Bank of England

Discussion Paper No 17

Investment, profitability and the valuation ratio

by

N H Jenkinson

September 1981

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No 17	Investment, profitability and the valuation ratio	N H Jenkinson	September 1981

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Contents

1

Introduction[1]

1 The promotion of a high level of fixed investment is necessary to boost the supply potential of the United Kingdom, which in turn will allow for sustained demand and real income growth without external constraints and inflationary pressures. It is therefore important to examine the past movements in investment and the factors contributing to this movement, in order to discover the set of economic conditions which might be necessary for sustainable economic growth.

2 For private companies, the decision to invest in extra capital would seem to hinge critically on the relationship between the likely increase in profits generated by the additional capital and the cost of acquiring it. Yet whilst most industrialists would agree with this view, the empirical support for such a dependence is rather limited in the United Kingdom. This study examines the treatment of profitability factors in theoretical models of investment and compares the performance of the models in the United Kingdom, a similar study for the United States having recently been undertaken by Clark (1979). Rather contrary to Clark's findings, the conclusions tentatively support the view that models with explicit treatment of profitability influences (Tobin's valuation ratio, q, and Jorgenson's neoclassical model) perform better than the simple accelerator model with no explicit allowance. It is very difficult to draw firm conclusions, however, because of the close correlation between changes in profitability and changes in output.

3 Section 2 of the paper compares the role of profitability in theoretical models of the determination of fixed investment. Section 3 concentrates on the links between investment and the valuation ratio, a model which has been used with some degree of

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[1] I would like to thank W A Allen, T A Clark, J M Hoffman, C T Taylor, A R Threadgold, N P Williams and participants in the Bank of England Econometrics Seminar, for many helpful comments and suggestions.

success in the United States [1] [Sheldon (1976), Malkiel et al. (1979)], and in the one study which has been undertaken for the United Kingdom - Oulton (1981). Section 4 discusses the formulation of the equations to be estimated and presents the empirical results, whilst Section 5 draws the conclusions of the study. Appendix 1 considers the nature of the response function between investment and its determinants, and presents a non-linear version of the simplest form of accelerator specification. The data used in the paper are described in Appendix 2.

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[1] But see Clark (1979) and von Furstenberg (1977), for contradictory views.

2

Profitability and investment models

4 The levels of current and expected future profitability are central inputs to any corporate planning exercise. Decisions regarding future levels of production, of the combination of factor inputs, of prices, sources of finance and many others, depend crucially on the current financial position of the firm and on managements' perceptions of the future profitability of the enterprise. Even though some economists disagree with the usual neoclassical prescription of the maximisation of profits as the main motivation for firms, and stress other goals, such as the maximisation of the speed of growth of the enterprise, in practice it seems unlikely that many firms pursue one goal to the complete exclusion of the others. Whatever the chosen behavioural model, profitability seems likely to play a significant role.

5 Planning the level of fixed investment is obviously only one of many decisions undertaken simultaneously by the firm. This particular decision has been isolated in this paper, however, and no attempt has been made to build a fully-integrated model of corporate behaviour.[1] [For approaches which tackle some aspects of the simultaneous nature of corporate planning, see the various papers by Anderson (1977, 1981a, b, c, d) and also Nadiri and Rosen (1969), Dhrymes and Kurz (1967) and Rowlatt (1978).]

6 Profitability can affect the decision to invest in two ways:

(i) As a source of finance. The level of existing profitability not only helps to determine the amount of internal funds which can be used for investment, but also influences the cost and amount of finance which external sources are willing to provide.

(ii) As an incentive. The level of expected profitability probably represents the principal incentive to invest. After adjusting for risk, and with a given supply of funds for investment, profit maximising firms will invest in the project with the greatest expected yield.

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[1] Simultaneity has, however, been considered in estimation.

In the three classes of investment model considered in this paper, the emphasis placed on profitability varies from no explicit role, in the case of the flexible accelerator, to a fundamental position in the neoclassical and valuation ratio approaches.

The accelerator model

7 The only assumption about profitability in the accelerator framework is that the production of the expected level of output is sufficiently profitable for the firm to remain in operation. Providing that this condition is satisfied, then the firm's investment authorisation will be dominated by the path of expected output.

8 The simplest form of accelerator assumes a technology where output and the gross capital stock are in fixed proportions. Whatever the relative cost, labour cannot be substituted for fixed capital, and consequently in order to produce their desired level of output, firms must invest to acquire the desired capital stock. Although the desired or expected level of output is the key variable in this framework, it is generally unobservable.[1] In theoretical models, the expected level of output is generally proxied by an adaptive expectations scheme which relates expected output to its past levels.[2] This is not a necessary feature of the accelerator framework. For example, profitability effects could be incorporated either as an alternative or as a complement to the adaptive expectations scheme. In such a model, the desired level of output would be at least partially dependent on the likely level of profitability, as determined by anticipated levels of demand and costs.[3]

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[1] Sample surveys such as that undertaken by the Confederation of British Industry in the United Kingdom often give an indication as to the short-term expectations of future changes in output, but, given the long-run nature of the investment process, no adequate indicator is available.

[2] This expectations scheme is often criticised as being too backward looking and for not taking all the available information into account.

[3] This scenario is very simplified. In practice the process is interactive with any additional investment obviously being a cost which must be considered as a variable in deciding the desired level of output. The desired level of output, the scale of operation, the intensity of use of capital, and the capital purchase decisions will be simultaneously determined.

9 Typically, though, theoretical accelerator specifications contain no explicit allowance for profitability or other financial factors. The basic models are, however, often augmented in estimation with additional explanatory variables to pick up financial effects, such as real net liquid assets or real cash flow [see Clark (1979) for example], but they are often found to have no significant statistical effect. A relatively successful augmentation is contained in the Treasury model [Bean (1981)] with the preferred equation containing terms in the real cost of capital and the nominal rate of interest, as well as output.[1]

The neoclassical model

10 The neoclassical model associated with Jorgenson and colleagues [see Jorgenson (1965)] stems from the neoclassical theory of the firm which assumes that firms act to maximise their net worth, defined as the discounted sum of future profits, subject to a feasible set of production possibilities given by a neoclassical production function. The role of profitability is therefore critical.

11 In the neoclassical framework, the maximising behaviour yields an optimal level of the capital stock for exogenously-determined levels of output and factor prices. In a strict neoclassical world, firms would always produce with an optimal level of capital, net investment would take place instantaneously when factor prices or the level of output altered, but would otherwise be zero.[2] In a more realistic scenario which is needed to generate a testable form of the model, firms are unable to operate with the optimal capital stock, because of delays in the authorisation of investment expenditure, in the implementation of orders and in the production and delivery of capital goods, and perhaps also

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[1] Bean's results also place much greater emphasis on dynamic properties than are usually found in simple models linking investment to output.

[2] If after the change in output or factor prices the current capital stock is too large, the neoclassical model assumes that capital will be sold on a perfect second-hand market. In practice, perfect second-hand markets do not exist, and much investment is irreversible, at least in the short run. This leads to an asymmetric investment function, which is discussed further in Appendix 1.

because of installation and adjustment costs.[1] Because of delivery lags, net investment (the addition to the capital stock) is modelled as a distributed lag of past changes in the desired capital stock. The introduction of lags in this rather arbitrary manner has been extensively criticised in the academic literature [see particularly Nerlove (1972)], and, although the framework has theoretical attractions, many of the neoclassical assumptions have been criticised as being too strong, and it is perhaps not too surprising that empirical support for the model is not particularly conclusive.

12 The basic accelerator model can be considered as a restricted version of the neoclassical model, with zero elasticity of substitution between capital and labour, which by implying that relative factor prices have no influence on investment, leaves output as the sole determinant. If the elasticity of substitution were freely determined, then as the accelerator model is a restricted form of the general neoclassical model, the latter would automatically give a better statistical fit,[2] and the validity of the accelerator specification would form a testable proposition. Unfortunately though, non-linear estimation techniques are required to estimate the general neoclassical model, and consequently researchers often estimate imposing the value of the elasticity of substitution and examining whether or not the model seems to perform better than the accelerator.[3] The most common form adopted is that implied by the Cobb-Douglas production function which constrains the elasticity of substitution to be unity [see, for example, Jorgenson (1965) and Clark (1979)], although a value of a half is often also adopted [Savage (1977) and Bean (1981)].[4]

[1] Installation and adjustment costs are usually ignored. If they are present the neoclassical firm will optimise taking these additional costs into consideration, but the optimum level of the capital stock in a dynamic investment model will no longer be equal to the strict neoclassical optimum level [see Nickell (1978), pages 256-64].

[2] In terms of the residual sum of squares.

[3] In principle using non-nested testing procedures.

[4] As a practical, rather than a theoretical, approximation.

13 The evidence in favour of the neoclassical approach for the United Kingdom is inconclusive. Savage (1977) reported that:

"The performance of the 'pure' neoclassical model is extremely disappointing and definitely inferior to that of the 'pure' accelerator."

Similar findings were discovered by Bean (1981) whose best neoclassical model was considerably worse than the flexible accelerator he estimated. These results may be contrasted with earlier research by Boatwright and Eaton (1972) over a much shorter estimation period, who found that the neoclassical model worked impressively well for UK manufacturing investment in plant and machinery.[1] Recent research by Anderson (1981c) also gives some support to the neoclassical framework, and indicates why profitability effects have been difficult to discover empirically. The neoclassical model can be considered as being composed of two effects, a scale or output effect (as in an accelerator model) which indicates that as output grows the capital stock tends to grow, and a relative factor price term which suggests that as capital becomes cheap relative to labour, firms will substitute capital for labour, thus necessitating additional investment. In empirical work it is often difficult to distinguish between the two effects. Anderson (1981c) has noted that in a theoretical neoclassical framework, changes in profitability (measured as a rate of return on capital) can only occur when relative factor prices change,[2] and he considers this to be the reason why the impact of profits on investment is difficult to measure:

"Since changes in profitability are simply the result of changes in relative prices and productivity which have a small (though nonetheless significant) impact on investment expenditures it is not surprising that evidence of a relationship between investment and profits has been so difficult to obtain."

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[1] Whereas Bean and Savage estimated their versions of the neoclassical model with imposed values for the elasticity of substitution, Boatwright and Eaton estimated a value by grid search. Their estimate (0.47) is, however, very close to the imposed values of Bean and Savage (0.5). Savage also tried unity.

[2] The neoclassical model assumes that all capacity is fully utilised. In practice, with the existence of spare capacity, profitability can also change as the rate of utilisation alters.

The valuation ratio model

14 The third type of model considered in this paper relates investment to the valuation ratio, q. The valuation ratio is the ratio of the post-tax real rate of return on capital to its cost, or more simply between the market value of the firm and the replacement cost of the firm's assets, and consequently proxies the incentive to acquire new capital. If the valuation ratio is above its equilibrium value (usually taken as unity[1]), then a profit maximising firm has an incentive to increase its capital stock, as the profit stream generated by the new capital will be greater than the cost of the extra finance needed to acquire it.

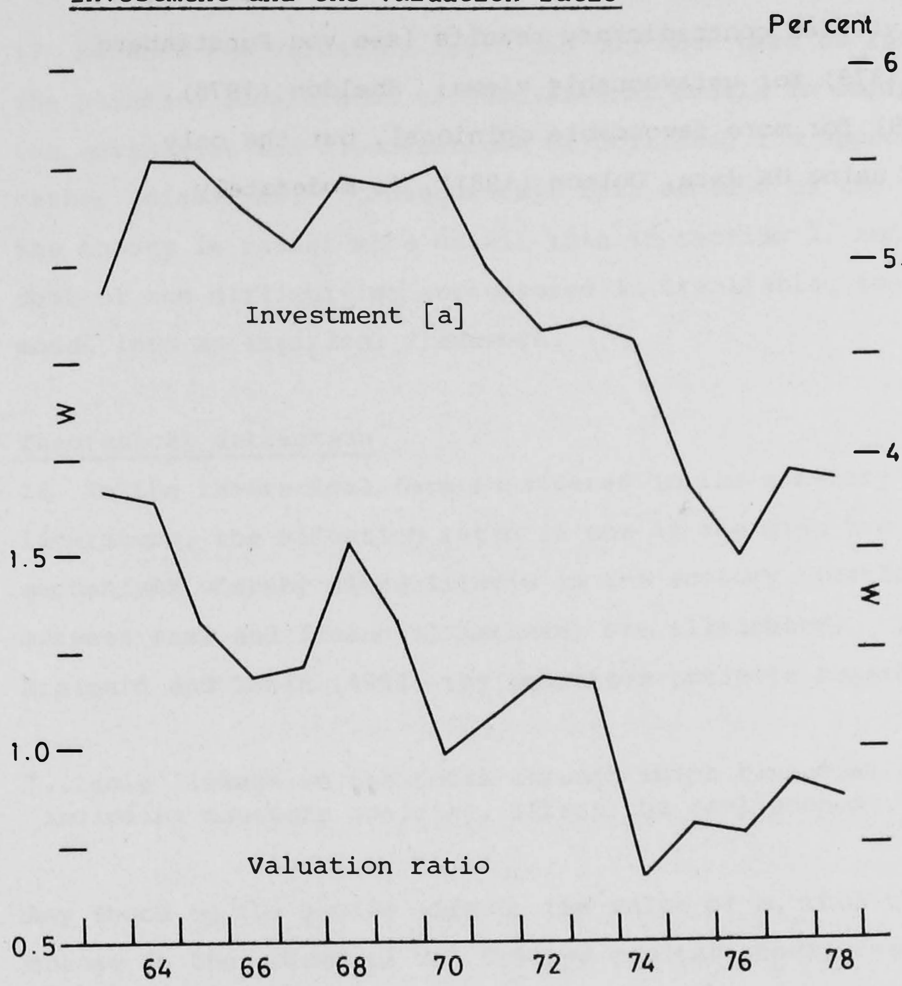
15 The valuation ratio model is very similar to the neoclassical, stressing the capital accumulation behaviour of a firm maximising its profits. In fact, under the traditional neoclassical assumptions, Abel (1979) has shown that in a very simple model, both approaches will give the same equilibrium capital stock. The difference between the models, in principle, is that the valuation ratio brings in the subjective view of the capital market as to the value of holding physical assets,[2] implicitly to the likely earnings stream generated by those assets, and consequently does not require the assumptions regarding market structure contained in the neoclassical model. By taking into account this subjective opinion, the valuation ratio contains extra information on the true market structure[3] and consequently might be considered to be preferable. A disequilibrium value of q can be eliminated instantaneously in a pure neoclassical context and, therefore, the basic theory contains no information about the dynamic adjustment process. The usual treatment has been to add lags in a rather ad hoc manner, similar to the neoclassical model, and consequently the criticism of arbitrariness of lags can be levelled at this model also [Nerlove (1972)]. Ideally, the costs and speed of adjustment should be incorporated into the theory, to give more acceptable dynamic behaviour. Abel (1979) has shown that

[1] But see later for reasons why the equilibrium value may differ from unity.

[2] More correctly, to the value of holding assets with claims on physical assets.

[3] If the true market structure conforms to the neoclassical assumptions then Abel's results apply.

Chart A
Investment and the valuation ratio



[a] Gross investment as a percentage of the previous end-year gross capital stock at replacement cost. The investment and capital series are proxies for the corresponding series for industrial and commercial companies. See Appendix 2 for details.

by introducing installation costs into the valuation ratio model, the investment-capital ratio becomes an increasing function of q.

16 Research linking fixed investment to the valuation ratio in the United States has yielded contradictory results [see von Furstenberg (1977) and Clark (1979) for unfavourable views; Sheldon (1976), Malkiel et al.(1979) for more favourable opinions], but the only published research using UK data, Oulton (1981), is moderately encouraging.

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The valuation ratio and investment

17 Because the valuation ratio has not been used as frequently as the standard accelerator or neoclassical models in empirical research, the advantages and disadvantages of utilising the approach may be rather unfamiliar. Consequently, this section of the paper discusses the theory in rather more detail than in Section 2, and highlights some of the difficulties encountered in translating the theoretical model into an empirical framework.

Theoretical attraction

18 In the theoretical form considered in the monetary economics literature, the valuation ratio is one of the main transmission mechanisms whereby disequilibria in the economy (particularly between real and financial markets) are eliminated. Thus, in Brainard and Tobin (1968) the valuation ratio is regarded as the:

> "...sole linkage in the model through which financial events, including monetary policies, affect the real economy."

Any shock to the system affects the value of q, thus stimulating a change in the volume of the desired capital stock, resulting in investment up to the level where the system returns to equilibrium. The adjustment path has been described by Tobin (1969) and Ciccolo (1978) for an economy with three types of assets; two types of financial asset, one with claims against the government (gilt-edged securities for example) and the other with claims against the third type of asset, physical capital in the private (company) sector. Consider the effect of an 'exogenous' change in monetary policy from a position of equilibrium, say, by the government buying back gilt-edged securities from the private sector through an open-market operation. By reducing the supply of these securities the government forces up their price and consequently lowers the rate of interest (the inverse of the price). The price of the other form of financial assets, those with claims against physical capital, are bid up to eliminate the disequilibrium between the yields on the two types of financial assets, which reduces the cost of capital to companies.

The price at which the company sector can raise extra finance thus becomes attractive relative to the cost of investing in new physical equipment (the cost of capital having fallen relative to the rate of return). The valuation ratio is forced above its equilibrium value (unity), stimulating fixed investment until new and existing assets are valued at the same price. Thus, the expansion of the money supply, by reducing the rate of interest and increasing the valuation ratio, leads to an increase in physical capital. The implications of the theory were noted by Keynes (1936):

"...the daily revaluations of the Stock Exchange, though they are primarily made to facilitate transfers of old investments between one individual and another, inevitably exert a decisive influence on the rate of current investment. For there is no sense in building up a new enterprise at a cost greater than that at which a similar existing enterprise can be purchased; whilst there is an inducement to spend on a new project what may seem an extravagant sum, if it can be floated off on the Stock Exchange at an immediate profit."

19 The role of q as a transmission mechanism between real and financial markets makes the approach particularly attractive for a macroeconometric model. If a stable relationship could be identified between investment and the valuation ratio, then a mechanism would be provided whereby the cost of capital and, with it, monetary policy, would have a clear influence on the volume of spending, a link which is often rather tenuous in most large forecasting models.[1] However, even if a stable equation could be determined empirically, a second equation explaining movements in the valuation ratio itself would be needed if the framework were to be adopted. As the valuation ratio is heavily dependent on movements in equity prices, which are notoriously difficult to

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[1] For example, in the Bank short-term forecasting model [Bank of England (1979)], the only major direct influence of monetary policy on real spending is contained in the equations for consumers' expenditure, which are influenced by the personal sector's stock of liquid assets [Townend (1976)]. Major indirect influences come, however, through the effect of monetary policy on the exchange rate which, in turn, affects output and physical investment. The discovery of a more direct route has theoretical attractions.

model, this secondary equation may not perform particularly well empirically, casting some doubt on the usefulness of the approach.[1]

20 Although the valuation ratio is most naturally considered as a measure of the incentive to invest, it may contain useful information on other aspects of corporate performance. It is a summary financial measure, and, as such, has been shown by Ciccolo and Fromm (1979b) to be an indicator of the likelihood of bankruptcy. They investigated the reasons for the different values of q ratios between firms and showed that, for firms with equal earnings, those with a lower probability of becoming bankrupt[2] had higher q ratios and stock market valuations. It is possible that further developments in the use of q as a summary indicator of financial performance will prove successful.

Measurement problems

21 The valuation ratio can alternatively be considered as the macroeconomic equivalent of the well-known net present value criterion of investment appraisal. The incentive to invest could either be measured as the ratio between the real post-tax rate of return, r, and the cost of capital, c (the valuation ratio, q):

$$I = f(\frac{r}{c}) \qquad f' > 0 \qquad \text{(a)}$$

where I = the level of investment, or as a difference:

$$I = g\ (r-c) \qquad g' > 0 \qquad \text{(b)}$$

Although it is quite likely that both approaches will give similar indications of whether or not to invest (in both cases when $r > c$) the ratio form (a) has the advantage of being easier to compute using the Bank methodology. This is because the valuation ratio reduces to the ratio of the market valuation of the company sector to the replacement cost of corporate sector assets, and thus avoids the necessity of finding a suitable proxy for expected profits [see

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[1] An attempt has been made to model the valuation ratio in Section 4 of the paper.

[2] Measured as the likelihood of a firm having insufficient earnings and liquid assets to meet its obligations to the debt holders.

Flemming et al.(1976a) and Appendix 2]. Consequently, measurement error is reduced, although there are still many potential sources of error remaining.

22 Probably the most serious difficulty in using the valuation ratio in an empirical study is that, whilst the appropriate variable giving the incentive to invest is the ratio of the profitability of new investment to the marginal cost of capital, it is only possible to measure the average value for existing capital. On a purely theoretical level, this measurement problem may not be particularly important - for example, if the capital stock is homogeneous and there is no embodied technical progress (Tobin 1969), then the marginal and average measures of q will be identical. In practice, as the capital stock is not homogeneous, and some technical improvements are only embodied in new equipment (an assertion which is theoretically plausible but which is difficult to prove empirically), then the two will no longer be equivalent. In equilibrium, marginal q is likely to be near unity,[1] then, with embodied technical progress, other vintages of capital will have low values of q, probably implying a 'normal' average value of q of less than unity. When using average q as a proxy for marginal value in an investment equation, it is not necessary that the proxy accurately portrays the level of the marginal value, but that the movement in the marginal valuation ratio is adequately captured. Although the two measures may move fairly closely on average, unfortunately there are periods when it seems quite likely that the two diverge. For example, it has been argued[2] that the structural shift in the major industrial economies in 1974 caused by the sharp jump in energy prices may have caused such an event; the higher energy prices probably lowered the profitability and incentive to invest in existing forms of high energy using capital (reducing the average value of q), whilst marginal q may have been unchanged or even increased because of the incentive to invest in new technology more suited to the new structure of relative energy prices. Some extremely tentative support for this

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[1] When depreciation is additionally considered, a 'normal' value of marginal q may be above unity, to give an incentive to firms to replace worn out capital [see Abel (1979)].

[2] See the comments by Shoven on von Furstenberg (1977), page 406. Average q fell sharply in the United Kingdom in 1974 (see Chart A).

view in the United States is provided by Clark (1979), with his valuation ratio model (based on data for average q) persistently underestimating the actual level of equipment investment after 1973.[1]

23 A further difficulty in identifying a relationship between aggregate company sector investment and a measure of the aggregate valuation ratio is that, whilst the relationship may be fairly well-determined at the level of the firm or even industry, the link may be distorted when aggregate measures are considered. The valuation ratio may be much better at explaining differences in investment at the firm or industry level, as it becomes closer to the net present value criterion.[2] Some support for this view has been obtained by a disaggregated study in the United States [Malkiel et al. (1979)].

24 The previous paragraphs have outlined some of the practical problems involved in developing the theoretical model into one suitable for estimation. The principal difficulty was that the theoretical concept (marginal q) has to be proxied by average q. Unfortunately, this is not the end of the list of problems in deriving an estimable equation; there are several conceptual difficulties in measuring the average level of q.

25 The first of these relates to the difficulty of calculating the market valuation of the existing capital stock. In calculating the market value of equity, for example, by capitalising the present flow of dividends by the current dividend yield, it is assumed that the dividend yield simply reflects the expected return from holding an equity share in the current stock of assets.[3] However,

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[1] However, the opposite is true for investment in buildings.

[2] The model may also be useful in explaining take-overs and mergers following the arguments of Keynes (1936) discussed above.

[3] Whereas the rate of return is the ratio of realised post-tax profits to the existing capital stock, in principle the cost of capital relates expected post-tax profits to the market valuation of capital. In practice, though, the cost of capital is measured by assuming that expected profits can be adequately proxied by current levels [see Flemming et al.(1976a)]. The cost of capital may therefore be rather less accurate than the valuation ratio (see paragraph 21). One way of improving the measure of the cost of capital may be to use a rational expectations model to estimate the market's expectations of future profit and dividend flows [see Abel (1979)].

expectations of future profit and dividend flows, and hence the dividend yield, may also depend on expectations of current and future investment decisions, implying that investment and the valuation ratio are simultaneously determined [but see Ciccolo (1978)].

26 Further difficulties in measuring the average value of q relate to the precise concept of capital. The method of calculating q in the Bank (see Appendix 2) attempts to calculate the financial valuation of physical capital (both fixed capital and stocks) in the United Kingdom, as a proportion of its replacement cost.[1] Consequently, all that q can measure is the incentive to invest in new capital, either fixed <u>or</u> working, rather than simply the addition to fixed capital which is considered in this study.[2] If firms are seriously understocked or overstocked, then this will affect the value of q; in the first instance q will be rather high, indicating that there is a profitable opportunity to increase stocks, with the opposite effect in the overstocked case. It is assumed in this study, however, that, in the aggregate, the level of stocks is relatively unimportant, and that the various short-run influences on stocks do not have a great impact on q and hence on fixed investment.

<u>Functional form</u>

27 As mentioned in paragraph 15, the theoretical valuation ratio model simply provides an instantaneous theory of investment behaviour, similar to the neoclassical model. If q changes from its equilibrium level, then there is an incentive to change the capital stock

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[1] Monetary assets are assumed to be valued at their nominal value and are netted out in the calculation of the market valuation. Other forms of capital are ignored, despite the criticism of Chirinko (1980), who argues that the market valuation additionally reflects other forms of capital, such as research and development and managerial ability, which may imply that the relationship between fixed investment and the valuation ratio is misspecified.

[2] Oulton (1981) attempts to avoid this difficulty by assuming that inventories are allowable for tax relief in exactly the same way as new fixed capital, thus attempting to find the average post-tax rate of return on fixed assets rather than total physical assets (which include stocks and work in progress). As the level of profits depends on the stock of working capital and the stock relief provisions are rather different from the capital allowance schemes, this does not seem appropriate.

instantaneously. This is obviously impossible in practice, and consequently the theory is generally modified to give an estimable equation, by the introduction of delivery lags or costs of adjustment, often in a rather ad hoc manner. Unless a theory of the dynamic adjustment behaviour of the firm is fully integrated into the specification, the theory does not yield very much information as to the appropriate functional form to use in estimation.

28 At the micro level, the principle adopted in investment appraisal is simply that it is profitable to invest in projects with a positive net present value - or, its approximate equivalent, projects with an internal rate of return greater than the cost of capital. It is unlikely to be true that the amount of investment in a particular project will increase linearly, or in any other continuous manner with, for example, a declining cost of capital. Nevertheless, it seems possible that the discontinuities are largely eliminated when an aggregate specification is considered, and that, at the aggregate level, there is a continuous positive relationship between investment and the valuation ratio. [See Oulton (1981) and Appendix 1]. Theory sheds little light on the appropriate empirical specification. Tobin (1969) was only able to assert that:

> "The rate of investment - the speed at which investors wish to increase the capital stock - should be related, if to anything, to q, the value of capital relative to its replacement cost."

This assertion gives little comfort to researchers trying to model aggregate investment.

29 Some possible forms of response function between investment and its determinants are discussed more fully in Appendix 1. Oulton (1981) derived a non-linear model linking investment to the valuation ratio, after consideration of the aggregation problem, but his results are no better than his naive model with no allowance for aggregation effects. There seems to be some theoretical justification for believing that the sensitivity of investment to changes in q is greatest when q is near its equilibrium value and diminishes at more extreme values. An increase in aggregate q from 0.9 to 1.1 is likely to increase the number of firms investing much

more than an increase from 1.5 to 1.7,[1] and, although this does not indicate anything about the relative change in the volume of investment, it is likely that the level of investment undertaken by a firm previously not investing (as q moves from 0.9 to 1.1) is greater than the extra investment undertaken by a firm already investing (as q moves from 1.5 to 1.7).[2] Some results are presented in Appendix 1, positing an elongated 'S' shaped response around a measured equilibrium value, using an arctan function, although this is admittedly *ad hoc*. In a similar way, the response between investment and other determinants, such as the change in output, may be non-linear; an attempt to derive a non-linear accelerator is contained in Appendix 1.

[1] Assuming that firms q ratios are distributed around an equilibrium value of unity.

[2] This argument ignores measurement errors in q, or supply bottle-necks in the capital goods market.

4

Empirical specifications and results

30 In this section of the paper empirical models of the differing investment theories are presented, and the resulting equations are tested to see how well they can explain the investment behaviour of industrial and commercial companies in the United Kingdom.

Empirical specification

31 None of the theoretical models considered in this paper leads naturally to a unique structural form which can be tested against a set of data. All of them have an arbitrary element; the accelerator model relates investment to expected output but does not indicate how this should be modelled, whilst the neoclassical and valuation ratio approaches are indicators of investment generating disequilibria between the extant and profit maximising levels of the capital stock, but do not suggest how to model the adjustment process. It is important to recognise that it is necessary to make additional assumptions and approximations before the theories can be tested - if these additional assumptions are invalid then the model may be incorrectly dismissed.

32 For example, the valuation ratio theory merely indicates that investment is an increasing function of q,[1] but does not indicate whether the relationship is likely to be linear, loglinear or any other monotonic increasing function. The assumption most commonly adopted in the academic literature is that the response is linear [von Furstenberg (1977), Ciccolo (1978), Clark (1979)] giving:[2]

$$\frac{IN_t}{K_{t-1}} = a + \sum_i b_i q_{t-i} \qquad (1)$$

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[1] Investment equations are often formulated in ratio terms to avoid heteroscedasticity [Clark (1979)].

[2] The introduction of lags into the valuation ratio equation can be justified by the inclusion of adjustment costs [Abel (1979), Yoshikawa (1980)].

where: IN_t = the change in the capital stock (net investment) in period t;

K_{t-1} = the capital stock in the previous period (usually measured as the replacement cost of the gross capital stock); and

q_{t-i} = the valuation ratio in period t-i.

As there seems to be no reason why the equation should not be loglinear this formulation has also been tried.[1] In order to estimate an equation for gross rather than net investment the treatment of depreciation must be considered. Many studies of investment have used the exponential depreciation assumption, pioneered by Jorgenson (1965), which gives:

$$IR_t = \delta K_{t-1} \qquad (2)$$

where: IR_t = replacement investment in period t; and

δ = the proportional decay factor.

This assumption has been criticised by Feldstein and Rothschild (1974) amongst others. Feldstein and Rothschild argue that the decision to replace capital is influenced by some of the same economic factors which influence net investment, perhaps leading to an equation of the form:

$$\frac{IR_t}{K_{t-1}} = c + \sum_i d_i q_{t-i} \qquad (3)$$

Adding net investment and replacement investment, and generalising to allow for the possibility that the depreciation equation 2 should be modified by the addition of a constant,[2] yields:[3]

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[1] This specification also allows the valuation ratio to be split into separate measures of the rate of return and the cost of capital to test whether their effects can be adequately captured in a ratio formulation.

[2] That is: $IR_t = a + bK_{t-1}$ (2a)

[3] The alternative hypotheses for replacement investment (equations 2 and 3) cannot be identified from estimates of equation 4, although equation 2a can be distinguished from equation 2 by the significance of β.

$$\frac{I_t}{K_{t-1}} = \alpha + \frac{\beta}{K_{t-1}} + \sum_i \gamma_i q_{t-i} \qquad (4)$$

33 The accelerator framework indicates that the desired capital stock is proportional to expected output:

$$K^*_{t+j} = \mu O^E_{t+j} \qquad j>0 \qquad (5)$$

where: K^*_{t+j} = the desired level of the capital stock in period t+j; and

O^E_{t+j} = the expected level of output in the same period.

Investment takes place when the desired capital stock (i.e.the expected output level) alters. If we assume a one period lag in the delivery of capital goods,[1] then firms invest in the present period to be able to produce the correct level of output one period hence, that is:

$$IN_t = K^*_{t+1} - K^*_t \qquad (6)$$

$$= \mu \Delta O^E_{t+1} \qquad (7)$$

where Δ is the backwards difference operator. Assuming that expectations are formed adaptively:[2]

$$O^E_{t+1} - O^E_t = \lambda (O_t - O^E_t) \qquad 0 \leqslant \lambda \leqslant 1 \qquad (8)$$

and substituting for O^E_{t+1}, O^E_t, etc., gives:

$$IN_t = \mu \sum_{j=0}^{\infty} \lambda (1-\lambda)^{t-j} \Delta O_{t-j} \qquad (9)$$

---

[1] An illustrative simplifying assumption. The model can be generalised to give a less restrictive dynamic model than equation 9 [see Malkiel et al.(1979) or Oulton (1981)].

[2] As stressed earlier this is not a necessary feature of the accelerator model.

with net investment depending on a geometric declining lag of past changes in output. In practice this distribution is often estimated freely, using an equation of the form:[1]

$$IN_t = \sum_i \eta_i \Delta O_{t-i} \qquad (10)$$

When account is taken of replacement investment and possible heteroscedasticity,[2] the equation to be estimated is:

$$\frac{I_t}{K_{t-1}} = \alpha + \frac{\beta}{K_{t-1}} + \sum_i \gamma_i \frac{\Delta O_{t-i}}{K_{t-i-1}} \qquad (11)$$

34 Many different varieties of investment equation have been estimated in the academic literature in the spirit of the neoclassical theory. The original formulation [Jorgenson (1965)] was based on the assumption that the production function was Cobb-Douglas; maximising the discounted future earnings of the firm subject to this production function gives a value for the desired stock of capital K_t^* of the form:

$$K_t^* = \alpha \left(\frac{P_t}{UC_t}\right) O_t \qquad (12)$$

where: P_t = the price of output;

UC_t = the rental flow price of capital (the 'user cost'); and

α = the elasticity of output with respect to capital.

Net investment depends on changes in the desired capital stock with an arbitrary lag structure imposed:

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[1] One justification for the introduction of lags in the accelerator mechanism is that of adjustment costs [Eisner and Strotz (1963)]. In the presence of adjustment costs it is optimal to move only partway towards the desired capital stock in any period.

[2] The change in output is scaled by K_{t-i-1} rather than the conceptually correct K_{t-1}, so that existing computer programs for estimating Almon variables could be used. This approximation is unlikely to seriously affect the results.

$$IN_t = w(L)\Delta(K_t^*) \qquad (13)$$

where w(L) = a polynomial in the lag operator L.[1]

Adding replacement investment and scaling by the capital stock in a similar manner to the accelerator equation gives:

$$\frac{I_t}{K_{t-1}} = \alpha + \frac{\beta}{K_{t-1}} + \sum_i \gamma_i \Delta \left[\frac{P_{t-i}}{UC_{t-i}} O_{t-i} \right] / K_{t-i-1} \qquad (14)$$

35 This formulation imposes the constraint that the distributed lag of investment with respect to a change in relative prices is the same as the distributed lag with respect to a change in output. This has been extensively criticised [Eisner and Nadiri (1968), Bischoff (1969)] because it implies that the underlying technology is putty-putty, which means that capital can be readily substituted for labour on both new and existing machines. A more realistic assumption about the underlying technology might be that it is putty-clay, which implies that factor proportions can be altered before a unit of capital is purchased (putty), but that once it is in place, factor proportions are fixed (clay). If the technology is putty-clay then changes in relative prices can only affect factor proportions as capital is replaced by new equipment, and consequently the reaction of investment to changes in relative prices is likely to be rather slower than the reaction of investment to changes in output which affect the desired scale of operation. The restriction that the reaction is the same can be relaxed by allowing the lag profiles on output and relative prices to differ.

36 The argument about whether technology is putty-putty or putty-clay revolves around the speed of the response of investment to relative price and output changes. Another criticism of the Jorgenson formulation considers the long-run magnitude of the response; the assumption that the technology is Cobb-Douglas implies that the long-

[1] This is typically modelled by a rational lag function, but it has been assumed here that it can be adequately represented by a 'long' lag function on ΔK^*.

run elasticity of investment with respect to both output and relative prices is unity. A more general production function such as the Constant Elasticity of Substitution (CES) function relaxes this condition and can be introduced by rewriting equation 12 as:

$$K_t^* = \alpha \left(\frac{P_t}{UC_t}\right)^{\sigma} O_t \qquad (12a)$$

where σ = the elasticity of substitution.[1]

37 A further criticism of the standard neoclassical approach is that the theory assumes a perfect product market for the firm's output (see Austin 1980). If this restriction is relaxed then labour costs rather than revenue affects the desired capital stock yielding:[2]

$$K^* = \frac{\alpha wL}{(1-\alpha)\, UC} \qquad (12b)$$

where wL = the wage bill.

38 The appropriate measure of the user cost of capital in the neoclassical framework poses some difficulty [see King (1974)]. The form adopted in this paper is based on the measure derived by King for an economy where the Modigliani-Miller theorem holds, which shows that the decision to undertake investment is independent of the decision of how to finance the investment. As has been noted in the literature [for example, Bean (1981)], the theorem ignores such important influences as the possibility of bankruptcy, which may have important repercussions for the cost of capital. The measure used is:

$$UC = \frac{P_k (1-A) R}{(1-t)} \qquad (15)$$

where: $R = \delta + R^*(1-t) - \gamma \hat{\Pi}_k$ = the post-tax real interest rate;

R^* = the nominal rate of interest;

---

[1] Estimating σ is extremely difficult and values are often imposed.

[2] See Austin (1980), page 77 who uses a Cobb-Douglas production function to derive this result.

t = corporation tax rate;

P_k = price of capital goods;

$\hat{\Pi}_k$ = expected rate of inflation in the price of capital goods;[1]

γ = a weighting variable on the capital gains term to reflect the fact that firms do not in general buy fixed capital to make capital gains [see Nickell (1978), page 265];

δ = rate of depreciation (including an element for risk); and

A = present value of investment allowances per unit of investment.

The novel characteristic of this formulation is the introduction of the weighting variable following Nickell's suggestion. Several studies have simply used nominal interest rates with $\gamma = 0$ [Feldstein and Flemming (1971)]. At the other extreme, taking full account of inflationary expectations ($\gamma = 1$) causes problems in this model, for unless the rate of depreciation plus the risk premium is set rather high, the post-tax real rate of interest may become negative, in which case the model breaks down.[2]

39 To take account of these respective criticisms, of putty-putty Cobb-Douglas technology, of perfect product markets and of difficulties in the measurement of the cost of capital, a general model along the lines of Feldstein and Flemming (1971) has been tested which allows the data to determine the form of the response to the factors thought to be important. Thus, in logs:[3]

$$\ln\left(\frac{I_t}{K_{t-1}}\right) = \alpha + \beta \ln\left(\frac{1}{K_{t-1}}\right) + \sum_i \gamma_i \ln O_{t-i} + \sum_i \delta_i \ln\left(\frac{p}{p_k}\right)_{t-i}$$

$$+ \sum_i \epsilon_i \ln R_{t-i} + \sum_i \eta_i \ln \left(\frac{(1-A)}{(1-t)}\right)_{t-i} \qquad (16)$$

---

[1] The unobservable expected rate of inflation is critical to the calculation. In this study is has been proxied by the current rate (see paragraph 41 and Appendix 2).

[2] A negative real rate of interest with no adjustment costs implies that firms should expand their capital stock infinitely.

[3] To take account of Austin's point that labour costs are important w (the wage rate) is substituted for p, and L (employment) is substituted for O in equation 16.

It is possible to test the restrictions imposed by Jorgenson against equation 16, namely, whether the cost of capital terms can be amalgamated into a composite measure:

$$\delta_i = -\varepsilon_i = -\eta_i \qquad (17)$$

$$= k_i \text{ say}$$

and under this constraint, whether the response to the relative price term is the same as that to output:

$$\gamma_i = k_i \qquad (18)$$

Results

40 The equations were initially estimated using cubic Almon polynomials, with the lag length set at 0 to 14 quarters after some preliminary investigation.[1] In common with most investment studies using Almon variables, the equations tended to suffer from serial correlation and consequently estimates are provided adjusted for first order autocorrelation.[2] Also, in order to combat possible dynamic misspecification some experiments have been undertaken with rational lag models (see Table C).

41 The results for the equations using Almon polynomials are given in Tables A and B.[3] Turning first to the linear equations (Table A), considerable experimentation was carried out with various forms of the neoclassical model. A grid search was undertaken to find the weight of inflation in the calculation of the user cost of capital (see paragraph 38), using the current annual inflation rate as

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[1] After setting up the lags and keeping eight observations for an out-of-sample forecasting test, the estimation period was 1967 Q2 to 1976 Q4.

[2] The Ljung-Box portmanteau statistic was used to test for higher order autocorrelation. All the presented equations satisfy the hypothesis of no higher order autocorrelation at the 1% level, although some fail at the 5% significance value.

[3] In all cases, the equations passed a test for the validity of the Almon constraints, calculated as a likelihood ratio statistic between an unrestricted model with the lags estimated freely, and the restricted model.

a proxy for the expected rate.[1] The grid search was undertaken with values of the weight ranging from zero to a half (it was not possible to set the weight higher as the real rate of interest would then be negative in 1975 causing the model to break down[2]). The best equations, both in terms of the degree of fit and of serial specification, were given by a zero weight on inflation, that is with the model reverting to a nominal framework,[3] with R calculated as:

$$R = \delta + R^* (1-t)$$

the post tax nominal rate of interest (adjusted for depreciation). The Austin approach, introducing labour costs rather than the value of sales into the measure of the user cost, was then compared with the more traditional model which incorporates the value of sales. For an elasticity of substitution of unity (the Cobb-Douglas production function), the Austin model was inferior[4] and although the theory seems worthy of further empirical study, this has not been undertaken in this paper. Finally, various estimates of the elasticity of substitution between capital and labour were introduced,[5] giving a preferred value of 0.25. The neoclassical equation shown in Table A is consequently of the form:

$$\frac{I_t}{K_{t-1}} = \alpha + \frac{\beta}{K_{t-1}} + \sum_i \gamma_i \Delta \left[\left(\frac{P_{t-i}}{UC_{t-i}}\right)^{0.25} O_{t-i} \right] / K_{t-i-1} \qquad (14a)$$

---

[1] In theory, the expected rate of inflation should be the expected rate over a long horizon to coincide with the term of the interest rate variable. Modelling long-run inflationary expectations is very difficult; some economists argue that long-run price expectations adjust with the nominal rate of interest to keep the long-run real rate of interest constant. If this approach is adopted it would imply that the rate of interest had no effect on the user cost of capital.

[2] In the neoclassical framework, a negative real rate of interest implies that firms increase their desired capital stock to infinity.

[3] This is a little worrying. Because of difficulties with the appropriate measure of the user cost of capital, some regressions were run with the cost of capital component of the valuation ratio as an alternative, but these were generally inferior.

[4] Although perhaps not significantly so.

[5] Values of 0 (the accelerator), 0.25, 0.5 and 1 were tried.

where $UC = \frac{P_k(1-A)R}{(1-t)}$

42 The results in Table A show that the neoclassical and valuation ratio equations fit the data rather better than the simple accelerator model, both in terms of the adjusted correlation coefficient and in serial properties, thus lending some weight to the argument that profitability factors should be taken into consideration in investment equations. All the lag profiles appear plausible, with the peak lag on the neoclassical equation four quarters behind that on the output equation, suggesting that the adjustment to changes in relative prices is rather slower than that on changes in output as the putty-clay hypothesis contends. Although the valuation ratio and neoclassical models perform better than the accelerator over the estimation period, the latter model is considerably more stable over the eight quarter forecasting horizon, with the valuation ratio equation tending to break down slightly.[1] The valuation ratio underpredicts investment throughout the forecast period, whilst forecasts derived from the other two models show no consistent bias (see Chart B).

43 The results for the logarithmic specifications are presented in Table B. The equations were compared with the linear models using the criterion suggested by Sargan (1964) [see also Aneuryn-Evans and Deaton (1980)], but the results were inconclusive, with the linear specification preferred for the neoclassical model, whilst the log linear equation performed better for the valuation ratio approach. For estimation, the accelerator and neoclassical models were modified slightly into a levels formulation, to avoid the problem of taking logs of negative numbers when output falls. Thus, the accelerator equation, relating the level of investment to changes in output, is modified into an equation relating the log of investment to the log of output:

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[1] The χ^2 statistic for the stability of the valuation ratio equation with 8 degrees of freedom is 17.5, whilst the 5% and 1% critical values of the $\chi^2(8)$ statistic are 15.5 and 20.1 respectively.

Table A
Linear models[a]

Estimation period 1967Q2-1976Q4

Constant	D1[b]	RK1[c]	Accelerator [equation 11]		Valuation ratio [equation 4]		Neoclassical[d] [equation 14a]		DW_u[e]	ρ[f]	$\bar{R}^2_u$[e]	$\bar{R}^2_c$[f]	LB[g]	$\chi^2_F(8)$[h]
			$\Sigma\gamma_i$	Comment	$\Sigma\gamma_i$	Comment	$\Sigma\gamma_i$	Comment						
0.34 (2.75)	0.115 (5.01)	103.6 (6.03)					20.01 (6.74)	All lags positive, peak at 10	1.13	0.40 (2.37)	0.943	0.950	12.91	7.02
0.24 (0.82)	0.113 (6.09)	112.9 (2.64)	28.62 (3.6)	All lags positive peak at 6					0.47	0.77 (7.24)	0.850	0.942	20.79	2.41
0.05 (0.45)	0.119 (5.45)	27.13 (0.71)			0.82 (3.99)	All lags positive, peak at 5			1.17	0.44 (2.67)	0.934	0.945	22.42	17.47

[a] Dependent variable is the ratio of investment to the lagged capital stock as a percentage. 0-14 lags of the accelerator, neoclassical and valuation ratio models are estimated by cubic Almon polynomials. All models are linear. 't' statistics are in parentheses.

[b] Dummy for the ending of the temporary increase in investment grants at the end of 1968. See Appendix 2 for details.

[c] Reciprocal of the lagged capital stock.

[d] With the elasticity of substitution $\sigma = 0.25$, and with R measured as a nominal rate of interest.

[e] Not corrected for autocorrelation.

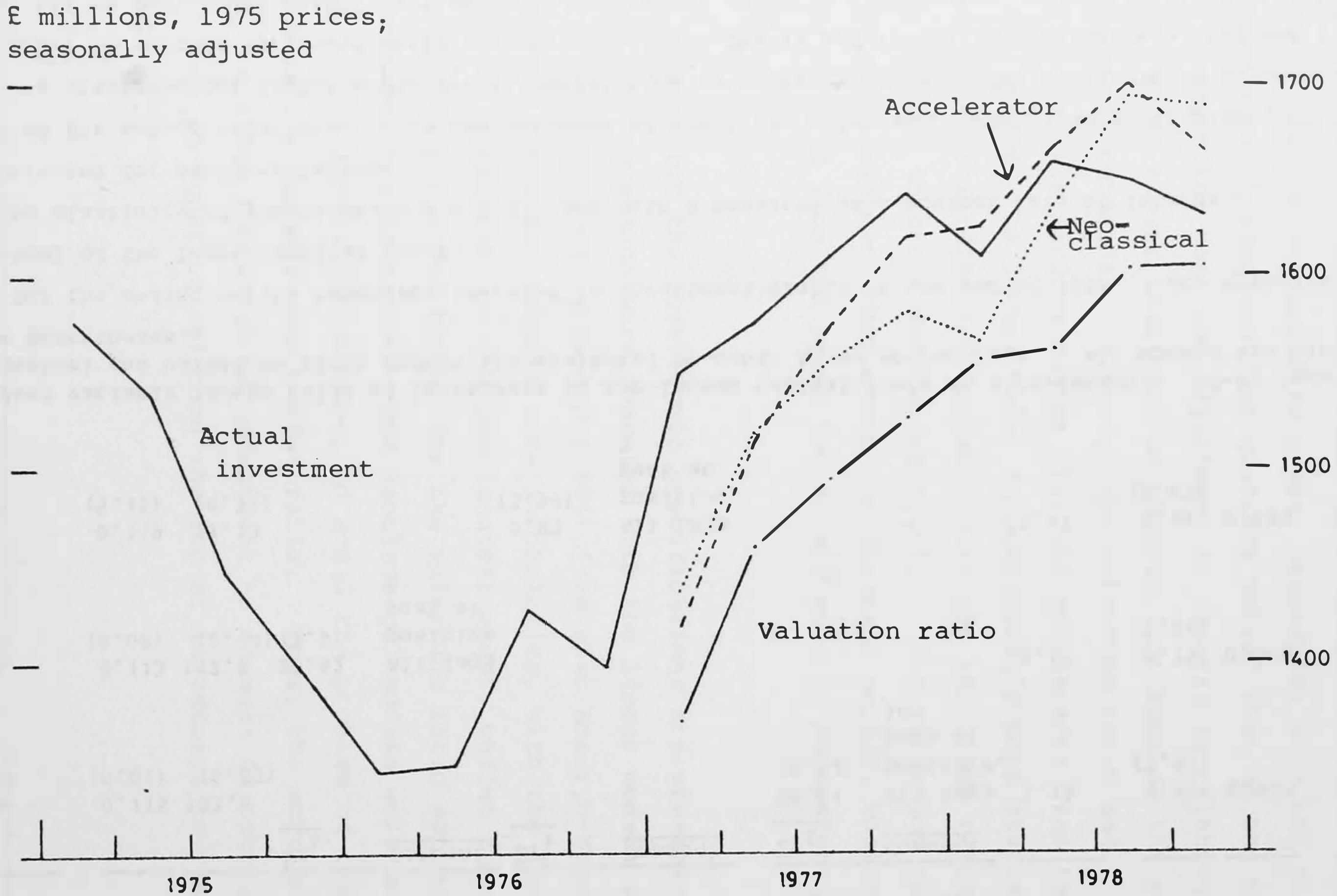
[f] Corrected for autocorrelation. ρ is the estimate of the first order autocorrelation coefficient.

[g] Ljung-Box statistic for higher order serial correlation up to tenth order. The statistic is asymptotically distributed as $\chi^2(9)$ after correction for first order autocorrelation. The 5% and 1% critical values are 16.9 and 21.7 respectively.

[h] Test of the ex post model stability from 1976Q4 to 1978Q4 which is distributed asymptotically as $\chi^2(8)$. The 5% and 1% critical values are 15.5 and 20.1 respectively.

Chart B

Forecasting performance of linear models[a]



[a] The forecasts of investment are estimates based on the published figures for the capital stock. The investment series is a proxy for the volume of industrial and commercial companies' investment. See Appendix 2 for details.

$$\ln\left(\frac{I_t}{K_{t-1}}\right) = \alpha + \beta \ln\left(\frac{1}{K_{t-1}}\right) + \sum_i \gamma_i \ln\left(\frac{O_{t-i}}{K_{t-i-1}}\right) \quad (19)$$

whilst the neoclassical variant became:

$$\ln\left(\frac{I_t}{K_{t-1}}\right) = \alpha + \beta \ln\left(\frac{1}{K_{t-1}}\right) + \sum_i \gamma_i \ln\left(\left[\left(\frac{P}{UC}\right)^{0.25}_{t-i} O_{t-i}\right] / K_{t-i-1}\right) \quad (20)$$

The conclusions drawn from the linear specification that the neoclassical and valuation ratio models outperform the accelerator hold also for the logarithmic equations, although rather less strongly. The equations are less satisfactory than the linear ones, with rather implausible lag profiles on the neoclassical and accelerator models, and evidence that all the models are unstable over the forecast period. It is interesting to note that the elasticity of the investment/capital ratio with respect to the valuation ratio is 0.7, similar to Abel's results for the United States [see Abel (1979)].

44 The logarithmic approach, however, has some advantage over the linear specification, in that it allows some of the constraints implicit in the neoclassical and valuation ratio models to be tested. Following the arguments of paragraphs 35 to 38, the logarithmic neoclassical model was reformulated in a more general form, as suggested by Feldstein and Flemming(1971). Initially, the term

$$\ln \left(\frac{P}{UC}\right)^{0.25}_{t-i} \frac{O_{t-i}}{K_{t-i-1}}$$

was split into two:

$$\ln\left(\frac{P}{UC}\right) \text{ and } \ln\left(\frac{O_{t-i}}{K_{t-i-1}}\right)$$

and then the term in relative prices was further disaggregated into:

$$\ln R,\ \ln\left(\frac{P}{P_k}\right) \text{ and } \ln\left(\frac{1-A}{1-t}\right)$$

Table B
Loglinear models[a]

Estimation period 1967Q2-1976Q4

Constant	D1[b]	LRK1[c]	Modified accelerator [equation 19]		Valuation ratio		Neoclassical[d] [equation 20]		DW_u[e]	ρ[f]	$\bar{R}_u^2$[e]	$\bar{R}_c^2$[f]	LB[g]	$X_F^2(8)$[h]
			$\Sigma\gamma_i$	Comment	$\Sigma\gamma_i$	Comment	$\Sigma\gamma_i$	Comment						
-0.82 (0.29)	0.08 (3.97)	-0.15 (0.29)					1.35 (1.78)	Last 4 lags negative, peak at 4	1.21	0.41 (2.36)	0.942	0.949	8.44	17.72
-3.91 (0.92)	0.08 (4.84)	-1.03 (1.08)	3.63 (2.00)	All lags positive, peak at 0					0.86	0.62 (4.03)	0.925	0.948	11.1	46.13
1.56 (1.57)	0.09 (4.98)	0.30 (1.50)			0.69 (4.56)	First lag negative, peak at 5			1.15	0.44 (2.81)	0.947	0.957	21.1	33.07

[a] Dependent variable is the log of the ratio of investment to the lagged capital stock as a percentage. 0-14 lags of the log of the output capital ratio, the valuation ratio and the undifferenced neoclassical model (see paragraph 43) are estimated by cubic Almon polynomials. All models are loglinear. 't' statistics are in parentheses.

[b] Dummy for the ending of the temporary increase in investment grants at the end of 1968. See Appendix 2 for details.

[c] Log of the reciprocal of the lagged capital stock.

[d] With the elasticity of substitution $\sigma = 0.25$, and with R measured as a nominal rate of interest.

[e] Not corrected for autocorrelation.

[f] Corrected for autocorrelation. ρ is the estimate of the first order autocorrelation coefficient.

[g] Ljung-Box statistic for higher order serial correlation up to tenth order. The statistic is asymptotically distributed as $X^2(9)$ after correction for first order autocorrelation. The 5% and 1% critical values are 16.9 and 21.7 respectively.

[h] Test of the ex post model stability from 1976Q4 to 1978Q4 which is distributed asymptotically as $X^2(8)$. The 5% and 1% critical values are 15.5 and 20.1 respectively.

Unfortunately, the general equation 16 was somewhat perverse, with the term in R significantly positive (the wrong sign), whilst the term in the output/capital stock ratio was also of the wrong sign (although not significantly so). A test that the three components of the relative price term could be amalgamated into the 'correct' variable was, not surprisingly, heavily rejected given the wrong-signed interest rate term.[1] However, when this constraint was applied (inappropriately) it was possible to apply the further constraint that the relative price and output terms could be combined into a single neoclassical variable,[2] despite the estimate on the relative price term being of the wrong sign (a feature of the wrong-signed interest rate term). Similarly, the valuation ratio can be split down into separate components for the post-tax real rate of return and the post-tax real cost of capital, and a test applied to see whether the effects of the two are equal and opposite as the valuation ratio theory implies.[3] The following equation was estimated incorporating the rate of return and cost of capital separately:[4]

$$\ln\left(\frac{I_t}{K_{t-1}}\right) = \underset{(3.78)}{2.69} + \underset{(4.73)}{0.09}\,D1 + \underset{(3.9)}{0.49}\ln\left(\frac{1}{K_{t-1}}\right) + \sum_{o}^{12} c_i (\ln r)_{t-i}$$

$$+ \sum_{o}^{12} d_i (\ln c)_{t-i} \qquad (21)$$

$$\sum c_i = \underset{(4.59)}{0.49} \qquad \sum d_i = \underset{(7.5)}{-0.59}$$

$$DW = 2.05, \quad \bar{R}^2 = 0.97, \quad LB^{[*]}(10) = 21.5 \quad \chi_F^{2[\neq]}(8) = 10.8$$

* The Ljung-Box test for up to tenth order autocorrelation. As the 5% critical value of the appropriate χ^2 statistic is 18.3 there is some evidence of misspecification.

≠ Test of forecasting stability for eight quarters. The equation easily passes.

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[1] The χ^2 likelihood ratio statistic with 8 degrees of freedom was 58.2, compared with a 5% critical value of 15.5.

[2] $\chi^2(4) = 8.0$ compared with a critical value of 9.5 at the 5% level.

[3] Although the measures of the rate of return and cost of capital are more prone to measurement error than is the valuation ratio (see paragraph 21).

[4] Estimated with cubic Almon polynomials for 0 to 12 quarterly lags. This equation performed much better than one for 0 to 14 quarters.

Although the coefficient estimates on the rate of return and the cost of capital are fairly close, the test that they could be combined was rejected at the 5% level and almost at the 1%.[1] The disaggregation of the neoclassical model thus cast some doubt about the appropriateness of the framework, although the valuation ratio model still appears to perform quite well.

45 To combat dynamic misspecification the linear models were re-estimated using the rational lag framework pioneered by Jorgenson (1965). A general model was estimated for each variant with four lags of the dependent variable, and five lags of the 'economic' variable.[2] Thus, the valuation ratio model was estimated as:[3]

$$\gamma(L)\left(\frac{I_t}{K_{t-1}}\right) = \alpha + \frac{\beta}{K_{t-1}} + \delta(L)q_t \qquad (22)$$

where $\gamma(L)$ and $\delta(L)$ are polynomials in the lag operator of degree 4 and 5 respectively. These equations were estimated using both ordinary least squares and instrumental variables[4] to combat potential simultaneity bias. The equations were then simplified, with the simplified model tested against the general specification, the restrictions being accepted in every case. The results are presented in Table C. No attempt has been made to respecify the models in error feedback form as suggested by Davidson et al.(1978) and undertaken by Bean (1981) and Anderson (1981c), because of the potential misspecifications in the lag structure which might be caused by using seasonally-adjusted data [Wallis (1974)].

---

[1] $F_{4,28}$= 4.08 compared with a 5% critical value of approximately 2.74 and a 1% critical value of around 4.1.

[2] All the general equations passed the Lagrange Multiplier Test for first order serial misspecification at the 5% level [see Breusch and Godfrey (1980)].

[3] This is a slight modification of the 'pure' rational lag approach which would take lags of the reciprocal of the capital stock into account also. This was not done because of severe collinearity between this term and its respective lags.

[4] The instruments used were the volumes of world trade (WTX), consumer spending (C) and government consumption (G), and import prices (PM).

Table C

Rational lag models[a]

Estimation period 1967Q2-1976Q4

	Constant	D1[b]	RK1[c]	X_0[d]	X_1	X_2	X_3	X_4	X_5	LDV_1[e]	LDV_2	LRE[f]	DW	h[g]	$\bar{R}^2$	Test against the general model [h]
Valuation ratio																
OLS	-0.04	0.16	28.07				0.090	0.019	0.064	0.466	0.222	0.55	2.44	-1.83	0.959	F (5,26) = 1.09
	(0.82)	(6.50)	(2.69)				(2.80)	(0.52)	(2.49)	(4.39)	(2.39)					The 5% critical value =2.59
OLS	-0.04	0.16	26.69				0.102		0.071	0.471	0.223	0.57	2.45	-1.81	0.960	F (6,26) = 0.96
	(0.78)	(6.62)	(2.67)				(4.60)		(3.32)	(4.51)	(2.44)					The 5% critical value =2.48
Accelerator																
IV	0.01	0.19	9.12	3.10				1.25		0.914		50.6	2.11	-0.41	0.929	F (7,26) = 1.36
	(0.16)	(5.88)	(0.57)	(2.56)				(1.86)		(10.6)						The 5% critical value =2.39
IV	-0.03	0.19	9.66	2.68						0.947		50.6	2.12	-0.44	0.928	F (8,26) = 1.35
	(0.45)	(5.73)	(0.63)	(2.69)						(11.33)						The 5% critical value =2.33
Neoclassical[j]																
IV	-0.02	0.17	21.5,	0.79				0.40		0.873		9.4	2.00	0.01	0.929	F (7,26) = 0.41
	(0.37)	(5.12)	(1.51)	(1.41)				(1.28)		(11.28)						
IV	-0.04	0.17	24.1	0.69						0.875		5.5	2.00	0.01	0.929	F (8,26) = 0.50
	(0.69)	(5.01)	(1.69)	(1.23)						(11.25)						

[a] The dependent variable is the ratio of investment to the lagged capital stock as a percentage. All models are linear. The accelerator and neoclassical models have been estimated using instrumental variables because of the contemporaneous effect. t statistics are in parentheses.

[b] Dummy for the ending of the temporary increase in investment grants at the end of 1968. See Appendix 2 for details.

[c] Reciprocal of the lagged capital stock.

[d] X_0 refers to the current period value of the relevant economic variable, X_1 to lag 1 etc.

[e] LDV_1 is the first lag of the dependent variable, etc.

[f] Long-run effect of X taking into account the lagged dependent variable.

[g] Durbin's 'h' statistic.

[h] The F test is not strictly valid for the equations estimated by instrumental variables, but may be a better approximation in small samples than an asymptotic test.

[j] With the elasticity of substitution $\sigma = 0.25$, and with R measured as a nominal rate of interest.

46 The preferred equation using the valuation ratio model includes lags of q from three to five quarters with two lags of the dependent variable. The lag at four quarters is not significantly different from zero and consequently the equation is also presented with this variable omitted.[1] The three quarters delay before a change in the valuation ratio affects investment is a little surprising, but can perhaps be rationalised by authorisation and order lags.[2] The equation performs satisfactorily on statistical grounds and fits the data very well. The accelerator and neoclassical equations perform similarly, both in terms of the goodness of fit and in respect of the preferred lag profiles. For both models, the equations can easily be simplified to the current and fourth quarter lag of the relevant explanatory variable,[3] together with a single lagged dependent variable. The fourth quarter effect can also be eliminated if desired, reducing the equations to the geometrically weighted Koyck model. This type of equation can be rationalised in terms of the pure adaptive expectations model (see paragraph 33), but the strong current period effect is somewhat disturbing when compared with the valuation ratio findings.

47 There are difficulties in interpreting the results given the somewhat unexpected outcomes, and consequently conclusions drawn must be regarded as rather preliminary.[4] It is nevertheless clear that the valuation ratio approach performs at least as well as, if not rather better than, the other models, supporting the conclusions reached from the estimates using Almon polynomials.

48 To complete the explanation of investment using the valuation ratio, it is necessary to model q itself in order to close the system. Modelling q is extremely difficult, as in theory the

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[1] The lagged dependent variable induces an effect at four quarters when the lag polynomials are expanded.

[2] This result indicates that the Almon results for the valuation ratio model may be misspecified. Re-estimating the Almon equations with the current and first period lag omitted, however, did not significantly alter the results.

[3] No intermediate lags appear to be at all important.

[4] It is a little worrying that the long-run effects of the explanatory variables diverge substantially between the rational and Almon lag specifications.

valuation ratio encapsulates all the information pertaining to the investment decision.[1] It is unlikely that all the influences can be easily encompassed in a stable econometric specification. Consequently, a fairly eclectic approach was taken in modelling q [see Appendix 2 for the variables considered and Abel (1979) for a theory of the important determinants]. Given the high degree of variability in the series for q (equity prices are rather volatile and difficult to model using econometric techniques), the following equation appears to be reasonably satisfactory, capturing several important effects. Whilst the term in real liquid assets proxies the current financial position of the company sector, the interest rate effect captures the change in the cost of external finance, and the term in competitiveness proxies the profitability of producing tradeable goods. These variables all seem plausible determinants of the valuation ratio.

$$q = \underset{(5.2)}{3.12} - \underset{(2.4)}{5.94}\, R^{*} + \underset{(4.7)}{0.00008}\, RNLI - \underset{(2.5)}{0.012}\, NULC \qquad (23)$$

Estimation period 1963Q2-1977Q4

$\bar{R}^2 = 0.67$ DW = 1.57 LB(10) = 20.2 $\chi^2_F(8) = 10.7$

where:

R* = the nominal interest rate;[2]

RNLI = a measure of industrial and commercial companies real net liquid assets;[2] and

NULC = a measure of UK competitiveness.[2]

Unfortunately the results of estimating a reduced form investment equation, which related investment directly to the determinants of the valuation ratio, were unsatisfactory, emphasising that more research needs to be undertaken before the approach could be introduced into a forecasting model with a strong degree of confidence.[3]

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[1] For example, all the information incorporated in the accelerator and neoclassical specifications.

[2] See Appendix 2 for the exact definitions.

[3] Although existing techniques for modelling investment are also rather unsatisfactory.

Conclusions

49 The empirical results tentatively support the conclusion that profitability influences investment through the valuation ratio and the neoclassical model - the results of the basic models are at least as good as those of the conventional flexible accelerator. Nevertheless the equations still suffer from econometric problems and do not offer full explanations of the investment process, which probably requires much greater concentration on the dynamic behaviour of the firm and the economy under conditions of uncertainty. Given the likely complexities of these processes, it is perhaps expecting too much to believe that any of the current theoretical models can fully explain investment behaviour.[1]

50 The use of the valuation ratio is a relatively new approach to the explanation of investment and the volume of empirical evidence for the usefulness of the approach is still rather limited. Despite the difficulties associated with proxying the theoretical concept,[2] the results of this study and those of Oulton (1981) indicate that a valuation ratio model performs reasonably well with UK data, and consequently it seems worthy of further consideration.

[1] Investment is likely to be particularly difficult to explain since the mid-1970s as the economy adjusts to the sharp increase in energy prices.

[2] Likely to be particularly severe in the late 1970s (see paragraph 22).

Appendix 1

Aggregation in investment models

51 Aggregate investment equations typically do not take into consideration the fact that the majority of investment is irreversible (at least in the short run), which at the micro level leads to an investment function which treats influences tending to cause an increase in investment asymmetrically from influences tending to cause a fall. With the exception of some types of vehicles, most capital goods are rather specific in nature and cannot be traded on efficient second-hand markets, implying that they cannot readily be sold or used for other purposes once they are in place. Thus, even if the sales of the firm slump sharply, the reduction in the stock of capital (net disinvestment) is likely to be at most equal to the depreciation rate,[1] and under these circumstances the gross investment of the firm cannot be less than zero.

52 Oulton (1981) considers this issue for the valuation ratio model, and derives an equation taking this potential asymmetry in the investment equation into account when forming an aggregate function from the micro theory. Firms who have q ratios less than the equilibrium value (unity) will be undertaking zero gross investment, whilst those with q ratios greater than unity will be continuing to add to their capital stock. In order to estimate the proportion of firms with q ratios less than unity (and hence the degree of asymmetry),[2] it is necessary to derive a probability function for the value of firms' q ratios with respect to the mean value of q. Oulton argues that, although share prices of firms tend to move broadly in line, the market valuation of an individual firm is affected by many special factors which can be regarded as multiplicative random shocks, and consequently postulates that firms' q ratios are lognormally distributed around the average level of q.

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[1] Although the size and speed of the reaction to the change in circumstances will obviously depend on the view of the firm as to the likely depth and length of the fall in sales. The depreciation and scrapping rates are unlikely to be constant in this situation.

[2] More exactly, the proportion of the capital stock owned by firms with q ratios less than unity.

Given a measure of the variance of firms' q ratios which Oulton takes from Tobin and Brainard (1977), an aggregate investment equation is derived. Although the empirical results are rather disappointing, this may be partly due to the many auxiliary assumptions necessary to generate an estimating equation.

53 The asymmetry of the investment function should also be taken into account in the accelerator and neoclassical models, although few studies have examined this point. One exception is Eisner (1978), who finds some tentative evidence from a time series approach to support the view that firms' investment reacts more sharply to increases in sales than to declines.[1] Eisner does not derive his estimating equation from a formal treatment of the aggregation problem - the following very simple theoretical model may illustrate the way in which the asymmetry may be built into an accelerator specification.

54 The simplest form of accelerator equation for a typical firm can be written as:

$$IN_t = b \Delta O_t^E \qquad (24)$$

where the company operates with a fixed capital-output ratio b. Assuming that the firm had the 'desired' capital stock in all periods prior to the present, i.e.:

$$K_{t-i} = bO_{t-i} = bO_{t-i}^E \quad i>0 \qquad (25)$$

which implies that the firm does not have excess capital capacity at the start of period t. Making the conventional assumption that depreciation is a fixed proportion of the capital stock at the end of the previous period[2] yields:

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[1] Unfortunately, cross section results in Eisner's study suggest the opposite conclusion.

[2] As mentioned earlier, this assumption has been criticised by Feldstein and Rothschild (1974) amongst others. The plausibility or otherwise of this assumption does not compromise the illustrative nature of this simple example.

$$I_t = \delta K_{t-1} + b \Delta O_t^E \qquad (26)$$

However, assuming that firms do not benefit from accelerated scrapping of their capital stock, then equation 26 only holds for values which give positive investment, otherwise gross investment will be zero, i.e.:

$$I_t = \delta K_{t-1} + b \Delta O_t^E \text{ if and only if } \delta K_{t-1} + b \Delta O_t^E > 0 \qquad (27)$$
$$= 0 \text{ otherwise}$$

as negative gross investment implies that capital is being eroded faster than the rate of depreciation, e.g. by accelerated scrapping.

55 Ideally, the restriction in equation 27 should be built into all forms of accelerator - in any period, particularly of declining output, many firms will not be investing. One way of approaching this problem is to assume that the economy consists of many 'identical' firms which operate with the same production function and level of output, but which differ in their expectations of the growth of output as it will affect their firm. Assume for the jth firm:[1]

$$I_{jt} = \delta K_{j,t-1} + b \Delta O_{jt}^E \text{ if and only if the right hand side (RHS)} > 0 \qquad (28)$$
$$= 0 \text{ otherwise}$$

Now, because all firms are initially of equal size:

$$K_{j,t-1} = \frac{K_{t-1}}{M}$$

where M = the number of firms

and:

$$O_{j,t-1} = \frac{O_{t-1}}{M}$$

---

[1] For purposes of illustration, this model assumes that the investment function is exact and does not have an associated error. If equation 28 were generalised so that $I_{jt} > 0$ if and only if $\delta K_{j,t-1} + b \Delta O_{jt}^E + U_t > 0$ where U_t is a normally distributed disturbance term, the model is of the Tobit type [see Maddala (1977)].

where O_{t-1} and K_{t-1} are aggregate measures, the assumption of initial equilibrium can be written as:

$$K_{j,t-1} = bO_{j,t-1} = bO^E_{j,t-1} \qquad (29)$$

and consequently equation 28 can be rewritten as:

$$I_{jt} = \delta bO_{j,t-1} + b\,\Delta O^E_{jt} \quad \text{if and only if the RHS} > 0 \qquad (30)$$

$$= 0 \text{ otherwise}$$

and investment is positive if:

$$\Delta O^E_{jt} + \delta O_{j,t-1} > 0 \qquad (31)$$

that is if: $$g^E_{jt} = \frac{O^E_{jt} - O_{j,t-1}}{O_{j,t-1}} > -\delta \qquad (32)$$

where g^E_{jt} is the rate of growth of output expected by the jth firm. Making the assumption that these expectations are normally distributed around the true aggregate growth path, i.e.:

$$g^E_{jt} \sim N\,(g_t, \sigma^2) \qquad (33)$$

where: $$g_t = \frac{O_t - O_{t-1}}{O_{t-1}}$$

and where σ^2 is a measure of the variation of growth rate expectations between firms, gives the condition that firm j will undertake positive investment with probability:

$$1 - \Phi\left(\frac{-\delta - g_t}{\sigma}\right)$$

where $\Phi(.)$ is the cumulated distribution function of the standard normally distributed variate with zero mean and unit variance.

Aggregating and taking expectations gives:

$$E(I_t) = ME(I_{jt}) \tag{34}$$

giving the final result:

$$E(I_t) = (b\Delta O_t + \delta K_{t-1}) \left[1 - \Phi\left(\frac{-\delta - g_t}{\sigma}\right) \right] \tag{35}$$

that is the standard form of the accelerator modified by the probability that a certain proportion of firms will not be investing because of poor output expectations. This equation has the intuitively pleasing property that as the aggregate growth rate increases the proportion of firms not investing falls, and in the limit as $g_t \to \infty$, $\Phi(.) \to 0$ and equation 35 reverts to the standard accelerator.

56 Despite the theoretical attraction of such a nonlinear accelerator framework, the above formulation has obvious drawbacks; for example, the assumption of initial equilibrium implies that the model breaks down after one period, as several firms not investing will be in disequilibrium (i.e. with unused capital capacity). Attempts to generalise the specification have proved unsuccessful and so it has not been possible to test empirically.

57 A further form of response which has been used with some success in the Bank is the arctan specification. The arctan function is similar to an elongated S (see Chart C) and is bounded above and below at $\pm \pi/2$. By manipulation of the general form arctan $\nu(x-\mu)$, the slope can be altered (by choice of ν) whilst the point of maximum slope (i.e. when the response is sharpest) is equal to μ. Although the use of this particular functional form is rather arbitrary, the shape of the arctan function is very similar to that of the cumulated standard normal distribution function discussed earlier $\Phi(.)$ (see Chart C), and it is possible that arctan specifications may pick up aggregation problems quite successfully. There are many areas in economics where this elongated S shaped response seems attractive.[1]

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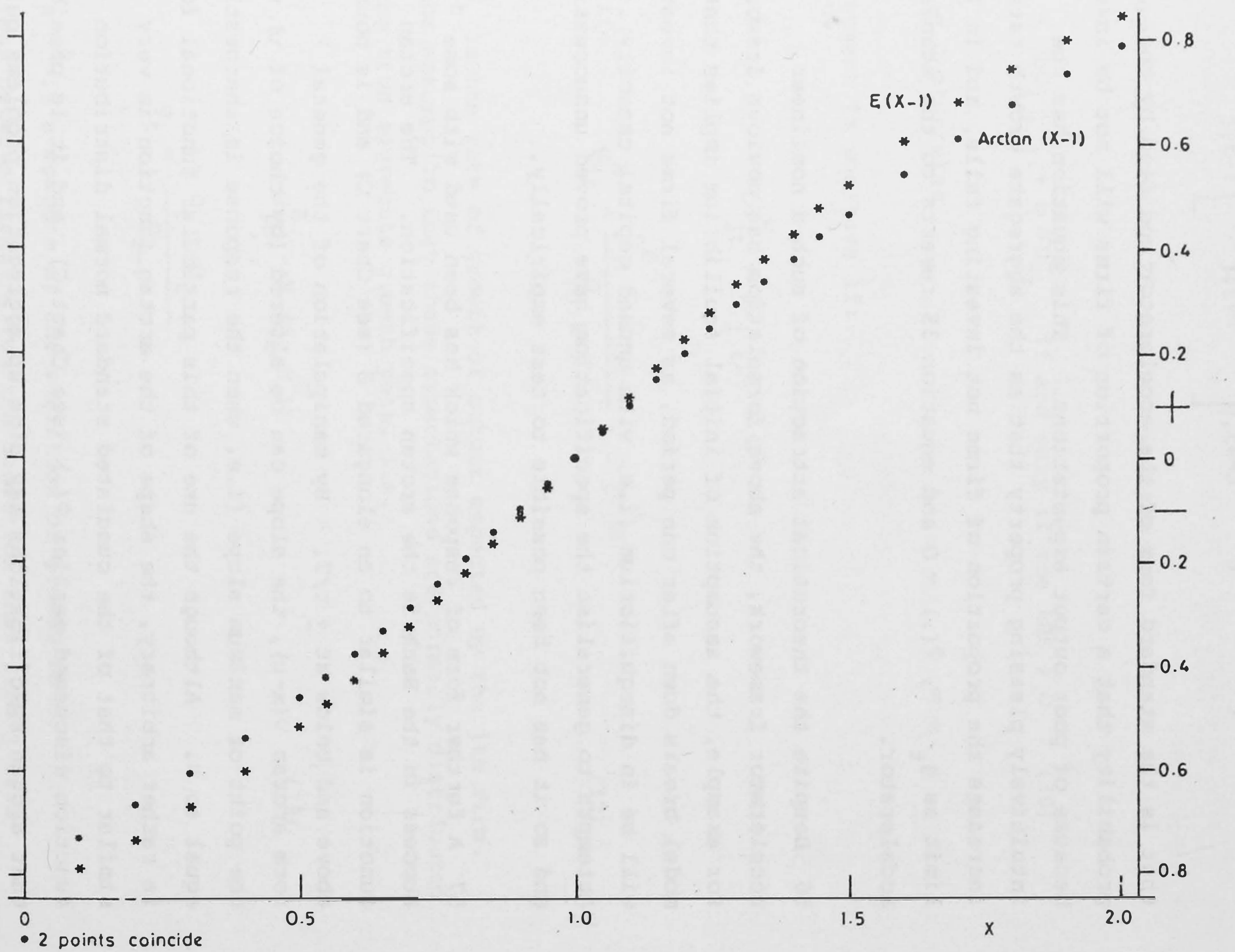
[1] For example, the arctan approach has been used in the Bank short-term model to model overtime payments and the degree of pressure on the exchange rate.

Chart C

Arctan function and the modified cumulated normal distribution function[a]



[a] The cumulated normal distribution function has been modified to lie within the region -1 to +1 by the transformation $E(.) = 2\Phi(\sqrt{2}(.)) - 1$.

58 In the current study, it seems reasonable to assume that investment responds more quickly to changes in the valuation ratio when it is nearest its equilibrium value[1] (which in theory is unity). For high values of q, desired investment will be high, but, because of installation costs and production costs in the capital goods industries, it seems unlikely that investment will respond linearly to higher and higher values of q. Similarly, when q is very low, because of the restriction that gross investment can never be negative, it is unlikely that investment will fall linearly with q. Consequently, the response is expected to be sharpest for values of q around the equilibrium value.[1] Estimation of the model:

$$\frac{I_t}{K_{t-1}} = a + \frac{b}{K_{t-1}} + \sum_i c_i \arctan\,[\nu(q-\mu)]_{t-i} \qquad (36)$$

by grid search over differing values of ν and μ gave the following best equation:

$$\frac{I_t}{K_{t-1}} = \underset{(9.4)}{1.16} + \underset{(5.1)}{0.128}\,D1 - \underset{(0.02)}{0.26}\,\frac{1}{K_{t-1}} + \sum_{0}^{14} c_i \arctan[10(q-1.1)]_{t-i} \qquad (37)$$

$\Sigma c_i = \underset{(10.2)}{0.296}$ DW = 1.67 $\bar{R}^2 = 0.956$ LB(10) = 22.2 $\chi^2_F(8) = 197.4$

Estimation period: 1967Q2-1976Q4.

Although the equation fits the estimation period very well, with no evidence of first-order autocorrelation, the Ljung-Box statistic indicates that higher order serial correlation may be a problem.[2] The most notable objection to the equation is that it is very unstable,

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[1] A possible counter-argument might be that there are measurement problems for q even at the micro level, and given the potential volatility of the series firms may only change their investment plans for values of q significantly different from the equilibrium value.

[2] The 5% critical value of the appropriate $\chi^2(10)$ statistic is 18.3, with the 1% critical value 23.2.

breaking down completely outside the estimation period, with severe underprediction of investment in 1977 and 1978. This is also shown by the instability of the coefficients when the equation is re-estimated up to the end of 1978 yielding:

$$\frac{I_t}{K_{t-1}} = \underset{(2.3)}{0.80} + \underset{(5.5)}{0.114}\, D1 + \underset{(1.1)}{52.5}\, \frac{1}{K_{t-1}} + \sum_{0}^{14} c_i \,\text{arctan}\,[10(q-1.1)]_{t-i} \qquad (38)$$

$\Sigma c_i = \underset{(2.4)}{0.153}$ $\quad DW_u = 0.84$ $\quad \bar{R}^2_u = 0.919$ $\quad \bar{R}^2_c = 0.945$

$\rho = \underset{(4.1)}{0.58}$ $\quad LB_c(9) = 13.4$

Estimation period: 1967Q2-1978Q4.

The importance of q is thus considerably diminished when the whole of the estimation period is considered, and first order autocorrelation is induced. Although the instability of the equation may be due in part to the rather ad hoc nature of the specification, other simpler forms of valuation ratio models did not prove to be particularly stable outside the estimation period (see Section 4).

59 Given the functional form, the estimate of μ can be considered as the equilibrium value of the valuation ratio, which rather surprisingly comes out at 1.1. Although the theoretical equilibrium value is unity, the problems of measurement outlined in the main text led to a prior expectation that the equilibrium value for average rather than marginal q would be less than 1.

60 The results of estimating the arctan functional form are thus somewhat disappointing, especially given the theoretical attractiveness of the shape of the implied response function. Further research on alternative non-linear specifications is, however, desirable.

Appendix 2

Data

61 A major problem in estimating equations linking financial variables such as profits and dividends to 'real' variables such as the volume of output or investment in the United Kingdom, stems from the different coverage of the industrial and financial sectors of the national accounts. Data on the volume of investment expenditures are available for the manufacturing and distribution and services sectors, whilst data for the valuation ratio and other measures of corporate financial performance are only readily available for industrial and commercial companies (ICCs).[1] This problem of inconsistent data has been tackled in several different ways. Anderson (1977, 1981a, b, c and d) in his series of papers, attempted to model totally in the nominal expenditure framework, arguing that firms' investment and other spending decisions are constrained by cash budgets rather than by volume considerations. Consequently, Anderson has derived an equation for nominal investment spending by industrial and commercial companies, using a proxy for the output of the sector. Rowlatt (1978), on the other hand, initially attempted to build proxies for financial variables appropriate for the manufacturing sector, but when this proved unsuccessful decided to use ICCs' financial variables together with 'real' variables for manufacturing. Oulton (1981) estimates an equation for real investment by ICCs, deflating nominal investment by the price deflator for private non-residential fixed investment. In the national accounts the data for ICCs' nominal investment are calculated from an allocation of total industrial investment into the sectors identified in the financial accounts, whereas investment by the manufacturing and distribution sector is based directly on sample surveys which are potentially more reliable. In this paper, the dependent variable is taken as real investment in manufacturing, distribution and non-financial services (excluding investment in iron and steel[2]). The series for the capital stock and for output are

[1] Industrial and commercial companies are largely, but not entirely, private profit-making enterprises.

[2] This is excluded because of the effects of steel nationalisation in 1967, which took steel out of private ICCs whilst leaving it in the manufacturing sector in the national accounts.

derived to be as consistent as possible with both investment and the valuation ratio, but there are still some differences of coverage.

62 Quarterly estimates of rates of return and the cost of capital are calculated in the Bank using seasonally-adjusted data, leading to an adjusted series for the valuation ratio. For consistency the remaining variables used in the regressions are also seasonally adjusted, although it is recognised that different seasonal filters may lead to dynamic misspecification in the regression results [Wallis (1974)].

63 The original calculation of the valuation ratio for UK ICCs was described in Flemming et al.(1976a). The measure used in this paper is based on the original approach but has been modified in the light of criticisms by Oulton (1981) and Williams (1980).

64 The valuation ratio, q, is defined as the ratio of the post-tax real rate of return, r, to the post-tax real cost of capital, c:

$$q = \frac{r}{c}$$

In turn, the real rate of return is calculated as the ratio of post-tax real profits (gross trading profits plus rent after adjustments for stock appreciation, replacement cost depreciation, and the effects of the corporate tax system) to the replacement cost capital stock, itself adjusted by the present value of tax allowances to give a measure of the cost to the company sector of replacing the extant capital stock. The numerator can alternatively be considered as the level of profits remaining for expansion of the business or distribution to the shareholders and creditors, after the commitments of tax and providing for inflation have been made [see Flemming et al. (1976b)]. The post-tax real cost of capital, on the other hand, is calculated as the ratio of the same post-tax real profits to the market valuation of the ICCs' sector.[1] The cost of capital can be

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[1] Ideally the cost of capital should be based on expected rather than the current level of post-tax real profits, as the market discounts future rather than present earnings in assessing the market value of claims on the corporate sector. Expected earnings are not observable and therefore the assumption is made that they can be adequately proxied by the present level of earnings, although this may be a source of considerable error in the calculation.

thought of as a rate of return to a unit of finance - the market demanding at least the existing rate for providing extra capital. Denoting ΠT as post-tax real profits, KT as the post-tax replacement cost of the capital stock and V as the market valuation of the company sector, then:

$$r = \frac{\Pi T}{KT} \quad ; \quad c = \frac{\Pi T}{V}$$

from which it is clear that:

$$q = \frac{V}{KT}$$

that is, the valuation ratio can be measured as the ratio of the market valuation of companies, implicitly a valuation of their assets, to the replacement cost of those assets.

65 The post-tax replacement cost of the capital stock is calculated by:

$$KT = (1-A)\ KFR + (1-d)\ BVS$$

where:

KFR = ICCs' net fixed capital stock at replacement cost (source: National Income and Expenditure, published by the Central Statistical Office, the 'Blue Book').

BVS = ICCs' book value of stocks (source: the 'Blue Book').

A = the present value of tax allowances per unit of fixed investment [calculated similarly to Melliss and Richardson (1976)]. No adjustments are made for differential subsidies between investing in old and new capital as Oulton (1981) has suggested. Capital equipment, with the exception of vehicles, is generally highly specific to the use for which it was purchased, and in most cases the decision as to whether to add to the capital stock is simply a decision about whether or not to purchase new equipment. There is generally no adequate alternative of purchasing old capital.

d = the present value of tax allowances per unit of addition to stocks (taken as the corporation tax rate after the introduction of the stock relief scheme in 1974, zero before).

The capital stock figures therefore do not include land or other forms of capital [see Chirinko (1980)] because of the absence of data, nor do they include any provision for leasing which is categorised by owner (generally financial companies) rather than by user in the national accounts. This treatment of leasing is consistent with the measure of the financial valuation, which is a measure of the market valuation of the physical assets owned by the company sector. Although the existence of productive leased capital will enhance the profitability of the corporate sector, no extra finance is required to undertake leasing, and therefore the decision to lease may be considered as similar to the decision to hire extra labour. (Profits are struck after leasing charges as well as labour costs.) Changes in the attractiveness of leasing vis-a-vis purchase will affect the cost of capital in a similar way to a change in the price of labour relative to the cost of purchasing new capital.

66 The financial valuation of ICCs is calculated by summing the market values of the various components of debt and equity finance. These are measured by dividing the relevant flows of interest and dividend payments by the yield on the respective assets as given by the appropriate interest rate or *Financial Times* share index. As the denominator in the calculation of the valuation ratio relates only to domestic physical assets, for consistency monetary assets are netted out of the financial valuation, and the market value of equity is adjusted by the ratio of domestic earnings to total earnings to exclude the value of assets held overseas.[1] Thus the financial valuation is calculated by:

$$V = MVOS.PIUK + MVDL + MVPS + BADN - LQAN$$

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[1] This calculation differs in two major respects from that in Flemming *et al.*(1976a). Firstly, the assumption is made, following Williams (1980), that only equity finances United Kingdom and overseas assets, and that the other sources of finance are used solely for UK assets. The second change is that the domestic overseas earnings ratio is calculated net of tax, following the criticism of Oulton (1981).

where:

MVOS = market value of ordinary shares (including equities held by the overseas sector);

PIUK = proportion of ICCs' income arising in the United Kingdom;[1]

MVPS = market value of preference shares;

MVDL = market value of debenture and loan stock;

BADN = stock of bank advances (definitionally this is equal to the market value) [source: Financial Statistics published by HM Stationery Office]; and

LQAN = stock of liquid assets (source: Financial Statistics).

The market values are calculated according to the following formulae:[2]

$$MVDL = \frac{DLII}{RYDL} *4$$

$$MVOS = \frac{DPOS}{DYOS} *4$$

$$MVPS = \frac{PRPI}{DYPS} *4$$

where:

DLII = payments of debenture and loan interest (unpublished);

RYDL = redemption yield on 20-year debentures (source: Financial Statistics);

DPOS = dividend payments on ordinary shares (adjusted for advance corporation tax and dividends remitted abroad) (source: Financial Statistics);

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[1] Calculated as the ratio of domestic income (taken as gross trading profits plus rent and non-trading income less capital consumption at historic cost, interest and tax) to domestic income plus income from abroad. The definition of domestic income has been revised to be consistent with the measurement of income from abroad. Capital consumption at historic cost is unpublished, but the remaining items are published in the ICCs' appropriation account in Economic Trends, published by HM Stationery Office.

[2] Multiplication by four annualises the quarterly dividend and interest flows.

DYOS = dividend yield on ordinary shares, proxied by the FT Actuaries industrial 500 shares index (source: Financial Statistics);

PRPI = preference share payments (unpublished); and

DYPS = dividend yield on preference stocks (source: Financial Statistics).

Investment

67 Investment (I) = $I_{MAN} + I_{DS} - I_{IS} - I_{FIN}$

where:

I_{MAN} = investment in manufacturing industry - 1975 prices;

I_{DS} = investment in distribution and service industries (including shipping) - 1975 prices;

I_{IS} = investment in iron and steel - 1975 prices; and

I_{FIN} = investment by finance industries - 1975 prices.

This measure of investment was considered to be a reasonable proxy for the volume of investment by industrial and commercial companies. All of the data were taken from Trade and Industry [more recently British Business] published by the Department of Trade and Industry, with early figures supplied by the Department of Industry.

Capital stock

68 The following components of the total gross capital stock at 1975 replacement cost were taken to derive a proxy for industrial and commercial companies:

Manufacturing (less Iron and Steel) plus Construction plus Road Passenger Transport plus Road Haulage and Storage plus Shipping plus Distributive Trades and Other Service Industries.

Annual data for end-years were taken from the 'Blue Book', and have been interpolated to give a quarterly path.

Output

69 Output (O) = $(a_1 O_{MAN} + a_2 O_{IS} + a_3 O_C + a_4 O_{TAC} + a_5 O_{DT}) / \sum_{i=1}^{5} a_i$

where:

O_{MAN} = output of manufacturing industry;

O_{IS} = output of iron and steel;

O_C = output of construction industry;

O_{TAC} = output of transport and communication; and

O_{DT} = output of distributive trades.

All the output series are index numbers (1975=100) and the weights $a_1 ... a_5$ are the respective 1975 output weights (a_2 is taken as negative). The output data were taken from Economic Trends with early figures supplied by the Central Statistical Office.

User cost of capital

70 The user cost of capital required for the neoclassical model has been derived from the formula used by King (1974), Nickell (1978) and Bean (1981):

$$UC = \frac{P_k (1-A) R}{1-t}$$

where:

$R = \delta + R^*(1-t) - \gamma \hat{\Pi}_k$ = post-tax real interest rate;

R^* = the nominal rate of interest, taken to be the rate on five-year British government stock (source: Financial Statistics);

t = corporation tax rate;

δ = depreciation rate, taken to be 7% per annum;

P_k = price of capital goods, taken to be the price deflator for investment in manufacturing, distribution and services;[1] and

$\hat{\Pi}_k$ = expected rate of inflation in the price of capital goods. The measurement of price expectations is very difficult - in this study expectations have been approximated by the actual current inflation rate in the capital goods price deflator.

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[1] Ideally this should exclude finance, but the data were not readily available.

The price of output, P, is also required in the neoclassical model; this was proxied by the total final expenditure, TFE, deflator (source: Economic Trends).

71 For the neoclassical model to remain valid the post-tax real interest rate must remain positive. However, over the estimation period, very high levels of inflation (presumably coupled with high inflationary expectations) have been associated with low nominal interest rates causing problems for the model. This difficulty has been glossed over by some authors who have used a nominal interest rate, e.g.Feldstein and Flemming (1971).[1] Nickell (1978)[2] argues that the inflationary expectations term may have a lower weight in the user cost of capital than implied by the theoretical formulae and following this argument alternative equations have been estimated with the weight on the inflationary expectations term varying from 0 to 0.5 (see paragraph 38).

72 Many other variables were used in the study, particularly as potential determinants of the valuation ratio:

NULC = normalised relative unit labour costs in manufacturing, defined as the ratio of UK unit labour costs (normalised for the level of the output cycle) to a weighted average of competitors' normalised labour costs. A rise in the index is thus equal to a deterioration in competitiveness (source: International Monetary Fund).

RNLI = real net liquid assets, defined as the difference between industrial and commercial companies' stock of liquid assets, LQAN, less their stock of bank borrowing, BADN, deflated by the final expenditure price deflator (source: Financial Statistics).

MULC = normalised unit labour costs in manufacturing industry in the United Kingdom (source: International Monetary Fund).

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[1] Although they acknowledged that a real rate is theoretically more appropriate.

[2] Page 265.

RCSH = ICCs' real cash flow, defined as undistributed income, less stock appreciation, plus net capital transfers, deflated by the final expenditure price deflator (source: Financial Statistics).

RPDI = real personal disposable income (source: Economic Trends).

KM£3 = the stock of sterling M_3 (source: Bank of England Quarterly Bulletin).

CU = an index of capacity utilisation. This was derived by regressing smoothed output, O, [1] on the capital stock, K, from 1963Q1 to 1973Q4, and then adjusting the fitted line to give 100% capacity utilisation in the period where actual output is above the fitted line by the maximum amount, in this case 1973Q2. The values for later years are derived by extrapolating the adjusted fitted line, given the published figures for the capital stock. This variable was also tried in some of the investment equations as a possible integral correction mechanism [Bean (1981)] but was not successful.

D1 = A dummy variable that has been included in some of the regressions to capture the unusual movements in investment at the end of 1968 associated with the abolition of the temporary higher rate of investment grants. This is thought to have brought some investment forward to qualify for the higher rate of grant. The dummy takes the value 1 in 1968Q4 and -1 in 1969Q1. For further discussion, see the 1979 'Blue Book', page 132, and Sumner (1979).

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[1] Smoothed by taking a nineteen-quarter moving average.

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