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AN EMPIRICAL STUDY OF THE INTERRELATIONSHIP BETWEEN EMPLOYMENT, PRICE AND INVENTORY DECISIONS IN U.K. MANUFACTURING

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A B S T R A C T

This paper investigates the dynamic behaviour of employment,
prices and inventories of finished goods when non-competitive
firms take joint decision rules based upon the optimisation
of a certain intertemporal criterion function.
A theoretical model is developed to provide the specification
of the Euler equations which characterize the previous
optimal solutions. These are jointly estimated using data from
the manufacturing sector in the U.K., providing favourable
evidence for the model.

1.   Introduction

The purpose of the present paper is to investigate the dynamic behaviour of employment, prices and inventories of finished goods when firms take joint decision rules based upon the optimization of a certain intertemporal criterion function. To do this, a theoretical model is developed to provide a specification of the various factors that influence the above mentioned variables.   The model is then fitted to data from the manufacturing sector in the UK in an effort to present some empirical evidence on the issue in question.

The model posses a number of broad features that are worth highlighting at this point.   First it is essentially an extension of Dolado (1987) (referred hence forward as DL1).   The latter paper focused solely on an analysis of joint intertemporal decision rules for employment and prices, excluding the explicit modelling of inventories and hours which jointly act as buffer stocks in order to equate planned supply and ex-post demand.   The present paper extends these results by undertaking the integrated analysis of investment in inventories in finished goods as well developing the linkage between the latter decisions and the price and employment decisions.   This model, as the previous one, rests upon the theoretical framework of the Layard and Nickell model (1986), (see also Bruno (1979) and Maccini (1984)), which has proved to be rather succesful when fitted to UK manufacturing employment data (see eg. Wadhawani (1986), Burgess (1986) and

Burgess and Dolado (1987)) and also to a wide range of other countries (see Bean, Layard and Nickell (1986)). Secondly, in terms of the recent empirical literature on inventories, the model is perhaps most closely associated with the work of Blanchard and Melino (1986) and Hall, Henry and Wren-Lewis (1987).[1] In common with the first paper I model prices, quantities and inventory decisions by firms which operate in non-competitive product markets, assuming the existence of non-interactive quadratic adjustment costs in changing prices employment and inventories. In that respect I extend their model by incorporating successfully adjustment costs in changing prices in order to explain stickness in the price equations, which in their work proved to be an unsuccesful attempt. In common with the second paper I integrate decisions on employment and stockbuilding, adding price decisions and allowing for the effects of relative factor prices, both issues being excluded in their study, but at the expense of not allowing for interactive adjustment costs as in there formulation. Finally, in carrying out the empirical work, I estimate jointly the Euler equation which characterize the first order conditions of the problem, instead of attempting to estimate closed-form decision rules as in both of the previous studies. Given the large set of conditioning variables which is used in this work and the complexity of the first order conditions, in part sidestepped by the use of log-linearisations, the gain in efficiency from estimating the closed-form rules seems rather small relative to the costs involved.

The plan of the paper is the following. In Section 2 we present the model, computing the steady state equilibrium of the supply side of an economy or sector in which firms with market power face quadratic adjustment costs in their control variables. Section 3 presents the dynamics of the model, incorporating the interaction of adjustment costs with the stock-flow equation governing the behaviour of inventories. Section 4 presents the estimation results as well as tests of the various restrictions implied by the model. Section 5 concludes. Finally there is a Data Appendix and a technical Appendix.

2. The model without adjustment costs

The model considered in this section is rooted in the work of Layard and Nickell (1986), where its general structure and implications are discussed in more detail. An economy or sector is considered which consists of m identical imperfectly competitive firms in the output market (indexed by i) but which operate as price-takers in the input and capital markets. Notwithstanding the identical firms assumption, it is assumed that each monopoly has its own insulated island of consumers, so that firms do not realize that they are all identical. This assumption is simply made for analytical convenience, especially when considering aggregation issues.

The i-th firm faces an expected demand function at time t determined by

$$Y^{ed}_{1t} = \left[\frac{P_{1t}}{P^e_t}\right]^{-\theta} \overset{=e}{Y}_{1t} \;, \quad \theta > 1 \tag{1}$$

whereas its supply function has the following form

$$Y^s_{1t} = F\left[\frac{N_{1t}}{P^e_t} \;, \frac{P_{mt}}{W_t}, A_t\right] K_{1t} H_t; \; F_1 > 0, \; F_2 < 0,$$

$$F_3 > 0, \; F_{11} < 0, \; F_{22} > 0 \; . \tag{2}$$

where P_{1t} is the price level charged by the i-th firm; P^e_t is the expected general price level in time t; $\overset{=e}{Y}_{1t}$ is the firm's expected share of the general level of demand; N_{1t} and K_{1t} are employment and capital; W_t is the nominal labour cost (nominal wage plus employers' contributions to Social Security); P_{mt} is the nominal domestic price of raw materials and energy; A_t represents an index of technical progress of unknown type; and H_t represents hours of work.

The demand function is of the constant elasticity type where, in a natural way, the general level of demand is measured relative to the potential output of the economy. Thus it has the form

$$\overset{=e}{Y}_{1t} = F\left[\frac{L_{1t}}{K_{1t}} \;, \frac{P_{mt}}{W_t}, A_t\right] K_{1t} \bar{H} \exp(\sigma^e_t) \tag{3}$$

where L_{1t} is the labour force in the i-th island (notice that

given the identical firms assumption $L_{1t}/K_{1t} = L_t/K_t$, the aggregates being given by $L_t = mL_{1t}$ and $K_t = mK_{1t}$ respectively); $\bar{H}$ is the standard level of hours, σ^e_t represents an index of expected aggregate demand relative to potential output.

The supply function has the form of a restricted supply function obtained from an original technology which exhibits constant returns to scale (CRTS) and which depends on three inputs: labour, raw materials + energy and capital. Although the analysis at this stage is static we will assume that labour represents a quasi-fixed input subject to adjustment costs, capital is a fixed factor, ie. predetermined when the other decisions are taken, and raw materials + energy is a variable input immediately adjustable. These assumptions, together with a one-shift production system in hours, allows us to write the technology as in (2) making use of cost minimisation to eliminate materials + energy.

In order to introduce a role for inventories of finished goods in the model, it is convenient to start by describing the timing of the decisions made by the firm. I assume that the representative firm makes pricing decisions one period in advance as a function of the expected price level and the expected shift in demand and subsequently fixes employment and inventories to satisfy total expected demand. When actual demand arrives one period later, the technology permits actual output to adjust to actual sales to some extent, by adjusting hours of work from their standard level. Deviations of actual inventories from planned inventories act as the residual variable. Since the

representative firm's expected sales are assumed to vary positively with its inventory level relative to expected demand in the market. it is assumed that a prior steady state optimization exercise leads firms to seek to maintain target inventories as a possible constant ratio of expected demand. Similarly target production is also assumed to be proportional to expected demand, namely (ceteris paribus)

$$I_{it}^{*p} = C_{1t} \ Y_{it}^{ed} \qquad (4)$$

$$Y_{it}^{*p} = C_{2t} \ Y_{it}^{ed} \qquad (5)$$

where I_{it} denotes the representative firm's inventory of finished goods and the superscripts (*) and (p) denote dynamic equilibrium and planned value respectively.[2] The ratios C_{1t} (i = 1,2) have been made time dependent in order to highlight possible dependence on, say, expected real interest rates, which may capture the opportunity costs of holding stocks. Given the stock-flow equation for planned inventories (using end-of-period definitions)

$$I_{it}^{p} = I_{it-1} + Y_{it}^{p} - Y_{it}^{ed} \qquad (6)$$

for consistency with (6) in steady state, $C_2 = 1 + C_1 \ (\delta/1+\delta)$, δ being the constant rate of growth in such a dynamic equilibrium.[3] For consistency with the rest of the model which produces log-linear decision rules, we replace (6) by its steady-state

log-approximation

$$\Delta i_{it}^{*p} = M \left[y_{it}^{*p} - y_{it}^{ed} \right] \qquad (7)$$

where $M = (1+\delta)/C_1$ [4]

and small letters denote logs of capital ones.

Since the actual outcomes are stochastic and (6) rather than (7) holds for the planned value, firms assign priorities to remove the disequilibrium attached to discrepancies ocurring between planned values and their respective steady state outcomes.

In order to determine the way in which the firms chooses price, employment and inventory plans, it is convenient to specify its revenue (R_{it}) and cost (C_{it}) at time t, given by

$$R_{it} = P_{it}^{p} \left[\frac{P_{it}^{p}}{P_t^{e}} \right]^{-\theta} \ \bar{Y}_{it}^{e} \qquad (8)$$

$$C_{it} = W_t N_{it}^{p} \ \bar{H} \ \mathfrak{z} \left[I_{it}^{p}, \ Y_{it}^{ed}, \ C_{1t} \right] \qquad (9)$$

The revenue function is written in a natural way. The cost function is multiplicative in the loss function $\mathfrak{z}(\cdot)$ which attributes penalties to moving away from the target level expressed in (4). It is assumed that $\mathfrak{z}(\cdot) = 1$ when the target (4) is achieved in planned values, and that away from this level, costs are of smaller order of magnitude when compared to the

ordinary wage bill for standard hours, $W_t N_{it} \bar{H}$. The following quadratic in logs functional form is used in order to derive log-linear decisions rules

$$\ln \gimel\left[I_{it}^p, Y_{it}^{ed}, C_{it}\right] = {}^b/_2 \left[i_{it}^p - c_{it} - y_{it}^{ed}\right]^2 \tag{10}$$

which approximates the joint effect of declining stockout costs as a function of the level of stocks and rising storage costs, convex beyond the target level (see e.g. Blanchard (1983)).

Once revenues and costs have been defined, the representative firm chooses plans to maximise the expected present value of its intertemporal cash flow $\left[\Pi_{it} = R_{it} - C_{it}\right]$

$$\max_{t} E \sum_{s=0}^{\infty} \phi^s \, \Pi_{it+s} \quad \text{subject to (7)} \tag{11}$$

where ϕ is a discount factor.

The first order condition read as follows

$$\partial/\partial p_{it} = R_{it} (1-\theta) - C_{it} \left[\theta b\left[i_{it}^p - c_{it} + \theta \tilde{p}_{it} - \bar{y}_{it}^e\right] + \lambda_{it} M\theta = 0 \tag{12.1}$$

$$\partial/\partial n_{it} = -C_{it} + \lambda_{it} M a_1 = 0 \tag{12.2}$$

$$\partial/\partial i_{it} = -C_{it} b\left[i_{it}^p - c_{it} + \theta \tilde{p}_{it} - \bar{y}_{it}^e\right] - \lambda_{it} + \phi \, E_t \lambda_{it+1} = 0 \tag{12.3}$$

$$\partial/\partial \lambda_{it} : \quad \Delta i_{it}^p = M\left[a_1(n_i^p - k_i)_t + o_t^e + \theta \tilde{p}_{it} - a_1(l_i - k_i)_t\right] \tag{12.4}$$

where λ_{it} is the Lagrange multiplier at time t, $\tilde{p}_{it} = p_{it} - p_t^e$ and the following log-linear approximations have been used for planned supply and expected demand

$$\ln Y_{it}^p \simeq a_1(n_i^p - k_i)_t - a_2(p_m - w)_t + a_3 a_t + k_{it} + \bar{h} \tag{13.1}$$

$$\ln Y_{it}^{ed} \simeq -\theta \tilde{p}_{it} + a_1 (l_i - k_i)_t - a_2 (p_m - w)_t + a_3 a_t + k_{it} + \bar{h} + o_t^e \tag{13.2}$$

Equation (12.1) characterizes the representative firm's sales, in the sense that sales have to be such that the sum of the price and marginal cost of being away from target inventories equals the shadow price of inventories. Equation (12.2) characterizes employment by equating marginal cost to the shadow price. Equation (12.3) characterizes the dynamics of the shadow price by equating the marginal benefit of getting the target inventory plus the expected discounted value of the shadow price next period relative to the contemporareous shadow price. In the next step, instead of obtaining explicit dynamic solutions for

the firm's plans derived from the system of equations (12), given that other types of adjustment costs have not yet been included, we prefer to concentrate on the dynamic steady-state equilibrium plans. These solutions correspond (apart from constants) to the long-run solutions in the Euler equations derived below, once the different adjustment costs have been incorporated. To obtain them the rate of growth of the variables are assumed constant and different time subscripts are equated. Eliminating the Lagrange multiplier between equations (12.1) and (12.2) yields,

$$1 - \left[a_1 b \left[i_{1t}^p - c_{1t} + \theta \tilde{p}_{1t} - \tilde{y}_{1t}^e\right]\right] = R_{1t}\left[(\theta-1)a_1/(\theta c_{1t})\right]$$

(14)

where the RHS of (14) is approximately unity.[5] Using the approximation $1+\ln x \approx x$ for $x \approx 1$, we have that (apart from constants)

$$\theta\left[1-a_1 b\right]\tilde{p}_{1t} - \left[1-a_1 b\right]\tilde{y}_{1t}^e - a_1 b\left[i_{1t}^p - c_{1t}\right] \approx \left[p_{1t} - w_t\right] - n_{1t}^p$$

(15)

Substituting n_{1t}^p from (12.4), where $\Delta i_{1t}^p \approx \delta$, in the previous expression, the equilibrium price rule is obtained. It is now assumed that there are two kinds of pricing behaviour. A proportion s of the firms price on 'marginal' cost basis (i.e. based on σ_t^e) and a proportion (1-s) of firms charge prices on a 'normal' cost basis, so that instead of tracking marginal cost over the cycle, they 'average' profit in order to fix a 'mark-up'

independently of σ_t, say for an average value $\bar{\sigma}$. Why they should behave in this way is a theoretical issue which is not analysed in this paper, since it has been tackled elsewhere (see e.g. Dombergen (1979)), but given that there is no shortage of empirical evidence in favour of such a hypothesis, we use it for aggregation purposes. Under this assumption (see Appendix) the following aggregate price rule follows in the plans equilibrium (denoted by the superscript (*p))

$$\left[p_t^{*p} - w_t\right] = \gamma_1^{-1}\left[-(k-1)_t + \gamma_2\left[p_m - p^{*p}\right]_t + \left[\eta-\gamma_3\right]\sigma_t^e - \gamma_4 a_t\right.$$
$$\left. - \theta\eta \tilde{p}_t - \gamma_5\left[i_t^{*p} - c_{1t} - k_t\right]\right]$$

(16.1)

Once the price rule has been specified, the 'target' level for inventories and the supply function yield the corresponding aggregate employment and inventory rules in steady state equilibrium

$$\left[n_t^{*p} - k_t\right] = -\gamma_1\left[w_t - p_t^{*p}\right] - \gamma_2\left[p_m - p_t^{*p}\right] + \gamma_3\sigma_t^e + \gamma_4 a_t +$$
$$\gamma_5\left[i_t^{*p} - c_{1t} - k_t\right]$$

(16.2)

$$\left[i_t^{*p} - k_t\right] = c_{1t} - \theta\tilde{p}_t + \sigma_t^e - \eta^{-1}(k-1)_t \quad \beta\gamma_2(p_m-w)_t + \beta\gamma_4 a_t$$

(16.3)

where $\gamma_1, \gamma_2, \gamma_3, \gamma_5, \eta, \beta > 0$ and $\gamma_4 \gtrless 0$. The equilibrium rules have been parameterised in terms of the previous

coefficients. The τ_i's coefficients represent the elasticities of employment normalised by capital, given CRTS, with respect to its arguments, i.e. real input prices, demand shift, technical progress and normalized inventories, in the long-run equilibrium. The coefficients η and β represent "technological" parameters. Obviously all these coefficients are functions of the original technological coefficients, a_i's and the proportion s, but we prefer to focus on the former as the underlying 'deep' parameters of the model, instead of on the latter set, since we have made numerous approximations in order to obtain linear decision rules. Note that if the original set of coefficients is assumed to be invariant to changes in the policy rules, convolutions of them will also be invariant.

The interpretations of the previous first order conditions have interesting theoretical implications which do not seem to have been previously explored in the empirical literature. Equation (16.1), characterizing the price rule, just expresses the familiar marginal revenue equal to marginal cost condition. Under the assumption that the cost of being away from target level of inventories is of smaller order of magnitude than total costs based on employment at fixed hours, the larger the level of inventory available to face demand, the smaller will be the increase in the total marginal cost, reflected in the negative sign of inventories in the price equation. Equation (16.2), characterizing the employment rule, stems from equating the marginal revenue product of labour to its marginal cost. The use of this condition together with the previous one is perfectly

valid once the production function has been eliminated from the analysis. Using similar arguments, we find that for a given price, inventories have a positive influence on employment. This sign is the opposite of that predicted by the analysis when the role of relative prices in a non-competitive framework is not considered (see Hall et al (1986)). Equation (16.3), characterizing the inventory rule, just represents the proportionality of sales to expected demand. Obviously once the inventory equation is substituted into the two previous equations, we will find employment and 'mark-up' prices related to real factor prices, demand shift, the capital-labour ratio and price surprises (see Maccini (1984) for similar implications).

When estimating the previous rules, we will assume that plans differ from observed realizations by white noise error terms. In particular, since firms are allowed to adjust hours in order to cover a certain proportion of the gap between expected and actual demand, we have that

$$i_t^* = i_t^{*p} - r\left[y_t^d - y_t^{ed}\right] = i_t^{*p} - r\left[-\bullet\ \tilde{p}_t + \tilde{\sigma}_t\right] \quad ;0 < r < 1 \tag{17}$$

where $\tilde{\sigma}_t = \sigma_t - \sigma_t^e$. That is when actual demand is higher (lower) than expected demand, actual inventories will be lower (higher) than the planned level. Also, relating to the estimation stage, it is important to notice that the existence of cross-equation restrictions in the three decision rules serve to identify all

the individual coefficients, except perhaps θ if the surprise term $\tilde{p}_t$ is subsumed in the error term when using a substitution method of estimation. This partial lack of identification, however, disappears once some dynamics are incorporated, as will be seen in the next section.

3. The model with adjustment costs

Once the equilibrium in the absence of adjustment costs have been examined, the next step is to introduce a further role for dynamics when adjustment costs are allowed to play a role together with the stock-flow equation. In DL1, the dyamics generated by the joint presence of adjustment costs in employment and prices were analysed. The former have been widely used in the literature (see Nickell (1987)), being basically rationalised by the existence of hiring and firing costs. The latter are rationalised by the implicit cost (increased search activity for substitutes, etc.) that results from unfavourable reactions of customers to large price changes (see Rotemberg (1980)). As in the inventory's loss function, a 'smoothing' by aggregation argument is invoked to justify the introduction of quadratic convex costs (see Muellbauer (1984)). Finally, the existence of quadratic convex costs in adjusting the level of inventories, is also assumed. The existence of all these costs create acceleration effects of sales on production which allow for a much richer relationship between the dynamics of the three different processes.

In common with the analysis in the absence of adjustment

costs, the cost function is redefined in a multiplicative form, so that each cost (ceteris paribus) is measured as a proportion of the total wage bill for standard hours, assuming again that each individual cost is of smaller order of magnitude than the wage bill. The generalised cost function of the representative firm at period t reads now as follows

$$C_{1t} = W_t \; N_{1t}^p \; \bar{H} \; \Rightarrow \left[I_{1t}^p , C_{1t} , Y_{1t}^{ed} \right] \Rightarrow \left[N_{1t}^p , N_{1t-1} \right] \Gamma \left[P_{1t}^p , P_{1t-1} \right] \Psi \left[I_{1t}^p , I_{1t-1} \right]$$

(18)

such that when $N_{1t}^p = N_{1t-1}$, $P_{1t}^p = P_{1t-1}$ and $I_{1t}^p = I_{1t-1}$, $\Rightarrow(\cdot)$, $\Gamma(\cdot)$ and $\Psi(\cdot) = 1$ respectively. As before the following parameterisations are used

$$\ln \Rightarrow(\cdot) = \; ^d/2 \; \left[\Delta n_{1t}^p \right]^2$$

(19)

$$\ln \Gamma(\cdot) = \; ^f/2 \; \left[\Delta p_{1t}^p \right]^2$$

(20)

$$\ln \Psi(\cdot) = \; ^g/2 \; \left[\Delta i_{1t}^p \right]^2$$

(21)

Again, the representative firm maximizes the expected present value of the discounted stream of cash-flows as in (11). It can be shown (see Appendix) that maximising the generalized version of (11) is equivalent to minimise the following expression

$$\min_{t} \; \Xi \; \sum_{s=0}^{\infty} \rho^s \left[1/2 \left[n_{1t+s}^p - n_{1t+s}^{*p} \right]^2 + b/2 \left[i_{1t+s}^p - i_{1t+s}^{*p} \right]^2 \right.$$

$$\left. + d/2 \left[\Delta n_{1t+s}^p \right]^2 + f/2 \left[\Delta p_{1t+s}^p \right]^2 + g/2 \left[\Delta i_{1t+s}^p \right]^2 \right] \quad \text{subject to (7)}$$

$$(22)$$

where n_{it}^{*p} and i_{it}^{*p} are the equilibrium planned values defined in (16.1) and (16.2) and ρ is a cost deflated discount rate defined as $(C_{t+1}/C_t)\phi$, which we take as a constant real interest rate.

Some lengthy algebra shows that the aggregate first order conditions for this problem are given by

$$\underset{t}{E} \left\{ \tilde{\Delta}^2 \; n_{t+1}^p - \left[d \, \pi + f \right]^{-1} \left[M^{-1} \eta \; f \; \tilde{\Delta}^3 \; i_{t+1}^p + f \; \tilde{\Delta}^2 \; l_{t+1} \right. \right.$$

$$\left. \left. + \eta \; f \; \tilde{\Delta}^2 \; o_{t+1}^e + \alpha \; f \; \tilde{\Delta}^2 \; p_{t+1}^e + \pi \left[n_t^p - n_t^{*p} \right] \right] \right\} = 0$$

$$(23.1)$$

$$\underset{t}{E} \left\{ \tilde{\Delta}^2 \; p_{t+1}^p - f^{-1} \left[M^{-1} d \, \eta \; \alpha \; \tilde{\Delta}^3 \; i_{t+1}^p + d\alpha\eta\tilde{\Delta}^2 \; o_{t+1}^e + d\alpha \; \tilde{\Delta}^2 \; l_{t+1} \right. \right.$$

$$\left. \left. - d\pi\tilde{\Delta}^2 \; \tilde{p}_{t+1} - \eta \; \alpha \; \tilde{\Delta} \; i_t^p + \alpha \; \gamma_1 \left[p_t^p - p_t^{*p} \right] \right] \right\} = 0 \quad (23.2)$$

$$\underset{t}{E} \left\{ \tilde{\Delta} i_{t+1}^p - \left[1 + (b/Mg) \right]^{-1} \left[\tilde{\Delta} \; i_t^p + (Mg)^{-1} \eta \; (\tilde{\Delta} n^p + \tilde{\Delta}(w-p))_{t+1} \right. \right.$$

$$\left. \left. + g^{-1} b \left[i_t^p - i_t^{*p} \right] + (\theta Mg)^{-1} f \; \tilde{\Delta}^3 \; p_{t+2}^p \right] \right\} = 0 \quad (23.3)$$

where $\alpha = \pi^{\frac{1}{2}} = \eta\theta$, $\tilde{\Delta} = \rho - L$ ($= \Delta$ for $\rho=1$) and $z_t^e = \underset{t-1}{E} z_t$. The planned equilibrium values $\left[n_t^{*p}, \; p_t^{*p}, \; i_t^{*p} \right]$ are given by (16). In order to estimate the equations, white noise error terms are added to the planned rules, in particular innovations in demand, as in (17), are included when substituting for actual inventories.

These equations basically state as before that, in expectation, marginal revenue equals marginal cost, such that in the long run, the equilibrium conditions (16) are recovered. The existence of adjustment costs implies that the variability of employment, prices and inventories to a given shock will depend on the relative size of such costs together with the firms' desire to attain a desired level of inventories.

Finally, it should be noticed that due to the complexity of the determination of the decision rules, it is very hard to obtain an explicit closed form solution. On top of this difficulty there is the case that most of the conditioning variables are likely to be interdependent and not even weakly exogenous in the structural form representation. Hence, a fully efficient estimation method has been discarded in favour of an IV substitution method in which expected values are substituted by actual values, thus embedding the surprise terms in the error term which will have the traditional moving-average representation. Obviously this procedure entails a loss of efficiency since it does not exploit the restrictions between the rules and the stochastic processes of the forcing variables. However, this potential gain in efficiency is more than offset by

the restrictive assumptions that need to be imposed in order to yield closed-form, rational expectations solutions. Moreover, the Euler equations and the closed-form solutions estimate the same set of parameters, including ϕ which is easily identified, even after applying the substitution method. In order to alleviate, somehow, the inefficiency stemming from using the substitution method, a second version of the model will be estimated where the surprises in prices and demand shift, $\tilde{p}_t$ and $\tilde{\sigma}_t$, will be included. The surprise $\tilde{p}_t$ will be linearly approximated by surprises in wages, i.e. $\tilde{p}_t = \phi \tilde{w}_t$ ($\phi > 0$), computed from a univariate process for wages. This is a rough approximation on various accounts, given that $\tilde{p}_t$ should stem from the rational expectations solution of the price equation. However, as we said before this solution is analytically very difficult to get. For operative purpose we assume that the price surprise would depend upon the wage surprise, as in the approach originally used by Layard and Nickell (1986), and Bean *et al* (1986). Similarly, a univariate process for σ_t is used in order to compute $\tilde{\sigma}_t$.

4. Estimation Results

In this section parameter estimates for the preceding set of first-order conditions are presented. The model has been estimated for the U.K manufacturing sector using seasonally unadjusted data for the sample period 1965(I) - 1982(IV). The price definitions of all the variables are detailed in the Data Appendix. The demand variable is approximated by a synthetic

index formed by competitiveness, deviations of world trade from a trend and Adjusted Public Sector Deficit as a proportion of GDP. The linear combination chosen is the same as in DL1, a restriction which will be tested later. The variable representing a technical progress index is approximated by a spline trend with breaking points in 1973(I), 1974(II) and 1980(III), according to the productivity analysis carried out by Mendis and Muellbauer (1984). In DL1, this variable appears combined with the rate of change of capital which acts as a proxy for technical progress embodied in new capital. The role of this variable was essential in order to achieve stationarity in the residuals of the equilibrium solution regressions, but its economic interpretation in order to justify its presence in the steady state is not completely satisfactory.

In DL1, the existence of a cointegrating vector (see Granger-Engle (1987)) was shown to be a necessary and sufficient condition in order to generate a sensible interpretation of the estimated Euler equation, given the integration characteristics of the time series involved in the model once deterministic trends are rejected in favour of stochastic trends. The standard econometric practice in the estimation of Euler equations has been to detrend the data prior to estimation, in order to achieve stationarity which is a statistical requirement in this type of model (see Hansen and Sargent (1982)). The new theory on integrated processes (see Phillips and Durlauf (1986)) has highlighted the serious defects associated with this approach and therefore the concept of stationarity around deterministic trends

should be substituted by the concept of cointegration among the several variables which appear in the long run solution of the Euler equations. Summarising the results concerning the orders of integration of these variables, $(n-k)$, $(l-k)$, $(p-w)$, (p_m-p), a and σ were found to be $I(1)$ (integrated of order one), according to a three lags version of the Augmented Dickey-Fuller (ADF) test for unit roots against alternatives representing stationarity around a deterministic trend. However, the corresponding equilibrium regressions did not reject the null hypothesis of absence of cointegration. The k_t variable was found to be $I(2)$ and therefore Δk_t turned out to have the correct order of integration as a potential candidate to pick up the unit root in the residuals of the previous regression.

When implementing the same tests for a unit roots in $(l-k)_t$, the Dickey-Fuller t-ratio is $-.84$ whereas the corresponding t-ratio for a second unit root is -5.20. Using a critical values of -3.47 for $I(1)$ and -2.90 for $I(2)$ at five per cent significance level, a unit root is not rejected but a second one is definitely rejected.[7] Therefore, it is of particular interest to examine whether the incorporation of the stockbuilding rule allows for the presence of cointegration among the variables which appear in the long-run solution represented by equations (16), without including the rate of change of capital in the definition of technical progress.

Table 1 contains a set of level regressions to investigate such a possibility. Using an approximate five per cent critical value of .50 for the DW test when the error term in

each equation is generated by a random walk, the computed DW values seem to reject the null hypothesis of a unit root in all cases, validating the estimation procedure which will be discussed below. Two features are worth noting at this stage. On the one hand, there is the absence of the demand index in the price equation.[8] As in DLl, the index or most of the unrestricted individual elements of the index appear insignificant and/or wrongly signed when included in the dynamic version of the model.[9] Moreover, the DW statistics in the equilibrium price equation hardly change when the index was included. On the other hand, the real interest rate which was allowed to play a role in the target level of inventories, possibly capturing opportunity costs of holding stocks, also proved to be incorrectly signed and generally insignificant in the various versions of the model. Using different nominal interest rates and allowing for distributed lag effects did not show much improvement, and thus it was removed from the set of regressors.[10] The lack of detectable influence from this variable in models of inventories for the manufacturing sector in the U.K is also a feature of the studies of Hall *et al* (1986,87). A possible statistical explanation for this empirical feature is that according to its integration properties, the real interest rate is on the borderline of being an $I(0)$ variable for the sample used in those studies, the t-ratio for a unit root being -2.68. Since the remaining variables which appear in the equilibrium relationship are $I(1)$ it is not very surprising that its coefficient is difficult to pin down.

The estimation was carried out using NL3SLS, replacing conditional expectations with actual values so that the surprise terms are incorporated to the error term. Thus, the estimated equations are the same as in (16) except that the zero vector on the right-hand is replaced by a vector of error terms u_t. The incorporation of the surprise terms to the disturbance plus the divergence between planned and actual outcomes induces serial correlation. The extent of such serial correlation has implications for which set of instruments is valid. For example, if the error term is a first-order moving average then, when the equation is estimated at t, only instruments dated at t-2 are valid. We investigated three sets of instruments dated at t-1, t-2 and t-3. Whereas there are no appreciable differences in the coefficient estimates between the sets at t-2 and t-3, there are some significant changes of sign when using the set dated at t-1. On these grounds, the estimates reported below are based upon a set of instruments at t-1 when estimating at t+1. The information set contains the following thirty six instruments: first and second lags of employment, labour force, capital, other inputs price, domestic price and inventory of finished goods and; first to fourth lags of nominal wage and index of demand; first lags of a missmatch index, union - non-union mark-up, tax wedge, unemployment vacancy ratio, fiscal stance, real interest rate, competitiveness, deviations of world trade from a trend, a constant, three seasonal dummies, two trend seasonal dummies, the spline trend and point seasonal dummy for 1973(I).[11] Since NL3SLS minimizes the correlation between instruments and the

residuals of the equations, the minimized value of this objective yields a statistic J which is asymptotically distributed as chi-square and which can be used to test the set of overidentifying restrictions of the model as well as any other structural restrictions implied by assumptions such as CRTS, the linear combination chosen for the index of demand, etc.

Parameter estimates are shown in Table 2. As in most of the studies in this area, the discount rate has been constrained to unity. This choice, however, is not arbitrary as in some other studies in the literature. As it was explained in DL1, the stochastic integration properties of the time series involved in the model justify such assumption. A value of .956, suggested by a sample average of -4.6 per cent of the after tax real interest rate, and a variable discount rate based on the expected real interest rate series were also tried, with very little effect on the estimated structural parameters. The unrestricted estimates presented in the first column of each equation, show quite encouraging results in terms of signs and significance of the variables, once the demand shift has been excluded from the price equation and the real interest rate from all the equations. The value of the J statistic, 78.3, is well below the critical value at the five per cent level for a $\aleph^2(67)$, which is 90.2, thus the overidentifying restrictions are not rejected. When testing for the particular set of cross-equation restrictions, the difference between the J values is 11.1, again well below 27.3 which is the five per cent critical value of $\aleph^2(16)$. With respect to some of the restrictions stemming from particular assumptions of the

model the following results were obtained. CRTS was tested by adding the level k_t to each equation, obtaining a value of 2.61 for a $\aleph^2(3)$, which is non significant. The choice of the index of demand was tested by adding a level of each of the three variables included in the index in each equation, yielding a value of 12.79 for a $\aleph^2(9)$ again non-significant. Finally the joint hypothesis that the regressands are parameterized as second differences for the employment and price equation and a first differences in the inventory equation is also accepted with a value of the test of 3.26 for a $\aleph^2(3)$.

The estimates of the employment elasticity with respect to its arguments, are in line with those obtained in DL1. In particular, the real wage elasticity, τ_1, has a value of -0.4 (t-ratio = 4.8) in line with the low values estimated by Nickell (1984) and Wadhwani (1987) in non-competitive models. The size of this elasticity can be considered rather low when compared with the often quoted results of an elasticity above or around unity in absolute value as obtained by Symons (1983) and Layard and Nickell (1986) respectively. However, the former elasticity is obtained in a purely competitive framework, thus subject to misspecification given that, as shown in this paper, othre variables pertaining to non-competitive behaviour also appear significant, besides the real input prices. The latter elasticity corresponds to a quarterly model of the overall economy instead of the manufacturing sector, and it is obtained from a feedback dynamic equation where the size of the error correction coefficient is -0.032 (t-ratio = 2.4), hence

non-distinguishable from zero using the correct Dickey-Fuller critical value. Parameter inferences based on this equation seems shaky. Similar considerations apply to the other input price elasticity, τ_2, which is -0.12 (t-ratio = 3.0), the negative sign implying a dominance of the negative output effect over the positive substitution effect. The elasticity of demand shifts, τ_3, is around 0.5 (t-ratio = 5.2), its significance casting doubts on, for instance, Symons' results. Competitiveness seems to be the strongest variable in the index, when the individual components are estimated freely. Its absence in the price equation can be interpreted along the aggregation argument expressed in the previous sections. Nevertheless, transient effects, stemming from the existence of adjustment costs appear significantly in the unrestricted estimates of the price equation. The negative sign in the spline trend, τ_4, seems consistent with labour saving technical progress although the rough approximation employed makes this assertion hazardous. The effect of inventory normalized by capital, τ_5, is estimated around 0.12 (t-ratio = 2.4), its significance stemming mainly from the price equation, where its effect is strong even in the unrestricted estimates. The positive sign in the employment equation, although weakly determined, is in agreement with its theoretical counterpart discussed in Section 2.

In relation to the adjustment costs, it is difficult to evaluate their absolute magnitude given the normalization imposed in going from (11) to (22) through a second order Taylor expansion (see Appendix). However, something can be said in

relation to their relative size. The estimates for d,f,g and b show that the convex costs of adjusting employment are almost three times those of adjusting prices, about six times those of adjusting inventories and about twenty times those of being away from the target inventory. Given that the sample averages of the absolute changes in n_t, p_t and i_t (1.25, 2.95 and 3.39, respectively), the relative ranking in terms of proportion of the total wage bill for fixed hours is reversed in favour of costs of adjusting prices, a result which also appears in the study by Blanchard and Melino (1986).

With respect to the remaining parameters, it is difficult to asses whether they are reasonable, without studying their implications for the dynamic behaviour of employment, pricing and stockbuilding. In any case they are consistent in sign with their theoretical counterparts.

As in DL1, parameter stability tests breaking up the sample in 1973(IV) showed a fine performance for the employment equation ($F(14,44) = 1.02$ with 1.85 as a five per cent critical value) and rejection for the price equation ($F(14,44) = 2.03$). However, given that much more unrestricted quarterly estimaters of price equations often reject stability and that the null hypothesis is easily accepted at one per cent significance level, the overall results are encouraging. Indeed, prediction tests for the last two years of the sample do not suffer rejections in any case (the values of the F tests being, 1.55, 1.72 and .17 respectively with 2.05 as the critical value).

Table 3 presents the results when the price and demand

surprises are added to the three equations, where price surprises have been linearly approximated by surprises in the nominal wage. Univariate time series representations of w_t and σ_t have been used to model their respective surprises. The results for the core set of parameters are similar to those in Table 2. The demand surprises are very weakly determined in the inventory equation, an empirical result also shared by the work of Hall et al (1986) who even exclude this variable in their reported equations. The low explanatory power of the random walk representation of the σ_t variable may be in part responsible for its poor performance. However both univariate time series models were acceptable restricted simplifications of unrestricted AR(4), the order restricted by the maximum lag in the instrument set. The wage surprises appear stronger, especially in the inventory equation where the value of the $\aleph^2(3)$ test for exclusion of the Δw_t variables is 9.16, capturing some of the deviation between planned and actual inventory. Again the signs of the proportionality parameters r and ϕ are correct although not very precisely estimated. Overall, the fact that the other parameters hardly change shows that the initial choice of instruments was acceptable.

Finally, in order to get a feeling for the dynamic properties of the model, Fig.1 shows the response of employment, price and inventories to a one per cent permanent shock in demand at period t.[12] This shock is assumed to be anticipated one period ahead.

According to the structural parameters which characterize

the equilibrium rules, a permanent increase in demand, say $\Delta\sigma$, will generate steady state changes in employment, price and inventory given by

$$\Delta n = \eta\Delta\sigma; \quad \Delta p = \left[\tau_1 + \tau_2\right]^{-1} \left[\eta - \tau_3 - \tau_5\right]\Delta\sigma; \quad \Delta i = \Delta\sigma$$

Hence according to the parameter estimates obtained in Table 2, employment would increase by 0.5 per cent, prices would decrease by -0.25 per cent, reflecting the dominating effect of inventory over demand and inventory itself would increase equiproportionally by 1 per cent. The dynamic paths show inventory failing temporarily to offset the cost of adjusting production to meet the higher level of demand. As employment and prices stabilize at their new levels inventories increase to achieve their target level. Prices suffer undershooting and overshooting reflecting the lagged response to inventories interacting with the effects of the shift in demand. Finally, employment decreases at the beginning reflecting the fact that higher demand is met by accumulated inventory. As stocks converge to their new steady state value, employment increases to match the higher level of demand.

5. Conclusions

The results presented in this paper concern several stages of the firm's decision problem: factor demand (employment for given capital) and prices on the one hand and inventories of finished goods on the other hand. The framework in which the

firms operate is an imperfectly competitive one in which they face quadratic convex costs of changing employment, prices and inventories together with penalties derived from non-attaining planned long-run equilibrium values. Firms, which are identical, operate in their own insulated island of consumers, facing uncertainty about the general price level and the aggregate level of demand shifts. When actual demand finally arrives, actual inventories are allowed to deviate from their planned level to some extent.

The results provide interesting evidence on some issues. First, all the specified costs seem to be very important in determining the joint decision rules and the structure of the model allows to identify all the interesting parameters from the estimated Euler equations. Second, and most interesting, aggregate demand (competitiveness, world income and fiscal stance) exerts a significant influence on employment and inventories in the long run, whereas the impact on prices is only transient. This result, which is quite common in the empirical literature on price equations, is justified on the assumption that firms charge prices on a 'normal' cost basis, instead of tracking marginal cost over the cycle. Third, the results concerning the incorporation of inventory decisions to employment, demand and pricing, support empirically the assumption that the costs of being away from the planned target inventory are of smaller order of magnitude than total costs based on employment at fixed standard hours of work. This is reflected in the long run negative sign of inventories in the

price equation and the positive sign in the employment equation, for a given price. These signs obtained in the structural representation of the complete model seem to offer a new perspective on the joint decision rules faced by the firms which does not seem to have been explored previously in the literature. Fourth, the interpretation of the 'core' structural parameters of the model has been offered in terms of elasticities of the several arguments in the employment decision rules instead of the primitive parameters which characterize the technology, because the large number of approximations carried out to obtain log-linear decision rules make such a retrieval unreliable. The sizes and signs of the estimated coefficients appear to be consonant with those obtained in other empirical analyses of the U.K manufacturing sector. Finally, with regard to the estimation procedure, the standard practice of detrending the variables prior to estimation, as if they were stationary around deterministic trends, has been abandoned in favour of exploting the integration and cointegration properties of the series in order to get interpretable results in the estimation of the Euler equations.

Table 1

Cointegrating Regressions

$$(n-k) = -2.706 + \Sigma \delta i Q i - .276(w-p) + .038(p_m-p) + .579\sigma - .012a$$
$$+ .185(i-k)$$
$$T = 72, \ se = .019, \ DW = .76, \ \bar{R}^2 = .994$$

$$(p-w) = 1.726 + \Sigma \delta i Q i + .158(p_m-p) - 2.823(k-1) + .017a$$
$$- .373(i-k)$$
$$T = 72, \ se = .045, \ DW = .83, \ \bar{R}^2 = .846$$

$$(i-k) = -3.707 + \Sigma S i Q i - .762(k-1) - .099(p_m-w) + .008a + .682\sigma$$
$$T = 72, \ se = .025, \ DW = .82, \ \bar{R}^2 = .898$$

Note: T denotes sample size; se denotes standard error of the regression; DW denotes Durbin-Watson statistic; $\bar{R}^2$ denotes multiple correlation coefficient adjusted by degrees of freedom; Seasonal dummies (Q_i's) are not reported for brevity; The coefficients' t ratio are not reported since they do not follow standard distribution (see Engle-Granger (1987)).

Table 2

Estimation with Costs of Adjustment in Employment, Price and Inventory

Employment Eqn ($\Delta^2 n_{t+1}$)	U	C	Price Eqn ($\Delta^2 p_{t+1}$)	U	C	Inventories Eqn (Δi_{t+1})	U	C
CONSTANT	.2816 (5.137)	.2669	CONSTANT	-0.1240 (1.028)	-0.1438	CONSTANT	0.9467 (3.508)	0.9450
$(n-k)_t$	0.0864 (5.196)	0.0820	$(1-k)_t$	-0.4024 (4.372)	-0.4325	$(1-k)_t$	-0.2079 (1.268)	-0.3943
$(w-p)_t$	0.3506 (4.917)	0.0308	$(p-w)_t$	0.1471 (9.547)	0.1626	$(w-p)_t$	-0.0250 (1.618)	-0.0253
$(p_m-p)_t$	0.0086 (2.722)	0.0100	$(p_m-p)_t$	-0.0672 (6.514)	-0.0528	$(p_m-p)_t$	0.0250 (1.618)	0.0253
a_t	0.0010 (5.138)	0.0009	a_t	-0.0042 (3.946)	-0.0048	a_t	-0.0019 (1.056)	0.0047
o_t	-0.0417 (13.781)	-0.0421	o_t	-	-	o_t	-0.0295 (1.485)	-0.2023
$(i-k)_t$	-0.0143 (0.986)	-0.0100	$(1-k)_t$	0.0910 (2.831)	0.0532	$(1-k)_t$	0.2517 (3.170)	0.2023
$\Delta^2 p_{t+1}$	0.097 (1.295)	0.1896	Δi_t	-0.0400	-0.3852	Δi_t	0.6533 (6.346)	0.6487
$\Delta^2 i_{t+1}$	0.0763 (4.530)	0.1259	$\Delta^2 i_{t+1}$	6.271 (3.070)	4.6071	Δn_{t+1}	0.3110 (2.486)	0.3604
$\Delta^2 o_{t+1}$	0.0488 (5.205)	0.0646	$\Delta^2 o_{t+1}$	2.652 (2.544)	2.3634	$\Delta(w-p)_{t+1}$	0.2112 (1.612)	0.3604
$\Delta^3 i_{t+1}$	0.0258 (2.056)	0.1123	$\Delta^3 i_{t+1}$	1.997 (1.025)	4.1032	$\Delta^3 p_{t+2}$	0.4019 (1.951)	0.8332
s.e.	0.00233			0.00663			0.01314	
D.W.	1.86			1.74			2.20	

Number of instruments: 36

Number of parameters: 41

$R^2(67) \sim 78.30 < R^2(67)_{.05}$

$J_u = 78.34$, $J_c = 89.40$. [No of constraints: 16]

STRUCTURAL PARAMETERS

γ_1	γ_2	γ_3	γ_4	γ_5	d	f
0.376 (4.776)	0.122 (3.027)	0.503 (5.232)	-0.011 (4.012)	0.123 (2.412)	10.652 (3.872)	3.482 (3.123)

g	b	x	η	ρ	θ	ρ
1.603 (3.510)	0.503 (5.232)	0.376 (1.173)	0.503 (5.232)	1.027 (1.871)	2.946 (2.371)	1.000 (-)

Note: In parenthesis asymptotic t-ratio; U and C denote Unconstrained and Constrained Estimates respectively. Seasonal and Trend-Seasonal dummies together with a point dummy in 1973(2) for the price equation, have also been included but not reported for the sake of brevity.

Table 3
Estimation with Costs of Adjustment plus Wage and Demand Surprises

Employment Eqn ($\Delta^2 n_{t+1}$)	U	C	Price Eqn ($\Delta^2 p_{t+1}$)	U	C	Inventory Eqn (Δi_{t+1})	U	C
CONSTANT	0.2702 (4.986)		CONSTANT	-0.0986 (1.227)		CONSTANT	1.035 (3.717)	
$(n-k)_t$	0.0904 (4.902)	0.0807	$(1-k)_t$	0.4449 (3.734)	0.4649	$(1-k)_t$	-0.2096 (1.096)	-0.3916
$(w-p)_t$	0.0304 (4.993)	0.0308	$(p-w)_t$	0.1399 (6.571)	0.1771	$(w-p)_t$	-0.0386 (2.089)	-0.0266
$(p_m-p)_t$	0.0093 (2.530)	0.0091	$(p_m-p)_t$	-0.0652 (5.475)	-0.0535	$(p_m-p)_t$	0.0386 (2.089)	0.0266
a_t	0.0009 (4.792)	0.0009	a_t	-0.0043 (3.358)	-0.0051	a_t	-0.0020 (0.954)	0.0025
σ_t	-0.0408 (13.673)	-0.0413	σ_t	-	-	σ_t	-0.0876 (2.743)	-0.2056
$(i-k)_t$	-0.0104 (0.902)	-0.0106	$(1-k)_t$	0.0910 (3.010)	0.0610	$(1-k)_t$	0.2094 (2.826)	0.2056
$\Delta^2 p_{t+1}$	0.2202 (1.226)	0.1734	Δ_t	-0.0453 (0.968)	-0.2380	Δi_t	0.6344 (6.184)	0.6685
$\Delta^2 i_{t+1}$	0.1038 (5.276)	0.0818	$\Delta^2 i_{t+1}$	6.584 (2.393)	5.287	Δn_{t+1}	0.3213 (2.380)	0.3314
$\Delta\omega_{t+1}$	0.0571 (3.286)	0.0419	$\Delta\omega_{t+1}$	3.371 (2.303)	2.707	$\Delta(w-p)_{t+1}$	0.3213 (2.380)	0.3314
$\Delta\omega_t$	-0.0783 (5.205)	-0.0525	Δ_t	-2.372 (2.431)		$\Delta\omega_t$	-0.0083 (0.431)	0.0722
Δu_t	-0.00068 (0.258)	-0.0000	$\Delta^3 i_{t+1}$	2.374 (1.328)	3.475	$\Delta^3 p_{t+2}$	0.5870 (2.286)	0.7130
Δu_{t-1}	-0.00047 (0.152)	0.0000	Δu_t	0.0923 (1.176)	0.1468	Δu_t	-0.0192 (1.161)	0.0033
Δu_{t-2}	0.0019 (0.822)	0.0000	Δu_{t-1}	0.0267 (0.033)	-0.1647	Δu_{t-1}	-0.0087 (1.271)	-0.0021

Δu_{t-2}	0.0062 (0.238)	-0.0076	Δu_{t-2}	-0.0223 (1.866)	-0.0012
Δu_{t-3}	0.199 (1.175)	0.0254			

se	.00233	.00717	.01237
DW	1.90	2.22	2.44

(cont)

Wage Eqn ($\Delta^2 w_{t+1}$)	U	C	Demand Eqn ($\Delta\omega_{t+1}$)	U	C
CONSTANT	0.0152 (3.351)	0.0137	CONSTANT	0.0646 (2.808)	0.0631
$\Delta^2 w_t$	-0.3875 (2.738)	-0.3589			
se	0.0194		0.0876		
DW	2.32		2.31		

Number of instruments: 36 $\bigg\{$ $x^2(117) = 126.18 < x^2(117)_{.05}$
Number of parameters: 63 $\bigg\{$

$J_u = 126.18$, $J_c = 137.61$, [No. of constraints: 28]

STRUCTURAL PARAMETERS

γ_1	γ_2	γ_3	γ_4	γ_5	d	f
0.381 (4.236)	0.115 (2.912)	0.152 (5.151)	-0.011 (3.876)	0.131 (2.519)	11.373 (3.676)	4.562 (2.973)

g	b	M	η	β	θ	ρ
1.707 (3.602)	0.512 (5.151)	0.605 (1.264)	0.512 (5.151)	1.153 (1.556)	4.141 (2.246)	1.000 (-)

f'	r
0.0063 (1.176)	0.362 (1.512)

Note: As in Table 2.

Fig. 1

Equilibrium Response of (n, p, i) to an

anticipated permanent shock in demand

QUARTERS

$- - -$: n_t

$-\cdot-\cdot$: p_t

$———$: i_t
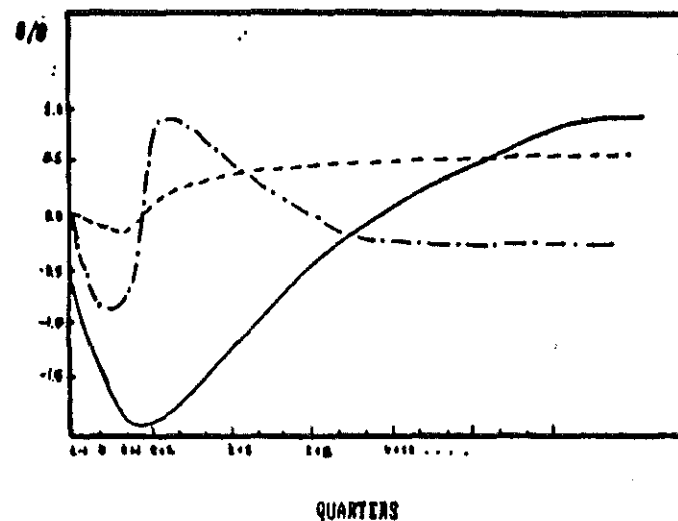
1. Another related work is that of Faini and Schiantarelli (1984) in which they try to provide an integrated account of firm's behaviour under the assumptions of an imperfectly competitive output market and a putty-clay technology. However, it differs from the references quoted in the maintext in the sense that the equations effectively estimated embody specifications which have little to do with the theoretical model.

2. Dynamic equilibrium is defined as the state in which variables grow at constant rates.

3. To obtain the relationship between C_1 and C_2, recall that $\left[I_{it}^{*p}/I_{it-1}^* - 1 \right] = \delta$ and divide the equivalent to (6) in steady state by Y_t^{ed}, making use of (4) and (5).

4. From the relationship $C_2 = 1 + C_1 (\delta/1+\delta)$, we get that

    $$\Delta i_{it}^{*p} \approx \frac{1+\delta}{C_1} \left[Y_{it}^{*p}/Y_{it}^{ed} - 1 \right]$$

    and given that the term in brackets is small, we make use of the approximation $x \approx \ln(1+x)$ for x small.

5. Note that for a constant elasticity demand function as (1) and a Cobb-Douglas specification for the technology, $R_t(\theta-1)a_i/\theta C_t$ is exactly unity.

6. For an attempt to endogenise the parameter representing adjustment cost in changing employment through arguments representing institutional and market factors, see Burgess (1986) and Burgess and Dolado (1987).

7. The ADF test used, as in the previous cases, contains a constant and trend when testing for I(1) and only a constant when testing for I(2), since we are interested in alternatives corresponding to stationarity around a linear trend. The critical values appear in Table 8.5.2 (second and third blocks) in Fuller (1976).

8. For example, in Layard and Nickell (1985, Table 2),
    demand does not show up in the price equatims of any of
    the major OECD economies, reflecting the well known
    empirical fact that it is difficult to find such effects
    in price equations.

9. There are various explanations to why firm's mark-up over
    average costs may decline as aggregate output rises.
    First, the existence of increasing returns. Second, an
    aggregation argument by which increases in demand raise
    the elasticity of demand by raising the share of new
    customers over old customers who have inelastic demand
    for the products they are use to (see Bils (1985)).
    Third, the gain to a firm from deviating from a collusive
    equilibrium when demand is high (see Rotemberg and
    Saloner (1986)). However, in our case, both the index of
    demand and its components were insignificant in the price
    equation.

10. The interest rates used were the Minimum Lending Rate and
    the Treasury Bill rate.

11. The sample mean for the rate of change of the price index
    is 2.4% whereas, for the period 73(1) - 77(4) is 4.0%
    (even when price controls where introduced in April
    1973). However in 1973(2), the rate of change is 0.45%
    reflecting the initial impact, which is all what it is
    left.

12. The interpretation of this shock is best understood as a
    shock in deviations of world trade around a trend (see
    the Data Appendix for a definition of the demand shift)
    instead of as a shock in competitiveness. There are at
    least two reasons to distrust the latter interpretation.
    First, competitiveness appears twice in the price
    equation, i.e. directly through the demand variable and
    indirectly through the £. price of imported inputs
    (p_m-p). The last effect has a positive level effect on

    prices , i.e. a depreciation raises prices. Second,
    competitiveness should be treated as an endogenous
    variable in the system, thus its role as an exogenous
    shock is not clear.

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Appendix

In order to determine the equilibrium planned decision rules described by equations (16) in the main text, it is convenient to start by eliminating n_{it}^p in (15) using (12.4) in steady state, i.e.

$$a_1 \left[n_{it}^{*p} - k_{it} \right] = -\vartheta \, \tilde{p}_{it} + a_1(1-k)_t + \sigma_t^e \qquad (A.1)$$

where contant terms have been eliminated to simplify notation, yielding

$$\left[p_{it}^{*p} - w_t \right] = \pi_0^{-1} \left\{ -\vartheta \, \eta \pi_1 \tilde{p}_{it} - \pi_1(k-1)_t + a_2(1-\eta^{-1}b) \right.$$

$$\left[p_{mt} - p_{it}^{*p} \right] - a_3 \left[1-\eta^{-1}b \right] a_t + \eta \pi_1 \sigma_t^e - \eta^{-1}b$$

$$\left. \left[i_{it}^{*p} - k_{it} - c_{it} \right] \right\} \qquad (A.2)$$

where $\quad \pi_0 = 1 - a_2 (1-\eta^{-1}b); \quad \eta = a_1^{-1}$

$$\pi_1 = 1 - \eta^{-1} (1-\eta^{-1}b)$$

If there is a proportion (1-s) of firms which price on 'normal' cost basis, say for an average contant value $\bar{\sigma}$, then the aggregate price rule is like equation (16.1) in the main text (apart from constants), where

$$\gamma_1 = \pi_1^{-1}\pi_0 > 0, \quad \gamma_2 = \pi_1^{-1} a_2 (1-\eta^{-1}b) > 0, \quad \gamma_3 = (1-s)\eta > 0$$

$$\gamma_4 = \pi_1^{-1} a_3 (1-\eta^{-1}b) \gtrless 0, \quad \gamma_5 = \pi_1^{-1} b\eta^{-1} > 0, \quad \eta > 0$$

Eliminating $\bar{p}_t$ in (16.1) using the aggregate version of (A.1) yields (16.2). Finally (16.3) stems from combining the long run solutions of (12.2) and (12.3) (apart from constants), where

$$\beta = (1-\eta^{-1} b)^{-1} - \eta^{-1} > 0$$

Finally, the equivalence between the generalized version of (11) in the presence of adjustment costs and (22) is derived from taking a second order Taylor expansion of the profit function around the equilibrium planned values in steady state given by equations (16) and normalizing by the coefficient of the second order term in the expansion around n_{it}^{*p}. Therefore, the convexities of the adjustment cost are identified only up to a scale factor. The normalization condition is chosen to be $b=\eta$, which was not rejected by the data. Although this normalisation leaves the parameter β undefined, it has been left unrestricted in the estimation, on the grounds of the several approximations used to get tractable log-linear equation.

Data Appendix

Employment (N): Employees employed in manufacturing industries (ETAS)

Wage (W): Paid hourly rates net of overtime for full time male manual workers in manufacturing (calculated as in Symons (1981))

Output price (P): Wholesale price index of manufacturing output (ETAS)

Price or Raw Materials (Pm): Wholesale price of materials and fuels (ETAS)

Capital Stock (K): Plant and Machinery, Manufacturing (BB)

Competitiveness (P/P_w): Relative Producer Prices (ETAS)

World Income (Yw): LBS data tape

Adjusted Fiscal Stance (AD): Weighted, cyclically – adjusted deficit from the National Institute. Inflation correction applied by subtracting .39 (Published Interest Cost – (.02 x Public Sector Debt Market Value) as obtained by GDP Wadwhani (1985)

Unadjusted Fiscal Stance (UD): Public Sector Financial Deficit/GDP (ETAS)

Interest Rate (R): Minimum Lending Rate (ETAS)

Demand (σ): Obtained as the following linear combination, $- \log (P/P_w)_{-1} + .29 \Delta AD_{-i} + 1.06 RSW + 2.62 \Delta RSW$ where RSW are the residuals from regressing log Yw on a quintic trend

Spline trend (A): Obtained as the following linear combination, $t + .01\, t73\, (I) + .05\, t79\, (III) + .04t\, 80\, (III)$

Labour Force (L): Obtained as $(1-u)^{-1}N$ where u is the unemployment rates in manufacturing (DEG)

Inventory of Finished Goods (I): Volume index of level of stocks, finished goods in manufacturing measured at end of quarter (ETAS & BB)

Key: ETAS: Economic Trends Annual Supplement
BB: Blue Book
DEG: Department of Employment Gazette

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APPLIED ECONOMICS DISCUSSION PAPER SERIES INDEX# 3