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Corporation Tax Asymmetries and Investment: Evidence from UK Panel Data

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DISCUSSION PAPER NO. 820

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Abstract

Theoretical work has emphasised the potentially powerful impact of corporation tax asymmetries on investment behaviour. Empirical work has been confined, however, to the essentially descriptive task of measuring implied effective tax rates. This paper uses panel data from 597 UK companies for 1973-1986 to address directly the central behavioural issue: are tax asymmetries important to understanding observed investment behaviour? An optimising investment model is developed and estimated both as an Euler equation in which the cost of capital appears and as a Q equation. Asymmetries are shown to generate considerable variation in firms' effective tax positions. Nevertheless, their careful modelling does not noticeably improve the empirical performance of these equations. Possible explanations of this puzzle are discussed.

1. Introduction

Corporate income taxes are generally asymmetric. Positive taxable profits give rise to an immediate payment by the firm but negative taxable profits typically do not generate an immediate payment to it. Unused tax losses may be carried forward, but only at zero interest and often only for a limited time; and carry back provisions are also imperfect. With many firms in the US, the UK and elsewhere finding themselves in tax loss positions over the last two decades, the implications of the consequent rather complex non-linearity in effective corporation tax schedules have received considerable attention. Theoretical work has pointed to a potentially powerful effect on corporate investment decisions: see, in particular, Auerbach (1986), Edwards and Keen (1985) and Mayer (1986). Empirical work has documented the impact on effective tax rates. Auerbach and Poterba (1987) and Altschuler and Auerbach (1990) do so for the US, Mintz (1988) for Canada and Devereux (1987) for the UK. But these two strands in the literature have remained disjoint. Little attempt has been made to assess empirically the central behavioural issue: are tax asymmetries important to an understanding of observed corporate investment decisions?[1] That is the question addressed here.

To this end, we develop two forms of investment equation which, while very different in structure, derive from a single model of corporate optimisation in the presence of an asymmetric tax code. One is a Q formulation, relating investment to the firm's market value (appropriately adjusted for taxes). The second is based on an Euler condition, and relates investment to (inter

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[1] Devereux (1989) is an exception, but uses an ad hoc formulation with no basis in optimising behaviour. Blundell et al (1989) report estimates from a Q model incorporating some aspects of tax exhaustion, but their principal concerns lie elsewhere and the characterisation of tax asymmetries is misspecified.

alia) the cost of capital (again, appropriately adjusted). This latter approach is in the spirit of Pindyck and Rotemberg (1983a, 1983b) and has also been used recently by, for instance, Bond and Meghir (1990). Here of course we develop the tax aspects in considerably more detail. The strategy is to compare for each of these approaches the performance of equations based on a range of alternative treatments of taxation, ignoring it altogether at one extreme and at the other taking as full account of asymmetries as we can.

Taking proper account of asymmetries has a potentially major advantage over empirical studies which attempt to assess the impact of taxation using only statutory tax data. This is because asymmetries introduce considerable variation in effective tax rates both across firms and over time which should help to obtain more precise estimates of their impact on investment.

The data set is a panel of several hundred UK companies. It has two particular advantages in the present context. The first is that the imputation system used in the UK (and most other European Community countries) creates an asymmetry additional to that noted above: a tax break on dividends is denied on payments in excess of an upper bound. This feature is not present, for instance, in the classical system of the US. Its proper treatment complicates both the theory and the empirics, the return to this effort being the existence of another route through which corporation tax asymmetries may influence observed investment behaviour. The second advantage is simply the prevalence of tax exhaustion in the UK. Devereux (1990a) estimates that in the early 1980s about 25 per cent of the firms in the sample - which is broadly representative of quoted manufacturing companies - had negative taxable profits (were "fully tax exhausted" in the terminology used below) and 50 per cent faced the tax penalty on dividends

(were "ACT exhausted"). Over the full sample period (1973 to 1986), 90 per cent at some point encountered one or both forms of tax exhaustion.

Section 2 develops the firm's optimisation problem in the presence of an asymmetric imputation system. The Q and cost of capital characterisations of optimal investment policy are derived in Section 3. It is shown there that the complexities introduced by tax asymmetries can be summarised by two key variables, both endogenous and firm-specific: the effective rate of corporation tax and the effective price of investment goods. Section 4 examines the distribution in the sample of these effective tax variables, Q and the cost of the capital, the procedure for their estimation being described in the Appendix. Estimation results are in Section 5. Section 6 concludes.

2 An Optimising Model with Tax Asymmetries

This is based on the standard assumption that the firm seeks to maximise the wealth of its current shareholders. In this it is constrained by the sources and uses identity:

$$D_t = p^y_t \tilde{\Pi}_t - p_t I_t + V^N_t + B_{t+1} - (1+i_t)B_t - X_t \qquad (1)$$

where D_t denotes dividends paid, $\tilde{\Pi}_t$ real profits, p^y_t the price of output and p_t the price of investment goods, I_t the number of machines purchased, V^N_t new equity issues (restricted to be non-negative[2] in the subsequent optimisation), B_{t+1} the amount of one period debt issued during period t and so redeemed during period t+1, i_t the interest rate, X_t corporation tax payments.

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[2] In the UK share repurchases are taxed as capital gains rather than income only under stringent conditions: see Gammie (1982).

The firm is assumed to operate in a perfectly competitive product market and to face internal costs in adjusting the capital stock, $G(I_t,K_t)$, that are convex in the level of investment. Gross profit net of variable costs (taken to have been optimised out) and of adjustment costs is given by

$$\tilde{\Pi}_t = \Pi(K_t) + \alpha_t K_t - G(I_t,K_t) \qquad (2)$$

where K_t denotes the capital stock at the beginning of period t, $\Pi(.)$ is increasing and strictly concave and α_t is a shock that is unobserved at the start of period t (when decisions are taken); thus α_t is an additive shock to the average rate of return to capital. For simplicity α_t is assumed i.i.d. with mean zero and known distribution function $H(\alpha_t)$. The equation of motion for K_t is

$$K_{t+1} = (1-\delta)K_t + I_t, \qquad (3)$$

where δ denotes the rate of depreciation.

The formalisation of the imputation system builds on Edwards and Keen (1985), Mayer (1986) and Keen and Schiantarelli (1990), and so will be brief. Corporate tax liabilities arise from two sources. First, the firm must pay corporation tax on its operating profit minus current allowances whenever this taxable profit, ψ_t, is positive. Interest and adjustment costs are assumed deductible so that

$$\psi_t = p_t^y \tilde{\Pi}_t - L_t - i_t B_t - \Gamma_t \qquad (4)$$

where L_t denotes tax losses brought forward from the previous period and Γ_t the sum of first year allowances and depreciation allowances on the tax written down value of the capital stock at the beginning of the period, K_t^T. That is,

$$\Gamma_t = (1-j)p_t I_t + \delta^T K_t^T \qquad (5)$$

where (1-j) is the fraction of investment expenditure that can be subtracted from profits in the year in which it is incurred, δ^T is the rate at which past investment can be depreciated for tax purposes and

$$K_{t+1}^T = (1-\delta^T)K_t^T + jp_t I_t. \qquad (6)$$

The allowances in (4) give rise to the first tax asymmetry: if $\psi_t<0$, then generally an immediate tax rebate is not paid, but the taxable loss may be carried forward indefinitely - without interest - to set against future taxable profits[3,4]. The second arises from the provision of the UK imputation system by which the firm in effect pre-pays a fraction of the shareholder's income tax at a rate g (the 'imputation rate') on grossed up dividends $D_t/(1-g)$. This payment, Advance Corporation Tax (ACT), can be deducted from the main component of corporation tax so long as gross dividends do not exceed taxable profits. If, however, gross dividends do exceed taxable profits then the 'unrelieved ACT' (U_{t+1}) must again be carried forward indefinitely, without interest, to be set against the main component of corporation tax in later years. The asymmetry that is thus introduced has a potentially important bearing on the firm's choice between raising funds through retentions or new equity issues: see Mayer (1986) and Keen and Schiantarelli (1990). It will emerge below that it also has a direct effect on the value to the firm of investment related tax breaks, and

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[3] Strictly, under the UK corporation tax system, losses can be carried back one period to set against the previous year's profit. Losses due to capital allowances may be carried back up to three years. These carry back provisions - and others relating to ACT - are ignored in the formal model but incorporated in the empirical work.

[4] Though losses can indeed be carried forward indefinitely in the UK and (from 1990) in Germany, this is not always the case: for example, losses may only be carried forward for 15 years in the US and 5 years in France and Italy.

hence, potentially, on investment itself.

The main features of the corporation tax system can therefore be summarised by:

$$X_t = \tau.\max\,[\psi_t, 0] + \frac{g}{1-g} D_t - \min\left\{\frac{g}{1-g} D_t + U_t,\ g.\max\,[\psi_t, 0]\right\} \qquad (7)$$

$$L_{t+1} = \max\,[-\psi_t, 0] \qquad (8)$$

$$U_{t+1} = \max\left\{\frac{g}{1-g} D_t + U_t - g.\max\,[\psi_t, 0],\ 0\right\} \qquad (9)$$

where τ is the statutory rate of corporation tax. Note that the two asymmetries introduce two additional state variables into the firm's optimisation problem, L_{t+1} and U_{t+1}.

This tax structure implies that there are three tax positions in which the firm might find itself[5]. For low values of the shock α_t, say $\alpha_t < a_t$, $\psi_t \leq 0$ and the firm is *fully tax exhausted*. The firm has no taxable income and so if, as may well happen, it nevertheless pays a dividend the associated ACT simply adds to the stock of unrelieved ACT. For intermediate values, say $a_t \leq \alpha_t \leq b_t$, the firm is *ACT exhausted*. In this case, ψ_t is positive but insufficient to absorb all current and accumulated unrecovered ACT: $gD_t/(1-g)+U_{t+1} > c\psi_t$. Finally, for high values of α_t, $\alpha_t > b_t$, the firm is *fully tax paying*, with $\psi_t > 0$ and $gD_t/(1-g)+U_{t+1} \leq c\psi_t$.

The specification of the firm's optimisation problem is completed by the capital market equilibrium condition

$$(1-m)R_t V_t = \frac{(1-m)}{(1-g)} E_t(D_t) + (1-z)\left\{E_t[V_{t+1}] - V_t - V_t^N(1+\omega_t)\right\} \qquad (10)$$

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[5] These are discussed in Keen and Schiantarelli (1990), though in a rather simpler context than the present. The precise details of the three regimes in the present setting are available from the authors.

where V_t is the market value of equity at the beginning of period t, R_t the (gross) return on comparable assets, m the marginal rate of personal income taxation, z the accrual-equivalent tax capital gains, ω_t (≥ 0) is a premium on new share issues - the notion being that their anticipation reduces the current share price by more than dilution alone would imply, reflecting transactions costs or informational asymmetries such as those discussed by Myers and Majluf (1984) and Fazzari et al (1988) - and $E_t[\ ]$ indicates an expectation conditional on information available at the beginning of period t.

Denoting by V(.) the maximum value function defined on the predetermined variables, rearranging (10) shows the firm's problem to be equivalent to that of maximising

$$V_t/\rho_t = \gamma E_t(D_t) - V_t^N(1+\omega_t) + E_t[V(K_{t+1}, B_{t+1}, L_{t+1}, U_{t+1}, K_{t+1}^T)] \qquad (11)$$

where $\gamma=(1-m)/(1-z)(1-g)$, and $\rho_t=\{1+(1-m)R_t/(1-z)\}^{-1}$, subject to the relations (1), (2), (4), (5), (7), the equations of motion (3), (6), (8), (9), and the constraint $V_t^N \geq 0$. Decisions are taken at the start of period t, before the realisation of α_t is known. The choice variables are taken to be I_t, B_{t+1}, and V_t^N; the dividend D_t is then determined as a residual, conditional on α_t. An important role is played in this optimisation by the premium and non-negativity constraints on new share issues: without these, an optimal financial policy would imply that the firm is fully tax-exhausted in every period with probability one: see Keen and Schiantarelli (1990).

3 Optimal Investment Policy: Two Characterisations

It is straightforward to show that the first order condition for investment can be written as[6]

$$E_t\left[\frac{\partial V_{t+1}}{\partial K_{t+1}}\right] = \gamma(1-\tau_t^*)p_t^y G_I(I_t,K_t) + \gamma p_t^* \qquad (12)$$

where G_I denotes the derivative of the adjustment cost function with respect to investment while τ_t^* and p_t^* denote respectively the 'effective' corporate tax rate and the 'effective' price of investment goods, defined momentarily. Apart from τ_t^* and p_t^*, the structure of (12) is standard: the number of machines purchased depends upon the difference between their shadow value and their effective replacement cost (including adjustment costs).

The definitions of τ_t^* and p_t^* look forbidding but have simple intuitive explanations. The effective tax rate is:

$$\begin{aligned}\tau_t^* = {} & \tau\left\{1-H(b_t)\right\} \\ & + \left\{\tau - g(\tau-g) + \frac{g(\tau-g)}{\gamma} E_t\left[\frac{\partial V_{t+1}}{\partial U_{t+1}} \;\middle|\; a_t \le \alpha_t \le b_t\right]\right\}\left\{H(b_t)-H(a_t)\right\} \\ & + \left\{g + \frac{1}{\gamma}E_t\left[\frac{\partial V_{t+1}}{\partial L_{t+1}}\middle|\alpha_t \le b_t\right] - \frac{g}{\gamma}E_t\left[\frac{\partial V_{t+1}}{\partial U_{t+1}} \;\middle|\; \alpha_t \le b_t\right]\right\} H(a_t). \qquad (13)\end{aligned}$$

This is the effective rate of corporation tax in the sense that $(1-\tau_t^*)$ is the answer to the question: "How much would the present value of net distributions to shareholders increase if the firm's operating profit in the current period (only) were to be £1 higher?"[7]. The three components of τ_t^*

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[6] The mechanics of the optimisation are lengthy but routine, and so omitted. Details are available from the authors.

[7] This follows on replacing $\tilde{\Pi}$ in (11) by $\tilde{\Pi}+\phi$ and noting that, at the optimum, $\left[\frac{1}{\gamma p_t}\right]\frac{\partial V_t}{\partial \phi}\Big|_{\phi=0} = 1-\tau^*$.

correspond to the three possible tax regimes described above. With probability $1-H(b_t)$ the firm will be a full taxpayer, in which case $\tau_t^* = \tau$. With probability $H(b_t)-H(a_t)$ the firm is ACT exhausted, in which case τ_t^* depends on the shadow value of an increment to the stock of unrelieved ACT. With probability $H(a_t)$ the firm is fully tax exhausted, in which case τ_t^* also depends on the shadow value of an increment to tax losses.

The effective price p_t^* is:

$$p_t^* = p_t\Bigg\{\Bigg[1 - g\Bigg(1 + \frac{1}{\gamma}E_t\Bigg[\frac{\partial V_{t+1}}{\partial U_{t+1}}\Bigg| a_t \le b_t\Bigg]\Bigg)H(b_t)\Bigg]$$

$$- (1-j)\Bigg[\tau\Big\{1-H(b_t)\Big\}$$

$$+ \Bigg\{(1-g)(\tau-g) + \frac{g(1+\tau-g)}{\gamma}E_t\Bigg[\frac{\partial V_{t+1}}{\partial U_{t+1}} \;\Bigg|\; a_t \le \alpha_t \le b_t\Bigg]\Bigg\}\Big\{H(b_t)-H(a_t)\Big\}$$

$$+ \frac{1}{\gamma}E_t\Bigg[\frac{\partial V_{t+1}}{\partial U_{t+1}} \;\Bigg|\; \alpha_t \le a_t\Bigg]H(a_t)\Bigg] \quad - \frac{j}{\gamma}E_t\Bigg[\frac{\partial V_{t+1}}{\partial K^T_{t+1}}\Bigg]\Bigg\}. \qquad (14)$$

This is the effective price of capital in the sense that P_t^* can be shown[8] to be the answer to the question: "Suppose the firm were to buy one more physical unit of capital, but this was never turned into productive capacity and involved no adjustment costs; what would be the effect on the present value of net distributions to shareholders?".

The three parts of p_t^* are readily interpreted. The first is the amount that purchasing the asset would cost the firm if there were no tax breaks on investment. If the firm is a full tax payer, this is simply p_t. If however the firm is ACT exhausted then the cost of purchasing the asset is - perhaps surprisingly - lower. This is most easily seen in the case of retention

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[8] Along the lines of footnote 7.

finance, since being ACT exhausted implies that cutting the net dividend by £(1-g) generates a tax saving of £g (the ACT due on the gross dividend) and hence frees £1 for additional investment. If the firm were a full tax payer, it would need to reduce its dividend by the full amount[9]. The second term in (14) reflects the fact that of each pound spent on investment a fraction 1-j receives free depreciation. The value of this relief depends on the tax position of the firm in a similar way to the effect of additional profit[10]. The remainder, j, is not available for tax depreciation purposes until period t+1, and so simply adds to the pool of capital available for tax depreciation next period; hence the third term. The final two parts of p_t^* thus simply represent the present value of allowances available on the purchase of one additional unit of capital, allowing for the possibility of tax exhaustion in the current and future periods. If, for instance, $j=\delta^T$, the firm is never tax exhausted and R_t is constant over time, then the effective price is given by the familiar Hall-Jorgenson formula $p_t\{1-(\tau\delta^T/(\rho+\delta^T))\}$.

(a) The Q formulation

For estimation, we assume adjustment costs to be quadratic:

$$G(I_t,K_t) = \frac{b}{2}\left\{\frac{I_t}{K_t} - a\right\}^2 K_t \qquad (15)$$

where b can be thought of as parameterising the speed of adjustment and a as

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[9] This effect is only temporary: the reduction in unrelieved ACT will eventually increase tax payments when the firm moves out of being ACT exhausted.

[10] It is not quite identical to the value of additional profit, because an additional relief yields no return to the shareholder until the firm can reduce its tax liability, whereas an additional unit of profit yields an immediate return.

the 'normal' rate of investment at which adjustment costs are zero. Using (15) in (12) then yields the investment equation:

$$\left(\frac{I_t}{K_t}\right) = a + \left(\frac{1}{b}\right)Q_t \qquad (16)$$

where

$$Q_t = \frac{E_t\left[\frac{\partial V_{t+1}}{\partial K_{t+1}}\right]}{\gamma(1-\tau_t^*)p_t^y} - \frac{p_t^*}{(1-\tau_t^*)p_t^y}. \qquad (17)$$

To deal with the non-observability of the marginal value of capital in (17) we follow Hayashi (1982) in assuming $\tilde{\Pi}$ and G to be linear homogeneous. It can then be shown that

$$E_t\left[\frac{\partial V_{t+1}}{\partial K_{t+1}}\right] = \frac{1}{K_{t+1}}\left\{E_t(V_{t+1}) - B_{t+1}E_t\left[\frac{\partial V_{t+1}}{\partial B_{t+1}}\right] - E_t\left[\frac{\partial V_{t+1}}{\partial L_{t+1}}L_{t+1}\right] - E_t\left[\frac{\partial V_{t+1}}{\partial U_{t+1}}U_{t+1}\right] - K_{t+1}^T E_t\left[\frac{\partial V_{t+1}}{\partial K_{t+1}^T}\right]\right\}, \qquad (18)$$

so that an estimate can be constructed by subtracting from average Q the expected values of the product of each state variable and its shadow value divided by the capital stock. The problem thus becomes that of constructing the shadow values on the right of (18). A procedure for the valuation of tax losses, unrelieved ACT and tax-depreciated capital is developed in the Appendix. The essence is to replace expected values with actual values, which introduces an expectational error term into (16).

For the valuation of debt in (18), the first order condition on B_t gives

$$E_t\left[\frac{\partial V_{t+1}}{\partial B_{t+1}}\right] = -\gamma_t^* \qquad (19)$$

where $\gamma_t^* = (1-m)/(1-z)(1-g_t^*)$ and

$$\frac{g_t^*}{(1-g_t^*)} = c\left\{ 1 - H(b_t) + \frac{1}{\gamma} E_t\left[\frac{\partial V_{t+1}}{\partial U_{t+1}} \middle| \alpha_t \leq b_t\right] H(b_t)\right\} \qquad (20)$$

denotes the effective rate of imputation (in tax-exclusive form). An estimate of g^* can be constructed by using in (20) the results on $\partial V_{t+1}/\partial U_{t+1}$ described in the Appendix. To estimate the shadow value of debt from (19), it then remains to specify (1-m)/(1-z). We have tried two approaches. The first is to assume m=z, as for a tax-exempt institution. The second is to use the estimated average marginal personal tax rates in Robson (1988)[11]. These alternatives correspond to somewhat different views as to nature of the firm's financial policy (which is discussed in detail in Devereux (1990a,b)). This emerges on noting that the first order condition on new equity issues requires that

$$\gamma_t^* = 1 + \omega_t - \lambda_t^N . \qquad (21)$$

If m=z then $\gamma>1$ and $\gamma_t^*\geq 1$ (the lower bound on γ_t^* being attained iff the firm is permamently ACT exhausted with probability one). For ω_t sufficiently small, an interior solution to (21) exists in which the firm issues enough new equity - paying out the proceeds as dividends - to ensure that $\gamma_t^*=1+\omega_t$. New issues are in this sense favoured when m=z. The Robson figures, however, show that typically (in 11 years out of 16) $\gamma<1$, implying $\gamma_t^*<1$. The second case is thus one in which new issues would generally be expected to be zero ($\lambda_t^N>0$).

In practice, the empirical performances of these two approaches were very close. Similar results were also obtained using a combination of the two, taking m=z for firms observed to issue new equity and the Robson estimates for all others. For brevity, we therefore report below only results for the

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[11] The accrual-equivalent capital gains tax rate was computed using the technique described by King (1977).

case in which m=z.

(b) The cost of capital formulation

Note first that (11) implies

$$V(t) = \rho_t \max \{\gamma E_t(D_t) - V_t^N(1+\omega_t) + E_t[V(t+1)]\} \qquad (22)$$

where V(t) denotes $V(K_t, B_t, L_t, U_t, K_t^T)$ and the maximisation is subject to the restrictions noted after (11). Updating (22) by one period and differentiating with respect to K_{t+1} (bearing in mind the equation of motion (3)) gives

$$\frac{\partial V_{t+1}}{\partial K_{t+1}} = \rho_{t+1}\left\{(1-\tau^*_{t+1})p^y_{t+1}\left[\Pi_K(t+1) - G_K(t+1)\right] + (1-\delta)E_{t+1}\left[\frac{\partial V_{t+2}}{\partial K_{t+2}}\right]\right\}. \qquad (23)$$

Solving for the final term on the right of (23) from the updated first order condition (12), substitution back into (12) gives the Euler equation

$$(1-\tau^*)p^y_t G_I(t) = E_t\left\{\rho_{t+1}(1-\tau^*_{t+1})p^y_{t+1}\left[\Pi_K(t+1) - G_K(t+1) + (1-\delta)G_I(t+1) + \alpha_{t+1} - c_t\right]\right\} \qquad (24)$$

where

$$c_{t+1} = \frac{p^*_t - (1-\delta)\rho_{t+1}\, p^*_{t+1}}{\rho_{t+1} p^y_{t+1}\,(1-\tau^*_{t+1})} \qquad (25)$$

is the user cost of capital in the sense that it is the quantity to which, in the absence of adjustment costs, the expected marginal product of capital at t+1 is equated; in the absence of taxation c_{t+1} reduces to the familiar expression $\{p_t R_{t+1} + \delta p_{t+1} - (p_{t+1} - p_t)\}/p^y_t$.

To make the Euler condition (24) estimable, we parameterize the adjustment cost function as in (15) and use linear homogeneity to substitute out the

term $\Pi_K(t+1) - G_K(t+1) + \alpha_{t+1}$. Defining primed variables as

$$x'_s = \rho_s(1-\tau^*_s)p^y_s x_s \qquad (26)$$

and replacing expected with actual values, the investment equation to be estimated can then be written as

$$\left[\frac{I_t}{K_t}\right]' = \beta_o w_t + \beta_1\left[\frac{I_{t+1}}{K_{t+1}}\right]' + \beta_2\left[\frac{I_{t+1}}{K_{t+1}}\right]'^{,2} + \beta_3\left[\frac{\Pi_{t+1}}{K_{t+1}}\right]' + \beta_4 c'_{t+1} + \varepsilon_{t+1} \qquad (27)$$

where

$$\beta_o=a; \quad \beta_1=1-\delta-a; \quad \beta_2=1; \quad \beta_3=\frac{1}{b}; \quad \beta_4=\frac{-1}{b};$$

$$w_t = (1-\tau^*_t)p^y_t - (1-\delta)\rho_{t+1}(1-\tau^*_{t+1})p^y_{t+1} \qquad (28)$$

whilst ε_{t+1} contains expectational errors introduced by replacing expected with actual values.

For estimation it is again necessary to specify (1-m)/(1-z), this time because of the dependence of c_t on ρ_{t+1}. We tried both of the approaches described in the previous sub-section. Again, the results were very similar. Again, therefore, we report only those for the case in which m=z.

4. Measures of Q, the cost of capital and effective tax variables

Before turning to the econometrics it is useful to examine the way in which tax exhaustion affects the critical variables τ^*, p^*, Q and c. This we now do for the sample of firms to be used in the estimation: an unbalanced panel of 597 UK manufacturing companies (each with at least ten years of continuous data) over the period 1973-1986[12]. In the Appendix we describe in

[12] A data appendix describing the characteristics of the sample and the construction of variables is available from the authors on request.

detail the construction of the effective tax rates and of the other variables.

Our basic approach is to replace expected values by realised values[13]. Assuming rational expectations, this would of course be exactly correct if there were no uncertainty. More generally, it introduces forecast errors into the estimation which are orthogonal to the information set currently available to agents. Since the tax variables may depend on profits more than one period into the future, the forecast error may present a moving average structure. In the econometric work, we therefore experiment with the choice of instrument set and report serial correlation and instrument legitimacy tests.

In the tables below we present means and standard deviations of τ^*, p^*, Q and c under three alternative views of the tax system:

(a) Ignoring tax exhaustion entirely: assuming, that is, that all firms are fully taxpaying ($\tau^*=\tau$, $\gamma^*=\gamma$).

(b) Accounting for full tax exhaustion, but ignoring ACT exhaustion ($\gamma^*=\gamma$)[14].

(c) Accounting for both aspects of tax exhaustion.

The same information on Q and the cost of capital is also reported when tax is entirely ignored. Finally, correlation coefficients between the different measures are presented.

Beginning with τ^*, Table 1 shows that tax exhaustion can have a substantial effect on the average effective marginal tax rate, and that cross-section

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[13] More sophisticated (and costly) approaches would be possible. Auerbach and Poterba (1987) and Altschuler and Auerbach (1990), for instance, allow for uncertainty about future tax positions in estimating the shadow value of losses by modelling transitions in and out of tax exhaustion as first or second order markov processes.

[14] This is essentially the approach taken, in a somewhat ad hoc form, by Blundell et al (1989).

variation in the effective tax rate was considerable in the 1970s and early 1980s. Comparing the third column with the first in each table, allowing for both aspects of tax exhaustion reduces the average tax rate by around 3 to 4 percentage points for much of the 1970s and early 1980s. Moreover, the standard deviation ranged between 5 and 7 percentage points[15].

Table 1 Estimated average effective tax rate, τ^*

year	no of cos	fully taxpaying	tax exhaustion (ignoring ACT exhaustion) %	tax exhaustion (including ACT exhaustion) %
1973	355	44.7 (3.8)	44.3 (5.0)	43.8 (3.9)
1974	389	51.9 (0.4)	47.9 (9.4)	48.3 (5.7)
1975	406	52.0 (0.0)	48.6 (8.7)	49.1 (4.9)
1976	580	52.0 (0.0)	48.3 (10.0)	49.3 (5.3)
1977	595	52.0 (0.0)	48.2 (9.6)	49.2 (5.4)
1978	595	52.0 (0.0)	48.3 (9.6)	49.0 (5.6)
1979	597	52.0 (0.0)	47.6 (10.5)	48.5 (6.4)
1980	596	52.0 (0.0)	46.8 (11.7)	48.1 (7.0)
1981	587	52.0 (0.0)	46.7 (11.9)	48.3 (6.8)
1982	581	52.0 (0.0)	47.3 (11.6)	48.7 (6.9)
1983	559	51.2 (0.6)	47.4 (11.0)	48.6 (6.2)
1984	540	48.1 (1.6)	45.1 (9.7)	45.7 (6.0)
1985	514	43.2 (1.7)	40.7 (8.7)	41.2 (5.6)
1986	446	38.3 (1.6)	37.0 (5.9)	37.3 (4.5)

Notes

1. Standard deviation in brackets.
2. Accounting years are attributed to the calendar year in which the year end occurs.
3. The estimates presented are an unweighted average of the effective tax rates facing all of the companies available in each year.

Since it is easily shown that τ^* cannot exceed the statutory tax rate τ, its high standard deviation mostly reflects values below the average value; there were many companies facing a very low effective tax rate. The second column presents estimates of τ^* ignoring ACT exhaustion. Two features stand

[15] It may seem strange that there is some variation in measured tax rates even when tax exhaustion is ignored (and that the mean rate sometimes differs slightly from any statutory one): this reflects the practice of apportioning a firm's taxable profits across the tax years spanned by its accounting year combined with cross-firm variation in reporting dates and changes in statutory rates.

out: the average values are slightly lower than those in the third column and the standard deviations are much larger[16].

Table 2 presents analogous statistics for p^*/p, averaged over both firms and asset types[17]. All figures are substantially below 100%, reflecting the generosity of investment incentives over this period (particularly until the

Table 2 Estimated average effective price of capital goods, p^*/p (%).

year	no of cos	fully taxpaying	tax exhaustion (ignoring ACT exhaustion) %	tax exhaustion (including ACT exhaustion) %
1973	355	63.6 (6.8)	64.2 (7.3)	63.4 (6.8)
1974	389	58.0 (7.1)	61.4 (10.0)	59.2 (7.0)
1975	406	56.1 (6.6)	59.2 (9.5)	57.3 (6.7)
1976	580	54.8 (6.0)	58.1 (10.3)	56.2 (6.5)
1977	595	54.5 (6.1)	57.9 (10.1)	56.1 (6.7)
1978	595	55.3 (6.7)	58.5 (10.5)	56.6 (7.1)
1979	597	55.2 (6.4)	59.0 (10.8)	57.0 (7.4)
1980	596	55.7 (7.0)	60.3 (11.7)	57.9 (7.9)
1981	587	55.6 (6.9)	60.2 (11.8)	57.8 (7.7)
1982	581	53.4 (5.5)	57.6 (11.6)	55.7 (7.4)
1983	559	53.7 (5.3)	57.3 (11.2)	55.6 (7.0)
1984	540	58.5 (5.9)	61.2 (10.0)	59.9 (7.1)
1985	514	67.4 (5.6)	69.3 (8.4)	67.5 (6.5)
1986	446	74.7 (5.4)	75.4 (6.4)	74.0 (6.2)

Note

1. Figures are shown as a percentage of the pre-tax price, p.

16 It may seem counter-intuitive that the average rate disregarding ACT exhaustion is almost always the smaller of the two, since 'less tax exhaustion' is then being allowed for. The explanation is that ACT to some extent has an offsetting effect to full tax exhaustion. Consider the value of τ^*_t when the firm is fully tax exhausted. Ignoring ACT, tax due in period t on an additional pound of earnings is zero; tax is deferred until the firm resumes a tax-paying position. However, allowing for ACT, an ACT charge of c is due immediately if the additional pound of earnings is paid out as a dividend (which is what τ^* measures). At some point in the future the firm will increase this to τ (ignoring discounting) by paying a corporation tax charge of τ and claiming ACT relief of c. The effect of this is that in the latter case τ^* cannot fall below c, whereas in the former case it can fall to zero.

17 Assets are split into three categories for this purpose: plant and machinery, industrial buildings and commercial buildings. Weights used are the investment in each asset in each period, and so cross-firm variation in p^*/p arises partly from variation in asset structure.

reform phased in from 1984); immediate expensing for plant and equipment and allowances up to 75% in the first year for industrial buildings. Comparing the values of p^*/p for the alternative treatments of taxation, there are two principal effects. First, a firm with tax losses - whether now or in the future - experiences a reduction in the present value of tax incentives, leading to a rise in the effective price. Second - and acting in the opposite direction - ACT exhaustion tends to reduce the effective price, for reasons described after (14) above. Comparing the first and third columns the former effect generally outweighs the latter.

Table 3 shows, perhaps surprisingly, that taking account of taxation substantially increases marginal Q. The dominant effect here is thus that through the first term in (17), which increases with the effective tax rate: intuitively, Q unadjusted for taxes is too low since taxes are implicitly deducted from the numerator (future liabilities being discounted in the share price) but not from the denominator. This proves to outweigh both the adjustment for tax-related state variables in (18) and the increase in the

Table 3 Estimated average tax-adjusted Q.

year	no of cos	no tax	fully taxpaying	tax exhaustion (ignoring ACT exhaustion) %	tax exhaustion (including ACT exhaustion) %
1973	355	0.57 (1.16)	1.69 (2.18)	1.69 (2.18)	1.57 (2.17)
1974	389	0.12 (0.95)	1.20 (1.97)	1.11 (1.91)	0.94 (1.93)
1975	406	-0.66 (0.59)	-0.37 (1.21)	-0.42 (1.19)	-0.58 (1.19)
1976	580	-0.81 (0.47)	-0.61 (0.96)	-0.64 (0.95)	-0.80 (0.98)
1977	595	-0.78 (0.48)	-0.53 (1.00)	-0.55 (0.99)	-0.70 (1.01)
1978	595	-0.68 (0.64)	-0.36 (1.31)	-0.39 (1.30)	-0.54 (1.33)
1979	597	-0.62 (0.55)	-0.26 (1.15)	-0.30 (1.13)	-0.44 (1.16)
1980	596	-0.61 (0.53)	-0.28 (1.11)	-0.32 (1.09)	-0.45 (1.13)
1981	587	-0.66 (0.59)	-0.38 (1.25)	-0.42 (1.27)	-0.53 (1.26)
1982	581	-0.71 (0.53)	-0.44 (1.10)	-0.46 (1.11)	-0.58 (1.13)
1983	559	-0.64 (0.62)	-0.30 (1.26)	-0.33 (1.30)	-0.42 (1.29)
1984	540	-0.55 (0.70)	-0.22 (1.36)	-0.24 (1.35)	-0.31 (1.38)
1985	514	-0.41 (0.87)	-0.08 (1.51)	-0.09 (1.51)	-0.14 (1.53)
1986	446	-0.39 (0.84)	-0.17 (1.35)	-0.17 (1.35)	-0.20 (1.36)

second term in (17) above p_t/p_t^y (except when there is free depreciation (j=0) and the firm is fully taxpaying). Comparing the final three columns shows moreover that Q is higher the less account one takes of tax exhaustion: this reflects both the effect on τ^* in Table 1 and that through the state variables.

Table 4 looks at the distribution of firms' average costs of capital, that is their costs of capital averaged across different types of investment. The cost of capital in the absence of taxation is taken to be simply the long run real rate of interest[18] plus depreciation minus capital gains. Even in this case, it is clear that there has been substantial variation over the period considered. Throughout much of the 1970s the real interest rate was negative, and the cost of capital positive only because of depreciation. By the recession in the early 1980s, however, real interest rates were very high.

Table 4 Estimated average cost of capital.

year	no of cos	no tax	fully taxpaying	tax exhaustion (ignoring ACT exhaustion) %	tax exhaustion (including ACT exhaustion) %
1973	355	-1.32 (1.80)	-5.00 (2.84)	-7.21 (6.15)	-4.20 (5.69)
1974	389	1.10 (1.85)	-6.13 (2.79)	-5.35 (5.72)	-5.06 (3.93)
1975	406	2.78 (2.03)	-2.75 (2.66)	-2.36 (7.48)	-1.73 (4.30)
1976	580	2.59 (1.71)	-1.71 (2.40)	-1.99 (6.90)	-2.02 (4.47)
1977	595	6.52 (3.33)	2.43 (3.15)	2.71 (6.48)	2.97 (4.89)
1978	595	4.06 (2.46)	1.06 (2.43)	0.26 (8.04)	0.80 (5.14)
1979	597	3.16 (1.57)	-0.02 (1.94)	-0.32 (8.90)	0.65 (4.90)
1980	596	8.38 (3.55)	4.74 (3.42)	5.80 (11.96)	5.94 (7.37)
1981	587	13.35 (2.80)	9.85 (1.54)	11.30 (9.60)	10.26 (5.54)
1982	581	14.42 (2.50)	11.12 (1.85)	12.80 (12.26)	11.81 (7.97)
1983	559	13.72 (2.06)	10.92 (1.34)	13.12 (13.92)	11.80 (6.60)
1984	540	9.92 (2.36)	-6.03 (15.62)	-2.28 (13.44)	-0.18 (10.03)
1985	514	7.50 (1.83)	-10.68 (10.33)	-7.37 (6.16)	-5.23 (5.77)
1986	446	8.62 (1.80)	-0.80 (5.03)	-0.12 (4.14)	3.49 (5.72)

Note: The average is constructed as described in the text.

[18] Taken to be the gross flat yield on 2.5% UK Government Consols.

Introducing taxation in all cases reduces the cost of capital relative to the no tax case, indicating that throughout this period the tax system acted, on average, as an incentive to invest. This reflects not only the investment incentives of Table 2 but also interest deductibility and the generous treatment of dividends under the imputation system. Accounting for tax asymmetries generally increases the cost of capital; the value of investment incentives falls, as shown in Table 2, and the lower effective tax rate implies a higher cost of debt finance. It is also clear from Table 4 that the cost of capital varies widely across companies once tax exhaustion is allowed for. The standard deviation shown for the fully taxpaying case is around 1 to 3 percentage points (up to 1984). By contrast, the standard deviation in the third column (allowing for full tax exhaustion but ignoring ACT exhaustion), ranges from around 6 to around 12 percentage points, and that for the fourth column (including ACT exhaustion as well) ranges from around 4 to around 8 percentage points.

Table 5 presents correlation coefficients between the different measures of τ^*, p^*/p, Q and c across all firms and years. Table 5(a) gives the correlations for τ^*. Those between the fully taxpaying case and the others are very weak, as would be expected, since the statutory tax rate, τ, changes little. There is a relatively high correlation for the two cases of tax exhaustion since the same estimates of periods of tax exhaustion were used so that the two forms of tax exhaustion tend to occur together. A similar pattern emerges for p^*/p in table 5(b), although the correlations are higher.

Table 5(c) displays a striking and crucial feature of the data: the various measures of Q are extremely highly correlated, with no correlation lower than 0.98. The implication, of course, is that these measures are almost

Table 5(a) Correlation of different measures of τ^*

	fully taxpaying	full tax exhaustion	full and ACT exhaustion
fully taxpaying	1.00		
full tax exhaustion	0.33	1.00	
full+ACT exhaustion	0.55	0.86	1.00

Table 5(b) Correlation of different measures of p^*/p

	fully taxpaying	full tax exhaustion	full and ACT exhaustion
fully taxpaying	1.00		
full tax exhaustion	0.68	1.00	
full+ACT exhaustion	0.84	0.87	1.00

Table 5(c) Correlation of different measures of Q

	no tax	fully taxpaying	full exhn	full and ACT exhn
no tax	1.00			
fully taxpaying	0.98	1.00		
full tax exhaustion	0.98	0.99	1.00	
full+ACT exhaustion	0.98	0.99	0.99	1.00

Table 5(d) Correlation of different measures of c

	no tax	fully taxpaying	full exhn	full and ACT exhn
no tax	1.00			
fully taxpaying	0.58	1.00		
full tax exhaustion	0.55	0.68	1.00	
full+ACT exhaustion	0.69	0.69	0.86	1.00

perfectly linearly related, and for later purposes it will prove helpful to characterise those relationships more precisely. OLS gives

$$QN = -0.4537 + 0.5093.QF \qquad R^2 = 0.967$$
$$\quad (0.0019) \quad (0.0031)$$

$$QF = 0.1321 + 0.9689.QE \qquad R^2 = 0.966$$
$$\quad (0.0031) \quad (0.0024)$$

where QN, QF and QE denote Q unadjusted for taxes, adjusted only for full

tax exhaustion and adjusted for both aspects of tax exhaustion respectively (and standard errors are in parentheses). The linearity of the relationship between the alternative measures of Q is not easily explained. Recalling (17) and (18), the adjustments involved in moving between them are far from being trivially linear operations with firm-independent parameters. The consequence, however, is both clear and troublesome: it is likely to be hard to distinguish empirically between the performances of Q models based on alternative treatments of the firm's corporation tax position.

In contrast, Table 5(d) shows that the correlations between the different measures of the cost of capital are quite low.

5. Estimation and Results

We now turn to the empirical implementation of the two investment equations, the Q formulation in (16)-(18) and the cost of capital formulation (27).

The same estimation procedure is applied to both. In each case the error for the ith firm at time t, ε_{it}, is modelled in a very general way as the sum of a specific effect η_i, a time-specific effect, η_t, and an idiosyncratic shock, u_{it}:

$$\varepsilon_{it}=\eta_i+\eta_t+u_{it}. \qquad (29)$$

To eliminate the firm specific effects, η_i, the forward Helmert or orthogonal deviations transformation (denoted by ∇) is applied to each variable, as proposed by Arellano and Bover (1990). To allow for potential endogeneity of the regressors, estimation is by Generalised Methods of Moments (Hansen (1982)), using lagged variables as instruments[19]. The

[19] The DPD programme developed by Arellano and Bond (1988) was used for estimation.

econometric methodology is described in more detail in Blundell et al (1989), and Arellano and Bond (1990). Since the effective tax parameters are constructed using future information, we use lagged values of Q calculated using statutory tax rates as instruments. The same instrument set is used for all equations in each table.

Table 6 presents estimates of a generalised version of the Q formulation including Q_t, Q_{t-1} and the lagged dependent variable[20]. We have also allowed ourselves some flexibility in the choice of the timing of the market value of the firm to be included in the numerator of Q. Heteroskedasticity-consistent standard errors are reported (White (1982)). The sample period used for estimation is 1973-86, with earlier periods providing instruments. The four columns in Table 6 report results for four measures of Q, corresponding to the four columns of Table 3:

(i) Ignoring taxation entirely ($\tau^*=0$, $\gamma^*=1$)

(ii) Allowing taxes, but assuming no tax exhaustion ($\tau^*=\tau$, $\gamma^*=\gamma$)

(iii) Allowing for full tax exhaustion, but not ACT exhaustion ($\gamma^*=\gamma$)

(iv) Allowing both forms of tax exhaustion.

The specification in the top part of Table 6 is general. If u_{it} follows an AR(1) process, the unrestricted parameters must satisfy the common factor restrictions for such a process. A formal test for this is presented in the lower half of the table, where the comfac restriction is imposed on the unrestricted parameter estimates by the minimum distance approach[21]. The data accept the restriction at 5% confidence levels in all cases.

Comparing coefficients across the four specifications, the picture is as the

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[20] This specification is discussed at length in Blundell et al (1989).

[21] Described in Blundell et al (1989).

Table 6 The Q formulation with alternative treatments of taxation
597 firms; 1973-1986

Dependent variable $\nabla(I/K)_{it}$

(a) UNRESTRICTED	(i)	(ii)	(iii)	(iv)
∇Q_t	0.0231 (0.0112)	0.0105 (0.0053)	0.0115 (0.0051)	0.0109 (0.0054)
∇Q_{t-1}	-0.0049 (0.0034)	-0.0024 (0.0017)	-0.0025 (0.0017)	-0.0024 (0.0017)
$\nabla(I/K)_{t-1}$	0.2904 (0.0230)	0.2886 (0.0232)	0.2910 (0.0227)	0.2925 (0.0228)
m1	1.56	1.64	1.53	1.58
Sargan (80)	89.0	89.5	88.3	89.6
Confidence level	0.771	0.782	0.755	0.783
WT (14)	282.3	260.4	257.2	271.6
(b) RESTRICTED	(i)	(ii)	(iii)	(iv)
∇Q_t	0.0211 (0.0109)	0.0099 (0.0052)	0.0106 (0.0050)	0.0101 (0.0053)
ξ	0.2875 (0.0227)	0.2866 (0.0229)	0.2881 (0.0224)	0.2898 (0.0224)
Comfac	0.600	0.320	0.490	0.454
Instruments for all equations (in GMM form)	Q_{t-2}, Q_{t-3}, ... , Q_{t-7}, $(I/K)_{t-2}$			

Notes:

1. ∇ denotes orthogonal deviations.
2. Time dummies are included as regressors and instruments in all equations.
3. Asymptotic standard errors are reported in parentheses. Standard errors and test statistics are robust to general time-series and cross-section heteroskedasticity.
4. m1 is a test for first order serial correlation in the residuals, asymptotically distributed as N(0,1) under the null of no serial correlation.
5. WT is a Wald test of the joint significance of the time dummies. The number of degrees of freedom is given in parentheses.
6. The Sargan statistic is a test of the over-identifying restrictions, asymptotically distributed as $\chi^2(k)$ under the null. It tests whether the instruments are correlated with the error terms. The number of degrees of freedom is given in parentheses.
7. The comfac statistic is a test of the common factor restrictions that the dynamics are generated by an AR(1) disturbance with parameter ξ, asymptotically distributed as $\chi^2(1)$.
8. The instruments are in their GMM form and are calculated using statutory tax rates.

data analysis in section 4 would lead one to anticipate. With the alternative measures of Q linearly related, the coefficients on the VQ variables would be expected to vary across specifications according to the slope of the underlying relationship between the Q measures being used. Recalling the regressions in section 4, this is indeed what one finds: these coefficients are essentially identical in the specifications ((ii) to (iv)) that make some allowance for taxation, and all about double when (in column (i)) taxation is simply ignored[22]. The estimates of 1/b implied by the coefficients on Q_t in columns (ii)-(iv) are broadly in line with previous estimates from both aggregate data (Summers (1981), Poterba and Summers (1983) and micro data (Salinger and Summers (1984), Fazzari et al (1989), Hayashi and Inoue (1989), Blundell et al (1989), so sharing the familiar feature of estimated Q models that the implied speed of adjustment is extremely low. In this respect the no-tax specification in column (i) actually performs more plausibly. The diagnostics (including the Sargan statistic that tests for the correlation between the instruments and the error term) provide little basis for selecting between the specifications: they all pass both tests at standard confidence intervals. Thus the performance of the Q formulation is not improved by careful treatment of tax exhaustion; indeed there is no clear gain from any kind of inclusion of corporate taxation.

Table 7 reports results for the cost of capital formulation, the columns corresponding to the same alternative treatments of taxation as in Table 6. The regressor w_t appearing in (27) is excluded, having showed signs of collinearity with the cost of capital term[23].

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[22] For the US, Summers (1981) also finds - but does not comment on - a larger coefficient on Q when corporation tax is ignored.

[23] This is not hard to explain. With immediate expensing (j=0) - as was indeed

Table 7 The Cost of Capital Formulation
597 firms; 1975-1985

Dependent variable $\nabla(I/K)_{it}$

(a) UNRESTRICTED	(i)	(ii)	(iii)	(iv)
$\nabla(I/K)_{t+1}$	0.2612 (0.1730)	0.2621 (0.1682)	0.2108 (0.1721)	0.2588 (0.1660)
$\nabla(I/K)^2_{t+1}$	-0.1030 (0.0516)	-0.1029 (0.0501)	-0.0863 (0.0511)	-0.1008 (0.0484)
$\nabla(\Pi/K)_{t+1}$	0.2991 (0.1454)	0.2816 (0.1404)	0.2599 (0.1354)	0.2729 (0.1375)
∇C_t	-0.4714 (0.1345)	-0.1947 (0.0470)	-0.1753 (0.0516)	-0.1979 (0.0528)
m1	1.11	1.08	1.12	1.16
Sargan (129)	146.9	150.1	148.4	147.1
Confidence level	0.866	0.901	0.884	0.868
WT (11)	72.8	152.1	130.3	141.2
Instruments for all equations (in GMM form)	I/K_{t-3}, I/K_{t-4}.....I/K_1 CF/K_{t-3}, CF/K_{t-4}.....CF/K_1 ∇C_t			

Notes: As in Table 6

Recalling the low correlations between the various measures of the cost of capital found in Table 5(d), there is remarkably little difference between the performances of the four specifications. In all cases we are unable to reject the implication of (28) that the coefficients on $\nabla(\Pi/K)$ and ∇c are equal in absolute value. The specifications also share two disturbing features: recalling (28) the coefficient on $\nabla(I/K)$ is lower than one might expect for plausible values of economic depreciation and 'normal' investment; and that on $\nabla(I/K)^2$ is far from the theoretical prediction of unity. Nevertheless, all specifications pass the diagnostic tests at standard confidence levels. Columns (i) and (iv) - the extremes of ignoring

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the case for plant and machinery over much of the sample period - and constant relative prices, $w_t = p^y c'_{t+1}/p$.

taxes altogether and incorporating both forms of asymmetry - display marginally lower Sargan statistics, but the effect is too slight to bear any weight.

These results - and those for the Q formulation - may of course be contaminated by omitted variables bias. The inclusion of the most natural additional regressors, however, has no effect on the qualitative conclusions. Incorporating agency costs of debt (along the lines of Jensen and Meckling (1977)), for instance, a term in $(B/K)^2$ appears in (27); this, however, proves statistically insignificant and has little impact on the other coefficients. Introducing imperfect competition (as in Schiantarelli

Table 8 The Cost of Capital Formulation with Imperfect Competition
597 firms; 1975-1986

Dependent variable $\nabla(I/K)_{it}$

(a) UNRESTRICTED	(i)	(ii)	(iii)	(iv)
$\nabla(I/K)_{t+1}$	0.3040 (0.1535)	0.3013 (0.1507)	0.3426 (0.1490)	0.3095 (0.1479)
$\nabla(I/K)^2_{t+1}$	-0.1082 (0.0398)	-0.1091 (0.0389)	-0.1224 (0.0406)	-0.1113 (0.0384)
$\nabla(\Pi/K)_{t+1}$	0.6474 (0.1454)	0.6615 (0.1630)	0.5257 (0.1305)	0.6195 (0.1432)
∇C_t	-0.5408 (0.1226)	-0.2165 (0.0458)	-0.2325 (0.0540)	-0.2594 (0.0565)
$\nabla(Y/K)_{t+1}$	-0.0414 (0.0086)	-0.0440 (0.0106)	-0.0325 (0.0078)	-0.0409 (0.0090)
m1	1.71	1.87	0.94	1.93
Sargan (194)	228.3	225.2	228.1	227.5
Confidence level	0.954	0.938	0.953	0.950
WT (11)	83.1	159.1	144.2	158.0
Instruments for all equations (in GMM form)	I/K_{t-3}, I/K_{t-4}.....I/K_1 CF/K_{t-3}, CF/K_{t-4}.....CF/K_1 Y/K_{t-3}, Y/K_{t-4}.....Y/K_1 ; ∇c_t			

Notes: As in Table 6

and Georgoutsos (1990), it is easy to show that the output-capital ratio, Y/K, should also appear as a regressor in both the Q and the cost of capital formulations. Table 8 reports results of this kind for the cost of capital formulation[24]. Output emerges as significant. Again, however, the differences arising from alternative treatments of taxation are barely perceptible. Similar results are obtained when output is included in the Q equation.

6. Conclusions

What then of the central question: are corporation tax asymmetries important in explaining observed investment behaviour? The econometric results reported here suggest not, in the sense that careful treatment of these asymmetries does not perceptibly improve the performance of either the Q or the cost of capital formulation. Indeed specifications that capture the full complexities of corporate taxation perform no better than ones which ignore it altogether.

This is a puzzle, for the data set has also been seen to be one in which these asymmetries generate considerable cross-section and intertemporal variation in firms' effective tax positions. Certainly none of the equations estimated is fully satisfactory, pointing to deeper problems (familiar and unresolved) in modelling investment behaviour. But the apparent irrelevance of tax considerations that appear in principle to establish powerful incentive effects remains perturbing. There are several possible explanations. While we have done our best to guard against omitted variables and measurement error, for instance, they cannot be precluded. Calculating the replacement values of firm's capital stocks, for example, is a hazardous exercise, and doubtless too there are errors in the effective tax variables

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[24] The coefficients β_3 and β_4 in (28) now become $\varepsilon/b(\varepsilon-1)$ and $-\varepsilon/b(\varepsilon-1)$ respectively, all others being unaffected. That on the output-capital ratio is $-1/b(\varepsilon-1)$.

that we have constructed.

There is another concern that deserves particular emphasis. When firms are in different tax positions one would expect them to find mutually advantageous arbitrage devices. One such is the practice of leasing, whereby tax exhausted firms, unable to make full use of their investment allowances, rent assets from taxpaying firms who can. Leasing has indeed been of considerable practical importance in the UK, particularly in the early 1980s. Its potential significance for investment equations of the kind estimated here is substantial. Edwards and Mayer (1990) show that if the relationship between the cost of capital and current investment expenditure is the same for all firms and they have access to the same lease rental rate, then in equilibrium (and in the absence of adjustment costs) both investment purchases and the cost of capital are equalised across firms. The only cross-section variation in our data would then be measurement error. More plausible circumstances give less nihilistic implications. Firms are likely to face different cost of capital schedules as a result of their distinct histories, and leasing is likely to involve real resources costs. Costs of capital and investment purchases will then vary across firms in equilibrium opening the way for a discernible impact of tax asymmetries. Nevertheless, the optimisation problem underlying the estimating equations developed here will be misspecified; when leasing is an option the cost of capital formulation, for instance, will tend to underpredict the investment expenditures of lessors. Little empirical light can be cast on these issues without better micro data on leasing than are available to us. It may be, however, that tax asymmetries impact investment behaviour more powerfully through the general equilibrium consequences of the arbitrage opportunities that they create than they appear to do through effective tax variables of the kind emphasised here.

APPENDIX

Constructing effective tax variables, Q and the cost of capital

In this Appendix we outline the calculation of four key tax related variables: τ_t^*, p_t^*, $E_t[V_{t+1}/K_{t+1}]$ and c_t^*. Recalling their definitions this requires constructing measures of the expected shadow values of tax losses L_{t+1}, unrelieved ACT U_{t+1}, and tax-written down capital K_{t+1}^T, and also (for Q) of the expectations of the product of each shadow value and the corresponding stock.

Starting with unrelieved ACT, differentiation of the recursion relation (22) gives

$$\frac{\partial V_t}{\partial U_t} = \rho_t \left\{ \gamma\left[1-H(b_t)\right] + E_t\left[\frac{\partial V_{t+1}}{\partial U_{t+1}} \middle| \alpha_t \leq b_t \right] H(b_t) \right\} \qquad (A.1)$$

Suppose then that the firm is certain to be ACT exhausted in period t ($H(b_t)=0$) and certain too to be fully taxpaying in t+1 ($E_t[H(b_{t+1})|\alpha_t \leq b_t]=1$). Using (A.1) and its update, and assuming that ρ is time-invariant, $\partial V_t/\partial U_t=\rho^2\gamma$. More generally,

$$\frac{\partial V_{t+1}}{\partial U_{t+1}} = \rho^n\gamma \qquad (A.2)$$

for a firm that first ceases to be ACT exhausted at t+n. Tax losses and tax-written down capital can be valued by similar methods. For a firm that is fully tax exhausted at t, certain to pass into ACT exhaustion at t+m and to become fully taxpaying at t+m+n, one arrives at

$$\partial V_{t+1}/\partial L_{t+1} = \rho^{m-1}\gamma(\tau-g)(1-g) + \rho^{m+n-1}\gamma g(1+\tau-g) \qquad (A.3)$$

and for the case in which investment incentives consist only of exponential tax depreciation at rate δ^T, so that $j=1-\delta^T$,

$$\partial V_{t+1}/\partial K^{T}_{t+1} = \left[\rho^{m-1}\gamma(\tau-g)(1-g) + \rho^{m+n-1}\gamma g(1+\tau-g)\right]\delta^{T} + (1-\delta)\partial V_{t+2}/\partial K^{T}_{t+2}. \quad (A.4)$$

For the effective tax rate variables (A.2)-(A.4) imply

$$\tau^{*}_{t} = g+(\tau-g)(1-g)\rho^{m-1} + g(\tau-g)\rho^{n-1} \quad (A.5)$$

$$p^{*}_{t} = p_{t}\left\{1 - g(1+\rho^{n-1}) + \sum_{s=t}^{\infty}\rho^{s-t}Z_{s}\right\} \quad (A.6)$$

where $Z_{s} = [\rho^{m(s)-1}\gamma(\tau-g)(1-g) + \rho^{m(s)+n(s)-1}\gamma g(1+\tau-g)]^{T}$ and m(s) and n(s) denote the number of periods of full tax exhaustion and ACT exhaustion from period s. Using (A.2) to (A.6) together with (19), Q is estimated from (17) and (18). The cost of capital in (25) is calculated using (A.5) and (A.6).

Equations (A.2) to (A.6) are fairly general: setting m=n=1, for instance, confirms that the effective tax rate faced by a fully taxpaying firm is indeed just the statutory rate τ. But more complex tax histories than those envisaged in these heuristics are possible: for example, a fully tax exhausted firm may enter ACT exhaustion but then return to full tax exhaustion before becoming fully taxpaying. The empirical work reported below allows for such complications[25].

In order to determine precisely when firms go in and out of tax exhaustion we use the detailed model of the UK corporate tax system described in Devereux (1990a). Since it is necessary to know if a firm is tax exhausted for several periods into the future, for which accounting data are not always available, these have been predicted out of sample using simple

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[25] Differing time limitations for carrybacks of tax losses and unrelieved ACT mean that in reality - though not in the model above - it is possible for a firm to have tax losses and pay a strictly positive dividend without accumulating unrelieved ACT. This too is allowed for in the empirical work.

autoregressive models, and the tax model applied to the resulting forecasts. Since UK tax reforms have generally been unanticipated (an exception being the transition period in the 1984 reforms) using the actual tax system for future periods may give a poorer proxy for firms' expectations than assuming static expectations for the tax system and perfect foresight for accounting data. In practice, we found no significant empirical difference between these two approaches. The results presented in the text assume static expectations for the tax system.

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