PROFITABILITY, CAPACITY, AND UNCERTAINTY:
A Robust Model of UK Manufacturing Investment

Ciaran Driver
Imperial College Management School
University of London SW7 2PG (U.K.)
c.driver@ic.ac.uk

Paul Temple
Department of Economics, University of Surrey
Guildford, Surrey GU2 7XH (U.K.)
p.temple@surrey.ac.uk

Giovanni Urga[1]
Faculty of Finance
City University Business School
Barbican Centre, London EC2Y 8HB (U.K.)
Tel. +/44/20/70408698; Fax. +/44/20/70408881
g.urga@city.ac.uk

This version: 16 January 2002

Abstract

This paper uses a model of capital investment that ascribes a theoretical role to profitability and uncertainty in determining the capital-output ratio. Empirical implementation uses quarterly data from UK manufacturing over a thirty-year period, and unique co-integrating relationships are obtained for two asset classes: buildings and plant and machinery. The corresponding dynamic equations are also well specified. Non-nested testing shows that the performance of the estimated investment models ranks similarly to the performance of predictions from direct investment intentions.

Keywords: Uncertainty, Investment, Profitability, Manufacturing UK, Time Series Models.

J.E.L. Classification Number: D80, E22, L60, C22.

---

[1] Corresponding author. We are greatly in debt to Stepana Lazarova for her help in checking the mathematical derivation of the model. We are grateful to participants to the international conference on *New Perspectives on Fixed Investment*, held at City University Business School (6-7 April 2001) for discussion and useful suggestions. We would also like to thank Robert Chirinko for helpful comments and advice, and Katsushi Imai and Sandro Tsang for data assistance. However, the usual disclaimer applies. ESRC funding under grant R022250159 is gratefully acknowledged.

PROFITABILTY, CAPACITY, AND UNCERTAINTY:
a Robust Model of UK Manufacturing Investment

I. Introduction

Modern theories of investment can be viewed as a response to the criticism that the dynamics of adjustment were not being explicitly modelled (see Chirinko 1993a). Two prominent lines of research have been pursued. During the 1980s, attention focussed on the specification of adjustment costs (Abel 1980; Hayashi 1982; Abel and Blanchard 1986). Neo-classical models were recast as Euler equation specifications to capture the dynamic adjustment of the capital stock. Subsequently the real options literature allowed irreversibility to affect the investment decision by modifying the threshold at which investment was optimal (Dixit and Pindyck 1994; Abel *et al.*, 1996).

Both these recent developments in investment theory have been largely concerned with exploring the dynamic behaviour of investment, i.e. to explain the speed of adjustment of the capital stock[2]. It has been implicitly assumed that there is less problem in understanding the determinants of the capital stock. Yet this implicit assumption may be questioned. It is not clear, for example, that the standard neo-classical model co-integrates for OECD data series (Ford and Poret 1991). In a steady state it should be possible to replace the capital stock by gross investment in a standard neo-classical co-integrating vector (Bean 1981). However recent evidence from the UK suggests that investment does not co-integrate in this way; moreover the user cost of capital is often signed perversely in aggregate models (Henry *et al.*, 1999). One reaction to these difficulties has been to focus research on micro-data, often at firm or plant level. While such studies have clear advantages in exploiting cross section variation they are not a substitute for estimating aggregate investment equations, since ultimately that is what is

[2] Indeed, Bloom (2000) shows that the real-options effect of uncertainty plays no role in the long-run rate of investment.

required in macroeconomic modelling. Furthermore, results that may be valid at the micro level may not hold under aggregation. In particular, this would be the case where financial constraints prevent some firms from exploiting opportunities but these opportunities are then grasped by unconstrained firms. Accordingly, the objective of this paper is to provide a robust model of aggregate investment. We do this for the UK manufacturing sector, where standard models of investment have proved less than adequate. This is important for policy because UK manufacturing investment has, by a number of accounts, been consistently lower than in competitor countries (Bond and Jenkinson 1996). While this paper follows the modern literature in considering the role of uncertainty, the actual approach we adopt in this paper however differs from other studies. It is our belief that it is more appropriate to model uncertainty variables as having a direct influence on the *capital stock* or the *capital output ratio*. This line of attack is suggested in key contributions by Malinvaud (1977, 1985), in which firms' margin of spare capacity is related (non-linearly) to profitability and uncertainty. In contrast to many previous contributions, this places the emphasis on the linkages between profitability and investment – a link considered to be of considerable importance to the classical economists.

While we consider an aggregate approach to be an important adjunct to micro level approaches, we nevertheless regard it as essential to distinguish between the main classes of physical asset: buildings on the one hand, and plant and machinery on the other.[3] This is because there are important differences between these assets in respect of substitutability with labour and in respect of depreciation rates. Expenditure on buildings is expected to be of the putty-clay type while much plant expenditure may be constrained by existing building configuration and thus correspond more to the clay-clay form. The differences between the depreciation rates have a bearing on the impact of uncertainty. Plant investment may be less affected because repeated replacement effectively neutralises irreversibility. Offsetting this, however, it may be that some building assets

[3] This is relatively rare in the literature. Exceptions are Chirinko (1993b) and Bell and Campa (1997). See also Pindyck and Rotemberg (1983).

are less dedicated, implying a lower sunk cost if the asset has resale value. Ultimately the relative effect of uncertainty on the two asset classes is an empirical matter.

The paper is organized as follows. In the next section we define and graph the main variables and examine their time-series properties; the discussion points to the limitations of standard theory. Section III then considers the relationship between profitability and the capital stock which is based on the idea that the ratio of capacity to expected output is an important decision variable for the firm. Section IV uses this relationship to derive an empirical model of investment behaviour. Section V reports empirical testing of the model; here we include a special test of robustness, which investigates whether survey-based expectations constitute a sufficient statistic for the regressors in the investment equations. Section VI concludes.

II. An Empirical Overview of UK Manufacturing Investment

One indication of the problem in explaining investment in conventional terms is given in Figure 1, which shows the investment-output ratio, the cost of capital, and the rate of profit in UK manufacturing. Not only is there a lack of correlation between the investment-output ratio and the cost of capital but there is no close correspondence between the cost of capital and the rate of profit.[4] The wedge between the latter two variables should be zero in the neo-classical model as long as the actual stock of capital is kept close to its equilibrium level by business investment. If the wedge is diverging for a significant period of time – as appears to be the case in the UK – the standard version of q-theory cannot provide an adequate explanation for investment: at the very least it must be modified to account for structural breaks or missing variables.[5]

[Insert Figure 1 somewhere here]

[4] This is true for pre-tax and post-tax measures. It is possible that the discrepancy may in part be due to the different coverage of the series. The cost of capital measure relates to Industrial and Commercial Companies including overseas assets.

Unless stated otherwise all variables discussed in this section are in log form and seasonally adjusted where required. We use the latest revised (but as yet unpublished) data for UK real manufacturing investment[6], disaggregated by asset class. These revisions correct substantial errors in previously published data. The main variables initially considered are:

- building investment valued at constant prices (IB);
- plant and machinery investment valued at constant prices (IP);
- the index of manufacturing output (OM);
- the ratio of average earnings in manufacturing to the price deflator for buildings (WB);
- the ratio of average earnings in manufacturing to price deflator for plant and machinery (WP), and
- the officially published series for net of depreciation profitability in manufacturing (PROF).

The variables are graphed in Figures 2 and 3 with a start date of 1972Q1, corresponding to the first point of survey data used later in the paper; data sources are reported in Appendix A. Tests on the order of integration (reported in Appendix B) suggest that all variables are integrated order one[7].

---

[5] The disconnect between q and the investment rate is also noted for US data in Bond and Cummins (2000).
[6] We are grateful to the Office for National Statistics for kindly supplying us with the requisite data.
[7] The test results for the variables IP and WB are somewhat ambiguous. The latter is the least problematic as the AIC (levels) rule suggests a shorter lag structure to the VAR and the chosen ADF(2) figure is -3.39, which (just) does not reject the I(1) hypothesis at the 5% level. The IP variable presents something of a puzzle. It seems unlikely that the two categories of investment are integrated of a different order. If the last year of data is omitted on the grounds that it may be revised, the levels ADF(4) is -3.32. Furthermore, the Phillips-Perron test yields a t-value of –1.12 for the full sample. The tests on the differenced IP data may tend to caution against a unit root interpretation as it is not unambiguously stationary (Dickey and Pantula, 1987). In assessing this it should be noted that there appears to be a quadratic rather than a linear trend in the series. When this is entered in conjunction with a linear trend it is highly significant in both the levels and first differenced specifications. The corresponding tests are then more in accord with a unit root interpretation of IP; the differenced data now appear to be stationary with a Phillips-Perron t-value of -4.38. In the remaining of the paper we assume that all six levels variables in can be represented by a I(1) process. See Appendix B for further detail.

[Insert Figure 2 and Figure 3 somewhere here]

Figure 4 shows the ratios of real (and nominal) investment between the two asset classes. It is clear that there was a long period of decline in expansionary (building) investment in UK manufacturing relative to efficiency (plant and machinery) investment, whether measured in real or nominal terms. The recovery of building investment from the trough during the 1980s was weak so that the capital stock will have continued to be rebalanced with a heavier weighting of plant and machinery. Some of this phenomenon can undoubtedly be explained by technology and some by the compositional changes in output that necessitated a higher component of plant and machinery relative to structures.[8] Whatever the reason for the shift away from buildings investment it is clearly preferable to estimate equations for both asset classes separately. Later in the paper we also attempt to estimate a relationship between investment in both assets.

[Insert Figure 4 somewhere here]

III. Profitability, Capacity, and Uncertainty

In standard models of investment, current profitability plays no apparent role in explaining investment: the representative firm has already exploited all profitable opportunities and is thus always at the point where risk-adjusted profitability equals the marginal cost of borrowing.[9] Nevertheless a sizeable number of recent studies have

[8] It may also be that pressures to increase capital productivity and to generate short-term returns was responsible in part, though it is difficult to discriminate between this and other explanations.

[9] Where a disequilibrium relationship can be demonstrated, however, say because of the operation of constraints or the opening up of new technological opportunities, this need not apply and in that case variation in the profit rate rather than in the cost of capital may be the important influence. For example European post-war construction presented firms with a large gap between the cost of capital and the marginal return from adopting best practice technology used in the US (Schultze, 1987). In theory one ought to be able to observe positive effects for profitability and negative ones for the cost of capital as in Feldstein (1982);but see Chirinko (1987, p.385) for a critique. Very often, however, the cost of capital seems to be perversely signed or insignificant when combined with profitability (Henry *et al*., 1999). One reason for this may be that interest rates are set with an eye to the demand effects of future expected profitability (Wallich, 1983). Robert Hall (1986) suggests that interest rates and investment are positively correlated due to their joint determination by "animal spirits". Micro-data studies, which avoid some of these problems, reveal a small but significant elasticity of investment to the user cost (Chirinko *et al.*, 1999).

argued for profitability as a determinant of investment.[10] Our model focuses on a world of imperfect competition in which the margin of spare capacity carried by firms (or the ratio of capacity to expected demand) is a choice variable related (non-linearly) to profitability and uncertainty (Malinvaud, 1977, 1983, 1985, 1987; Muellbauer, 1978; Catinat *et al*., 1987; Lambert and Mulkay, 1990; see also Carlin and Soskice 1990). Using the inventory "Newsboy" model adapted to fixed capital input, the ratio of capital input to expected output [K/E(Y)] may be shown to be a simple function of the price-cost ratio and the variance of demand (Nickell 1978; Aiginger 1987; Driver 2000). Intuitively, a higher price-cost ratio or profitability will lead the firm to hold more excess capacity due to the higher cost of stock-out. It turns out that investment will be affected in a multiplicative manner by profitability and uncertainty.

More formally, first order conditions for the ratio of capacity to expected demand (z) can be derived as follows. z is generally not equal to unity because of asymmetry in the loss function so that the cost of under-capacity and over-capacity differ, Consider a production function with constant returns to scale, where capital K is chosen *ex-ante*[11]. Capacity output Y^* corresponding to full use of K is defined as K/k and the production function may be written as $Y^* = F(K,L) = \min(K/k, L/b)$, where labour hours adjust to demand $(L = bY)$ for $Y < Y^*$. By definition z, the capacity stance, is the ratio of capacity to expected demand:

$$z = Y^* / E[D] \tag{1}$$

where demand is $D = uE[D]$ with $E[u] = 1$ and u is distributed as $[0,h]$.

Expected production is

$$E[Y] = E[\min(Y^*, D)] \tag{2}$$

$$= E[\min(Y^*, E[D].u)] = E[D].E[\min(z,u)] \tag{3}$$

$$= E[D][\int_0^z uf(u)du + z\int_z^h f(u)du] \tag{4}$$

[10] See Feldstein (1982) , Schultze (1987), Catinat *et al.* (1987), Rowthorn (1995), Henry *et al.*(1999), Carruth *et al*., (2000a), Blanchard *et at.* (1993), Bond and Cummins (2000).
[11] We are grateful to Jean-Bernard Chatelain (1998) for simplifying the presentation.

$$= E[D][I(Z)]$$

where I(Z) is an expectational term representing the extent to which expected output exceeds or falls short of expected demand.

Defining E[CU] as expected capacity utilisation:

$$E[CU] = E[Y]/Y^{*} = I(z)/z \qquad (5)$$

The firm chooses $K = Arg\,\max(p - wb)E[Y] - rp^{k}K$

where r is the cost of capital and p^{k} is the unit price of capital goods. Equivalently, the firm chooses the ratio of capacity to expected demand:

$$z = Arg\,\max(p - wb)/p^{k}kI(z) - rz$$

A first order condition may thus be obtained; integration by parts gives:

$$I(z) = \int_{0}^{z}[1 - F(u)]du \qquad (6)$$

where $F(.)$ is the distribution function. This gives:

$$(p - wb)/p^{k}k(1 - F(z)) = r \qquad (7)$$

The optimal capacity-to-expected-demand ratio is given by

$$z^{*} = F^{-1}[1 - r/\{(p - wb)/p^{k}k\}] \qquad (8)$$

which is analogous to the simple Newsboy expression (Aiginger 1987; Nickell 1978).

Writing (8) as $z^{*}=F^{-1}(1-r/B)$,

B is capacity-adjusted profitability given by:

$$\pi = (1/ECU)(pY - wL)/p^{k}K \qquad (9)$$

The planned quantity of spare capacity implicit in (8) is thus determined by the ratio of full-capacity profitability to the cost of capital (π/r) and by $F(.)$ which depends on uncertainty.[12]

[12] A more extensive model which simultaneously optimizes the K/L ratio and the desired margin of spare capacity may be found in Lambert and Mulkay (1990)

Before we move to empirical implementation of this model, it is useful also to consider briefly alternative channels of influence linking profitability to investment. First current profits simply proxy of future company earnings. Bond and Cummins (2000) show that earnings forecasts by equity analysts can be used to construct long-term forecasts for future earnings that outperform sales or cash flow in investment equations for US companies. Other work shows that for investment equations that include market-based q, current profit outperforms other proxies for managerial expectations of future average earnings such as the dividend pay-out ratio (Blanchard *et al.* 1993). It is not clear from the latter, however, whether current profit represents a (possibly inefficient) managerial forecast of wealth or whether it plays an independent role such as suggested in our model above. Alternative channels of influence depend upon information asymmetries. These may either act through the fact that managers may be more aware of investment opportunities than an external capital market (Myers and Maljuf 1984) or because they allow mangers to pursue different objectives from owners (Marris, 1964, Odagiri, 1981, 1992; Jensen 1993). In the former case profitability acts as a proxy for liquidity constraints and in the latter managers may "over-invest". In the context of an aggregate model, it may not be possible to distinguish fully between these channels of influence and our own mechanism. We nevertheless keep these distinctions in mind as we move onto empirical analysis. First, we derive a model of investment which employs the above considerations and which is capable of estimation.

IV. A Model of Investment

We begin by deriving a generalised specification of the linear-quadratic model in Taylor (1982) and Blanchard and Fischer (1989, pp.299-300). Maximising the value of the firm with capital as the only quasi-fixed factor subject to a production function with exogenous demand yields a closed form solution if the implied cost minimand is approximated by a quadratic form. Specifically, the industry is assumed to minimise the discounted sum of a penalty function (C_t) comprising the cost of being out of equilibrium and quadratic adjustment costs which reflect supply conditions when the industry as a whole attempts to invest. Writing K_t for capital, Y_t for net output, GI_t for gross investment, a_t for the desired capital-output ratio, we have:

$$C_t = 0.5[a_t(x_{1t})Y_t - K_t]^2 + 0.5b_t(x_{2t})GI_t^2 \qquad (10)$$

Where $x_{1,t}$ and $x_{2,t}$ are vector arguments of a_t and b_t discussed below and where the usual depreciation condition applies:

$$K_t = (1-\delta)K_{t-1} + GI_t \qquad (11)$$

Using a discount factor, β, it is straightforward to derive a solution for K_t of the form[13]:

$$K_t = \lambda_t K_{t-1} + \beta\lambda_t \sum_{i=0}^{\infty} (\beta\lambda_t)^i F_{t+i} E[Y_{t+i} \mid t] \qquad (12)$$

where λ_t is a calculable root depending on b_t, β, δ and $0 < \lambda_t < 1$ and where F_t depends on a_t, b_t, β, δ

Using (11) we obtain:

$$I_t = \kappa_t K_{t-1} + \beta\lambda_t \sum (\beta\lambda_t)^i F_{t+i} E[Y_{t+i} \mid t] \qquad (13)$$

with $\kappa_t = \lambda_t + \delta - 1$.

Where demand follows a random walk, immediate past output may provide the best guide to future summed, discounted demand. If so we may replace the expectation term in (13) by Y_{t-1} and (13) then reduces to :

$$I_t / K_{t-1} = \kappa_t + \gamma_t CU_{t-1} \qquad (14)$$

where $CU_{t-1} = Y_{t-1} / K_{t-1}$ is a measure of the previous period capacity utilisation.

It is evident that the coefficient on CU is not a constant as it is a composite of a_t, b_t, δ and β. It seems reasonable to regard β as constant because of the observed tendency for firms to keep discount rates fixed for lengthy periods of time (Sumner, 1999; Wardlow, 1994). Variation in δ may reflect capacity utilisation according to the user cost effect (Keynes, 1973; Greenwood *et al.*, 1988), thus introducing a putative non-linearity

[13] See Appendix C for a formal derivation of the model.

effect in the γ_t coefficient, which we address in functional form tests. [14]

Variation in γ_t depends then on the underlying variables $a_t(x_1)$ and $b_t(x_2)$. The vector x_2 should include variables that influence the speed of adjustment. In addition to the usual parameters governing external costs of adjustment, such as the elasticity of supply in the capital goods sector (Chirinko, 1994), x_2 should include profitability (π_t) in so far as this captures a liquidity effect (Prior 1976; Cuthbertson and Gasparro 1995) and uncertainty in demand (σ_t) as discussed in Price (1995,1996), Dixit and Pindyck (1994).[15]

Thus, we write $b_t = f(\pi_t, \sigma_t)$ (15)

$b_\pi < 0$; $b_\sigma > 0$.

Variation in a_t depend on the x_1 vector of variables which cause the capital-output ratio to change. As demonstrated in section 3, this will include both the level of (full capacity) profitability, uncertainty about demand[16], in addition to the relative price of capital goods. Thus we may write $a_t = f(\pi_t, \sigma_t, w_t)$ (16)

$a_\pi > 0$; $a_\sigma < 0$; $a_w > 0$

Combining (15) with (16)

$$\gamma_t = f(\pi_t, w_t, \sigma_t) \tag{17}$$

$\gamma_\pi > 0$; $\gamma_w > 0$; $\gamma_\sigma < 0$.

---

[14] We adopt the quadratic form for I in (1) because it is likely to mirror external adjustment costs. Internal costs of adjustment will be reflected in b_t. Such costs will be low when capacity utilisation is low as this is when disruption caused by shutdowns will be least severe; this may again result in a non-linearity in the γ_t coefficient.

[15] In addition, internal costs of adjustment will be reflected in b_t. Such costs will be low when capacity utilisation is low as this is when disruption caused by shutdowns will be least severe; this may again result in a non-linearity in the γ_t coefficient.

[16] A more direct role for the influence of uncertainty may come from convexity (see Ghosal 1991).

Linearising equation (14) in logs, representing the past capital stock as a function of trend and capacity utilisation, and adding a general error term gives an empirical specification for the log of gross investment (I) [17]:

$$I_t = const + a_1 * trend + a_2 * CU_{t-1} + a_3 * \pi_t + a_4 * \sigma_t + a_5 * w_t + \varepsilon_t \qquad (18)$$

(+) (+) (-) (+)

This specification uses two new variables: capacity utilisation (CU_t) and uncertainty (σ_t).[18] Capacity utilisation is measured by the logit of the survey response on capacity utilisation in the Industrial Trends Survey of the Confederation of British Industry (Question 4, NO).[19] Uncertainty is measured by the dispersion of subjective forecasts for GDP across a range of forecasting organisations as discussed in Appendix A. The interpretation of the profitability term, π, is also somewhat different in (18) from the PROF variable graphed in Figure 3. The appropriate measure of profitability in the stochastic rationing framework is profitability at full capacity as explained below. Accordingly, the PROF variable is scaled by capacity utilisation, following the same procedure used in Schultze (1987), Bean (1989).

The three (CU, σ, π) new variables in (18) are graphed in Figure 5. Order of integration tests for the three variables are reported in Appendix B, Table A2. The variables CU and π appear to be I(1), while σ follows a stationary process. [20]

---

[17] In UK manufacturing over the sample period the capital stock has been virtually constant. This means that the capital stock figures will depend heavily on the accuracy of δ which is low. Because of this we prefer to model the capital stock by trend and cycle terms. Using the ratio of investment to the capital stock along with cycle and trend terms yields broadly similar results, which are available on request.

[18] It may be noted that this specification is similar to that in Bean (1989), though that paper does not explicitly justify the specification used.

[19] The raw replies are in the form of a count. Under the assumption of an approximately normal distribution of replies, the logit transformation results in an index of utilisation (Minford *et al.*, 1988). For the typical values of the replies to this survey the logit and log are closely correlated (r=0.99).

[20] The CU result is unambiguous – see also Henry *et al.* (1999) – while the other variables require judgement. It is not clear that we should expect a trend in either π or σ variables but a trend or long cycle seems to be present in the samples. The ADF tests for π suggest that it is I(1), though the DF test with trend rejects a unit root at the 5% level. However, further evidence from the Phillips-Perron test again suggests treating it as I(1). The tests for the uncertainty measure σ (which has a pronounced downward trend over its

[Insert Figure 5 somewhere here]

V. Empirical Results

This paper is largely concerned with long-run relationships and accordingly we make extensive use of co-integration analysis which can detect long-run relationships irrespective of how complex are the underlying dynamics; the latter can be examined separately. With a set of k variables each integrated or order one there may be up to k-1 independent linear relationships of order zero. Economic theory predicting long-run equilibrium conditions can be represented as a co-integrating vector or set of vectors and these should be compatible with the linear relationships found for the co-integrating space (Johansen, 1988). In the case of the neo-classical and flexible accelerator models of investment co-integration should be obtained for the variables capital stock (K), output (OM) and the cost of capital (COC). In stationary state with low growth such as has characterised British manufacturing during the sample period, the capital stock is often proxied by investment (GI) interpreted as replacement investment (Bean 1981). A test of standard models is then whether GI, OM and COC are co-integrated in logs. In our sample we failed to find significant co-integrating vectors for investment, output and the cost of capital (or relative price of capital goods to output), confirming the earlier result in Henry *et al*. (1999) for the case of combined assets. [21]

---

short sample) are again ambiguous with the DF and Phillips-Perron tests both suggesting stationarity but the ADF(4) test failing to reject a unit root. The AIC criterion fails to distinguish meaningfully between the DF and ADF alternatives as it is virtually flat (-38.6 as compared with –38.4). The Schwartz-Bayes criterion, not surprisingly, substantially favours the DF test. Overall, it seems reasonable to conclude that the σ variable may be taken as stationary.

[21] The VAR indicated lags of 3 and 5 respectively for plant and buildings. The user cost of capital is also consistently perversely signed for both asset classes, as for the combined category in Henry *et al.* (1999). [21] One possible explanation for the failure of cointegration is that the severe composition changes in manufacturing, allied to subcontracting from the services sector have made the capital-output ratio unstable. But the result seems to apply beyond the confines of manufacturing. Carruth *et al.* (2000a) find that for UK Industrial and Commercial Companies, investment does not co-integrate with GDP.

We now report tests for a co-integrating relationship between the variables in our preferred model (18) using a maximum lag of 7 obtained from an unrestricted VAR.. We report two sets of results in Table 1, with and without the uncertainty variable as the available data dictates a slightly shorter estimation period (1977q4-1999q2) when the uncertainty variable is included.

In all cases a single co-integrating relationship is indicated by the Eigenvalue test; this is also the case for the Trace test, except for a marginal failure in row (3) where the test statistic narrowly accepts two cointegrating vectors against the alternative of one (42.8 against a 95% critical value of 42.3). However, the Schwartz Bayes Criterion continues to suggest a single co-integrating vector. The figures in parentheses are the probability levels for rejecting the null hypotheses of zero coefficients. Significance is obtained for all coefficients except the relative price term, though WP is marginally significant in equation 3 and perversely signed.[22] All other coefficients are signed as expected confirming the value of the theoretical model[23].

---

[22] The expected sign of the relative price effect is controversial. In a putty-clay world substitution may only be possible where new building is involved. Partly this may be due to technical reasons – much plant and machinery is just replacement of like for like on existing sites. Partly it may reflect industrial relations problems and the other costs of redundancy which may make it prohibitive to replace workers by machines or to change the composition of output unless greenfield expansion is taking place. Furthermore, wage pressure may lead to more intensive use of capital if substitution is difficult, resulting in a greater component of overtime pay in earnings; this could explain a perverse relationship between real earnings and investment (Denny and Nickell, 1992). For these reasons it is likely that the sign of WP is indeterminate and may be negative. Other considerations are that the capital goods price deflator has a dual role in that it also captures capital gains which arguably should be added to the numerator of the profits term, at least in so far as they are realized (Chirinko, 1987). This could induce a negative sign in the earnings to deflator ratio. It may be noted that the CBI indicator for skilled labour constraint on investment (q16cf – see Appendix 1) is significant as an I(1) variable in the co-integrating vector for plant and machinery with a shortage of skilled labour contributing to *higher* investment. This suggests that when wages are prohibitively high (labour shortage) substitution does operate.

[23] It is also possible to derive the results in Table 1 by running the co-integrating regressions with the full-capacity profitability term π replaced by PROF and reparameterising the vector. The two procedures yield near identical results. Again single co-integrating vectors are indicated by the tests and the vectors corresponding to rows (1) and (3) of Table 1 of the form { I CU PROF W} are:

(1A) {-1 -0.30 1.12 -0.29} and…

(3A) {-1 –0.07 0.56 -1.4}.

It may be seen that the coefficients on PROF are the same as those on π and that the (negative) unrestricted coefficients on CU in (1A) and (3A) are approximately equal to the implied coefficients on CU in (1) and (3), formed by subtracting the coefficient on π from that on CU in those equations.

TABLE 1

COINTEGRATION TESTS AND VECTORS

		CU	π	W (W_b or W_p)	L_R	L_T
(1)	IB	0.83	1.12	-0.29	42.2*	81.4*
		(0.00)	(0.00)	(0.51)		
(2)	IB[a]	0.81	1.05	0.27	50.2*	85.2*
		(0.00)	(0.00)	(0.39)		
(3)	IP	0.50	0.56	-1.40	47.0*	86.5* [b]
		(0.00)	(0.00)	(0.06)		
(4)	IP[a]	0.36	0.43	0.13	47.2*	80.7*
		(0.00)	(0.00)	(0.73)		

- significant at 5% level

[a] With the stationary uncertainty variable included, 1977Q4-1999Q2 only.

[b] The tests also accept two cointegrating vectors – see text.

The figures in parentheses are the probability levels for rejecting the null hypotheses of zero coefficients.

All equations include restricted deterministic time trends.

The coefficient on profitability is much higher for building investment than for plant. One reason for this may be that buildings investment tends to correspond to expansionary activity whereas plant and machinery investment is often defensive in nature reflecting a response to weak profits.

Note that the results allow us to comment on the different channels of influence for profitability discussed above. The fact that the coefficients on CU are both negative in the co-integrating vector where profitability is not cyclically adjusted may be evidence that the investment equation should be specified with full-capacity profitability as the appropriate regressor. This supports our Malinvaud-type “stochastic rationing” model of investment and possibly the “managerial q” model over the alternative interpretation of profitability as proxy for cash flow or liquidity. However, since the profitability term used in this paper is net of depreciation, the link with cash flow will, in any case, be weakened. Accordingly, we tested for omitted liquidity constraints by adding to the dynamic equation the logged first difference of the reported incidence of internal or external finance constraints in the CBI Industrial Trends Survey (Question 16CB or 16CC in Appendix A)[24]. These were not significant for either of the asset classes. These findings support the interpretation by Chirinko (1997, p.202) of the UK manufacturing estimates in Devereux and Schiantarelli (1990), namely that they "do not generally support the FCH [Financial Constraint Hypothesis]".

The dynamic error correction equations (the first differenced form of (18) with the addition of an error correction term ECT) are shown in Table 2 for the four equations corresponding to rows (1) through (4) of Table 1. In each case exclusion tests on the set of lagged variables are shown for the regressors along with the error correction terms and a set of standard diagnostics.[25] For equations (1) and (2) variants (1A and 2A) are shown based on a slightly shorter sample for the co-integration which excludes the initial turbulence of the first oil shock. This has the effect of improving the diagnostics, in particular for the building equation. In general the diagnostic tests indicate just marginal specification problems. For plant and machinery, however, the functional form test indicates some mis-specification though this is marginal for the case where uncertainty is included. We experimented with adding non-linear terms in output or capacity utilisation, reflecting the argument that non-convex adjustment costs may introduce such dynamics (Caballero et al 1995, Bloom 2000) but without success. In any event these non-convex adjustment costs might be thought more likely to refer to building investment. It seems probable that the functional form test is indicating that profitability may have a distinct effect from full-capacity profitability in the case of plant and machinery. Some support for this is found when the dynamic error correction equation corresponding to the

[24] These CBI variables are only available from 1979Q4. Henry *et al.* (1999) use an alternative liquidity variable (ratio of liquid assets to liabilities). We do not find that the models reported in the text are improved by adding this as a stationary variable in the co-integrating regression with the existing profits term. Without the profits term, the liquidity term is *negatively* significant. The liquidity ratio is positively significant for manufacturing investment in Woods (1995) without a profit variable; alternatively a profit share variable interacted with the incidence of credit constraint is found to be significant. But this is not tested against an unconstrained profitability model. Other possible financial variables include the capital gearing ratio (Cuthbertson and Gasparo 1995). Henry *et al.* (1999) find that for an extended sample that model does not co-integrate.

unrestricted cointegration (using PROF rather than capacity adjusted profitability, Π) is estimated.
In that case the functional form test is comfortably passed, though the overall results are somewhat inferior.

In all cases the CUSUM and CUSUM_SQUARE tests for parameter stability are within normal bounds. It may also be noted that the residual sum of squares obtained in estimating the combined variable for both asset classes is about a third higher than the sum of the corresponding RSS for the disaggregated regressions, suggesting that it is indeed important to estimate separate equations for the two assets.[26]

The results for the equations with GDP uncertainty, (σ), (where a start point of 1977Q4 is necessitated by data availability), show that the variable exerts a significant negative effect on investment for both asset types, with a somewhat stronger effect in the case of new buildings. As explained in Appendix A, σ is based on dispersion across forecasting agents of one-year-ahead GDP forecasts. We also experimented with an alternative indicator of uncertainty specific to manufacturing industry. Following Ghosal and Loungani (2000) we estimated an auto-regression for the manufacturing mark-up as measured in the CBI Industrial Trends Survey. The standard deviation of the residuals over the previous five quarters was entered as a proxy for profit uncertainty.[27] In this case we again found negative significance at the 1% level for plant whereas for building the coefficient was also negative but with a p-value of only 0.12.

In all the results reported so far in the paper we have used pre-tax series for relative prices and profitability. This is justified by the available evidence which suggests that it is inappropriate to interpret the behavioural response to tax induced incentives in the same way as other economic signals. As noted in Sumner (1999)…"measuring relative

---

[25] These exclusion tests have low power because they are not testing whether specific individual lags may be excluded. Furthermore multicollinearity between the CU and π variables result in a higher significance for a joint test on the two sets.
[26] The combined equation also has diagnostic problems which are difficult to resolve.
[27] We are grateful to Katsushi Imai (City University Business School) for help in constructing this index and to Sandro Tsang (University of Surrey) who helped construct the data for σ.

prices on an after-tax basis is not necessary for co-integration; on the contrary it weakens the performance of the model." (pp 295-6). One justification for avoiding the use of post-tax prices is that companies expect government policy to be endogenous resulting in a prediction that the tax wedge will be adjusted to attenuate movements in the cost of capital. We have attempted to capture a tax influence by including the Bank of England measure for the gross-net yield ratio in the co-integrating vector but this was unsuccessful.[28] The inclusion of dummies in the dynamic equations was also tested for, using the set usually argued to be relevant (D1=+1 in 1985q1;-1 in 1985q2 and D2=1 in 1986q2;-1 in 1986q3). While both these dummies were significant in Woods (1995) we found significance only for D2 in the case of buildings where it was significant at the 1% level and raised the $\overline{R}^2$ in column (1) to 0.33 without noticeably affecting the other coefficients or their significance.

The estimation of separate equations for the two asset classes leaves open the question of the overall determinants of investment as there is a significant trend in both co-integrating vectors – positive for plant and machinery and negative for buildings. The

[28] This measure is described in Meliss and Richardson (1976) and Sargent (1995). It takes account of both investment allowances and taxation and represents the present value of profits before tax on a unit of capital expenditure needed to attain a given after-tax yield. Where the ratio is unity the effects of allowances and tax cancel out.

TABLE 2

DYNAMIC ERROR CORRECTION EQUATIONS

Dependent Variable/ Regressor	(1) ΔIB 1972.1-99.2	(1A) ΔIB 1974.3-99.2	(2) ΔIB 1977.4-99.2	(3) ΔIP 1972.1-99.2	(3A) ΔIP 1974.3-99.2	(4) ΔIP 1977.4-99.2
Constant	0.42 (1.74)	0.88(2.75)	1.51(3.86)	0.81 (3.36)	1.08 (3.30)	2.58(3.90)
$\beta_1(L)\Delta I$	[0.08]	[0.05]	[0.07]	[0.10]	[0.08]	[0.02]
$\beta_2(L)\ \Delta CU$	[0.41]	[0.51]	[0.57]	[0.66]	[0.79]	[0.36]
$\beta_3(L)\ \Delta\pi$	[0.34]	[0.19]	[0.03]	[0.89]	[0.78]	[0.13]
$\beta_4(L)\ \Delta W$	[0.26]	[0.39]	[0.13]	[0.99]	[0.98]	[0.72]
ECT	-0.15 (1.74)	-0.22 (2.74)	-0.31 (3.88)	-0.09 (2.11)	-0.13 (3.27)	-0.15 (3.90)
Uncertainty σ			-0.04 (2.50)			-0.02 (2.24)
RBARSQ	0.19	0.26	0.36	0.24	0.25	0.38
AR(4) P-VALUE	0.03	0.10	0.05	0.17	0.74	0.32
FF P-VALUE	0.65	0.40	0.40	0.01	0.09	0.04
NORM P-VALUE	0.44	0.68	0.35	0.76	0.68	0.97
HET P-VALUE	0.63	0.36	0.25	0.26	0.58	0.80
SEE	0.083	0.081	0.079	0.040	0.040	0.037
ARCH1 P-VALUE	0.20	0.09	0.67	0.94	0.65	0.47

Note:ECT is the error correction term. Figures in round brackets are t-values. Probability values for Wald exclusion tests are given in square brackets for the full set of lags on each regressor. AR4 is an LM test of up to fourth order autocorrelation; FF is Ramsey's RESET test for functional form; NORM is a Jarque-Bera test; Het is White's test for hetorescedasticity; SEE is the standard error of estimate; ARCH1 is a test for first-order autoregressive heteroscedasticity.

proportion of buildings investment has fallen sharply over the sample as can be observed in Figure 4. We may estimate an equation for the behaviour of the ratio (in real terms) of buildings to plant and machinery using the variables in the individual equations.[29] As this ratio (I_B- I_P) is unambiguously I(1) we can test for co-integration as in Table 3. The table shows a single co-integration vector linking the (log) investment ratio with the (log)ratio of the deflators for each of the categories, P_{KB}- P_{KP} ; and (log) profitability. The tests indicate a single co-integrating vector and a restriction imposing unit elasticity of the investment ratio to the price ratio is accepted. The corresponding dynamic equation is well behaved and passes all the diagnostic tests used in Table 2, though with some hint of residual correlation rob=0.04).

TABLE 3

COINTEGRATION VECTOR FOR INVESTMENT COMPOSITION

(I_B- I_P)	$P_{KB} – P_{KP}$	PROF	L_R	L_T
-1	-1.33	0.38	45.1*	67.1*
		(0.00)		

- significant at the5%. A unit restriction on the relative price term is accepted (prob.=0.33) The figure in parentheses is the probability levels for rejecting the null hypotheses of zero coefficient on profitability.

The co-integrating vector in Table 3 also contains a trend term (-0.007). The failure of expansionary building investment to keep pace with cost-reducing plant and machinery investment is a feature of a number of economies and probably reflects a combination of technical effects and possibly the influence of corporate governance regimes in enforcing higher profitability on managers in recent decades (Marris 1996).

[29] Theoretically, the real interest rate should also be relevant in that an increase in this variable should bias investment away from long-lived assets such as buildings, where the effect of the change in the discount factor will have greater weight. The user cost can replace profitability in the co-integrating relationship for (I_B- I_P) with similar diagnostic performance.

The failure of standard models to co-integrate (e.g. flexible accelerator and q) makes it difficult to attempt to discriminate our model from many previously reported models in the literature. In any case, it is not appropriate to use a single aggregate q with heterogeneous assets. Instead, and in order to pursue our investigation of the robustness of our model further, we adopt a different approach, comparing the estimated model with direct survey-based expectations of investment. This represents a considerable challenge for our model because these series are widely used by business and academics to forecast actual investment. Confirmation of the accuracy of these series may be found in European Commission (1997). Here we report tests of whether lagged investment intentions can outperform the model-based specification of equation (18). The additional data used is the survey response on expected authorisation of investment in buildings or plant and machinery (CBI Question 3 - see Appendix A). We employ a set of tests to discriminate between the specifications reported in Table 2 and a simple alternative specification which contains only the intentions variable, lagged once to account for the forward looking expectations. Test results are shown in Table 4, where the columns identifications correspond to Table 2.

TABLE 4

TESTING THE MODEL (M1) AGAINST DIRECT INTENTIONS (M2)

	(1A)DIB	(2)DIB	(3A)DIP	(4)DIP
TEST	1974.3-99.2	1977.4-99.2	1974.3-99.2	1977.4-99.2
AIC	2.98	8.19	-14.17	-6.14
	M1	M1	M2	M2
ENCOMPASSING (5%)	NO	YES	YES	NO

These results indicate that it is difficult to discriminate between the original and alternative models as they are highly collinear. Using the AIC rule the alternative specification using the intentions data (M2) is favoured for plant and machinery but not for buildings. The intentions specification for plant encompasses the original model only when the uncertainty variable is not included. For building, the original model (M1) encompasses M2 when the uncertainty variable is included. These results are not sensitive to the inclusion of a second lag on the intentions variable which could be justified on the grounds that the intentions refers to the following year. If just the second lag is entered for plant and machinery, the original model M1 with uncertainty outperforms M2, but encompassing (just) fails. These results from non-nested testing suggest that for both asset classes the estimated equation (18) ranks in performance similarly to direct investment intentions and thus captures the main sources of information needed to explain investment. Bearing in mind that the estimated model includes no dummy variables for shocks or taxation effects this is a highly satisfactory result[30].

VI. Conclusions

Based on a model emphasising utilisation-adjusted profitability as a positive determinant of planned spare capacity, we have reported estimates of robust separate investment equations for the two major asset types of physical capital in the UK. This contrasts with standard formulations of the neo-classical model. Single co-integrating relationships are obtained with an important effect for capacity utilisation and utilisation-adjusted profitability in each case; the corresponding dynamic equations have acceptable diagnostics. When the effect of uncertainty is factored in, the estimated models perform similarly to a simple investment intentions variable, lagged one or two quarters, where the intention expressed is to authorise investment over the coming twelve months. The estimated equations thus provide a satisfactory account of UK manufacturing investment over the last three decades.

Our main explanation for the significance of utilisation-adjusted profitability is as a positive determinant of planned spare capacity. However, we also recognise that it incorporates information on long-run expected earnings. The significance of net

[30] We also tested the aggregate specification (18) at a more disaggregated (sectoral) level from data

profitability along with a lack of significance for liquidity or financial constraint variables constitutes evidence against cash-flow and liquidity effects working at an aggregate level (but not necessarily at a micro level). We also found little evidence of tax policy effects apart from a single impact dummy.

Of particular note is the differing elasticities between the asset classes with respect to profitability. In the long-run profitability tends to stimulate building investment much more than plant and machinery. This feature is, however, tempered by trends in the two co-integrating vectors – positive for plant and negative for building. We confirmed the relationship between investment in the two asset types by showing that profitability was co-integrated with the asset composition of investment. The negative deterministic trend in expansionary relative to efficiency investment remains to be explained but is probably due to a mix of technological factors and to changes in corporate governance. Indeed the same institutional factors that have led to UK manufacturing investment being so profit-oriented in the sample period considered here may help explain the decline in commitment to longer-term expansionary investment.

The effect of uncertainty is to depress aggregate investment and this effect seems strongest for building investment. The uncertainty effect is found both when the main uncertainty variable is entered (representing dispersion across one-year-ahead forecasts) and also when an alternative index (representing time-series volatility in the price mark-up) is used. In the latter case, however, the effect on building investment is less significant.

In summary, we have specified a new model of investment which allows for the impact of profitability and uncertainty on the *level* of the capital stock rather than simply determining investment timing. This model has performed well in a horse race against direct surveys of investment intentions. The results have allowed us to test a number of key issues such as the additional role of liquidity and taxation and the differential effect of uncertainty and profitability on different classes of investment.

---

obtained from the CBI’s Industrial Trends Survey with very similar results. Details available on request.

REFERENCES

Abel, A.B. (1980). "Empirical investment equations: an integrative framework", *12th Carnegie Rochester Conference on Public Policy* vol. 12, pp.39-91.

Abel, A.B. and Blanchard,O.J. (1986). "The present value of profits and cyclical movements in investment", *Econometrica* vol. 54, pp. 249-73.

Abel, A.B., A.K. Dixit, J.C.Eberly and R.S.Pindyck (1996) "Options, the value of capital and investment", *Quarterly Journal of Economics* vol. 111, pp.753-77.

Aiginger, K. (1987). *Production and Decision Theory under Uncertainty*. Oxford: Basil Blackwell.

Bean C. (1981) "An econometric model of manufacturing investment in the UK", *Economic Journal* vol. 91, pp.106-121.

Bean, C. (1989) "Capital Shortage", *Economic Policy* April, pp.11-54.

Bell,G.K. and Campa, J.M. "Irreversible investment and volatile markets: a study of the Chemical Processing Industry", Review of Economics and Statistics, LXXIX,1, 79-87

Blanchard,O.J. (1986). "Comments and Discussion" on M.D.Shapiro "Investment, output and the cost of capital" in *Brookings Papers on Economic Activity* vol.1, pp.111-164.

Blanchard, O. J. and Fischer,S. (1989). *Lectures on Macroeconomics.* Cambridge Massachusetts: The MIT Press.

Blanchard, O.J., Rhee,C. and Summers,L. (1993). "The stock market, profits and investment", *Quarterly Journal of Economics* vol.108, pp.115-36.

Bloom, N (2000) "The real options effect of uncertainty on investment and labour demand", Institute for Fiscal Studies WP 00/15.

Bond S.R. and Cummins J.G (2000) "The stock market and investment in the new economy: some tangible facts and intangible fictions", *Brooking Papers of Economic Activities*, 1, 61-124.

Bond, S. and Jenkinson, T. (1996). "The assessment: investment performance and policy", *Oxford Review of Economic Policy*, vol.12, pp.1-29.

Caballero,R.J, Engel,E.M. and Haltiwanger,J.C.(1995) "Plant-level adjustment and aggregate investment dynamics", *Brookings Papers on Economic Activity* 2, 1-54

Carlin,W and Soskice,D (1990) *Macroeconomics and the Wage Bargain*, Oxford, OUP

Carruth, A., Dickerson,A. and Henley,A. (2000a). "Econometric modelling of UK aggregate investment: the role of profits and uncertainty", *The Manchester School*, vol. XX, pp. 276-300.

Carruth, A., Dickerson,A. and Henley,A. (2000b). "What do we know about investment under uncertainty?", *Journal of Economic Surveys*, vol. 14, pp. 119-136.

Catinat M., Cawley,R., Ilzkovitz,F., Italianer,A. and Mons, M. (1987). "The determinants of investment", *European Economy*,31.

Chatelain J.B. (1998). "Investment facing credit rationing", *The Manchester School* vol. 66 (supplement), pp.102-115.

Chirinko, R. S. (1987). "The ineffectiveness of effective tax rates on business investment: a critique of Feldstein's Fisher-Schultz Lecture", *Journal of Public Economics* vol. 32, pp. 369-87.

Chirinko, R.S. (1993a). "Business Fixed Investment Spending: Modelling Strategies,

Empirical Results and Policy Implications”, *Journal of Economic Literature* vol.31, pp.1875-1911.
Chirinko, R.S. (1993b).”Multiple capital inputs, q and investment spending”, *Journal of Economic Dynamics and Control* vol.17, pp. 907-28.
Chirinko, R. S. (1994). “On the Keynesian investment function and the investment funciton(s) of Keynes”. In (P.Davidson, ed.) *Can the Free Market Pick Winners?: What Determines Investment,* Armonck, NY, M E Sharpe.
Chirinko, R.S. (1997) “Financial constraints, liquidity and investment spending: theoretical restrictions and international evidence”, *Journal of the Japanese and International Economies*,11(2) 185-207.
Chirinko, R.S., Fazzari M. and Meyer, A.D. (1999). “How responsive is business capital investment to its user cost? An exploration with micro data”, *Journal of Public Economics* vol.74, pp. 53-80.
Cuthbertson, K. and Gasparro,D. (1995). “Fixed investment decisions in UK manufacturing: the importance of Tobin’s Q, Output and Debt.” *European Economic Review* , vol.39, pp. 919-41
Denny, K. and Nickell, S. J. (1992). “Unions and investment in British Industry.” *The Economic Journal* vol.192, pp. 874-887.
Devereux, M. and Schianterelli, F. (1990) “Investment, financial factors, and cash flow: evidence from U.K. panel data” in Asymmetric information, corporate finance, and investment” in Hubbard, R.G. (ed), *Asymmetric Information, Corporate Finance, and Investment*, Chicago: Chicago University Press.
Dickey, D.A. and Pantula,S.G. (1987). “Determining the order of differencing in autoregressive processes.” *Journal of Business and Economic Statistics* vol.5, pp.455-461.
Dixit, A. and Pindyck,R. (1994). *Investment under Uncertanty*. Princeton: Princeton University Press.
Driver , C. (2000). “Capacity Utilisation and Excess Capacity: Theory and Evidence.” *Review of Industrial Organisation* vol.16, pp. 69-87.
Driver, C. and Moreton, D. (1991). “The influence of uncertainty on UK manufacturing investment”, *The Economic Journal*, 101, 1452-59.
Driver,C. and Temple, P. (1999). *Investment, Employment and Growth*. London: Routledge.
European Commission (1997) “The Joint Harmonised EU Programme of Business and Consumer Surveys.” *European Economy*, No 6.
Feldstein, M. (1982). “Inflation, tax rules and investment: some econometric evidence.” *Econometrica* vol. 50, pp. 825-862.
Ford,R. and Poret,P. (1991). “Business investment: recent performance and some implications for policy”. *OECD Economic Studies* vol.16 (Spring), pp.79-131.
Ghosal, V. (1991) “Demand uncertainty and the capital-labour ratio: evidence from the US manufacturing sector”, *Review of Economics and Statistics*, 157-61
Ghosal, V. and Loungani, P. (2000). “The differential impact of uncertainty on investment in small and large businesses.” *Review of Economics and Statistics*, vol. LXXXII, pp. 338-43
Greenwood, J., Hercowitz,Z. and Huffman,G. (1988). “Investment, capacity utilisation and the real business cycle.” *American Economic Review*, vol.78, pp. 402-17.

Hall, R.(1986). "Comment" on M.D.Shapiro "Investment, output and the cost of capital" in *Brookings Papers on Economic Activity* vol.1, pp.111-164.
Hayashi, F. (1982). "Tobin's marginal q and average q: a neoclassical approach." *Econometrica* vol. 50, pp.213-24.
Henry B, Sentence,A. and Urga,G. (1999). "Finance, profitability and investment in manufacturing." In (C Driver and P. Temple,eds.) *Investment, Growth and Employment*. London: Routledge.
Jensen, M.C. (1993) "The modern industrial revolution, exit, and the failure of internal control systems", Journal of Finance, July
Johansen, S. (1988) "Statistical analysis of cointegration vectors", *Journal of Economic Dynamics and Control*, 12, 231-254.
Kathuria, R. and Mueller, D.C. (1995) "Investment and Cash Flow: Asymmetric Information or Managerial Discretion?" *Empirica*, 22, pp.211-234.
Keynes, J.M. (1973). *The Collected Writings of John Maynard Keynes, Vol. VII: The General Theory*. London: Macmillan.
Lambert, J-P and Mulkay,B. (1990) "Investment in a disequilibrium model or does profitability really matter?" In (Gabszewicz J.J, J.F.Richard and L.A.Wolsey, eds.) *Economic Decision Making: Games, Econometrics and Optimisation.* Amsterdam: North Holland.
Malinvaud, E. (1977). *Profitability and Unemployment*. Cambridge: Cambridge University Press.
Malinvaud,E. (1983). "Profitability and investment facing uncertain demand", INSEE Working Paper no. 8303.
Malinvaud, E. (1985). *The Theory of Unemployment Reconsidered*. Oxford: Basil Blackwell.
Malinvaud, E. (1987). "Comment on H.R.Sneessens", *European Economic Review*, vol.31, pp. 808-811.
Marris, R.L. (1964). *The Economic Theory of Managerial Capitalism*, London: Macmillan.
Marris, R .L. (1996) *How to save the Underclass*, London: Macmillan.
Melliss,C.L. and Richardson, P.W. (1976). "Value of investment incentives for manufacturing industry 1946-74." In (A. Whiting, ed.). *The Economics of Industrial Subsidies*. London: HMSO.
Minford ,M., Wall,M. and Wren-Lewis,S. (1988). "Manufacturing capacity: a measure derived from survey data using the Kalman Filter." NIESR Discussion Paper no.146, London: National Institute for Economic and Social Research.
Muellbauer, J. (1978). "Macrotheory versus macroeconometrics: the treatment of disequilibrium in macromodels." Economic Discussion Paper no.2, London: Birkbeck College.
Myers, S.C. and Maljuf, N.S. (1984), "Corporate financing and investment decisions when firms have information that investors do not", *Journal of Financial Economics*, 13, pp.187-221.
Nickell, S. J. (1978). *The Investment Decision of Firms*. Cambridge: Cambridge University Press.
Odagiri, H (1981). *The Theory of Growth in a Corporate Economy: Management*

Preference, Research and Development, and Economic Growth, Cambridge: Cambridge University Press.
Odagiri, H. (1992). *Growth through Competition, Competition through Growth,* Oxford: Oxford University Press.
Pindyck, R.S. (1991). “Irreversibility, uncertainty and investment.” *Journal of Economic Literature* vol. 29, pp.1110-48.
Pindyck, R.S. and Rotemberg J.J. (1983) “Dynamic factor demands under rational expectations”, *Scandinavian Journal of Economics*, 85, 223-238
Price, S. (1995). “Aggregate uncertainty, capacity utilisation and UK manufacturing investment.” *Applied Economics* vol. 27, pp.147-154.
Price, S. (1996). “Aggregate uncertainty, investment and asymmetric adjustment in the UK manufacturing sector.” *Applied Economics* vol. 28, pp.1369-79.
Prior, M.J.(1976). “The effect of distinguishing between new orders and deliveries on the rate of adjustment in investment demand functions.” University of Essex Economics Discussion paper no. 80, March.
Rowthorn, R. (1995). “Capital formation and unemployment”, *Oxford Review of Economic Policy* vol.1, pp.26-39.
Sargent, J.R. (1995). “Roads to full employment.” *National Institute Economics and Social Review*, February, pp.74-89.
Schultze, C. (1987). “Savings, investment and profitability in Europe.” In (R.Lawrence and and C. Schultze, eds.) *Barriers to European Growth,* Brookings Papers on Economic Activity, pp.509-539.
Sumner, M. (1999). ”Long-run effects of investment incentives.” in C. Driver and P. Temple (op cit).
Taylor, J.B. (1982). “The Swedish investment funds system as a stabilisation policy rule”, *Brooking Papers of Economic Activities*, 1, 57-105.
Wallich, H. C. (1983). Statement by Henry C Wallich, member, Board of Governors of the Federal Reserve: before the subcommittee on Domestic Monetary Policy Committee on Banking, Finance and Urban Affairs, House of Representatives, Washington DC, 5th October.
Wardlow, A (1994). “Investment appraisal criteria and the impact of low inflation”, *Bank of England Quarterly Bulletin*, August, pp. 250-54.
Woods, R. (1995). “Econometric models of business investment: the role of factor prices, Q and financial constraints.” *Government Economic Service Working Paper* No 127 (also Treasury Working Paper No. 69).

APPENDIX A: DATA AND SOURCES

All data series are obtained from official sources : UK Office of National Statistics (ONS); Bank of England (BOE) or HM Treasury (HMT) or alternatively are extracted from the publicly available Industrial Trends Survey of the Confederation of British Industry (CBI)

IB: log, building investment, constant prices (ONS)

IP: log, plant and machinery investment, constant prices (ONS)

OM: log, index of manufacturing output (ONS)

WB: log, ratio of wages in manufacturing to price deflator for buildings(ONS)

WP: log, ratio of wages in manufacturing to price deflator for plant and machinery (ONS)

PROF: log, official series for net of depreciation profitability in manufacturing. From 1989Q1 the data is available quarterly from the ONS. Earlier data were obtained by quadratic interpolation using the algorithm of the Centre for Economic Forecasting, London Business School;

CU: logit of response to question 4 (NO) of the CBI Survey, specified as follows:
"Is your present level of capacity below capacity (i.e. are you working below a satisfactory full rate of operation?)" YES/NO. For the range of values encountered over the sample this variable is highly correlated with the log of the response (r=0.99);

π: PROF-CU.

σ: uncertainty measure. This was calculated from data obtained from Her Majesty's Treasury (HMT) Comparison of Forecasts (COF) for the period 1986(3) to 1999(2). This publication contains information regarding the forecasts across a range of major variables for a number of (City and non-City) forecasting teams. The measure of uncertainty employed here is based upon the standard deviation of the 12 month ahead forecast for GDP of 6 independent teams who were (almost) ever present over the period (NIESR, CBI, OEF, LBS, Henley and Liverpool). The forecast data was collected on a quarterly basis (January, April, July, and October). Since the COF only contains data on a calendar year basis for the current and the forthcoming year, the twelve month implied forecast was constructed as follows. First, that growth for the remaining quarters of the current calendar year was assumed to be that given by the constant quarterly growth rate implied by the difference between the actual out-turn for GDP (during the current calendar year prior to the observation point) and the forecast for GDP for the calendar year as a whole. Second, that the quarterly growth for the relevant quarters of the subsequent calendar year was at a constant rate determined by the implied path of GDP in the current year and the forecast for GDP for the subsequent year as a whole.

For observations prior to 1986(3) data was obtained by a linear regression (of the overlapping observations) of this series on an earlier series constructed by Driver and Moreton (1991) and updated by Rina Bhattarcharya and Paul Hope at the Bank of England in 1996. This series was available between 1977(4) and 1992(2)
An alternative indicator of uncertainty is also reported in the text. This is the standard deviation over the last five quarters of the residuals from a fifth order autoregression (with constant and seasonals) of a measure of the mark-up in manufacturing industry.

Direct Investment Intentions. The data here is constructed as the balance of "more" minus "less" from Question 3 of the CBI Industrial Trends Survey which asks separately for buildings and plant and machinery: "Do you expect to authorise more or less capital expenditure in the next 12 months than you authorised in the past 12 months?"

APPENDIX B: TABLES

TABLE

TESTING THE ORDER OF INTEGRATION

VARIABLE	DF LEVEL	DF DIFFERENCE	ADF(4) LEVEL	ADF(4) DIFFERENCE
IB	-2.31	-11.08	-2.20	-4.74
IP	-1.99	-3.33	-3.79	-2.31
OM	-1.85	-8.97	-2.17	-4.56
WB	-2.87	-5.73	-3.55	-3.53
WP	-2.04	-9.40	-2.38	-3.53
PROF	-2.10	-7.31	-2.95	-4.84

- All tests include a deterministic trend: critical value =-3.45

TABLE A2

TESTING THE ORDER OF INTEGRATION

VARIABLE	DF		ADF(4)		Phillips-Perron
	No Trend	Trend	No Trend	Trend	(with trend)
CU	-2.29	-2.41	-2.74	-2.97	-1.97
π	-2.64	-3.82	-1.88	-3.14	-2.77
σ	-3.85	-5.07	-2.25	-3.32	-5.82

APPENDIX C: THE DERIVATION OF EQUATION (12)

Consider a firm which minimises

$$\min E(\sum_{t=0}^{\infty} \beta^t C_t) \qquad \text{(A1)}$$

subject to

$$K_t = (1-\delta)K_{t-1} + I_t \qquad \text{(A2)}$$

where

$$C_t = 0.5(a_t Y_t - K_t)^2 + 0.5 b_t (I_t)^2 \qquad \text{(A3)}$$

where C_t, Y_t, K_t and I_t represent cost, output, capital and investment respectively at time and $\beta = 1/(1+r)$. (A4)

Value maximization is equivalent here to the minimisation of the present value of costs, subject to the capital accumulation equation. Introducing λ_t as the Lagrange multiplier associated with the capital accumulation constraint at time t, we get the following two first-order conditions:

$$\beta(1-\delta)E(\lambda_{t+1} \mid t) = \lambda_t + a_t Y_t - K_t \qquad \text{(A5)}$$

$$b_t I_t = -\lambda_t . \qquad \text{(A6)}$$

Substituting for λ_t and $E(\lambda_{t+1} \mid t)$ using (A2), we get the following second order linear expectational difference equation

$$E(K_{t+1} \mid t) - [\frac{1+b_t}{\beta(1-\delta)b_t} + (1-\delta)]K_t + \frac{1}{\beta}K_{t-1} = -\frac{a_t}{b_t(1-\delta)\beta}Y_t . \qquad \text{(A7)}$$

By using the method of factorisation (see Blanchard and Fisher (1989), Chapter 5), we solve for K_t:

$$K_t = \lambda_t K_{t-1} + \beta\lambda_t \sum_{i=0}^{\infty} (\beta\lambda_t)^i F_{t+i} E[Y_{t+i} \mid t] \qquad \text{(A8)}$$

where λ_t is the smallest root of

$$\lambda_t^2 - [\frac{1+b_t}{\beta(1-\delta)b_t} + (1-\delta)]\lambda_t + \frac{1}{\beta} = 0 \qquad \text{(A9)}$$

and

$$F_t = -\frac{a_t}{b_t}\frac{1}{(1-\delta)\beta} \tag{A10}$$

FIGURE 1
Investment, the Rate of Return, and the Cost of Capital in UK Manufacturing 1972-1998

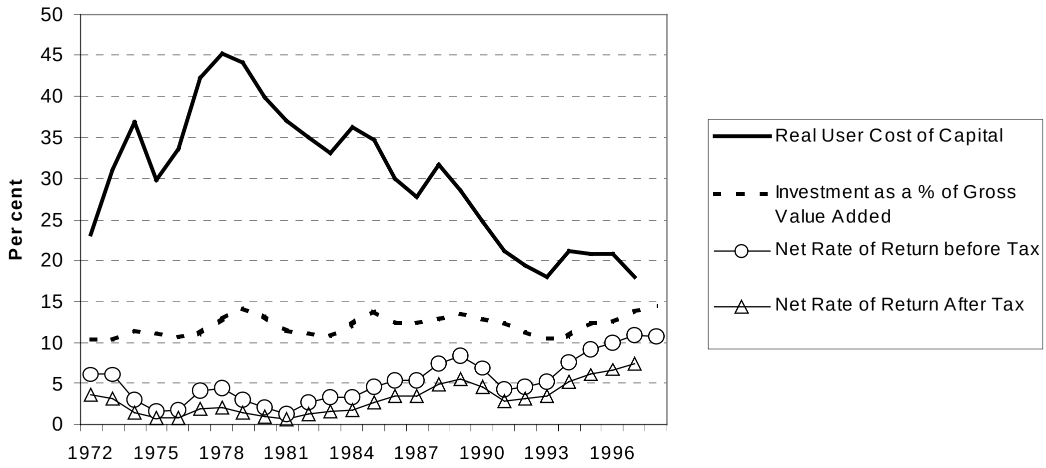

FIGURE 2
Manufacturing Output and Investment by Type of Asset 1972-1999

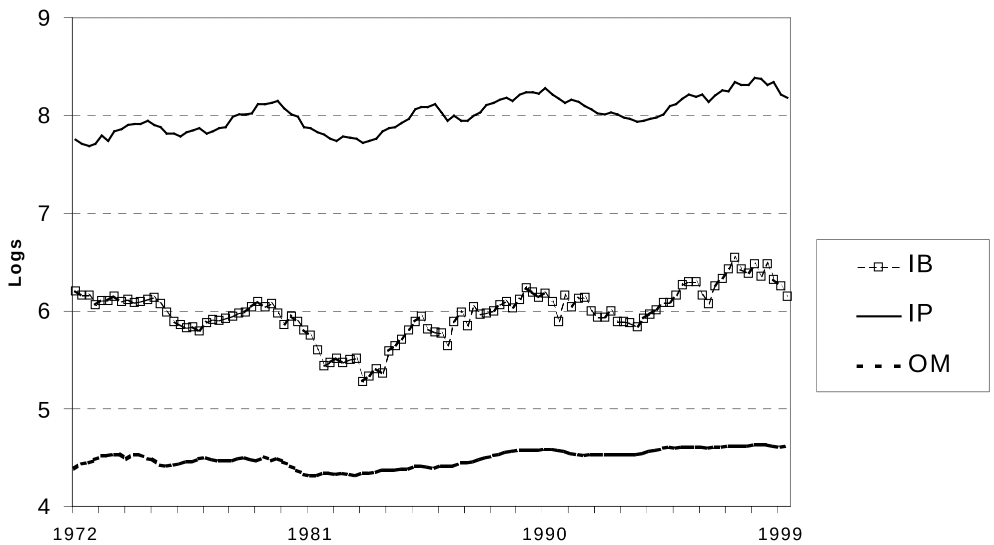

FIGURE 3
Relative Investment Good Prices and Net Profitability
1972-1999

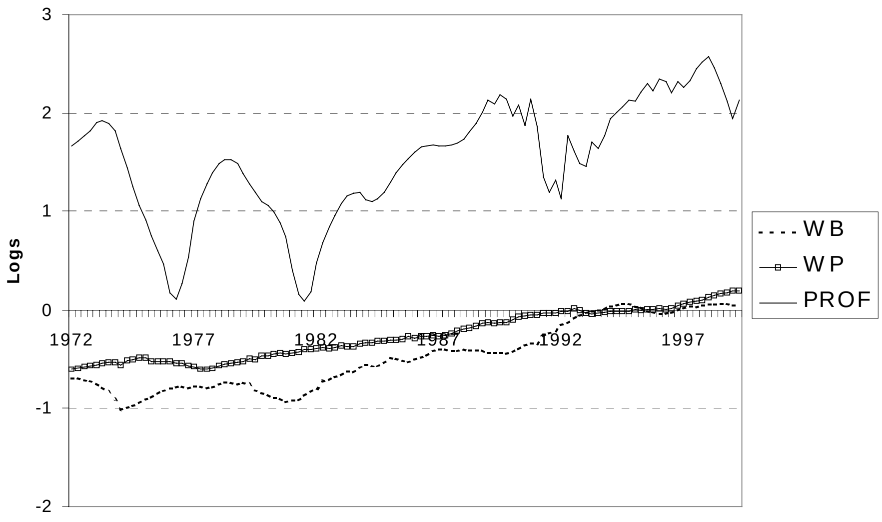

FIGURE 4
Ratios of Building to Plant and Machinery Investment
1972-2000

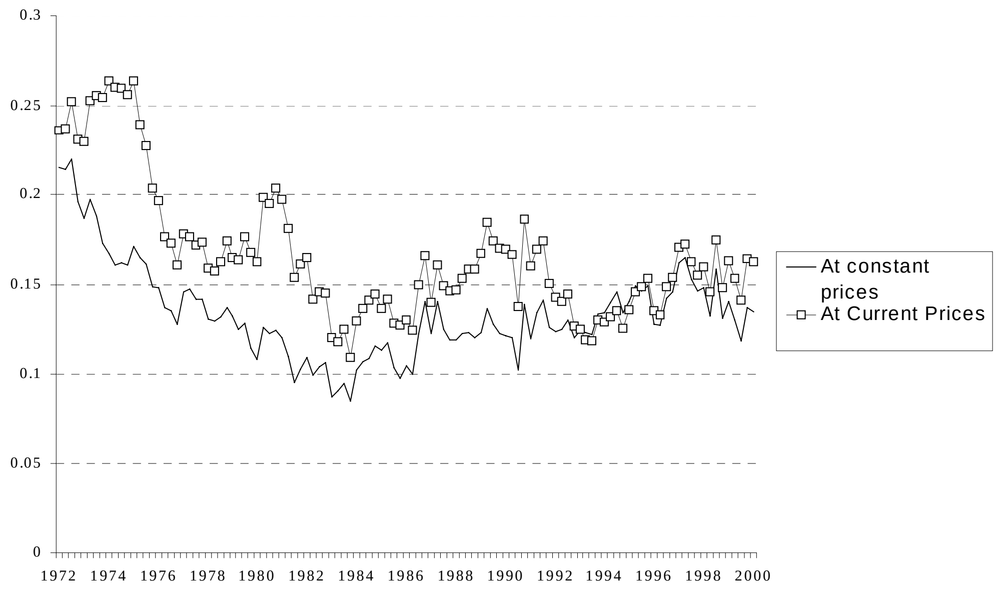

FIGURE 5
Capacity Utilisation, Full Capacity Profitability, and Uncertainty in UK Manufacturing