost of the firm in sector 1, as discussed below. Using equation (7), this can be written as $\lambda_t^d = \alpha/w_t + f_t$. The following lemma shows that a reduction in fixed labour cost f_t leads to an increase in unemployment and a reduction in the wage level. Similarly, an increase in market power, that is a reduction in α, leads to an increase in unemployment. The intuition is that firms with more monopoly power are inclined to produce less output at a given wage rate. Hence they hire less labour and unemployment is higher. This is the negative static effect of market power on employment. Below this static effect is contrasted with the dynamic effect of market power on unemployment.

Lemma 1

$\partial(1-\lambda_t^d)/\partial f_t < 0$ and $\partial w_t/\partial f_t > 0$.

$\partial(1-\lambda_t^d)/\partial \alpha < 0$ and $\partial w_t/\partial \alpha > 0$.

Proof

The first inequality follows from $\partial w_t/\partial f_t = [-b'(.)]/(1+[-b'(.)]\alpha/w_t^2) > 0$, since $b'(1-\alpha/w_t-f_t) < 0$. So an increase in f_t increases the wage rate by reducing unemployment. The second inequality follows from $\partial w_t/\partial \alpha = ([-b'(.)]/w_t)/(1+[-b'(.)]\alpha/w_t^2) > 0$.□

Now I turn to the structure of innovations in the model. Since the focus of this paper is on the innovation decisions in sector 1, the innovations in sector r are exogenously given both for the agents and the social planner. So the time path r_t is taken as fixed and the level of fixed costs in sector r is normalised at 0.

In sector 1, an innovation at time t has a quality dimension γ_t and a fixed cost dimension f_t. Following the endogenous growth literature, the research laboratory that wins the patent race sells an infinitely lived patent on the innovation to a production firm. This firm then starts to produce in sector 1 with this technology, until it is replaced by a firm with the next (higher quality) innovation. As innovations here have two dimensions already, to keep things simple the frequency of innovations is assumed to be fixed. In particular, there is an innovation for sector 1 in each time period, $t = 1, 2, 3...$

At time t, the R&D laboratories invest to win the patent on innovation (γ_{t+1}, f_{t+1}), which produces good 1 with quality $q_{t+1} = \gamma_{t+1}q_t$ and fixed costs f_{t+1}. For ease of exposition, it is assumed that R&D laboratories employ human capital only and no labour, which is used only for production[1]. Further, suppose human capital is supplied inelastically. These two assumptions fascilitate the analysis of firms' innovation bias towards defensive investments. Now the resource constraint for the R&D sector can be modelled by the requirement that $(\gamma_{t+1}, f_{t+1}) \in I_{t+1}$ where the innovation possibility set $I_{t+1} \subset \Re^2$ is assumed to be compact. Further it is assumed that all innovations are drastic. That is at any time t, for each $f \geq 0$ it is the case that $\max_\gamma \{ \gamma \mid (\gamma, f) \in I_{t+1} \} \geq 1/\alpha$. With $\gamma_{t+1} \geq 1/\alpha$ the innovation is drastic, as can be seen as follows. The firm with the patent on quality $q_{t+1} = \gamma_{t+1}q_t$ sets a price equal to $p_{1t+1} = w_{t+1}/\alpha$ as in equation (2). Then the firm with the patent on quality q_t leaves the market, since with quality gap $\gamma_{t+1} \geq 1/\alpha$ it cannot produce profitably at this price level w_{t+1}/α. Further, it must be the case for each $t \geq 0$ that $\min_{\gamma,f} \{f \mid (\gamma, f) \in I_{t+1}\} < 1$. Otherwise the firm in sector 1 cannot produce since total labour supply equals 1. Figure 1 gives an example of a convex set I_{t+1}.

Figure 1 here

To interpret the set I_{t+1}, one can think of two ways to use human capital. One is technical in the sense that is used to increase the quality of a product by γ_{t+1}. The other use is in the realm of management consultants seeking to reduce the organisational overhead f_{t+1}. When a lot of human capital is used to reduce fixed costs, less human capital is available to increase the quality of the product. The social planner takes the structure of the R&D sector as given in the sense that the innovation possibility set I_{t+1} is the same for the social optimum and the private outcome. It is the choice of the point $(\gamma_{t+1}, f_{t+1}) \in I_{t+1}$ that differs as the next two sections show.

2. The private outcome.

Without specifying the details of the R&D sector, it is assumed that the laboratory that wins the patent on (γ_{t+1}, f_{t+1}) sells it to a production firm in sector 1 and gets a share of the profits[2]. Since the innovation is drastic by assumption, equation (2) implies that the profits of the production firm with (γ_{t+1}, f_{t+1}) equal

$$\begin{aligned}\pi_1(\gamma_{t+1}, f_{t+1}, t+1) &= \max_{x \geq 0} \{\gamma_{t+1} q_1 A_{t+1} x^{-(1-\alpha)} x - w_{t+1} x - w_{t+1} f_{t+1}\} \\ &= \tfrac{1-\alpha}{\alpha} w_{t+1} \left(\frac{\alpha \gamma_{t+1} q_1 A_{t+1}}{w_{t+1}}\right)^{\frac{1}{1-\alpha}} - w_{t+1} f_{t+1}\end{aligned} \tag{8}$$

until the firm is replaced next period by technology (γ_{t+2}, f_{t+2}).

Because the R&D laboratory gets a share of the profits, it chooses (γ_{t+1}, f_{t+1}) to solve

$$\max_{\gamma, f \in I_{t+1}} \pi_1(\gamma, f, t+1), \tag{9}$$

where it takes A_{t+1} as given, like the firms.

<u>Proposition 2</u>

The private outcome (γ_{t+1}, f_{t+1}) is a solution to

$$mrs^p_{t+1}(\gamma_{t+1}, f_{t+1}) \in \nabla I_{t+1}(\gamma_{t+1}, f_{t+1}) \tag{10}$$

where the private marginal rate of substitution is defined as $mrs^p_{t+1}(\gamma, f) \equiv -\frac{d\pi_1(\gamma, f, t+1)/df}{d\pi_1(\gamma, f, t+1)/d\gamma}$

and the superdifferential as $\nabla I_{t+1}(\gamma, f) \equiv \{ \rho \in \Re \mid (\gamma' - \gamma) \leq \rho(f' - f) \text{ for each } (\gamma', f') \in I_{t+1} \}$.

Proof

First note that the optimisation problem in (9) has a solution because $\pi_1(\gamma, f, t+1)$ is continuous in γ and f, as can be seen in equation (8), and the set I_{t+1} is compact by assumption. Second note that the set $\nabla I_{t+1}(\gamma, f)$ is convex, hence it is a subinterval of $\Re$. Now suppose the claim is not true, then one of the following two situations must arise:

- $mrs^p_{t+1}(\gamma_{t+1}, f_{t+1}) > \rho$ for each $\rho \in \nabla I_{t+1}(\gamma_{t+1}, f_{t+1})$, but then reducing f and γ slightly along the boundary of I_{t+1} increases profits;
- $mrs^p_{t+1}(\gamma_{t+1}, f_{t+1}) < \rho$ for each $\rho \in \nabla I_{t+1}(\gamma_{t+1}, f_{t+1})$, but then increasing f and γ slightly along the boundary of I_{t+1} increases profits.

Therefore, if $mrs^p_{t+1}(\gamma_{t+1}, f_{t+1}) \notin \nabla I_{t+1}(\gamma_{t+1}, f_{t+1})$, it cannot be the case that (γ_{t+1}, f_{t+1}) solves the maximisation problem in equation (9).□

If the boundary of I_{t+1} is differentiable, equation (10) reduces to the familiar result that (γ_{t+1}, f_{t+1}) is a tangency point of I_{t+1} and an isoprofit line $\pi_1(\gamma, f, t+1) = \text{constant}$. Note that proposition 2 gives a necessary condition for (γ_{t+1}, f_{t+1}) to solve (9), but not a sufficient condition. However the results below hold for all solutions to (10) so in particular it holds for the optimum. The next proposition characterises the mrs^p in terms of sector 1's share s_1 and the wage level w.

Proposition 3

$mrs^{p}_{t+1}(\gamma, f) = \frac{\gamma w_{t+1}}{s_{1t+1}}$.

Proof

Equation (8) implies $-\frac{d\pi_t(\gamma,f,t+1)}{df} = w_{t+1}$ and $\frac{d\pi_t(\gamma,f,t+1)}{d\gamma} = \frac{w_{t+1}}{\alpha}\left(\frac{\alpha\gamma q_t A_{t+1}}{w_{t+1}}\right)^{\frac{1}{1-\alpha}}\frac{1}{\gamma}$. Further, the expression for A_{t+1} in (4) yields $d\pi_t(\gamma,f,t+1)/d\gamma = s_{1t+1}/\gamma$.□

The next result shows how a change in parameters changes $mrs^{p}_{t+1}(\gamma,f)$ for *all* $(\gamma,f) \in \Re^2_+$. It is straightforward to show that if $mrs^{p}_{t+1}(\gamma,f)$ is increased for all (γ,f), then γ_{t+1} and f_{t+1}, in the solution to (9), fall. Similarly, if $mrs^{p}_{t+1}(\gamma,f)$ is reduced for all (γ,f), then γ_{t+1} and f_{t+1} rise. Writing the wage relation temporarily as $w_{t+1} = \beta b(1-\lambda^{d}_{t+1})$, it is routine to verify that a rise in scalar β increases the wage rate w_{t+1}. Such a rise in β can be interpreted as an exogenous rise in labour union bargaining power for a given unemployment level. In terms of the efficiency wage model, a rise in β can be interpreted as a fall in the detection probability of shirking workers. Such an exogenous rise in β has been represented in (ii) below, by a slight abuse of notation, as an increase in the endogenous wage directly.

Corollary 4

(i) $\frac{\partial mrs^{p}_{t+1}}{\partial\left(r_{t+1}/q_t\right)} > 0$,

(ii) $\frac{\partial mrs^{p}_{t+1}}{\partial w_{t+1}} > 0$,

(iii) $\frac{\partial \text{mrs}^{p}_{t+1}}{\partial \alpha} > 0$.

Proof

Using the expression for $\text{mrs}^{p}_{t+1}(\gamma, f) = \frac{\gamma w_{t+1}}{s_{1t+1}}$ in proposition 3,

(i) follows from $\frac{\partial s_{1t+1}}{\partial (r_{t+1}/q_t)} = \frac{\partial \left(\frac{\gamma^{\frac{1}{1-\alpha}}}{\gamma^{\frac{1}{1-\alpha}} + (r_{t+1}/q_t)^{\frac{1}{1-\alpha}}} \right)}{\partial (r_{t+1}/q_t)} < 0$ together with the observation that

$w_{t+1} = b(1-\alpha/w_{t+1}-f)$ does not depend on r_{t+1}/q_t,

(ii) follows from proposition 3 immediately.

(iii) follows both from $\frac{\partial s_{1t+1}}{\partial (1-\alpha)} = \frac{\partial \left(\frac{1}{1 + (r_{t+1}/\gamma q_t)^{\frac{1}{1-\alpha}}} \right)}{\partial (1-\alpha)} > 0$ since sector 1 is small compared

to the rest of the economy, $r_{t+1} > \gamma q_t$, and from $\partial w_{t+1}/\partial \alpha > 0$ as derived in lemma 1.□

The first result says that if sector 1 grows more slowly over time than the rest of the economy, that is r_{t+1}/q_t increases over time, the innovations in sector 1 move in the direction of investing more in lowering fixed costs than in increasing quality. This is in line with casual observation that firms in declining industries, that is industries which experience growth lower than the economy average, tend to focus more and more on cost cutting. The reason is that increasing the quality of a product is more profitable the more products you sell. So as an industry becomes marginalized in the economy (q/r decreases) firms invest more in cost cutting than in increasing quality. Although such efficiency enhancing measures are usually welcomed by the stockmarket, the next section shows that firms overinvest in defensive investments. Finally, note that for a given time path r_t, this tendency strengthens itself. As research laboratories start to invest more in reducing fixed costs, quality in sector 1 grows more slowly over time, thereby increasing the relative quality r_{t+1}/q_t, which leads again to more investment in reducing fixed costs.

The second result says that countries with high wage levels, either due to high union bargaining power or due to low shirking detection probabilities, tend to invest more in reducing fixed costs than in quality improvements. The intuition is that higher wages lead to higher cost savings as fixed labour is fired. A tentative interpretation of this result could refer to the British bias towards defensive investments after the second world war, as mentioned in the introduction. Due to the institutional setting in the UK, the bargaining power of labour unions has been high, as discussed by Bean and Crafts (1996: 154). As this has led to high wage levels, result (ii) implies, in line with the observations of Eltis (1996: 184,186), that investment becomes more defensive in character, reducing fixed costs rather than increasing quality of products. Indeed this bias towards lowering f leads to higher unemployment levels as shown in lemma 1. This is my interpretation of the finding by Kitson and Michie (1996: 198), mentioned in the introduction, that in the UK 'manufacturing productivity grew in the 1980s ... largely due to job cuts rather than increased output and these jobs were not being lost in a period of full employment when the labour would be taken up productively elsewhere'. The welfare implications of employees being fired while there is unemployment already in the economy are discussed below.

The last result implies that more competitive industries (that is high α industries) are more preoccupied with cost cutting than with quality improvements. This is due to two effects. First, there is an appropriability effect. More competition implies that firms appropriate a smaller share of consumer surplus. Therefore they are less willing to invest to improve quality. The other effect is a labour market effect. Since an increase in competition leads to higher output levels, labour demand increases, as shown in lemma 1. This raises the wage level. Hence in a competitive economy, there is more incentive for firms to reduce fixed costs.

Since quality improvements are harder to measure empirically than cost reductions, this results sheds a new light on the welfare implications of results found by for instance Nickell (1996) and Porter (1990). They find that more competition gives firms a higher incentive to improve efficiency. However, if these efficiency gains come largely from fixed cost reductions, the next section shows that they are welfare reducing. Of course, if the efficiency gains in competitive industries, found by Nickell and Porter, come through marginal cost reductions (which are in the framework here equivalent to quality improvements) there will be welfare gains. Yet the framework here points out that equating efficiency gains with welfare gains is not correct in general.

The effect of market power on unemployment is ambiguous. For given q_t and r_{t+1}, a rise in competition α reduces unemployment since more competitive firms produce higher output levels, as shown in lemma 1. On the other hand, such a rise in α increases $mrs^{P}_{t+1}(\gamma_{t+1}, f_{t+1})$, which reduces γ_{t+1} and f_{t+1} because more competitive firms appropriate less of the consumer surplus associated with a rise in quality. This dynamic effect of competition, related to the form of innovations chosen by firms, increases unemployment by encouraging downsizing. The curvature of the innovation possibility set I_{t+1} determines the magnitude of the latter effect and whether or not it dominates the former. In other words, with labour union bargaining or efficiency wages the static negative effect of product market power on employment, as discussed by for instance

Layard et al. (1991: 27), has a dynamic counterpart. From a dynamic point of view, market power makes firms more inclined to adopt enterprise investments rather than defensive investments, thereby decreasing unemployment.

3. The social optimum.

This section considers the welfare implications of the private outcome. It is shown that in each period the social planner prefers to raise γ and f compared with the private outcome (γ_{t+1}, f_{t+1}) in equation (9).

The social planner's welfare function is the consumers' discounted utility $\sum_{t\geq 0}\delta^t \ln[u(x_{1t},x_{nt},t)]$, where the social planner takes the labour market imperfection and output choices of firms as given. As shown in equation (6), this yields utility at time t equal to $u(x_{1t},x_{nt},t) = \frac{\alpha}{w_t}\left(q_t^{\frac{1}{1-\alpha}} + r_t^{\frac{1}{1-\alpha}}\right)^{\frac{1-\alpha}{\alpha}}$ where the wage rate w_t solves $w_t = b(1 - \alpha/w_t - f_t)$. Hence the social planner chooses a sequence of innovations $\{(\gamma_t, f_t) \in I_t\}_{t=1}$ to maximise welfare $\sum_{t\geq 0}\delta^t \ln[u(x_{1t},x_{nt},t)]$ as of time 0:

$$W(q_0,f_0,\delta,0) = \max \sum_{t\geq 1}\delta^t \left\{\ln\alpha - \ln w_t + \tfrac{1-\alpha}{\alpha}\ln\left[\left(\prod_{s=1}^{t}\gamma_s q_0\right)^{\frac{1}{1-\alpha}} + r_t^{\frac{1}{1-\alpha}}\right]\right\}. \quad (11)$$

Assuming δ is small enough that the right hand side of (11) converges, this optimisation problem can be rewritten as a Bellman equation. Then the social planner at time t chooses (γ, f) to solve

$$W(q_t,f_t,\delta,t) = \max_{(\gamma,f)\in I_{t+1}} \{\ln\alpha - \ln w_{t+1} + \tfrac{1-\alpha}{\alpha}\ln\left[(\gamma q_t)^{\frac{1}{1-\alpha}} + r_{t+1}^{\alpha}\right] + \delta W(\gamma q_t, f, \delta, t+1)\}. \quad (12)$$

Welfare W at time t+1 depends on γ because the higher the quality increase now, the higher the quality level enjoyed in the future. As in the endogenous growth literature, for instance Aghion and Howitt (1992: 338), the firm that buys the patent of an innovation overlooks the positive spillover of an increase in quality on the next innovations which will be bought by future firms. This is called the intertemporal spillover effect. Since a social planner does take this spillover effect into account, firms tend to underinvest in increasing quality as compared to the social optimum.

There may also be knowledge spillovers that are overlooked by firms. For instance, increasing quality now may generate knowledge that facilitates future quality improvements. Or reducing fixed costs now may facilitate future fixed cost reductions, which would lead to $-\partial W(.,t+1)/\partial f > 0$ in (12). Moreover, it is possible that reducing fixed costs (increasing quality) now generates knowledge that facilitates quality improvements (fixed cost reductions) in the future. In order to avoid the comparison of knowledge spillovers from γ and f, which are very hard to quantify empirically, such knowledge spillovers are assumed absent here.

For the welfare results below to hold, I only need that knowledge spillovers generated by a reduction in f_{t-1} are small compared to the *sum* of the intertemporal spillover effect and the knowledge spillovers generated by a rise in γ_{t-1}. One can check that theorem 6 below holds as well if $-\partial W(.,t+1)/\partial f$ is small compared to $\partial W(.,t+1)/\partial \gamma$ in (12). This may not be an unreasonable assumption. It seems that organisational structures change horizontally over time in the sense that some structures are better suited to some environments but not to others[3]. Therefore improvements in one organisational structure, say Ford's mass production organisation, do not necessarily spill over to improvements in the more marketing orientated organisations in the 1970s. In this sense the model assumes that a reduction in organisational overhead at time t does not lead to knowledge which permanently lowers the level of fixed costs in the future.

Further note that whether knowledge spillovers from reducing f_{t-1} exist or not, sustained long run growth is only driven by the time paths of the quality indices q_t and r_t. This can be seen as follows. Suppose that through investments in reducing fixed costs, f_t converges to 0 over time. This reduces wages w_t over time, thereby increasing output levels and utility. However, the smaller fixed costs become, the smaller the effect of a further reduction in f on wages and utility and hence the smaller the effect on the growth rate of utility. As fixed costs approach 0, the effect on growth of investments in reducing f becomes negligible. This is the fundamental difference between quality improvements and fixed costs reductions. As fixed costs become small, further reductions in fixed costs have negligible effects, but increases in quality keep generating growth effects. Hence the only contribution of sector 1 to sustained long run growth comes through investments in quality γ_{t+1}.

If knowledge spillovers are absent, W(.,t) no longer depends on f_t and (12) becomes

$$W(q_t,\delta,t) = \max_{(\gamma,f)\in I_{t+1}} \{\ln\alpha - \ln w_{t+1} + \tfrac{1-\alpha}{\alpha}\ln\left[(\gamma q_t)^{\frac{1}{1-\alpha}} + r_{t+1}^{\alpha}\right] + \delta W(\gamma q_t,\delta,t+1)\} \tag{13}$$

with $w_{t+1} = b(1 - \alpha/w_{t+1} - f_{t-1})$. Further, without knowledge spillovers the effect of γ_{t+1} on W(.,t+1) equals

$$\frac{\partial W(\gamma_{t+1}q_t,\delta,t+1)}{\partial\gamma_{t+1}} = \sum_{\tau\geq 0}\delta^{\tau}\frac{s_{1t+2+\tau}}{\alpha\gamma_{t+1}} \tag{14}$$

where (14) can be derived directly from (11) or recursively from (13).

The social planner's choice of (γ,f) in the innovation possibility set I_{t+1} is determined by the social marginal rate of substitution, defined as

$$mrs^{s}_{t+1}(\gamma, f) \equiv -\frac{d\left\{\ln\alpha - \ln w_{t+1} + \frac{1-\alpha}{\alpha}\ln\left[(\gamma q_t)^{\frac{1}{1-\alpha}} + r_{t+1}^{\frac{1}{1-\alpha}}\right] + \delta W(\gamma q_t, \delta, t+1)\right\} \Big/ df}{d\left\{\ln\alpha - \ln w_{t+1} + \frac{1-\alpha}{\alpha}\ln\left[(\gamma q_t)^{\frac{1}{1-\alpha}} + r_{t+1}^{\frac{1}{1-\alpha}}\right] + \delta W(\gamma q_t, \delta, t+1)\right\} \Big/ d\gamma}.$$

The following result characterises the social marginal rate of substitution.

<u>Proposition 5</u>

$$mrs^{s}_{t+1}(\gamma, f) = \frac{\frac{dw_{t+1}}{df} \Big/ w_{t+1}}{\frac{s_{lt+1}}{\alpha\gamma} + \delta\frac{\partial W(\gamma q_t, \delta, t+1)}{\partial\gamma}}.$$

<u>Proof</u>

Follows immediately from differentiating $\{\ln\alpha - \ln w_{t+1} + \frac{1-\alpha}{\alpha}\ln\left[(\gamma q_t)^{\frac{1}{1-\alpha}} + r^{\alpha}_{t+1}\right] + \delta W(\gamma q_t, \delta, t+1)\}$ with respect to γ and f respectively.□

As the proposition shows, although in the private outcome in proposition 3 the wage *level* is relevant, in the social outcome the relative change in the wage rate $(dw_{t+1}/df)/w_{t+1}$ is important. The social planner only invests in reducing fixed costs to the extent that the resulting increase in unemployment decreases the wage rate thereby increasing the output levels of sectors 1 and r. Further, the intertemporal spillover effect is represented by $\partial W(.)/\partial\gamma > 0$ in the denominator of mrs^s. This works in the direction of lowering mrs^s and hence of the social planner being willing to invest more in quality than the private outcome. The next result shows that this is in fact always the case in the model here.

Theorem 6

If $\delta = 0$ then $\frac{mrs^{s}_{t+1}(\gamma, f)}{mrs^{p}_{t+1}(\gamma, f)} = \frac{\alpha}{w^{2}_{t+1}} \frac{dw_{t+1}}{df} < 1$, and more generally

for each $\delta \geq 0$ it is the case that $\frac{mrs^{s}_{t+1}(\gamma, f)}{mrs^{p}_{t+1}(\gamma, f)} < 1$.

Proof

From propositions 3 and 5 it follows that

$$\frac{mrs^{s}_{t+1}(\gamma, f)}{mrs^{p}_{t+1}(\gamma, f)} = \frac{\dfrac{\frac{dw_{t+1}}{df} \Big/ w_{t+1}}{\frac{s_{1t+1}}{\alpha\gamma} + \delta \frac{\partial W(\gamma q_t, \delta, t+1)}{\partial \gamma}}}{\frac{\gamma w_{t+1}}{s_{1t+1}}}. \tag{15}$$

Hence if $\delta = 0$, one gets

$$\frac{mrs^{s}_{t+1}(\gamma, f)}{mrs^{p}_{t+1}(\gamma, f)} = \frac{\alpha}{w^{2}_{t+1}} \frac{dw_{t+1}}{df}. \tag{16}$$

Substituting $\frac{dw_{t+1}}{df_{t+1}} = \frac{-b'(.)}{1+[-b'(.)]\frac{\alpha}{w^{2}_{t+1}}}$, as shown in the proof of lemma 1, into (16) yields

$$\frac{mrs^{s}_{t+1}(\gamma, f)}{mrs^{p}_{t+1}(\gamma, f)} = \frac{[-b'(.)]\frac{\alpha}{w^{2}_{t+1}}}{1+[-b'(.)]\frac{\alpha}{w^{2}_{t+1}}} < 1$$

since $b'(1 - \alpha/w_{t+1} - f_{t+1}) < 0$.

In order to prove the result for $\delta > 0$, note that the expression for $\partial W(\gamma q_t, \delta, t+1)/\partial\gamma$ in (14) is increasing in δ because $s_{1t+2+\tau}/\alpha\gamma_{t+1}$ is positive for each $\tau \geq 0$. Hence increasing δ in (15), reduces $\frac{mrs^{s}_{t+1}(\gamma, f)}{mrs^{p}_{t+1}(\gamma, f)}$ and therefore $\frac{mrs^{s}_{t+1}(\gamma, f)}{mrs^{p}_{t+1}(\gamma, f)} < 1$ for each $\delta \geq 0$.□

To understand this result, first consider the benchmark case without imperfections. That is, choose $\delta = 0$ to eliminate the intertemporal spillover effect and let the wage clear the labour market, $\alpha/w_{t+1} + f = 1$. Then it follows that $w_{t+1} = \alpha/(1-f)$

and $dw_{t+1}/df = w_{t+1}^2/\alpha$. Substituting this in equation (16) above yields $\frac{mrs_{t+1}^s(\gamma, f)}{mrs_{t+1}^p(\gamma, f)} = 1$. Hence without labour market imperfections and ignoring the intertemporal spillover effect, the private and social incentives coincide.

Labour market imperfections as union bargaining and efficiency wages lead to unemployment in equilibrium and a wage level that lies above the shadow price of labour. Therefore the social marginal rate of substitution is smaller than the private marginal rate of substitution for all γ and f. Consequently, the social planner will choose γ and f that exceed the private outcome (γ_{t-1}, f_{t+1}) in (9). In other words, firms in the private outcome overinvest in reducing fixed costs and underinvest in increasing quality and hence sustained long run growth. Introducing the intertemporal spillover effect ($\delta > 0$) strengthens this result.

So comparing the private and the social outcome, one finds lower sustained long run growth, higher unemployment and lower welfare in the private outcome. In other words, the above analysis suggests a mechanism that leads the market to choose a form of technological progress that reduces welfare and increases unemployment. So indeed there is reason to be sceptical about the welfare effects of downsizing. Although downsizing improves the firm's efficiency level and may therefore be welcomed by stockmarkets, firms overinvest in it. Overinvestment in downsizing increases unemployment and reduces welfare. Note that this result has been established without assuming that unemployment benefits have to be paid by the government which would introduce another negative externality of downsizing overlooked by firms. Such considerations strengthen the result above that firms overinvest in firing people.

4. Conclusion.

This paper has endogenized the form of technological progress by introducing a framework with two dimensional innovations. Firms can invest to increase the quality of their product. or to reduce the fixed labour costs of the production process. It has been shown that firms overinvest in reducing fixed labour costs and underinvest in increasing quality. This leads to higher unemployment. lower long run growth and lower welfare in the private outcome as compared to the social optimum. In this sense I think that the mass firings in the 1980s and 90s have indeed been welfare reducing. although they have raised firms' efficiency levels. In the same vein. this framework can explain why UK manufacturing firms' bias towards defensive investments in 1980s may have been welfare reducing.

Further. it has been shown that firms' incentives to invest in defensive projects are higher in high wage industries. in more competitive industries and in declining industries.

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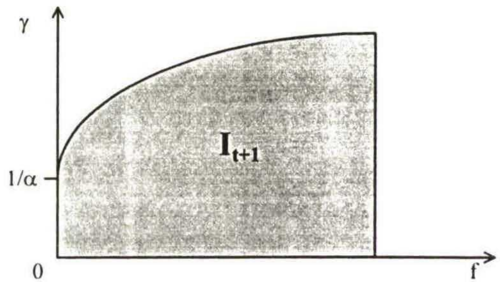

Figure 1.

Note for referee

This note shows the aggregation property of the CES utility function referred to in the text. To prove this property the time index, used in the text, can be dropped here.

Let the utility function for the desaggregated case be

$$u(x_1, x_2, \ldots, x_n) = \left(\sum_{i=1}^{n} q_i x_i^{\alpha}\right)^{1/\alpha},$$

where q_i denotes the quality of good i. Each good i is produced by only one firm which is a monopolist in its market.

With expenditures normalised to 1, the consumers' maximisation problem

$$\max_{x_1,\ldots,x_n} \left\{ \left(\sum_{i=1}^{n} q_i x_i^{\alpha}\right)^{1/\alpha} \middle| \sum_{i=1}^{n} p_i x_i = 1 \right\}$$

leads to demand functions of the form

$$p_i(x_i) = q_i A x_i^{-(1-\alpha)}$$

with

$$A = \frac{1}{\left(\sum_{i=1}^{n} q_i^{\frac{1}{1-\alpha}} p_i^{\frac{-\alpha}{1-\alpha}}\right)^{1-\alpha}}.$$

Then, with monopolistic competition, each firm chooses x_i so as to maximise profits

$$x_i \in \operatorname{argmax}_x \{q_i A x^{-(1-\alpha)} x - wx\},$$

where it takes A as given and with the cost structure as in the text.

It is routine to verify that

$$x_i = \left(\frac{\alpha q_i A}{w}\right)^{\frac{1}{1-\alpha}}$$

as in equation (2) in the text.

Now if one wants to focus on sector 1 only, goods 2,....,n can be brought together in a composite commodity x_r with aggregate quality index q_r as shown in the following lemma.

Lemma

Define the quality index q_r and the composite commodity x_r as

$$q_r \equiv \left(\sum_{i=2}^{n} q_i^{\frac{1}{1-\alpha}}\right)^{1-\alpha}$$

$$x_r \equiv \left(\sum_{i=2}^{n} \frac{q_i}{q_r} x_i^{\alpha}\right)^{1/\alpha}$$

that is q_r is a CES average of the quality levels $q_2, \ldots, q_n$ and x_r is a CES weigthed average of the output levels of firms 2,....,n.

Proof

In order to show that these definitions of the composite good and its quality index are consistent with my use of them (as r_t and x_{rt}) in the text, I have to show two things.

First, it has to be the case that $u(x_1,x_r) \equiv \left(q_1 x_1^{\alpha} + q_r x_r^{\alpha}\right)^{1/\alpha} = \left(\sum_{i=1}^{n} q_i x_i^{\alpha}\right)^{1/\alpha}$, which can be verified as follows: $u(x_1,x_r) = \left(q_1 x_1^{\alpha} + q_r \left(\sum_{i=2}^{n} \frac{q_i}{q_r} x_i^{\alpha}\right)\right)^{1/\alpha} = \left(q_1 x_1^{\alpha} + \sum_{i=2}^{n} q_i x_i^{\alpha}\right)^{1/\alpha}$.

Second, it needs to be the case that $x_r = \left(\frac{\alpha q_r A}{w}\right)^{\frac{1}{1-\alpha}}$ as in equation (3) in the text. This can be verified as follows:

$$x_r \equiv \left(\sum_{i=2}^{n} \frac{q_i}{q_r} x_i^{\alpha}\right)^{1/\alpha} = \left(\sum_{i=2}^{n} \frac{q_i}{q_r}\left(\frac{\alpha q_i A}{w}\right)^{\frac{\alpha}{1-\alpha}}\right)^{1/\alpha} = \left(\sum_{i=2}^{n} \frac{q_i^{\frac{1}{1-\alpha}}}{q_r}\left(\frac{\alpha A}{w}\right)^{\frac{\alpha}{1-\alpha}}\right)^{1/\alpha} = \left(\frac{q_r^{\frac{1}{1-\alpha}}}{q_r}\left(\frac{\alpha A}{w}\right)^{\frac{\alpha}{1-\alpha}}\right)^{1/\alpha} = \left(\frac{\alpha q_r A}{w}\right)^{\frac{1}{1-\alpha}}$$

□

Finally, one can define a price index p_r, which is a CES weighted average of $p_2,\ldots,p_n$. However, since for each good i it is the case that $p_i = w/\alpha$, it is no surprise that $p_r = w/\alpha$ as well.

Note incidentally that the assumption in the text that sector 1 is small compared to the rest of the economy ($r_t > q_t$ for each t) can here be written as $q_r > q_1$. Then the definition of q_r above shows that this assumption will be satisfied if n is big enough, that is if there are enough other sectors in the economy apart from sector 1.

[1] Hence this paper does not compare the market allocation of resources between production and R&D with the social optimum. The effects determining this allocation between production and R&D are well documented by (among others) Aghion and Howitt (1992), Grossman and Helpman (1991), Romer (1990) and Stokey (1995). My paper focuses on the allocation of (a fixed amount of) human capital between different forms of R&D.

[2] More precisely, for the analysis here it is needed that the laboratory's pay offs are strictly increasing in the production firm's profits. This seems a natural assumption.

[3] A stronger version of the idea that the ground covered today by organisational change does not necessarily help the organisational change of tomorrow is found in the following observation by Micklethwait and Wooldridge (1996: 20): '*Business Week* quoted one American manager delivering his verdict on management fashion: "Last year it was quality circles ... this year it will be zero inventories. The truth is, one more fad and we will all go nuts." That was in 1986, and since then the velocity of fads - and their ability to contradict one another- has increased considerably'.

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