Industrial Structure and the Employment Consequences of Technical Change
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INDUSTRIAL STRUCTURE AND THE EMPLOYMENT CONSEQUENCES OF TECHNICAL CHANGE

By I. M. DOBBS, M. B. HILL and M. WATERSON*

1. Introduction

In recent years, there has been considerable debate over whether technological change creates unemployment. Undoubtedly this is a complex issue, involving as it does both microeconomic and macroeconomic elements. Conceptually, it seems useful to divide the overall impact of technical change upon a particular industry into the following three ‘stages’:

(i) technical change at the firm level and its diffusion through the industry.2

(ii) adaptation of the industry, with entry/exit of firms and changes in market structure.

(iii) the general equilibrium impact—where factors transfer to or from alternative uses in response to the own-industry changing patterns of factor and product demand.

The focus of this paper is on the first and more particularly the second stages of the above process, associated with relatively long-term industry-specific effects. Naturally, impacts on employment at this stage are of importance when considering the overall extent of unemployment at the third, economy-wide, stage. Although there has been some consideration of macroeconomic effects (Sinclair, 1981, Venables, 1985) and some empirical work (e.g. Freeman, Clarke and Soete, 1982, Prais, 1981), there have been few analytical studies focussing on the effects of technical change at the industry level.3 In this paper a framework for examining the potential impacts of change on different industry types is developed.

In what follows, we concentrate on capital augmenting technical change. There are two reasons for this; (i) in developed countries with relatively well-fed and well-educated work forces, there is likely to be more scope for improvement in efficiency on the capital side, (ii) at the intuitive level, such innovations are far more likely to be biased against employment creation.

* We would like to thank participants at the Warwick University Summer Workshop 1984 on the Economics of Technological Change and two anonymous referees for some very helpful suggestions. Since starting work on this paper Martyn Hill has moved to the Commodity Research Unit; the views expressed in the paper are not necessarily in line with their views.


2 On the diffusion process, see e.g. Reinganum (1981), Waterson and Stoneman (1985). Of course the diffusion process can take some time.

3 One specific “plea for more research” in the Oxford Economic Papers Supplement of November 1983 concerned “the impact of changing industrial structure and technical progress on employment.” (p. viii). Very recently, an important contribution, extending from the industry to the macroeconomic level, has been made by Katsoulakos (1986).
However, it is straightforward to modify the approach to analyse other versions of neutral technical change. The plan is as follows. Section 2 makes clear an important link between elasticities of factor demand with respect to factor prices and with respect to technical change. Using these relationships, factor demand changes consequent upon a technical change in a competitive and an oligopolistic industry are analysed in Sections 3 and 4, respectively, by examining factor price changes. Influences on the technical change/labour demand relationship are considered in Section 5 whilst Section 6 contains some concluding remarks.

2. Technical change and factor demand elasticities

Since we shall deal principally with the firm’s cost function, we first consider in more detail the nature of the capital augmenting technical progress involved, starting from a fairly general formulation. Variable costs (superscript $v$) are distinguished from long run fixed costs (superscript $f$) and it is assumed that capital and labour feature in both but that they may be considered as separate factor inputs (being different varieties of capital and labour): these are $(k^v, k^f, l^v, l^f)$ with associated factor prices $(r^v, r^f, w^v, w^f)$ respectively. The production function is

$$y = g(k^v, l^v) \quad \text{if} \quad k^f \geq \bar{k}^f, \quad l^f \geq \bar{l}^f$$

$$y = 0 \quad \text{otherwise} \quad (1)$$

where $\bar{k}^f, \bar{l}^f$ are fixed amounts. The associated cost function may be represented as:

$$C(y; r^v, r^f, w^v, w^f) = \delta F(r^f, w^f) + V(y, r^v, w^v)$$

$$\delta = 0 \quad \text{if} \quad y = 0$$

$$\delta = 1 \quad \text{if} \quad y > 0 \quad (2)$$

In this formulation, $F$ represents long run fixed costs (see Baumol, Panzar and Willig, 1982, chapter 10); $F = r^f/\bar{k}^f + w^f/\bar{l}^f$.

In general, technical progress can affect either $F$ or $V$ both. As an example of the former, consider Baumol and Willig’s (1981) railway track cost where process innovations could reduce (and have reduced) the cost of maintenance. Capital augmenting technical progress which reduces fixed costs does not affect the demand for $l^f$ (from (1)) but affects $l^v$ and $k^v$ indirectly through its reduction of $F$. Hence there is no need to consider fixed cost factors explicitly since the impact of such technical progress can be investigated simply by considering the impact of reducing $F$. Analytically, this is straightforward and it is left on one side until Section 5 of the paper.

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4 We will not consider the case where a technical change influences both $F$ and $V$; it is difficult to think how this could be modelled.
Our principal concern is with technical progress which reduces variable costs, ceteris paribus. With capital augmenting technical progress, we have:

\[ y = g(\theta k^v, l^v) = g(\tilde{k}^v, l^v) \]  

(3)

where \( \tilde{k}^v \) is capital input measured in efficiency units, and an increase in \( \theta \) represents technical progress. The firm’s (variable) cost minimisation problem which was \( \min V = r^v k^v + w^v l^v \) subject to \( y = g(k^v, l^v) \) now becomes: \( \min V = r^v k^v + w^v l^v = \frac{r^v}{\theta} \tilde{k}^v + w^v l^v \) subject to \( y = g(\tilde{k}^v, l^v) \) so that, by analogy, we may write the variable cost function as \( V(y; r^v/\theta, w^v) \). The associated cost function is:

\[ C = F + V(y; r^v/\theta, w^v) \]  

(4)

where we have suppressed the arguments of \( F \). To economise further on notation, since \( w^f \) and \( r^f \) no longer feature explicitly, superscripts \( v \) are henceforth omitted and in talking about the demand for labour or capital, we shall mean the demand for \( l^v \) and \( k^v \) respectively.

Using cost function (4), we wish to develop the effect of a change in \( \theta \) on factor (particularly, labour) demands, a task which will occupy much of the rest of the paper. From (4), using Shepard’s lemma, the firm’s demand for labour is:

\[ l(y; \frac{r}{\theta}, w) = C_w(y; \frac{r}{\theta}, w) = V_w(y; \frac{r}{\theta}, w) \]  

(5)

Differentiation of equation (5) with respect to \( r \) and \( \theta \) allows us to develop a technology/factor demand elasticity relationship:

\[ \frac{\partial l}{\partial r} = \frac{l_2}{\theta} \quad \text{and} \quad \frac{\partial l}{\partial \theta} = -\frac{r}{\theta^2} l_2 \]

(subscript 2 denoting the partial with respect to the second argument) hence:

\[ -\frac{\theta}{l} \frac{\partial l}{\partial \theta} = \frac{r}{l} \frac{\partial l}{\partial r} \]

Denoting \( \varepsilon_{ij} \) as the firm’s elasticity of demand for factor \( i \) \((i = l, k)\) with respect to price \( j \) \((j = w, r, \theta)\), where \( w \) is the price of labour then:

\[ \varepsilon_{\theta l} = -\varepsilon_{lr} \]  

(6)

Thus, in order to investigate the effects of a capital augmenting technical change on labour demand, we simply need look at the cross price elasticity of labour with respect to the price of capital.

The impact upon the demand for capital is slightly different as the firm
can be viewed as demanding \( \bar{k} \) rather than \( k \) i.e. \( \bar{k} = \bar{k}(y; r/\theta, w) \). The demand for capital is therefore \( k = \frac{1}{\theta} \bar{k}(y; r/\theta, w) \). Differentiating this function with respect to \( r \) and \( \theta \) respectively we obtain:

\[
\frac{\partial k}{\partial r} = -\frac{\bar{k}^2}{\theta^2} \quad \text{and} \quad \frac{\partial k}{\partial \theta} = -\frac{\bar{k}}{\theta^2} - \frac{r}{\theta^3} \bar{k}^2
\]

Thus, in terms of elasticities:

\[
\varepsilon_{k\theta} = -(1 + \varepsilon_{kr}) \quad (7)
\]

The effect of a capital augmenting technical change on the demand for capital is therefore related to capital's own price elasticity. A technical improvement will increase (decrease) the demand for capital as the own price elasticity is less than (greater than) \(-1\).

The relations derived above relate to the firm's demand for factors. These relations however remain unchanged at the industry level. Making the conventional symmetry assumption that the industry comprises \( n \) identical firms, the industry demands for labour, \( L \), and capital, \( K \), are given by:

\[
L = nI(y; r/\theta, w) \quad (8)
\]

\[
K = nk(y; r/\theta, w)
\]

Denoting \( \eta_{ij} \) as the industry elasticity of demand for factor \( i \) \((i = L, K)\) with respect to the \( j \)th price \((j = w, r, \theta)\), then the general relation between firm and industry elasticity, allowing for free entry, is easily seen from (8) to be:

\[
\eta_{ij} = \varepsilon_{nj} + \varepsilon_{ij} \quad (9)
\]

where \( \varepsilon_{nj} = \frac{\partial n I}{\partial j n} \). Substituting (9) into (6) yields:

\[
\eta_{L\theta} - \varepsilon_{n\theta} = -(\eta_{Lr} - \varepsilon_{nr})
\]

Thus with fixed \( n \), \( \varepsilon_{n\theta} = \varepsilon_{nr} = 0 \) so \( \eta_{L\theta} = -\eta_{Lr} \). In the free entry case, \( n \) depends on output and factor prices; \( n = n(y; r/\theta, w) \) but reasoning similar to that used to derive (6) implies that \( \varepsilon_{n\theta} + \varepsilon_{nr} = 0 \) and so

\[
\eta_{L\theta} = -\eta_{Lr} \quad (10)
\]

holds for both cases. Similarly equation (7) will hold at the industry level:

\[
\eta_{K\theta} = -(1 - \eta_{Kr}) \quad (11)
\]

In what follows, we are primarily interested in the demand for labour (although it is straightforward to extend the analysis to capital).

This analysis demonstrates that if technical change augments a factor of production, then simple relationships hold between the elasticity of demand.
with respect to the technological parameter $\theta$ and factor price elasticities at both firm and industry level. Qualitative results for the impact of technical innovation therefore follow immediately from the study of cross-price and own price elasticities of demand for factors.

### 3. Factor demands under competition

Pursuing the analogy between capital augmenting technical change and a change in the price of capital, this section treats the effect of factor price changes in an industry composed of price-taking firms, whilst Section 4 builds on this to consider the oligopolistic case. We examine both fixed numbers and zero profit equilibria.

Here, industry output $Y$ is produced by $n$ identical firms and is homogenous. Price is determined by the industry inverse demand function, $P = P(Y)$ whilst, if there is free entry, $n$ is determined by a zero profit condition.

We shall assume homotheticity in $g$ (equation (3)) for simplicity. Therefore the equivalent equation to (4) for firm $i$ is:

\[
C_i = F + c(w, r) \cdot h(y_i)
\]

where $y_i$ is the $i$th firm’s output. If the firm and industry responses to changes in $r$ are established, the impact of technical change is given by the analysis of Section 2 (equations (6)–(11)). $F$ represents fixed costs, as discussed above and $c(w, r)$ is strictly increasing and concave in $w, r$.

We shall further assume (and this is purely to simplify presentation of results) that $h$ is homogenous of degree $\gamma$, a constant, so that $h'\gamma = \gamma h$. $\gamma$ is the elasticity of scale and $\gamma \geq 1$ denotes decreasing/constant/increasing returns to scale respectively. Of course only the first two of these three cases are possible under the assumptions of price-taking behaviour.

Profits for the $i$th firm are (henceforth omitting the subscript $i$)

\[
\pi = P(Y)y - c(w, r)h(y) - F
\]

Using this framework, the fixed-$n$ and variable-$n$ equations are now examined.

(i) **Fixed firm numbers**

This may be thought of as the case of short-run adjustment. Profit maximisation requires

\[
P(Y) - c(w, r)h'(y) = 0
\]

where, by assumption, $P(Y)$ represents the firm’s perceived marginal

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5 Similar elasticity relationships are used by Dobbs and Hill (1984) as a basis for examining the impact of technical progress on final product demand in a household production framework.
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revenue. Given \( n, w, \) and \( r, \) equation (14) determines \( y. \) From Shephard’s Lemma, firms’ demands for labour and capital are

\[
\begin{align*}
l &= c_w(w, r)h(y) \\k &= c_r(w, r)h(y)
\end{align*}
\]

so industry demands are given by

\[
\begin{align*}
L &= nl = nc_w(w, r)h(y) \quad (15a) \\
K &= nk = nc_r(w, r)h(y) \quad (15b)
\end{align*}
\]

At this stage it is convenient to introduce certain important concepts; \( \alpha_k = \frac{rc_c}{c} \) denotes the value share of capital in total variable cost, \( \alpha_L = \frac{wc_w}{c} \) denotes labour’s share, \( \sigma = \frac{cc_{rw}}{c_r c_w} \) denotes the elasticity of substitution, and \( \beta = \frac{P}{YP'} \) is the elasticity of demand. From (15a) and (10), after some manipulation, we obtain the result

\[
\eta_{L, \theta} = - \eta_{L, r} = - \frac{r}{L} \frac{dL}{dr} = - \alpha_k [\sigma + z_1] \quad (16)
\]

where \( z_1 = \frac{\gamma \beta}{1 + \beta - \gamma \beta}. \) Discussion of (16) and the other results in this section is deferred to Section 5.

(ii) Free entry; \( n \)-variable

With free entry, equilibrium requires in addition the zero profit condition

\[
yP(Y) - c(w, r)h(y) - F = 0 \quad (17)
\]

In this case, (14) and (17) simultaneously determine \( n \) and \( r. \)

The overall response of factor demands to changes in factor prices may now be calculated from (15a) as:

\[
\frac{r}{L} \frac{dL}{dr} = \frac{rc_{rw}}{c_w} \frac{r}{y} \frac{dy}{dr} + \frac{r}{n} \frac{dn}{dr} \quad (18)
\]

By total differentiation of (14) and (17) and with the use of Cramer’s rule, we obtain

\[
\begin{align*}
\frac{dy}{dr} &= c_r(h'P'y^2 - hP'y)/\Delta \\
\frac{dn}{dr} &= c_r(P'nh' - chh'' - P'nyh')/\Delta
\end{align*}
\]
where
\[ \Delta = -P'y^2ch'' = -P'ch\gamma(\gamma - 1) \]
Hence, from (18);
\[ \eta_{Lr} = \frac{r}{L} \frac{dL}{dr} = \alpha_K \left( \sigma + \frac{1 - \gamma}{\gamma} + \frac{chh'}{ny} \right) \tag{19} \]
Using the first order condition (14) and the elasticity relationship (10) then
\[ \eta_{L0} = -\alpha_K [\sigma + z_2] \tag{20} \]
where \( z_2 = (1 - \gamma + \beta)/\gamma \).
This can be seen as a generalisation of Allen’s (1938, p373) expression for the cross elasticity of factor demand; it collapses to his expression if \( \gamma = 1 \). Note that, in the competitive case with free entry, the second order necessary condition is
\[ -c(w, r)h''(y) = -c(w, r)(\gamma - 1)h'(y)/y \leq 0, \]
so only \( \gamma \geq 1 \), constant or decreasing returns to scale, is possible here.

4. Factor demands under oligopoly
Again we assume output is homogeneous and produced by \( n \) identical firms. Profit maximisation (compare (14)) is given here by
\[ P(Y) + yP'(Y)\lambda - c(w, r)h'(y) = 0 \tag{21} \]
where \( \lambda = \frac{\partial Y}{\partial y} \) is the conjectural response in total output \( Y \) to a change in the output of the \( i \)th firm. Following Seade (1980), we assume each firm conjectures that other firms follow in full or in part its own change in output,\(^7\) thus \( 1 \leq \lambda \leq n \). One other difference is that \( \gamma < 1 \) is now permissible.

Factor demands are still given by (15). We again consider the two types of equilibrium; fixed-\( n \) and free-entry. In the latter case, (13) and (21) determine \( y \) and \( n \).

Similar manipulations to those encountered in the previous section (see also Seade, 1980, De Meza, 1982) yield formulae equivalent to (13) for these oligopolistic cases. In reporting the results, we employ the following additional definitions: \( m \) is the number of effective firms in the industry \( (m = n/\lambda) \), \( E \) is the elasticity of the slope of industry demand \( (E = YP''/P') \)

\(^6\) Recent, and as yet unpublished, results obtained by Seade concerning the effect of taxes on oligopolistic industries (and also some results in de Meza, 1982) suggest that the assumption of complete symmetry employed here could be relaxed somewhat without affecting the results overmuch.

\(^7\) See Seade (1980) for a full discussion of this ‘quasi-Cournot’ assumption. In Section 3 we assumed \( \lambda = 0 \).
and \( q = 1 - \frac{ch''}{\lambda p} \). Seade (1980) notes that \( q \) (his \( k \)) > 0 and \( E + m + q > 0 \) are necessary and sufficient conditions for stability, conditions which prove helpful to our qualitative analysis. The relevant industry elasticities for the fixed-\( n \) case are:

\[
\eta_{L0} = -\eta_{Lr} = -\alpha_K(\sigma + z_3) \tag{22a}
\]
\[
\eta_{K0} = -(1 + \eta_{Kr}) = \alpha_L\sigma - \alpha_Kz_3 - 1 \tag{22b}
\]

where

\[
z_3 = \frac{\gamma(1 + m\beta)}{E + q + m} \tag{22c}
\]

and, with the assumption that \( h(.) \) is homogeneous:

\[
q = 1 - (\gamma - 1)(1 + m\beta) \tag{22d}
\]

Hence, after substitution and rearrangement:

\[
z_3 = \frac{\gamma}{1 - \gamma + [(E + m + 1)/(1 + m\beta)]} \tag{22e}
\]

No distinction is made between industry and firm derived demand elasticities because the analysis of Section II verified that, for fixed \( n \), the two are the same.\(^8\) However, it is perhaps worth noting the case where technical change is not assumed to occur in all firms simultaneously but, rather, occurs through some diffusion process. Suppose that a single firm achieves the technical break-through before the rest. Then the impact on this firm’s demand for labour arising from its innovation is given by

\[
\epsilon_{i \theta} = -\alpha_K\left[\sigma + \frac{z_3}{q}(s^oE + q + m^o)\right] \tag{23}
\]

where the superscript \( i \) refers to this firm and superscript \( o \) to the others, who have a share \( s^o \) of industry output.

Clearly, if the innovating firm is large relative to market size, the impact of technical progress will be similar to that on the industry (as \( s^o \rightarrow 0 \), \( m^o \rightarrow 0 \), so \( \epsilon_{i \theta} \rightarrow \eta_{L0} \)). However, if the firm is a small innovator, hence \( n \), \( m \) large, then \( s^o \rightarrow 1 \), \( m^o \rightarrow m \) and

\[
(s^oE + q + m^o)/q \rightarrow 1 + (E + m)/q
\]

Now \( q > 0 \) and so, although \( E < 0 \), for \( m \) large, \( (E + m)/q \rightarrow 0 \). Thus the impact of \( z_3 \) in (22a) is magnified in (23). As we shall see, \( z_3 < 0 \), hence in this case, it is more likely that the innovator will increase its labour demand, consequent upon technical progress, as compared to the case of industry

\(^8\) Notice also that, with fixed \( m \), if \( \gamma = 1 \) and \( \beta \) is a constant (so that, as shown below, \( E = (1/\beta) - 1 \)), equations (22a) and (22c) reproduce Allen’s (1938) result.
wide adoption of the technique. This makes intuitive sense—new innovators, with their consequent cost advantages, gain output at the expense of those who have not yet adopted and hence increase labour demand.9

(ii) n Variable

We now have the free entry condition, (17), as well as (21). As before, we use $\varepsilon_{ij}(\eta_{ij})$ to denote the firm (industry) elasticity of demand for factor $i$ ($i = k, l$) with respect to price $j$ ($j = w, r$). Manipulations along the lines of those above give

$$\varepsilon_{ir} = \alpha_{K}(\sigma + W_{1})$$

where

$$W_{1} = \frac{(1 + \beta m)[(\gamma - 1)m - E]}{E + m + mq}$$

The associated industry elasticities require the calculation of $\varepsilon_{nr}$, the elasticity of industry size with respect to $r$, which is given by:

$$\varepsilon_{nr} = \alpha_{K} W_{2}$$

where

$$W_{2} = \frac{(1 + \beta m)(E + q + m + \gamma(1 - m))}{\gamma(E + mq + m)}$$

Thus applying (9) and (10), the industry elasticity of demand for labour becomes:

$$\eta_{Lo} = -\eta_{Lr} = -\alpha_{K}(\sigma + z_{4})$$

where

$$z_{4} = \frac{1 + m\beta}{\gamma(E + m + mq)} \{(1 - \gamma)^{2}m + (1 - \gamma)E + q + \gamma\} \quad (24a)$$

Note that the denominator of $z_{4}$ is again positive, given Seade’s stability condition. Again, after replacement of $q$ from (22d) and some manipulation, we may write:

$$z_{4} = \frac{(1 - \gamma)[(1 - \gamma + \beta) + (1 + E)/m] + (1 + \gamma)/m}{\gamma[(1 - \gamma) + (2 + E/m)/(1 + m\beta)]} \quad (24b)$$

This completes the task of relating factor demand elasticities following technical change to potentially observable magnitudes. In the next section we develop the implication of these results.

9 For a detailed examination of the interactions on the diffusion path within a similar type of model, see Waterson and Stoneman (1985).
5. Influences on the elasticities

The response of industry labour demand to technical change is given in each case by

\[ \eta_i = \eta_{L0} = -\alpha_K (\sigma + z_i) \]  

(25)

where \( \alpha_K \), \( \sigma > 0 \) and \( z_i \) \( (i = 1, 2, 3, 4) \) depends upon market structure as summarised in Table I.

**Table I**

<table>
<thead>
<tr>
<th>Values of the z parameter</th>
<th>No entry</th>
<th>Free entry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( n ) fixed</td>
<td>( n ) variable</td>
</tr>
</tbody>
</table>

**Competition**

\[ z_1 = \frac{\gamma}{1 - \gamma + 1/\beta} \]

\[ z_2 = \frac{1 - \gamma + \beta}{\gamma} \]

\[ (1 - \gamma)[(1 - \gamma + \beta) + (1 + E)/m] \]

\[ + (1 + \gamma)/m \]

**Oligopoly**

\[ z_3 = \frac{\gamma}{1 - \gamma + [(E + m + 1)/(1 + m\beta)]} \]

\[ z_4 = \frac{\gamma[(1 - \gamma) + (2 + E/m)/(1 + m\beta)]}{(1 - \gamma + m + m\beta)} \]

In all cases but one, \( z_i \) is definitely negative, so that the bracket in (25) normally contains two components of opposite sign. To confirm this, note that \( z_1, z_2 < 0 \) since \( \beta < 0 \) and \( \gamma \geq 1 \) (non-increasing returns to variable factors). Also, oligopolistic stability requires that \( E + m + q \), \( E + m + mq > 0 \) (Seade, 1980) and, using the first order conditions (21), this implies \( 1 + (1/m\beta) = ch'/p > 0 \), so \( (1 + m\beta) < 0 \) and hence \( z_3 < 0 \). However \( z_4 \) is ambiguous in sign,\(^{10}\) though likely to be negative. Certainly, if there are diminishing returns (\( \gamma > 1 \)), then each element in the term in braces in (24a) is positive so that \( z_4 < 0 \).

In considering the impact of the various parameters on \( \eta_{L0} \), we must be careful of certain interdependencies. Thus \( \sigma \) and \( \alpha_K \) are not independent; however the sign of \( \eta_{L0} \) depends only on \( \sigma \) and so in looking for effects on sign we can treat \( \sigma \) as parametric. Even then, since, from (25),

\[ \frac{\partial \eta_i}{\partial \sigma} = -\alpha_K \left( 1 + \frac{\sigma}{\alpha_K} \frac{\partial \alpha_K}{\partial \sigma} \right), \]

interpretation is not completely straightforward. Nevertheless, if we focus on (25), it is clear that the sign of \( \eta_i \) depends on \( (\sigma + z_i) \). It then follows that as \( \sigma \to 0, \eta_i > 0 \), (except in the unusual case where \( z_4 > 0 \)), whilst for \( \sigma \) sufficiently large, \( \eta_i < 0 \), whichever of the cases in Table I we are considering. Intuitively, as \( \sigma \to 0 \) and less substitution is possible, the induced output expansion effects of capital improving technical change tend to increase labour demand. A high \( \sigma \) would allow capital-for-labour substitution to a greater extent and thus make a decrease in labour demand more likely.

\(^{10}\) Presumably what can happen here is that each firm increases output by so much when costs fall that exit is necessary to restore equilibrium.
Turning now to the analysis for $\beta$, $\gamma$ and $m$, from (25) we have:

$$\frac{\partial \eta_i}{\partial \phi} = -\alpha_k \frac{\partial z_i}{\partial \phi}, \quad \text{for } \phi = \beta, \gamma, m. \quad (26)$$

Evaluation is straightforward in principle, but will differ somewhat between cases. It is easiest if we first consider the two “competition” cases, then compare oligopoly with these. Differentiation of the expressions $z_1$ and $z_2$ in Table I immediately yields the results:

$$\frac{\partial \eta_i}{\partial \beta} < 0; \quad \frac{\partial \eta_i}{\partial \gamma} \geq 0 \quad \text{as } \beta \geq -1, i = 1, 2.$$

The first of these extends Allen’s (1938, p. 508) basic result. The more elastic is demand (the more negative is $\beta$) the more likely is it that demand for labour will increase consequent upon technical change. This is intuitively sensible since a high demand elasticity implies a large output expansion effect so a lesser likelihood that labour demand might contract when capital is substituted for labour. The result on demand elasticity is also robust to some additional modifications in specification. In particular if demand is of constant elasticity form $E = (1/\beta) - 1^{11}$, so that $z_3 = z_1$. There is a straightforward intuitive explanation since, with constant elasticity of demand, the proportionate price reduction is equal to the proportionate cost reduction (cf. Waterson, 1980).

The influence of the elasticity of scale upon the derived demand for labour under competition is very much bound up with the size of demand elasticity. Again, some intuitive feel can be injected into this result. An increase in $\gamma$, by itself, increases the extent of diseconomies of scale, so reduces the optimal scale of the firm; whilst a decrease in $r$, by itself, reduces diseconomies of scale, so increasing optimal scale (Baumol, Panzar and Willig, 1982, ch. 6). The net effect therefore would appear to depend upon the output effect of the fall in the cost curves (the vertical, as opposed to horizontal impact) and the increase in scale, compared with the $\gamma$ effect of output reduction and a rise in cost curves. For these reasons it depends upon the elasticity of demand. This effect carries through to the constant elasticity of demand oligopoly case.

Before leaving the competition case, we should consider the relative size of short versus long run effects. Examining $z_1$ and $z_2$ from Table I, $z_1 = z_2$ if $\gamma = 1$ but with $\gamma > 1$, $z_1 < z_2$ and hence $\eta_1 > \eta_2$. This suggests that, consequent on a technical change, the short run impact on employment is likely to be more beneficial than the long run impact. Thus, suppose initially the industry is at a zero-profit equilibrium and consider the impact of an increase in $\theta$. With fixed-$n$, industry output will tend to increase by less than

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11 If $P = aY^{1/\beta}$ then $P' = \frac{1}{\beta} \left( \frac{1}{\beta} - 1 \right) aY^{1/\beta - 2}$ so $E = YP'/P' = 1/\beta - 1$. 
in the variable-n case (except if $\gamma = 1$) and hence one would expect higher labour demand in the long run. On the other hand, however, in the short run, firms operate away from the minimum of their average total cost curve and are affected by diminishing returns to scale: this tends to imply a relatively greater labour demand. The latter effect appears to dominate the former.

How does oligopoly differ in terms of consequential labour demand effects from perfect competition? In particular, we must first examine whether demand is more or less elastic under oligopoly. It is evident from inspection of the $z_i$ values in Table I that as $m \to \infty$, $z_3 \to z_1$ and $z_4 \to z_2$, as we would expect. Oligopolistic behaviour becomes ‘competitive’ as the number of effective firms increases. But do the $z_i$ approach the competitive values from above or below?

Examining $z_1$ and $z_3$, we have $\eta_3 \leq \eta_1 \Leftrightarrow z_3 \geq z_1 \Leftrightarrow (E + 1)\beta \leq 1$. Whether $\eta_3 < \eta_1$ thus depends on $E$: with linear demand ($E = 0$), $\eta_3 < \eta_1$; with isoelastic demand, $\eta_3 = \eta_1$. Clearly, if $E + 1 > 0$, $\eta_3 < \eta_1$. If $E + 1 < 0$, then it is still the case that $\eta_3 < \eta_1$ if $(0 > )\beta > 1/E + 1$, i.e. so long as $\beta$ is not too elastic. This case is probably the more likely; if so, it follows that labour demand is less likely to increase consequent upon a technical change under oligopoly than under competition (especially in the short run, as intuition would perhaps suggest). Comparisons of $z_4$ with $z_2$ appear substantially more difficult, though if $\gamma = 1$ and $\beta$ is parametric, $z_4$ is normally greater than $\beta$, the $z_2$ value.

In terms of the influence of the parameters $\beta$ and $\gamma$ on the sign of $\partial \eta_i / \partial \phi$ in oligopoly cases ($i = 3, 4$), no general results are available. We have examined three special cases, namely constant demand elasticity, as discussed above, linear demand and parametric $E$. The results obtained are listed in Table II. As may be seen, these largely parallel the competition results in the case of demand effects, but there is no clear trend (except to say that demand elasticity matters) in the case of the scale parameter. Table II also includes results concerning the effects of changing the number of firms (keeping $\lambda$ constant) on the employment effects as discussed immediately above. In general, industry structure does matter, though its influence is not clear cut.

Turning to the long run versus short run comparison in oligopoly, it is less easy to deduce whether and under what conditions $\eta_3 \geq \eta_4$ although, if $\gamma = 1$, then:

$$z_4 - z_3 = \frac{(1 + m\beta)(E + 2)}{(E + 2m)(E + m + 1)}$$

and $\eta_4 \leq \eta_3$ as $E \geq -2$. Thus in the linear demand case, $E = 0$, $\eta_4 > \eta_3$ whilst in the isoelastic demand case, $\beta \geq -1$ implies $\eta_4 \leq \eta_3$. It seems difficult to give an intuitive interpretation of this kind of effect.

Finally, let us return to the case mentioned in Section 2 where technical change has the effect of reducing $F$. It is evident that in the short run ($n$
TABLE II
Effect on employment (sign of $\partial \eta L_0 / \partial \phi$) is/depends upon*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Market structure</th>
<th>$E = (1/\beta) - 1$</th>
<th>$E = 0$</th>
<th>$E$ : general case</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>$\beta \geq -1$</td>
<td>$\beta \geq -1 - 2/m$</td>
<td>$E + 2 + m(1 + \beta) \geq 0$</td>
<td>$(m$ large: $\beta \geq -1)$</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Complex</td>
<td>Complex</td>
<td>$(\beta = -1 + 0; m$ large: $\beta \leq -1)$</td>
<td>$(0 \geq E \geq -1: -1)$</td>
</tr>
<tr>
<td>$m$</td>
<td>$0 + \beta(E + 1) \geq 1$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Where (as with $\gamma$) there is a split result, the convention is that the upper inequality refers to a positive sign e.g. constant elasticity, $fn$; $\partial \eta L_0 / \partial \gamma \geq 0$ as $\beta \geq -1$.

† $vn, fn$, refer to variable-$n$ and fixed-$n$ cases. i.e. free and non-free entry, respectively.
‡ These results evaluated at $\gamma = 1$.
§ Variable-$n$ case is not considered since this implies $n$ is endogenous, given $\lambda$.

fixed), this will have no impact, since each firm has no cause to change its output under oligopoly or competition. When $n$ is variable we can expect some impact. Clearly if $F$ has fallen, established firms are earning supernormal profits, so we can expect entry. Seade (1980) shows this will lead to increasing industry output $Y$. This in turn will normally give an increased demand for labour, though analytically the result does not appear clear-cut if there are decreasing returns.12

6. Concluding discussion

Our analysis makes clear the potential for a diversity of responses by industries to technological change. How an industry responds to technical change depends upon various factors—predictably important are final demand elasticities13 and elasticities of substitution, but it turns out that industry structural influences—such as firm numbers, economies of scale factors, long run as against short run effects and so on—are also important.

12 From (15a), we have:

$$\frac{dL}{dn} = c_u h \left(1 + \gamma \frac{n dy}{y \ dn}\right)$$

and $dY/dn > 0$ implies $\frac{n dy}{y \ dn} > -1$,

but the product of that with $\gamma$ might conceivably be less than $-1$.

13 This result confirms the more casual arguments of Pras (1981) on this point. A recent illustration of the point is provided by discussion concerning the effects of Sunday trading on employment in retailing.
Does the model provide insights into real world behaviour? We feel that it does, though we recognise the dangers of casual and selective verification. First, consider the elasticity of substitution. The greater this is, ceteris paribus, the more likely it is that capital augmenting technical change will reduce the demand for labour. Thus, there is a rationale here for workers to try to limit the degree of substitution available by resisting changes in manning levels when new machinery is introduced.\textsuperscript{14} This however only makes sense for a ‘closed’ industry—such as newspaper printing—or for the ‘siege’ economy. If the market is not barred to national or international competition then the indigenous industry is vulnerable, with those firms resisting technical change likely to be the casualties of the first stage adjustment process. Thus we would expect to see more restrictive practices in relatively ‘closed’ industries such as printing and the docks than in more open markets such as domestic electrical goods and cars.

The difference between open and closed markets may be related more directly to the elasticity of demand impact. An indigenous ‘industry’ facing international competition is more likely to be facing a more elastic demand for its product. In such a case the elasticity of demand effect is likely to swamp any elasticity of substitution effect—and there is likely to be a more substantial increase in labour demand following technical improvement in this case. This is even more the case if structural effects are considered—some experiments we have tried in applying numerical values suggest that small-numbers industries with increasing returns to scale and elastic industry demand would have large proportionate increases in labour demand in response to capital augmenting technical progress. This accords well with observations of the development of several industries now in their maturity. Equally it would appear that industries today exhibiting these properties (e.g. home computing products) are expanding employment and that (though individual firms may rise and fall) skilled employees in these areas have little or nothing to fear from such technical change.

It is also important to note that our analysis strongly suggests technological change is not (at least directly) the cause of the rapidly falling employment in U.K. textile industries. The U.K. elasticity of demand for textiles, according to several of Deaton’s (1975) estimates, is insignificantly different from \(-1\). Hence from Table I, \(z_1\) and \(z_2\) (we assume textiles is a fairly competitive industry) are around \(-1\). Consequently it is only if \(\sigma > 1\), which is unlikely, though not out of the realms of possibility (see Nerlove, 1967), that the elasticity of demand for labour with respect to technical change is negative. The underlying cause is more likely to be foreign competition partly occasioned by failure to adapt to technological change.

Of course there are potential effects apart from those we have detailed in earlier sections. There is, for example, what we characterised in our

\[\text{14} \text{ Though, of course, such investments appear less attractive under a low—}\sigma\text{ regime than under a high—}\sigma\text{ regime. Ceteris paribus, a lower } \sigma \text{ implies less investment.}\]
introductory remarks as the third stage. This is the (explicit or implicit) focus for much of the analysis others have concentrated on. Here, at least two influences emanating directly from those discussed above would seem to be important. First, there is the effect on the capital goods producing industry. Using equations (22a) and (22b), we find that:

\[ \eta_{K8} = (\sigma - 1) + \eta_{L8} \]  

(27)

Hence, if \( \sigma = 1 \) there is the same proportionate effect on capital demand as on labour demand, so if technical change has reduced the demand for labour in the industry in question (e.g. footwear) it is also likely to reduce it in the industry producing equipment for it (the footwear machinery industry). Also, from (25), a low \( \sigma \), while being good for employment in this industry, is less likely to be good for employment in the capital goods industry, and vice versa for high \( \sigma \).

Secondly, a lower effective factor price will imply a lower final good price for this industry.\(^{15}\) This will have both income and substitution effects. As well as the substitution in favour of this good away from others, people who formerly bought the good will have had their real income increased and will therefore spend more on other goods. Increases in such expenditure will be proportionately greater on luxury items and, within a closed economy at least, this would lead to increases in labour demands in those industries. In an open economy, such offsetting effects are less clear-cut, and luxury purchases may come largely from overseas; Thirlwall (1982) suggests this may be a particular worry for the U.K. Extending the analysis to this further stage is naturally rather more speculative and difficult.

What we wish to emphasise then, is the diversity of responses that might be expected, since effects in one particular industry can have long-lasting consequences. We have therefore examined the impact of particular forces common to (but having differing effects on) different industrial structures. Predictably important amongst these have been final demand elasticities and the elasticities of substitution, but we believe we have progressed beyond straightforward intuition in noting also the effect of structural influences such as firm numbers and scale factors, and in the distinction between shorter and longer run effects.

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\(^{15}\) This assumes factor price effects are not outweighed by structural effects.