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ABSTRACT

This paper derives and estimates models of nonresidential investment behavior in which current and future tax conditions directly affect the incentive to invest. The estimates suggest that taxes have played an independent role in affecting postwar U.S. investment behavior, particularly for investment in machinery and equipment.

In addition, the paper develops a method for assessing the impact of tax policy on the volatility of investment when such policy is endogenous. Illustrative calculations using this technique, based on the paper's empirical estimates, suggest that tax policy has not served to stabilize investment in equipment or nonresidential structures during the sample period.

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1. Introduction

Though it has typically accounted for a small fraction of the Gross National Product in most countries (in recent years, about 12 percent in the United States), business fixed investment has occupied a much more important role in the theory of economic fluctuations and growth and, perhaps as a result, in the design of tax policy.

In the United States, changes in the corporate tax rate, the investment tax credit and the schedules provided for depreciation deductions have occurred frequently during the postwar period. Among the most significant of these changes were the introduction of accelerated depreciation in 1954, the introduction of the investment tax credit in 1962, the sharp increase in depreciation benefits provided by the Accelerated Cost Recovery System in 1981, and, under the Tax Reform Act of 1986, the repeal of accelerated depreciation and the investment tax credit combined with a reduction in the statutory tax rate.

Such frequent manipulation of tax policy suggests that policy-makers believe it to be an effective tool for altering the level and composition of investment. Yet, despite all the policy changes that have occurred, there is very little convincing empirical evidence that this view is accurate. Our primary objective in this paper is to estimate the influence of tax policy on fixed nonresidential investment in the United States over the period 1956-88, and to consider whether changes in tax policy have served to stabilize investment. We find that tax changes have played a significant role in affecting the level and pattern of investment, although this impact has not necessarily been a stabilizing one.

In the past, the ability of researchers to evaluate the efficacy of investment-oriented tax policies has been limited by the absence of satisfactory structural models of investment behavior. To evaluate the effects of tax policy on investment, one needs a structural model in which the tax policy parameters of interest appear as explanatory variables. However, over the years there has been a tension between the restrictions theory imposes on models of investment and the difficulty of explaining investment behavior very well with such rigorous structural models.[1]

Though modelling difficulties can hardly be ignored, a structural model, however problematic, is necessary if one wishes to perform policy analysis, interpreting the coefficients of policy variables as the partial effects of such variables on investment. This paper presents a model of investment behavior that we view as better suited to this task than previous models found in the literature. Unlike other models that have explicitly included tax policy variables, it is derived from a model of optimizing behavior by firms with rational expectations. Unlike many other models based on the optimizing behavior of rational agents, this model provides direct estimates of the effects of tax policy variables on investment, rather than ignoring changes in taxes or inferring their effects on the basis of the underlying theoretical model. Hence, the model provides estimates of the effects of tax policy that permit a structural interpretation.

The next section introduces the model (derived in Appendix A) that we use to estimate the effects of taxes and other factors such as interest rates and profitability on investment behavior and discuss this model's relationship to those found in the literature. After a discussion of the data in section 3, the paper provides, in section 4, a variety of estimates of this model using postwar U.S. data on investment in both nonresidential structures and equipment. Using these estimates, we develop and apply, in Section 5, a technique for assessing the impact of tax policy on the variability of investment over the sample period. Section 6 offers some concluding comments.

2. Determinants of Investment Behavior

The model we use is based on the assumption of forward-looking investment behavior by value-maximizing firms that are motivated by adjustment costs to smooth their capital expenditures over time. These are the same basic assumptions that give rise to equations relating investment to "q", the ratio of the market valuation of the firm to the replacement cost of its capital stock. In the past, researchers have estimated this relationship of investment to q directly (e.g. Summers 1981, Abel and Blanchard 1986), or estimated Euler equations, relating current investment to expected future investment (Pindyck and Rotemberg 1983, Shapiro 1986).

Our approach differs in a couple of respects. First, we relate investment to the determinants of q directly, rather than to q or the expected change in investment. While the different approaches should be equivalent if the underlying behavioral model is correct (we are simply combining the Euler equations of the q model with the transversality condition on firm value to obtain a particular solution), our procedure has practical advantages. It allows us to estimate the effects of tax policy and its different components directly (rather than by indirect inference), thus enabling a simple comparison to estimates from the literature relating investment to the user cost of capital (e.g. Hall and Jorgenson 1967) and effective tax rates (e.g. Feldstein 1982) and a straightforward evaluation of the stabilizing effects of tax policy, historically. Second, past work has typically failed to allow fully for changes in tax regime, either assuming static expectations or ignoring the impact of anticipated future tax changes on the value of investment incentives.[2] Our methodology readily permits us to allow fully for the effects of anticipated changes in the tax system and to evaluate their effects separately.

Our approach has its disadvantages as well, since the derivation of a specific investment rule from an Euler equation requires additional, restrictive assumptions. However, we believe direct estimates of the impact of tax policy are worth the additional assumptions, and that the current approach is complementary to those taken in the past.

Consider a firm that produces according to a stochastic function of capital, F(K). One may also interpret F(·) as a profit function of K alone derived from a more general production function and the optimal choice of variable inputs. The firm purchases new capital subject to a convex cost function of investment, C(I) reflecting the presence of adjustment costs. Both F(·) and C(·) may vary over time. We assume that the capital stock is homogeneous, but that its geometric depreciation rate, δ_t, is stochastic and serially uncorrelated, with constant mean $\bar{\delta}$. Let r be the real, risk-free discount rate, let ρ be the discount rate that the holders of the firms' securities apply to the firm's real, after-corporate-tax cash flows excluding investment incentives, and let g be the price of investment goods relative to output. We may express the firm's objective of maximizing its market value as

$$(1) \quad W_t = E_t \left\{ \sum_{s=t}^{\infty} (1+\rho)^{-(s-t)} \left[\frac{(1-\tau_s)\, F_s\, (K_s)}{(1+r)} - g\, C_s\, (I_s) I_s (1-\Gamma_s) \right] + A_t \right\}$$

where $E(\cdot)$ is the expectations operator, τ_s is the corporate tax rate at date s, Γ_s is the present value of tax savings from investment credits (k) and real depreciation allowances (D) per dollar of investment (assumed to be discounted with the risk-free rate):

$$(2) \qquad \Gamma_s = k_s + \sum_{z=s}^{\infty} (1+r)^{-(z-s)} \tau_z D_{z-s}$$

and A_t is the present value of depreciation allowances on investment made before date t.[3] In expression (1), the price of output is normalized to unity. In cases where the firm is assumed to possess market power with respect to its output price, we simply reinterpret the function $F(\cdot)$ as the firm's revenue rather than its output (see Appendix A).

The decision problem in (1) gives rise to an Euler equation that takes the form of a second-order stochastic nonlinear differential equation in the capital stock, given in expression (A3) in Appendix A. To obtain a solution to this equation, we make a number of simplifying assumptions. We assume that the firm has an underlying production function in capital and labor that is Cobb-Douglas, which implies that $F(\cdot)$ has a Cobb-Douglas form as well; that the adjustment cost function $C(\cdot)$ is quadratic; and that the stochastic shocks to production center around a trend growing at rate n.[4]

Linearizing the firm's Euler equation around this trend yields the following investment rule, given as (A10) in Appendix A:

$$(3) \qquad \frac{I_t}{K_{t-1}} = \left[\left(\frac{1-\mu_1}{\alpha}\right) + n + \delta_t \right] - \left(\frac{1-\mu_1}{\alpha c_K^*}\right) \cdot E_t \sum_{s \geq t} w_{s-t} c_s K_{t-1}^{\alpha} .$$

where μ_1 is the stable root $(1 > \mu_1 > 0)$ of the second-order linearized difference equation characterizing the evolution of the capital stock, α is a measure of the curvature of the production function, the terms w_{s-t} are geometrically declining weights that sum to one and are based on the unstable root, $\mu_2 > 1$, of the second-order difference equation in K:

$$(4) \qquad w_{s-t} = (\mu_2 - 1)\,\mu_2^{-(s-t+1)} \quad ; \quad \sum_{s\geq t} w_{s-t} = 1$$

and the term c_s is a comprehensive measure of the "user cost of capital" at date s. It is given by expression (A9) in Appendix A:

$$(5) \qquad c_s = \frac{g\left(1-\Gamma_s\right)\left(\rho + \bar{\delta} + \dfrac{\Gamma_{s+1} - \Gamma_s}{1 - \Gamma_s}\right)}{(1 - \tau_s)\,\theta_s}$$

where ρ is the discount rate applicable to the firm's risky flows, excluding depreciation allowances.

In expression (5), the term θ_s is a measure of productivity at date s. Like the other determinants of investment in the expression, it is exogenous from the firm's point of view. For the Cobb-Douglas specification with homogeneous capital, θ_s is before-tax profits at date s, say Y_s, divided by $K_s^{1-\alpha}$. Since the term K_{t-1}^{α} also appears on the right hand side of (3), we may combine them to get $\theta_s/K_{t-1}^{\alpha} = Y_s/K_s \cdot (K_s/K_{t-1})^{\alpha}$; i.e., to form $c_s K_{t-1}^{\alpha}$. Thus, the terms being summed on the right-hand side of (3) are based on the traditional user cost that accounts for expected changes in tax rules, divided by a measure of the rate of profit. This profit rate is multiplied by a term that corrects for the fact that θ is meant to reflect underlying productivity, while the actual rate of profit will also be affected by capital deepening. That is, with decreasing returns ($\alpha > 0$), Y/K will decrease with K, given θ.[5] The term $c\overset{*}{K}$ appearing in expression (3) equals the "long run" value of cK^{α}, making $(1-\mu_1)/\alpha$ the response of the investment to a proportional change in the forward summation of this "full" user cost of capital.

The interpretation of the curvature term α depends not only on the structure of production but also the degree of competition in the industry. For example, for a Cobb-Douglas production function of capital and labor, (with corresponding exponents a and b) and an elasticity of demand λ perceived by the firm for its output, the solution for α, given as expression (A13) in Appendix A, is:[6]

$$(6) \qquad \alpha = \frac{1-(a+b)(1-1/\lambda)}{1-b(1-1/\lambda)}$$

Aside from the fact that the investment equation (5) specifies that future rather than lagged values of the cost of capital affect investment, the cost of capital itself differs from the standard user cost familiar in the investment literature in several respects.[7] First, the discount rate ρ depends on the riskiness of capital flows, and is not necessarily the same as the rate used to discount depreciation allowances.[8] Second, the term Γ, as defined in expression (2), is based on actual future tax rates rather than the current one. Third, the change in Γ, which represents a change in the effective price of capital goods to the firm, appears as a correction to the discount rate. Finally, the productivity shift parameter θ appears in the denominator of c, putting the cost in terms of a standardized measure of capital services. When capital is relatively unproductive, θ is low and the overall cost of capital is high. This term may be viewed as an alternative to the insertion of output in the investment equation.

It is easy to see how the current model is related to the q theory of investment, since the ratio of the cost of capital to the rate of profit defines the relationship between an asset's replacement cost and its market value.[9] Expression (3) provides a convenient, simple model whose coefficients have a structural interpretation. From it, one can recover estimates of the responsiveness of investment to a deviation in the cost of capital, $(1-\mu_1)/\alpha$, and the discount factor applied to future costs of capital, (μ_2-1), which in turn may be solved for the underlying parameters of the production and adjustment cost functions.

4. Data

This section describes the data to be used in estimating the model derived in the previous section. We work primarily with annual data (for the period 1953-88), because of the difficulty of identifying the correct timing of tax changes at higher frequencies, and investigate separately the behavior of investment in producers' durable equipment and nonresidential structures, which have been subject to quite different tax rules over the period.

A. The required rate of return, ρ

The rate of return ρ is one that the firm should use in discounting its risky after-tax flows, excluding depreciation allowances. Because of the complexity of estimating this, we base our measures on the overall rates of return to debt and equity. Still, there are several issues to be resolved before obtaining a satisfactory measure.

It is logical to use some weighted average of the costs of debt and equity in computing the overall cost of funds for new investment. Calculation of the relevant interest rate is relatively straightforward. Our results below are based on the 4 to 6 month commercial paper rate, multiplied by the factor $(1 - \tau)$ to account for the deductibility of interest payments by business borrowers.

Computation of an equity cost of capital is considerably more difficult, because we do not observe expected rates of return on equity the way we observe interest rates on bonds. There are a variety of possible proxies for the unobservable expected return to equity, and we have considered two in our research. One is the expected earnings-price ratio for the firm, after taxes and corrected for the capital consumption and inventory valuation adjustments. The other is the expected return to equity in the market, equal to the dividend yield plus rate of capital gain on shares. We use these measures as proxies for the unobserved required returns by including them in the cost-of-capital measure on the right-hand side of (3), and correct for the errors-in-variables problem this introduces by estimating the equation using instrumental variables taken from the information set available when the expectations were formed.

Each of the equity-return measures has its drawbacks. The expected earnings-price ratio will be only as accurate as the measurement of corrected firm earnings, while the volatility of capital gains makes the market-based measure extremely unreliable in short samples. Moreover, the relationship of each measure to the underlying required return depends on one's assumptions about the marginal valuation of newly invested equity funds. If such funds come from retained earnings, and the stock market reflects this by capitalizing taxes on distributions into the value of shares, then the earnings-price ratio and, to a lesser extent, the market rate of return, will overstate the firm's cost of equity capital.[10] Although we ignore this complication here, it would be useful to explore the sensitivity of our results to this decision.

In our empirical investigation, we experimented with both definitions. In each case, we formed a weighted average cost of funds using aggregate debt-equity ratios, using these same aggregate weights for equipment and structures.[11] Because the results were generally similar, and our estimates of the effect of the cost of capital on equipment investment were somewhat more robust to specification changes using the capital gain measure, we report only those based on this definition of the equity cost of capital.

B. The productivity of capital, θ

In the models estimated, the term θ/K^{α} may be interpreted as the marginal rate of profit on new capital investment of the type considered. Under the assumption of capital stock homogeneity, we obtain an ex post measure of this by dividing the return to capital, equal to earnings before interest and taxes (EBIT) corrected for the capital consumption and inventory valuation adjustments, by the net capital stock. This procedure assigns the same rates of profit to equipment and structures. While separate measures might be appropriate, it is not clear how one would estimate them given the information available, and further decomposition is left for future research.

C. Other data

We use the methodology described in Auerbach and Hines (1987) to calculate the present value (per dollar of investment) of the tax benefits of investment tax credits and depreciation allowances based on expression (2) above, assuming the tax rate τ to be constant after 1988. (Recall that expression 2 is based on future tax rates.) It is true, of course, that future tax rate changes cannot be known with certainty, but, as with rates of return, our instrumental variables procedure corrects for this.

Data on investment, output, profits and cash flow come from the national income accounts,[12] while capital stock series for equipment and structures come from Musgrave (1989).

5. Empirical Results

Table 1 presents statistics on U.S. nonresidential fixed investment in equipment and structures during the past three decades, expressed in relation to their respective net capital stocks.[13] The patterns of behavior are different for the two investment aggregates. Equipment investment has had two periods of weakness, from the late '50s through the early '60s, and briefly during the early 1980s. Equipment investment was especially strong during the late '60s, and again during the expansion of the late 1970s. Investment in structures, like that in equipment, strengthened in the mid-1960s. However, unlike equipment investment, its performance was relatively weak in the late 1970s and relatively strong in the early 1980s.

Perhaps the most striking difference between the two investment series has been seen during the past few years. While equipment investment has, in each year, exceeded its average of the past three decades, investment in structures has experienced its three lowest annual levels (relative to the capital stock) during the entire period! This divergent behavior of structures and equipment investment supports our decision to consider the empirical behavior of the two series separately.

We begin with our basic estimates of the effects of the cost of capital on investment in structures and equipment, as specified by equation (3) above.

In this model, there are three parameters to be estimated, each of which has an interpretation in terms of the underlying structural model: the constant, the "survival rate", on which the weights of future capital costs are based (corresponding to $1/\mu_2$ in expression (4)), and the coefficient of this summation. The basic results appear in the first column of Table 2 for equipment, and Table 3 for structures.

These and all subsequent equations are estimated using the Generalized Method of Moments (henceforth GMM; see Hansen 1982, Hansen and Singleton 1982).[14] Experiments with the number of leads suggested that once the current and three subsequent annual values of the cost of capital were included, adding further future values did not alter the results. Therefore, we report estimates based on the current and three future values. The results for equipment investment are in general somewhat more satisfactory, and we begin by discussing these.

A. Equipment

In the basic equation for equipment, the estimated survival rate for future values of the cost of capital is .583; each successive year's cost of capital is found to be slightly more than half as important as the previous one. The coefficient on the summed current and future capital costs is a significant -.253, while the constant is .218 and also significant. Thus, the cost of capital does affect investment, and the impact of future values conforms in a general way to one's expectations.

To interpret these coefficients, we note from (3) that the constant should equal $(1-\mu_1)/\alpha + n + \bar{\delta}$, while the coefficient of the cost of capital should equal $[(1-\mu_1)/\alpha]/c_K^*$. Using the average value of c for our sample period of approximately .21, the implied value of $(1-\mu_1)/\alpha$, the responsiveness of the investment-capital ratio to a proportional change in the cost of capital, implied by the coefficient on the cost of capital is .053.

Combination of this value and the mean depreciation rate for equipment calculated by Auerbach and Hines (1987), $\bar{\delta} = .137$, yields from the constant an implied growth rate of n = .028, close to the actual growth rate of net investment of.039 over the estimation period 1956-88. Hence, the coefficients are internally consistent, in that they easily pass a test of the overidentifying restriction on the constant that n = .039.

The coefficient of the cost of capital itself suggests that a permanent increase of one percentage point in the cost of capital (roughly the magnitude of change associated with a 10 percent investment tax credit) will initially reduce the ratio of investment to capital by .253 percentage points, or roughly 1.5 percent of gross investment (at the sample average investment-capital ratio of .170). This is not a particularly large response in light of the previous literature relating investment to the cost of capital directly.[15]

It is also possible, using expression (A8) in Appendix A, to translate estimates of the cost-of-capital coefficient and the survival rate into estimates of the scale parameter α and the slope of the adjustment cost function C(•). However, the implied estimate for α based on column 1 falls above the feasible interval of [0,1] and, while estimated imprecisely, allows us to reject the hypothesis that $\alpha = 0$, the value consistant with the constant-returns-to-scale/perfect-competition assumption made by many studies. As discussed in Appendix A, if $\alpha = 0$, the survival rate $1/\mu_2 = 1/(1 + \rho + \bar{\delta})$. For equipment, our sample value of $\rho + \bar{\delta} = .18$, implying a survival rate of .85 at $\alpha = 0$; this value exceeds the estimated rate, .58, by a statistically significant amount. Some, but not all, of the other estimates in the table permit a rejection of $\alpha = 0$.[16] The clearest exception, discussed below, is given in column 4.

Given our inability to estimate α precisely, it is still interesting to consider the structural implications of the model by reestimating it with a range of feasible values of α imposed. When we constrain α to equal 0 (by fixing the survival rate at .85), the coefficient of the cost of capital rises slightly to -.315, implying that the term $(1-\mu_1)/\alpha$ rises from .053 to .066. When $\alpha = 0$, this term is comparable to those obtained from regressions of the investment-capital ratio on Tobin's q (the term $1/\psi$ defined in Appendix A), essentially the inverse of the quadratic adjustment cost parameter that appears in the q-model. For the other extreme value, $\alpha = 1$ (imposed through a nonlinear restriction on the cost-of-capital coefficient and the survival rate) the implied survival rate is .80 and the coefficient on the cost of capital is virtually the same as for $\alpha = 0$, -.313, and hence, again, the implied value of $(1-\mu_1)/\alpha = .066$. However, for the assumed value of $\alpha = 1$, this term translates into a higher implied value of the underlying structural parameter $(1/\psi) = .090$.

This range for $(1/\psi)$ of .066 to .090 is considerably larger than estimates typically found in the literature studying aggregate investment (e.g. Summers 1981, whose preferred point estimate was .031), implying lower adjustment costs. However, as we are considering only equipment investment here, and as the adjustment costs implied by the structures regressions presented below are much higher, the finding of lower adjustment costs is not necessarily at variance with past work.

Thus, our basic equation for equipment is in general accord with previous research on investment. However, we also share with past work the finding of positive serial correlation. The Durbin-Watson statistic of 1.32 suggests that there may be a problem of omitted explanatory variables. Therefore, we turn to alternative specifications.[17]

One possible term to include is the cost of capital for the "other" type of capital good, in this case structures. Although our specification has assumed separate investment processes, this may not be valid. The ability to substitute structures for equipment in production would dictate inclusion of both costs of capital.[18] Doing so produces the results in the second column of Table 2. The coefficient and implied survival rate of the distributed lead on future structures capital costs are both quite reasonable. However, neither is significant and the standard error of the equipment cost of capital rises, possibly reflecting multicollinearity.

The results to this point do indicate a significant role for the cost of capital, based on current and future conditions, in affecting investment. However, they do not necessarily indicate that the tax components of the cost of capital are themselves important; we have imposed the condition that such components affect investment through the cost of capital term. To test the validity of this assumption, we present estimates, in columns 3 and 4 of Table 2, based on splitting taxes out of the cost of capital. Because of the difficulty of estimating the decay rate for the influence of future costs of capital with several future variables in the equation, we choose a common survival rate for the components.

In column 3, we add the cost of capital, without taxes, to the basic model. Our theory predicts that this term should have a coefficient of zero. However, while the coefficient on the full cost of capital is still significant, so is the cost of capital without taxes. This suggests that nontax determinants of the cost of capital may have stronger effects than tax factors. Another possible explanation may be that it is relatively difficult to predict the tax terms using our instruments. We evaluate this interpretation in column 4, estimating the impact of taxes by putting the no-tax cost of capital in the equation along with the actual, ex post tax terms. While this avoids the problem of inadequate instruments, under the assumption of rational expectations these ex post terms should be distributed with error around the true expected values; hence (as discussed by Garber and Klepper 1980), at least one of their coefficients should be biased toward zero.

In fact, both coefficients have the correct sign. While neither is quite significant, each coefficient has a size relative to the one on the no-tax cost of capital itself that is extremely close to what theory would predict[19], and the hypothesis that they are exactly so is easily accepted. It is also interesting to note that the Durbin-Watson statistic is somewhat higher than in the original specification and the estimated survival rate is essentially that predicted by the constant-returns/perfect-competition assumption of α = 0, .85. These results, and those of the previous specification, suggest that tax factors do indeed play an independent role in affecting the path of investment.

One of the differences between the current cost of capital measure and those used in the past is the explicit account taken of expected policy changes. As an additional test of the importance of tax policy effects, we consider the performance of our cost of capital measure relative to a more traditional one based on the assumption of an unchanging tax law, which we refer to in the table as the myopic cost of capital. When both terms are entered at the same time, in column 5, each is significant.[20] However, the coefficient on the forward-looking cost of capital is about twice as large, suggesting (since the units of the two variables are the same) that it is a better measure.

All of the estimates to this point have preserved the model's assumption of perfect capital markets. Recent work has focused on interpreting the failure of past models by incorporating market imperfections in the form of imperfect credit markets into models of firm investment. Fazzari et al (1988), for example, show that under certain well specified conditions, a firm's cash flow may be expected to appear in the investment equation. They find that there is interesting cross-sectional variation in the importance of cash for determining investment.[21] In particular, firms which on a priori grounds might be expected more likely to face borrowing constraints were found to alter their investment much more in response to changes in cash flow than large firms, which probably do not face credit constraints.

The sixth column of Table 2 adds cash flow to the basic equation. This variable exerts a significant effect on investment, with a coefficient of .098. Its inclusion reduces the size of the constant term and slightly increases the coefficient of the cost of capital. One possible interpretation of the coefficient of cash flow is that it tells us the fraction of assets held by liquidity-constrained firms, for which marginal investment finance is completely limited to internal funds. For such firms, the coefficient on cash flow should be 1; for other firms, it should be zero. Likewise, the coefficient on the cost of capital should be nonzero only for unconstrained firms. Given this interpretation, roughly 10 percent of equipment investment is by constrained firms and the coefficient on the cost of capital for the remaining group is roughly 10 percent larger than that of the previous specification.

If cash-flow affects investment because of the liquidity it provides, then the tax and nontax components of cash flow should exert equal effects on investment. However, if cash flow appears to influence investment because it is correlated with some other determinant of investment omitted from the equation, there is no reason that tax payments should have the same impact. To distinguish between these two situations, we add to equation 6 the ratio of gross cash flow to capital, equal to the net cash flow variable with tax payments added back. This new variable should have a zero coefficient if tax and nontax components of cash flow exert the same impact on investment.

The results, in column 7, offer some support for the liquidity-constraints interpretation of the cash-flow term, in that the coefficient of gross cash flow is insignificant. However, the point estimate for net cash flow is considerably changed and its large standard error suggests that gross and net cash flow may be too closely correlated for this experiment to have much power.

None of the equations for equipment investment succeed in completely eliminating the serial correlation present in the original specification, and one might be tempted to conclude that this suggests remaining model misspecification. An alternative explanation lies not in misspecification but in the fact that the predicted value of the cost of capital that enters into the investment equation, while unbiased, may be subject to serially correlated prediction error. Since the prediction errors of the future costs of capital will be incorporated in the error term of the final stage of estimation, serial correlated errors in predicting the cost of capital lead to serial correlation of the error term in the investment equation.

To summarize our findings for equipment, the cost of capital, augmented to include variations in productivity and based on future expected values of tax and nontax variables, has a significant impact on investment. However, previous indications that cash flow may also affect investment appear to be corroborated, at least in some specifications.[22]

B. Structures

As already indicated, the equations estimated for structures are somewhat less satisfactory than those reported for equipment. The Durbin-Watson statistics are lower, indicating greater serial correlation than can be explained by serially correlated errors in predicting the cost of capital itself. Moreover, the survival rate of future costs of capital often had to be constrained to lie below 1.0. Part of this latter problem, however, may be associated with the greater durability of structures and the fact that future capital costs **should** matter more than they do for equipment.[23] Because of the difficulty of estimating the survival rate of future costs of capital, we employ a grid search technique, varying this parameter from .05 to .95 by increments of .05, choosing the value that minimizes the sum of squared residuals or, in the case that a local minimum is not reached, the boundary value with the lower sum.

Despite these estimation problems, the signs of the cost of capital and its components are generally the same as in the case of equipment and the tests of the separate importance of the forward-looking cost of capital supportive. The first column of Table 3 reports the results for the basic model specification. The cost of capital has a smaller coefficient than was true for equipment, implying that adjustment costs are much higher.[24]

Equations 2 through 4, reporting the effects of including the equipment cost of capital and the separate tax terms of the structures cost of capital, provide results similar to those found in the case of equipment. The cross-effect of the equipment cost of capital (column 2) has the "correct" sign, is marginally significant and has an estimated survival rate similar to those given in Table 2. Including the "no-tax" cost of capital (column 3) actually increases the explanatory power and size of the coefficient of the theoretically correct term, while the new term is insignificant and has the wrong sign. Addition of the <u>ex post</u> tax terms (column 4) does not lead to fully satisfactory results. Neither of the tax terms is significant (one has the wrong sign), and the remaining component of the cost of capital also has an insignificant coefficient. Column 5 repeats the experiment of including both myopic and forward-looking costs of capital, finding once again that the forward-looking version remains significant and is more important than the myopic cost of capital, which is insignificant.

As was true in the case of equipment, the addition of cash flow to the equation, in column 6, introduces a significant variable and also raises the coefficient on the cost of capital. For structures, the coefficient of cash flow is considerably higher than for equipment, suggesting, under the liquidity-constraints interpretation, that a higher proportion of the structures capital stock is held by firms facing capital market constraints. However, when gross cash flow is added to the equation (column 7), it, rather than net cash flow, is significant, a result that is not in accord with the liquidity-constraints interpretation.

5. Stabilization Policy

The results in Tables 2 and 3 suggest that taxation has played a role in influencing investment behavior in the United States. It is important to know whether this influence has been a stabilizing one.[25] Equation (3) indicates that the more unstable the forward sum of capital costs, the more unstable is investment. Hence, a naive approach would be to see how the standard deviation of the fitted values of this forward sum are influenced by the presence of taxes.

For equipment, the fitted aggregate cost of capital term has a slightly higher standard deviation (.049 versus .047) than the fitted value of the same term with taxes omitted. For structures, we find that tax policy has reduced the standard deviation of the cost of capital (.039 with taxes versus .040 without taxes). If we take the difference between these two series as the effect of tax policy on investment, then it follows that tax policy has destabilized equipment investment slightly over the postwar period, although the outcome of this experiment is sensitive to the set of instruments chosen for the prediction of future terms in the cost of capital.

This interpretation has several limitations. One is the usual uncertainty about which model specification is most appropriate. Another is the fact that general equilibrium effects make it difficult to compute the correct "counterfactual" cost of capital that would have prevailed in the absence of taxes. This is something for which we cannot control without resorting to a full general equilibrium model.

There are also two statistical problems with the naive approach of comparing the variability of the fitted costs of capital. As discussed above, we cannot directly observe the <u>ex ante</u> cost of capital, only an asymptotically unbiased estimate of this. Thus, the true cost of capital is distributed with error around the value fitted using instrumental variables. It is not possible to draw any firm conclusions about relative variance of capital costs without knowing the relationship of the "true" cost of capital to our fitted value. Second, through the action of policy makers, some of the variations in the cost of capital could be acting to offset other shocks to investment anticipated by policy-makers[26].

These "fine-tuning" policy changes would probably be eliminated by our procedure of using doubly-lagged instruments in fitting the <u>ex ante</u> cost of capital. However, while this estimation procedure eliminates the problem of potential inconsistency if the true cost of capital is not independent of the stochastic shock in the investment equation, it also means that we mismeasure the impact of the cost of capital on the variance of investment by ignoring the purged countercyclical tax policy reaction.

In Appendix B, we derive upper and lower bounds for the effects of tax policy on the variance of the investment-capital ratio that take account of these two statistical problems. When these problems are absent, the bounds reduce to a single measure based on the variance of the fitted cost of capital. For the basic model given in column 1 of Tables 2 and 3, in which the cost of capital is the only determinant of investment, the estimated impact of tax policy on the variance of the dependent variable, the investment-capital ratio is (from expression (B6)):

$$(9)\quad \Delta = \beta^2\,[V(\bar{c}+\bar{\tau}) - V(\bar{c})] + X$$

where $-\beta$ is the coefficient of the cost of capital in the regression, $\tilde{c}+\tilde{\tau}$ is the fitted value of the cost of capital, including tax effects and $\tilde{c}$ is the corresponding value with taxes set equal to zero. The term X represents the correction factor just discussed, and equals (from (B11)):

$$(10) \quad X = 2\beta\, C[I-\hat{I},\ \bar{\tau}-\tilde{\tau}] - \beta^2 V(\tau-\tilde{\tau})$$

where $\hat{I}$ is the fitted value of the dependent variables (based on $\tilde{c}+\tilde{\tau}$), $\bar{\tau}$ is the ex post value of the tax component of the cost of capital, and τ is the "true" tax component of the cost of capital, i.e. the value expected by investors.

Each of the terms in expression (10) has an intuitive interpretation in terms of the statistical problems discussed. The first term is based on the covariance of residuals from the equations explaining investment and the tax component of the cost of capital. If tax policy depends on the contemporaneous shock to investment, this covariance will be nonzero. The second term that appears in (10) corrects for the difference between the true tax effect in the cost of capital and the effect estimated by the econometrician. However, since τ is unobservable, we can only establish bounds on this latter term based on the alternative extreme assumptions that $\tau = \bar{\tau}$ (i.e., investors have perfect foresight) and $\tau = \tilde{\tau}$ (i.e., the econometrician makes no error). This yields the alternative estimates of X (from expression (B12)):

$$(11a) \quad \underline{X} = 2\beta\, c[I-\hat{I},\ \bar{\tau} - \tilde{\tau}] - \beta^2\, v(\bar{\tau}-\tilde{\tau})$$

$$(11b) \quad \bar{X} = 2\beta\, c[I-\hat{I},\ \bar{\tau} - \tilde{\tau}]$$

Table 4 presents illustrative estimates[27] of the stabilization effect Δ and its components for the basic investment model normalized by the variance of investment. Our results are consistent with the view that tax policy has had little stabilizing effect on investment. The total effect on equipment investment is between .064 and .481, suggesting that the net effect has been destabilizing. For structures the range is much smaller, suggesting that the net effect is between .060 and .112, consistent with the previous findings that tax effects on structures investment are not as large.

In each case, the correction term X is more important than the "naive" effect itself, confirming the relevance of the correction for contemporaneous correlation of shocks to tax policy and shocks to investment. The direction of this additional effect is **away** from stabilization in each case, suggesting that contemporaneous tax policy changes have increased the volatility of investment. However, some caution is necessary with respect to this interpretation. What we have actually estimated are the effects of changes in **expected** tax policy on investment. If, for example, the government announced a future tax cut during a period of low investment, but investors expected taxes to rise, the effect of expected policy would be a further drop in investment.[28]

6. Conclusions

The model estimated in this paper incorporates expected fluctuations in productivity and taxes in a comprehensive measure of the user cost of capital. This term is successful in explaining the level of investment in both equipment and structures. Tests of the specification show taxes playing a clear role, rather than simply having one attributed by assumption. In this sense, the results represent a victory for the hypothesis that tax factors, properly specified, do influence investment.

However, as many recent studies have found, cash flow seems also to influence investment, and our underlying theoretical model does not offer a precise interpretation of this effect. In ongoing research, we are attempting to clarify the role of cash flow in affecting investment by examining the behavior of individual firms with different degrees of access to capital markets. While such experiments have already been performed in the past, we would find it useful to reconsider the past results in light of the success of this paper's cost of capital specification.

Applying our methodology for measuring the impact of tax policy on investment variability suggests policy has not stabilized investment, but further work is needed to explore the alternative channels through which tax policy affects investment behavior before any definitive conclusions may be drawn.

Table 1

U.S. Investment Behavior

(Relative to Capital Stock)

Year	Equipment	Structures
1957	0.163	0.098
1958	0.134	0.088
1959	0.147	0.087
1960	0.147	0.090
1961	0.139	0.088
1962	0.151	0.090
1963	0.157	0.087
1964	0.172	0.091
1965	0.193	0.102
1966	0.205	0.103
1967	0.187	0.096
1968	0.185	0.095
1969	0.186	0.096
1970	0.171	0.090
1971	0.161	0.084
1972	0.172	0.084
1973	0.195	0.087
1974	0.185	0.083
1975	0.154	0.072
1976	0.156	0.071
1977	0.176	0.073
1978	0.189	0.079
1979	0.190	0.085
1980	0.168	0.086
1981	0.164	0.091
1982	0.143	0.085
1983	0.148	0.074
1984	0.176	0.082
1985	0.183	0.083
1986	0.175	0.070
1987	0.177	0.067
1988	0.190	0.067
Mean	0.170	0.085

Table 2

Estimates - Equipment

Independent Variable	Specification (1)	(2)	(3)	(4)	(5)	(6)	(7)
constant	.218 (21.83)	.204 (15.25)	.232 (20.12)	.319 (4.81)	.211 (22.74)	.191 (10.87)	.149 (4.40)
cost of capital	-.253 (-5.37)	-.210 (-2.97)	-.177 (-3.89)	---	-.144 (-2.54)	-.256 (-4.78)	-.224 (-4.49)
survival rate, c-of-c	.583 (7.04)	.440 (2.23)	.569 (6.07)	.822 (5.83)	.65*	.583 (6.52)	.521 (4.02)
structures c-of-c	---	.076 (0.60)	---	---	---	---	---
survival rate struc. c-of-c	---	.619 (0.98)	---	---	---	---	---
c-of-c without taxes	---	---	-.158 (-2.30)	-.365 (-5.49)	---	---	---
$(1-\Gamma)/(1-\tau)$	---	---	---	-.072 (-1.66)	---	---	---
$\Delta(1-\Gamma)/(1-\tau)$	---	---	---	.250 (1.99)	---	---	---
c-of-c, myopic	---	---	---	---	-.077 (-2.75)	---	---
cash flow, net	---	---	---	---	---	.098 (2.98)	.756 (1.93)
cash flow, gross	---	---	---	---	---	---	-.400 (-1.70)
Durbin-Watson statistic	1.32	1.42	0.65	1.47	1.58	1.32	1.42
χ^2 p-value	.95	.97	.96	.99	.95	.99	.99

*fixed by grid-search procedure, described in text

Note: t-statistics are in parentheses.

Table 3

Estimates - Structures

Independent Variable	Specification (1)	(2)	(3)	(4)	(5)	(6)	(7)
constant	.090 (36.63)	.081 (13.97)	.092 (42.91)	.051 (1.25)	.091 (30.60)	.022 (0.89)	.036 (1.81)
cost of capital	-.045 (-2.34)	-.048 (-3.43)	-.111 (-2.23)	---	-.041 (-2.11)	-.111 (-4.04)	-.007 (-0.09)
survival rate, c-of-c	.95*	.95*	.85*	.85*	.90*	.95*	.95*
equipment c-of-c	---	.045 (1.79)	---	---	---	---	---
survival rate equip. c-of-c	---	.50*	---	---	---	---	---
c-of-c without taxes	---	---	.041 (0.30)	-.133 (-1.40)	---	---	---
$(1-\Gamma)/(1-\tau)$	---	---	---	.028 (1.19)	---	---	---
$\Delta(1-\Gamma)/(1-\tau)$	---	---	---	.214 (1.50)	---	---	---
c-of-c, myopic	---	---	---	---	-.010 (-0.52)	---	---
cash flow, net	---	---	---	---	---	.353 (3.00)	-.142 (-0.95)
cash flow, gross	---	---	---	---	---	---	.293 (4.59)
Durbin-Watson statistic	.47	.85	.62	.73	.43	.88	.77
χ^2 p-value	.92	.96	.96	.99	.94	.97	.97

*fixed by grid-search procedure, described in text

Note: t-statistics are in parentheses

Table 4

The Stabilizing Effects of Tax Policy

	Equipment	Structures
Effects of Taxes on the Variance of Investment:		
naive effect (Δ)	.047	-.003
cost of capital correction (X):		
$\underline{X}$	.017	.063
$\bar{X}$	.437	.115
Total:		
lower bound	.064	.060
upper bound	.481	.112

References

Abel, Andrew B., 1983, Optimal investment under uncertainty, American Economic Review 73, 228-33.

Abel, Andrew B. and Olivier Blanchard, 1986, The present value of profits and cyclical movements in investment, Econometrica 54, 249-73.

Auerbach, Alan J., 1983, Taxation, corporate financial policy and the cost of capital, Journal of Economic Literature 21, 905-40.

Auerbach, Alan J., 1985, Real determinants of corporate leverage, in B. Friedman, ed., Corporate Capital Structures in the United States (University of Chicago Press, Chicago), 301-22.

Auerbach, Alan J., 1989, Tax reform and adjustment costs: the impact on investment and market value, International Economic Review 30, 939-62.

Auerbach, Alan J. and James Hines, 1987, Anticipated tax changes and the timing of investment, in M. Feldstein, ed., The Effects of Taxation on Capital Accumulation (University of Chicago Press, Chicago), 163-96.

Auerbach, Alan J. and James Hines, 1988, Investment tax incentives and frequent tax reforms, American Economic Review 78, 211-6.

Bernanke, Ben, Henning Bohn and Peter Reiss, 1988, Alternative non-nested specification tests of time series investment models, Journal of Econometrics 37, 1-38.

Fazzari, Steven M., R. Glenn Hubbard, and Bruce C. Peterson, 1988, Financing constraints and corporate investment, Brookings Papers on Economic Activity 19, 141-95.

Feldstein, Martin, 1982, Inflation, tax rules and investment: some econometric evidence, Econometrica 50, 825-62.

Garber, Steven and Steven Klepper, 1980, Extending the classical normal errors-in-variables model, Econometrica 48, 1541-6.

Goldfeld, Steven, and Alan Blinder, 1972, Some implications of endogenous stabilization policy, Brookings Papers on Economic Activity 3, 585-640.

Hall, Robert E., 1989, Invariance properties and Solow's Productivity Residual, NBER Working Paper #3034.

Hall, Robert E. and Dale W. Jorgenson, 1967, Tax policy and investment behavior, American Economic Review 57, 391-414.

Hansen, Lars P., 1982, Large sample properties of generalized method of moments estimators, Econometrica 50, 1029-54.

Hansen, Lars P. and Kenneth J. Singleton, 1982, Generalized instrumental variables estimation of nonlinear rational expectations models, Econometrica 50, 1269-86.

Hayashi, Fumio, 1982, Tobin's marginal and average q: a neoclassical interpretation, Econometrica 50, 213-24.

Hoshi, Takeo, Anil Kashyap and David Scharfstein, 1989, Corporate structure, liquidity, and investment: evidence from Japanese panel data, Federal Reserve Board of Governors working paper.

Musgrave, John C., 1989, Fixed reproducible tangible wealth in the United States 1985-8, Survey of Current Business 69, 89-92.

Newey, Whitney K. and Kenneth D. West, 1987, A simple positive definite heteroskedasticity and autocorrelation consistent covariance matrix, Econometrica 55, 703-8.

Pindyck, Robert and Julio Rotemberg, 1983, Dynamic factor demands and the effects of energy price shocks, American Economic Review 73, 1066-79.

Shapiro, Matthew, 1986, The dynamic demand for capital and labor, Quarterly Journal of Economics 101, 513-41.

Solow, Robert and John Kareken, 1963, Lags in monetary policy, in A. Ando et al, Stabilization Policy (Prentice-Hall, Englewood Cliffs), 14-96.

Summers, Lawrence, 1981, Taxation and corporate investment: a q-theory approach, Brookings Papers on Economic Activity 12, 67-127.

Taylor, John B., 1982, The Swedish investment funds system as a stabilization policy rule, Brookings Papers on Economic Activity 13, 57-99.

Appendix A: The Model

This appendix sketches the derivation of the paper's model of investment behavior, following Auerbach (1989) and Auerbach and Hines (1988).

Assume the firm has a production function in capital, $F_t(\cdot)$, subject to stochastic shocks, and that depreciation δ_t is also uncertain, with $E(\delta) = \bar{\delta}$. As will be discussed below, the function $F(\cdot)$ may also be interpreted as a profit function of K alone derived from a multi-factor production function by setting variable factors to their optimal levels. For simplicity, let the relative price of capital goods, g, the risk-free rate of return r, and ρ, the firm's required rate of return, be known with certainty. Normally, $\rho > r$, reflecting the riskiness of the firm's net cash flows. (For ease of exposition alone, we will also assume these variables to be constant. This assumption is not made in the empirical section of the paper.) The full unit cost of acquiring investment goods is $g\, C_s(I_s)$, where $C_s(\cdot)$ is some convex function reflecting costs of adjustment.

The firm's objective is to maximize its market value,

$$\text{(A1)} \quad W_t = E_t\left\{ \sum_{s=t}^{\infty} (1+\rho)^{-(s-t)} \left[\frac{(1-\tau_s)\, F_s\, (K_s)}{(1+r)} - g\, C_s\, (I_s) I_s (1-\Gamma_s) \right] + A_t \right\}$$

where $E(\cdot)$ is the expectations operator, τ_s is the corporate tax rate at date s, Γ_s is the present value of tax savings from investment credits (k) and depreciation allowances (D) per dollar of investment:

$$\text{(A2)} \quad \Gamma_s = k_s + \sum_{z=s}^{\infty} (1+r)^{-(z-s)}\, \tau_z D_{z-s}$$

and A_t is the present value of tax savings from depreciation allowances on investment made before date t. Note that Γ_s depends on tax rates at $z>s$.

We assume that, at each date t, the current tax rate τ is known but that future tax rates (and hence Γ_t), the depreciation rate δ_t and the productivity shock to F are unknown. We will further assume that δ is i.i.d. with mean $\bar{\delta}$ and independent of tax policy and that the cost function $C(\cdot)$ is such that the desired capital stock K_{t+1} (and hence q_{t+1}) does not depend on δ_t. With these assumptions, (A1) yields an Euler equation with respect to I_t which, for short time periods, is approximated by:

$$\text{(A3)} \qquad 0 = -q_t(1-E_t(\Gamma_t))(1+\rho+\bar{\delta}) + (1-\tau_t)E_t(F'(K_t)) + E_t[q_{t+1}(1-\Gamma_{t+1})]$$

Since q is a function of I, which in turn is related by identity to the change in K, (A3) is a nonlinear stochastic difference equation in K. It is sometimes possible to obtain a solution to such an equation for specific stochastic processes and functional forms for $C(\cdot)$ and $F(\cdot)$ (e.g. Abel 1983). To allow somewhat greater generality, we choose instead to approximate the optimal solution for small perturbations by solving a linearized version of (A3). Even with this restriction, it is still necessary to impose some structure on the functions $C(\cdot)$ and $F(\cdot)$.

We consider the case in which the economy has an underlying trend growth rate of n, the production function is subject to multiplicative shocks, and the adjustment cost function is linear in K and I. That is, we assume that:

$$\text{(A4)} \qquad F_s(K) = \theta_s G_s(K) = \theta_s(1+n)^s G(K/(1+n)^s)$$

(where θ is normalized to have an unconditional expectation of 1 but may be serially correlated) and:

$$\text{(A5)} \qquad C_s(I_s) = 1 - (n+\delta_s)\phi \frac{K_s}{(1+n)^s} + {}^1/_2\phi \frac{I_s}{(1+n)^s}$$

Expression (A4) implies that, given θ, the marginal product of capital is constant over time if capital grows at rate n. Expression (A5) implies that $q_s = g(1+\phi(K_s - K_{s-1}/(1+n))/(1+n)^s)$, i.e., that Tobin's q, here q/g, equals 1 at trend growth.

To solve the model, we linearize around a deterministic "long run" in which $\theta = 1$ and tax policy is constant, which together imply that the capital stock will grow at rate n. After considerable algebra, the resulting optimal decision rule may be written:

$$\text{(A6)} \qquad \frac{I_t}{K_{t-1}} = -(1-\mu_1-n-\delta_t) + (1-\mu_1)\, H\left[\frac{E_t \sum_{s\geq t} w_{s-t}\, c_s}{K_{t-1}}\right]$$

where $H(\cdot) = G'^{-1}(\cdot)$,

$$\text{(A7)} \qquad w_{s-t} = (\mu_2 - 1)\, \mu_2^{-(s-t+1)} \quad ; \quad \sum_{s\geq t} w_{s-t} = 1$$

$\mu_2 > 1 > \mu_1$, are the roots of the linearized difference equation[29]:

$$\text{(A8)} \qquad \mu_i = 1 + .5 \cdot \left\{(\rho + \bar{\delta})\cdot(1 + \frac{\alpha}{\psi}) \pm \left[[(\rho + \bar{\delta})\cdot(1 + \frac{\alpha}{\psi})]^2 + \frac{4i\alpha}{\psi}\right]^{.5}\right\}$$

where $\psi = \phi K^*$ (expressing the adjustment cost term ϕ in units of the ratio of investment to the detrended steady state capital stock K^*) and

$$\text{(A9)} \qquad c_s = \frac{g(1-\Gamma_s)(\rho + \bar{\delta}) - [g(1-\Gamma_{s+1}) - g(1-\Gamma_s)]}{(1-\tau_s)\theta_s}$$

is a measure of the user cost of capital incorporating the productivity shock θ. One may interpret the decision rule (A6) as calling for the partial adjustment of investment toward a desired capital stock based on a weighted average of expected current and future use costs of capital.

One could, in principle, estimate equation (A6) directly. However, to further simplify the investment equation (and, as explained below, the calculation of θ), we assume at this point that the function G(•) takes the simple Cobb-Douglas form, $G_s(K) = A_s K^{1-\alpha}$. Linearization of (A6) then yields

$$\text{(A10)} \qquad \frac{I_t}{K_{t-1}} = \left[\left(\frac{1-\mu_1}{\alpha}\right) + n + \delta_t \right] - \left(\frac{1-\mu_1}{\alpha c_K^*}\right) \cdot E_t \sum_{s\geq t} w_{s-t}\, c_s\, K_{t-1}^{\alpha}.$$

where $c_K^* = c^* K^{*\alpha}$ is the steady state value of the summation.

Given c_K^*, the reduced form coefficients in (A10) provide estimates of the ratio $(1-\mu_1)/\alpha$, the sum $(n+\bar{\delta})$ and (see A7) the discount rate applied to future costs of capital, (μ_2-1). Although the expressions for μ_1 and μ_2 are complicated, one may show that each root approaches 1 as adjustment costs rise, making the speed of adjustment, $(1-\mu_1)/\alpha$, and the discount rate (μ_2-1) smaller. On the other hand, a fall in capital's durability (i.e., a rise in $\bar{\delta}$), reduces the importance of future capital costs. As α decreases, the speed of adjustment increases. As α approaches its minimum feasible value of 0 (which, as discussed below, is consistent with the assumption of constant returns to scale and price-taking behavior), the speed of adjustment $(1-\mu_1)/\alpha$ approaches $1/\psi$, the inverse of the proportional adjustment cost term (and the interpretation of the coefficient in regressions of the investment-capital ratio on Tobin's q; see Summers 1981), and the discount rate applied to future capital costs, (μ_2-1), approaches $(\rho + \bar{\delta})$.

Expression (A10) forms the basis for our estimation in this paper. To proceed, however, we need to estimate the cost of capital terms c_s. The estimation of tax variables is straightforward. For the discount rate ρ, we wish, in principle, to measure the discount rate applicable to cash flows, net of tax savings from depreciation. Because of the complexity of deriving such a rate, we simply use overall rates of return to the firm. We estimate these by calculating an <u>ex post</u> rate of return to holders of debt and equity and using an instrumental variables procedure based on instruments in the relevant information set to obtain consistent estimates in of the investment equations.

The final component needed to estimate c is θ. Given the assumption that the shock enters in a multiplicative way, we may express it as the ratio of output to the function $G(\cdot)$, $\theta_s = Y_s/G_s(K_s)$. (A similar approach is taken by Shapiro 1986.) For the Cobb-Douglas specification, $\theta_s = Y_s/A_sK_s^{1-\alpha}$. Since the term K_{t-1}^{α} also appears on the right hand side of (A10), we may combine them to get $\theta_s/K_{t-1}^{\alpha} = Y_s/K_s \cdot (K_s/K_{t-1})^{\alpha}$; i.e., we should divide the traditional user cost, without θ, by some measure of the output-capital ratio, multiplied by a term that may be interpreted as correcting for the fact that θ is meant to reflect underlying productivity, controlling for capital deepening. That is, with decreasing returns, Y/K will decrease with K, given θ. Given that we will be using data for which s and t are separated by at most a few years, this correction term is empirically insignificant and will be omitted from further discussion. As noted below, when there are other factors of production, $F(\cdot)$ may be reinterpreted as a profit function, with variables factors set at their optimal values. Given this interpretation, the ratio F(K)/K is the average rate of return to capital, before tax.

With other, variable factors of production, we simply interpret the function $F(\cdot)$ as a profit function of capital alone, after the optimization decision with respect to labor. For the Cobb-Douglas case, we have:

(A11) $F_t(K) = A_t K^a L_t^{*b} - \left(\frac{w}{p}\right)_t L^*_t$

where L* is chosen optimally. The result is:

(A12) $F_t(K) = A_t^{\frac{1}{1-b}} b^{\frac{b}{1-b}} (1-b) \left(\frac{w}{p}\right)_t^{\frac{-b}{1-b}} K^{\frac{a}{1-b}} = \theta_t K^{1-\alpha}$

where $\alpha = \frac{1 - (a+b)}{1 - b}$

Thus, capital's exponent $1-\alpha < 1$ if the underlying production function in capital and labor exhibits decreasing returns. However, this result is based on the assumption of perfect competition. Recent evidence (e.g. Hall 1989), suggests a considerable mark-up of price over marginal cost in the United States, which may be rationalized as necessary to permit a zero-profit equilibrium in the presence of increasing returns to scale.

The model is easily adapted for a particular case of imperfect competition, monopolistic competition, where firms do not collude but face downward-sloping demand curves. In this case, the profit function F(•) must include an explicit expression for the price of output. For example, suppose demand is isoelastic, of the form $p_t = BY_t^{-\frac{1}{\lambda}}$ (λ being the price elasticity of demand). Then, using the two factor example just discussed, we obtain:

(A13) $F_t(K) = \theta_t K^{1-\alpha}$

where $\alpha = \dfrac{1 - \left(a + b\right)\left(1 - \frac{1}{\lambda}\right)}{1 - b\left(1 - \frac{1}{\lambda}\right)}$

Appendix B: Estimating the Effects of Stabilization Policy

In models where an expected future tax rate affects investment behavior, we must account for two factors in evaluating the success of stabilization policy, we must account for two factors; first, the expected tax rate may be correlated with the contemporaneous shock to investment, if policy reacts to shocks to the investment process. Second, our estimated costs of capital are not the true expected value.

Suppose that investment behavior follows the process

(B1) $I_t = \alpha + \beta\ (c_t + \tau_t) + \epsilon_t + \nu_t$

where c is the cost of capital in the absence of taxes and $c + \tau$ the cost of capital in the presence of taxes. The terms ϵ and ν are stochastic shocks, with ϵ observable to policy-makers. Let tax policy be determined by the rule:

(B2) $\tau_t = \gamma z_t + \zeta c_t + \omega \epsilon_t + \eta_t$

where η us another stochastic term and z is a vector of additional determinants of tax policy (budget deficit, unemployment rate, etc.). Expression (B2) says that tax policy is affected by the no-tax cost of capital (interest rates, profitability, etc.) as well as the current shock to investment, ϵ (which may be serially correlated). To stabilize investment, one would want both ζ to be negative and ω positive.

Note that because τ is the expected effective tax burden on new investment, (B2) is not really a policy rule, but a relationship characterizing the determination of expected tax policy. Presumably, this will incorporate not only announced policy changes, but anticipated ones as well.

In estimating equation (B1) consistently, we use an instrumental variables procedure, starting from <u>ex post</u> observed values of c and τ, say $\bar{c}$ and $\bar{\tau}$. For convenience, define Ω to satisfy:

(B3) $\bar{\tau} = \tau + \Omega$

where $C(\tau,\Omega)=0$. The doubly-lagged instruments are independent not only of Ω, since they are in the date t information set, but are also assumed to be independent of the shock term, ε_t. That is, ε_t is assumed to be unpredictable with the set of instruments. Thus, even though the true expectation τ is correlated with ε, the projection of τ on the instrument set, say $\bar{\tau}$, is independent of ε. The same is true of the projection of c, $\bar{c}$, even if $C(c,\varepsilon)\neq 0$. Hence, the IV estimates of α and β will be consistent. Let these estimates be denoted $\hat{\alpha}$ and $\hat{\beta}$. Also, note that (B2) implies that $\bar{c}$ and $\bar{\tau}$ are related by:

(B4) $\bar{\tau}_t = \gamma z_t + \zeta \bar{c}_t$

To measure the stabilizing effects of tax policy, we wish to measure the change in variance of I due to tax policy, or

(B5) $$\begin{aligned}\Delta = V(I) - (V|\tau=0) &= V[\alpha + \beta(c+\tau) + \varepsilon + \nu] - V[\alpha+\beta c + \varepsilon + \nu] \\ &= \beta^2\ V(c+\tau) + 2\beta C(\tau,\varepsilon) - \beta^2\ V(c) \\ &= \beta^2\ V(\bar{c} + (c-\bar{c}) + \bar{\tau} + (\tau-\bar{\tau})) + 2\beta C(\tau,\varepsilon) - \beta^2 V(\bar{c}+(c-\bar{c}))\end{aligned}$$

which, given the independence of $\bar{c}$ and $\bar{\tau}$ from the stochastic terms $(c-\bar{c})$, $(\tau-\bar{\tau})$ and ε, yields:

(B6) $$\begin{aligned}\Delta &= \beta^2\ [V(\bar{c}+\bar{\tau}) - V(\bar{c})] + 2\beta^2 C[(c-\bar{c}),(\tau-\bar{\tau})] + \beta^2\ V(\tau-\bar{\tau}) + 2\beta C(\tau-\bar{\tau},\varepsilon) \\ &= \beta^2\ [V(\bar{c}+\bar{\tau}) - V(\bar{c})] + X\end{aligned}$$

To estimate the first term in Δ, we simply multiply $\hat{\beta}^2$ by the difference in the variances of $\tilde{c} + \tilde{\tau}$. This is the "naive" approach we discussed first in the text, incomplete because $(c,\tau) \neq (\tilde{c},\tilde{\tau})$ and because $C(\tau,\varepsilon) \neq 0$.

To estimate the term X, let $\hat{I}$ be the fitted value of investment:

(B7) $\hat{I} = \hat{\alpha} + \hat{\beta}\,(\tilde{c}+\tilde{\tau})$

so that

(B8) $I - \hat{I} = \beta(c-\tilde{c} + \tau-\tilde{\tau}) = \varepsilon+\nu + [(\alpha-\hat{\alpha})+(\beta-\hat{\beta})(\tilde{c}+\tilde{\tau})]$

Since (from (B3))

(B9) $\tilde{\tau}-\bar{\tau} = \tau - \bar{\tau} + \Omega$

it follows that, asymptotically,

(B10) $C(I-\hat{I},\ \tilde{\tau} - \bar{\tau}) = \beta C(c-\tilde{c},\tau-\tilde{\tau}) + \beta V(\tau-\tilde{\tau}) + C(\varepsilon,\tau-\tilde{\tau})$

Comparing (B10) to (B6), we find that

(B11) $X = 2\beta\ C[I-\hat{I},\ \tilde{\tau}-\bar{\tau}] - \beta^2 V(\tau-\tilde{\tau})$

$$= 2\beta\ C[I-\hat{I},\ \tilde{\tau}-\bar{\tau}] - \beta^2 V(\tilde{\tau}-\bar{\tau}) + \beta^2 V(\tilde{\tau}-\tau)$$

The first two of these terms are based on observables. The last depends on τ, which we do not observe. However, since $V(\tilde{\tau}-\bar{\tau}) > V(\tilde{\tau}-\tau) > 0$, we may obtain upper and lower bounds for X,

(B12a) $\underline{X} = 2\beta\ C[I-\hat{I},\ \tilde{\tau} - \bar{\tau}] - \beta^2\ V(\tilde{\tau}-\bar{\tau})$

(B12b) $\bar{X} = 2\beta\ C[I-\hat{I},\ \tilde{\tau} - \bar{\tau}]$

Footnotes

1. For example, a recent statistical evaluation of competing models of investment behavior by Bernanke, Bohn and Reiss (1988) found that naive, atheoretical models performed as well as models suggested by economic reasoning. In particular, variables not predicted by theory to matter, such as output, have a statistically significant effect on investment.

2. That is, the present value of tax savings associated with depreciation allowances on today's investment depends on future tax rates.

3. One may question our discounting of depreciation allowances with the risk-free rate, since their provision in nominal terms leaves them subject to inflation risk. However, they are as safe as other "safe" assets, such as nominal government securities, from which we calculate the "safe" rate.

Although depreciation schedules have often been changed by legislation in the United States, the new rules have never been applied to capital already in place. Until 1986, there were also no significant changes in the corporate tax rate. Hence, the nominal certainty of the depreciation deductions in (2) seems a fair approximation of reality. To allow for the slight risks that may be inherent in depreciation allowances (including the possibility that they may not be immediately deductible because of future tax losses) we discount them using a real rate of 4 percent, which is somewhat higher than historical risk-free rates.

4. This is not an especially restrictive assumption, since shocks around a trend that eventually die out can still be nonstationary, i.e. a fractionally integrated productivity shock with $d<1$ is admissible. Hence, we are not imposing the assumption of trend stationarity on the aggregate time series being considered.

5. In practice, the ratio K_s/K_{t-1} does not vary very much, so it is ignored in the empirical results presented below.

6. For equation (3) to be valid, α must fall between zero and one. The first condition, $\alpha > 0$, is simply the requirement that the optimal capital stock is defined, i.e. that the slope of the marginal revenue curve is more negative than that of the marginal cost curve. For a perfectly competitive firm, this requirement becomes one of decreasing returns to capital plus labor. The second condition, $\alpha < 1$, is that capital has a positive marginal revenue product.

7. In our empirical work below, we will refer to the entire term cK^{α} as the cost of capital, since these two terms appear together in the estimated equations.

8. An earlier version of this paper, available upon request, considers the determination of ρ in greater detail.

9. A related approach may be found in Feldstein (1982), using lagged tax variables and profit rates in some estimated models. This specification is also related to that used by Abel and Blanchard (1986), who regressed

investment on a value of q based on estimated future rates of profit, discounted by estimated future costs of funds. However, their model did not incorporate taxes in a way that permitted the evaluation of the effects of changes in tax regimes.

10. The theory and evidence on this question is discussed in Auerbach (1983). If a dollar of earnings retained by the firm is valued by the market at $q < 1$ and the marginal return to this investment is ρ, then the earnings-price ratio will be $\rho/q > \rho$. For any positive dividend yield, the market return will also exceed ρ.

11. In principle, the weights might differ. However, empirical evidence does not provide very conclusive evidence on this question (see, e.g. Auerbach 1985), which is certainly a valid one for future research.

12. We use real (1982$) series for investment and output, and deflate profits and cash flow by the GNP deflator.

13. Throughout the paper, we focus on <u>gross</u>, rather than <u>net</u> investment. There has been a widening gap over the postwar period between these two figures, as depreciation has become more significant. However, this is largely due to the shift toward investment in equipment, which we discuss below. Because we focus separately on equipment and structures investment, the gross-net distinction is not as important.

14. The estimation was performed using RATS, with a standard Newey-West (1987) covariance matrix of lag length 4. Our instrument set includes a time trend and three lags (beginning with twice-lagged values) of the <u>ex post</u> cost of capital and the ratio of after-tax cash flow to the capital stock of the type of investment being considered. Because the normal <u>ex post</u> cost of capital term is based on future tax parameters, we use a version based on myopic expectations. That is, the value of c_s used as an instrument is based on the tax parameters in date s.

To check the robustness of this procedure, we also estimated the equations using a standard instrumental variables procedure with a correction for serial correlation with an MA(1) structure. The results were generally quite similar. This alternative estimation procedure also allows one to consider the goodness of fit of the first stage of the instrumental variables estimator. The adjusted R^2 of the equations explaining the aggregate cost of capital were typically in the neighborhood of .2.

15. For example, Feldstein (1982) estimated a response of the total investment-output ratio (equipment plus nonresidential structures) to the rate of return minus the cost of funds of .32. Since the average ratio of output to fixed capital is less than 1 in his data, the implied response of the investment-capital ratio is closer to .4.

16. This statement does not apply to equation 5, in which the survival rate has been estimated by a grid search technique, where we do not have standard errors for the survival rate and hence cannot calculate them for α.

17. The serial correlation evident from this statistic might lead one to suspect that the instruments used to identify the parameter estimates may be inadmissable, as they may not be orthogonal to the implied moving average error terms. To examine the sensitivity of these estimates to instrument choice, we pursued estimation with alternative instrument sets and found little change in the results. In addition, we report the results of the chi-squared test of our over-identifying restrictions, which are accepted in every case.

18. Replacing F(K) with $F(K_1, K_2)$ in the optimization problem results in a linearized difference equation system that may be decomposed into two problems like the one already considered if and only if $F_{12} = 0$. Otherwise, one must solve the system jointly for the dynamic behavior of the two capital stocks. This leads to a decision rule for each capital stock that depends on the discounted future values of each cost of capital. While this provides a justification for adding cross-effects to the investment equation (3), the terms in the decision rule are quite complicated functions of the underlying structural parameters, so it is difficult to give the coefficients a structural interpretation.

19. Given a linear approximation of the formula for the cost of capital in (5), the coefficient of $(1-\Gamma)/(1-\tau)$ should be roughly $(\rho+\delta)/[(1-\Gamma)/(1-\tau)]$ (evaluated at the means of these variables) times the coefficient of the no-tax cost of capital term, This implies a ratio of coefficients of about .18, extremely close to the ratio of .072 to .365 (about .20). The coefficient of $\Delta(1-\Gamma)/(1-\tau)$ should be $1/[(1-\Gamma)/(1-\tau)]$, or about .86, times the coefficient of the no-tax cost of capital term, compared to the ratio of .250 to .365 (about .68).

20. Because it was difficult to obtain convergence for this specification when the survival rate was estimated, we employed a grid search method to choose the common survival rate for the two cost-of-capital terms, with a grid size of .05. The standard errors reported in this column, as well as all those in Table 3, should be interpreted as conditional upon the choice of the survival rate.

21. Hoshi et al (1989) find similar cash-flow effects for investment in Japan.

22. Adding cash flow to some of the specifications, for example that in column 4, resulted in an insignificant cash flow coefficient, due to an increase in the coefficient's standard error.

As a further test of whether cash flow is proxying for a cyclical measure not properly included in the equation, we added output to the sixth specification of Table 2. This new variable was found to have an insignificant coefficient, with cash flow still significant.

23. Recall that for a value of $\alpha = 0$, the survival rate should be $1/(1+\rho+\bar{\delta})$. This implies a value of about .93 for structures, compared to .85 for equipment.

24. As already discussed, under the assumption that $\alpha = 0$ (consistent with the estimated survival rate for structures), the coefficient, multiplied by the mean value of the cost of capital (in this case about .11), is an estimate of the relationship of the investment-capital ratio to Tobin's q. The resulting estimate of .005 is less 1/10 of the responsiveness of equipment investment.

25. Whether the government should attempt to stabilize investment or output is, of course, a relevant question, but well beyond the scope of this paper.

26. This is the issue of endogenous stabilization policy discussed by Solow and Kareken (1963) and Goldfeld and Blinder (1972), among others. In the past, the literature on this subject has concentrated more on the incorrect policy multipliers one would derive from reduced form models than on evaluating past stabilization efforts. One exception is Taylor (1982), who considers the success of the Swedish investment fund scheme. Taylor's approach differs from the one taken here in a number of respects, including his specification of a simple policy rule for the investment subsidy rate.

27. We present only point estimates for the various stabilization effects just described. The distributions of the estimates appear to be quite complicated.

28. Another caution involves the potential importance of cash flow. If cash flow does affect investment, then average, as well as marginal tax rates should be included in our stabilization calculation. Without a better structural model of the channel through which cash flow affects investment, however, we are unsure of how to model this affect.

29. This differs slightly from the expression in Auerbach (1989) because of the use of discrete rather than continuous time and a different specification of the adjustment cost function.