BUSINESS INVESTMENT AND TAX POLICY: A PERSPECTIVE ON EXISTING MODELS AND EMPIRICAL RESULTS**

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ABSTRACT

This critical review endeavors to serve as an introduction to the voluminous literature on econometric investment models with special emphasis on the role of tax policy. The two most frequently utilized investment specifications—the Neoclassical model of Jorgenson and the Q model of Tobin—are given explicit consideration and, for each model, the underlying theory, available empirical results, and appropriate caveats are discussed. The paper also provides a brief review of the Return-Over-Cost and Effective Tax Rate models of Feldstein and of the Unobserved Shadow Price model. An organizing framework is provided by focusing on two key elements characterizing each of the four models—the formulation of the expected marginal benefits and costs of acquiring capital, and the relationship between these unobservable expectations and observable variables.

"Estimation of investment functions is a tricky and difficult business and the best posture for any of us in that game is one of humility."

Robert Eisner (1974, p. 101)

"No matter how precisely the coefficients of any particular specification may appear to be estimated, . . . estimating alternative models to study the same question can be a useful reminder of the limits of our knowledge."

Martin Feldstein (1982, p. 831)

I. Introduction

FOR academic economists, the study of business investment behavior poses significant challenges; for policymakers, the empirical results can provide improved understanding of an economic process playing important roles in both short-term cycles and long-term growth. As a result of a large number of studies, general agreement has been reached on the primary determinants of business investment spending; however, disputes remain concerning the measurement of key variables and the magnitude of their effects, broadly differentiated between output and "prices." Quantifying these magnitudes is not part of an idle academic debate, but rather has a crucial bearing on the appropriateness of various monetary and fiscal policies. For example, assessing the ability of current tax reform initiatives to alter the federal budget deficit, reduce distortions inherent in the tax code, or direct resources toward activities with presumed positive externalities depends on our maintained knowledge of the parameters characterizing the capital accumulation process.

That "knowledge," it must be admitted, is far from definitive. A recent study examining investment equations found in large-scale macro-econometric models concluded that "One can get almost any answer one wants by making sure that the chosen model has specifications appropriate to one's purpose."[1] In the face of sharp disagreements over the magnitude (elasticity) of output and "price" effects and given the lack of *the* critical experiment, the most promising research strategy is to study a number of alternative models and to determine whether they yield similar implications for investment elasticities. In this survey, we examine four different classes of investment models, all of which make strong assumptions to arrive at testable econometric equations. Within each class, there are a number of variants with still more assumptions. The maintained assumptions and modeling strategies will bias the estimated parameters in each of the models in unknown ways. If we are to learn anything useful for the conduct of policy, it will have to be from a number of investment studies, seeing if they reach a general consensus on the relevant parameters. The greater the convergence of results, the more confidence

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we can have in the estimated impacts of government policies.[2]

In order to provide a comprehensible introduction to this assortment of investment models, this survey presents in Section II an organizing framework that focuses on two key elements characterizing each of the four models under consideration—the formulation of the expected marginal benefits and expected marginal costs of acquiring capital, and the relationship between these unobservable expectations and observable variables. In terms of this framework, Section III and IV then provide a detailed examination of the two most frequently utilized investment specifications—the Neoclassical model pioneered by Dale Jorgenson and the Q model popularized by James Tobin. For each model, the underlying theory, available empirical results and appropriate caveats are presented. The more recently postulated Return-Over-Cost and Effective Tax Rate models of Martin Feldstein and the Unobserved Shadow Price model are discussed briefly in Section V. A conclusion is offered in Section VI.

II. An Organizing Framework

Before examining the specific models, we note two elements important to the investment process and common to all of the models under consideration. The first is based on standard economic principles, and states that the firm will invest up until the point where, for the final unit of investment (or newly acquired capital), the

$$\text{expected marginal benefit} = \text{expected marginal cost.} \tag{1}$$

Should tax policies or other factors disturb (1), the firm will continue to invest until the equality is reestablished. While such a smooth scenario may not be precisely applicable to the behavior of any individual firm, it *may be* useful in relating investment to tax policy and other determinants at the level of industries or the aggregate economy. Whether any particular framework *is* useful remains an empirical matter.

Investment is essentially forward-looking, and dependent upon the current situation and expectations of future conditions. The unobservability of expectations poses a serious problem for the applied econometrician, and the second crucial element is the way in which the four models link unobservable expectations to observable variables that can be utilized in an investment function. As we shall see, each model addresses the unobservable expectations problem and formulates the decision rule (1) differently.

III. The Neoclassical Model

A. *Theory*

The point of departure for the Neoclassical model is the specification of the firm's cash flow in the current and all future periods. With the assumption that the firm operates so as to maximize the discounted value of these cash flows, it can be shown that the firm will invest up until the point where the expected marginal revenue product from an additional unit of capital ($P^e f^e_K$) equals the expected marginal cost of capital (C^e),

$$P^e f^e_K = C^e, \tag{2}$$

where (2) is a specific instance of our general decision rule (1).

From the viewpoint of tax analysis, the key element in the Neoclassical theory of investment, pioneered in a number of papers by Dale Jorgenson and his various collaborators,[3] is the expected user cost of capital C^e, which can be viewed as the current dollar "rental price" of one unit of capital for a single period. This "rental" is all-inclusive, containing interest costs, depreciation, and taxes, and a general formulation is (ignoring expectations for a moment),

$$C = \frac{q(\rho + \delta)(1 - k - \tau_c z)(1 + D)}{(1 - \tau_c)}, \tag{3}$$

C = user cost of capital;

q = purchase price of a unit of new capital;
ρ = financial cost of capital net of inflation, taken in various studies as the cost of equity, the cost of debt, or a weighted average of these two costs;
δ = rate of depreciation of the capital good;
k = rate of the investment tax credit;
τ_c = rate of income taxation;
z = discounted value of tax depreciation allowances;
D = net cost of debt finance (acquisitions, retirements, and net-of-tax interest payments).

A number of tax parameters that can be altered by policymakers enter the user cost expression: those affecting the firm directly (k, τ_c, z) and indirectly through the financial variables ρ and D (e.g., an increase in the rate of dividend taxation may raise the cost of equity through higher dividend yields required by shareholders). Considering the role of personal taxes in (3) is beyond the scope of this survey; see Auerbach (1983a) and Poterba and Summers (1983) for further discussion.

By assuming that the firm's production technology can be represented by a constant elasticity of substitution production function, we can relate the expected marginal product of capital (f_K^e) to the capital stock and the expected level of real output. Given its forecasts of relevant variables, the profit-maximizing firm will choose a "desired" stock of capital so that the expected marginal benefit and cost are equalized, thus satisfying the decision rule (2).[4]

$$K^* = A(Y^e)^{\phi}(C^e/P^e)^{-\sigma} \tag{4}$$

K^* = optimal ("desired") capital stock;
A = a scale factor;
Y^e = expected level of real output;
ϕ = elasticity of the optimal capital stock with respect to expected output; this elasticity is a mixture of substitution and returns-to-scale parameters;
C^e = expected user cost of capital;
P^e = expected price of output;
σ = elasticity of the optimal capital stock with respect to the relative price of capital services. This elasticity is identical to the elasticity of substitution between labor and capital inputs.

The optimal capital stock will rise with an increase in Y^e or P^e or with a decline in C^e. If inputs can be combined in the production process only in fixed proportions ($\sigma = 0$), then tax policy, operating through C^e, can have no direct effect on the firm's capital stock decision.

The problem of unobservable expectations in (4) is resolved by assuming that firms base their expectations of future variables on an extrapolation from the historical data for that particular variable. This "backward-looking" or extrapolative expectations scheme can be represented as a distributed lag of past variables,

$$Y_{t+1}^e = \sum_{i=0}^{I_1} \alpha_i Y_{t-i}, \tag{5a}$$

$$(C_{t+1}^e/P_{t+1}^e) = \sum_{i=0}^{I_2} \beta_i (C_{t-i}/P_{t-i}), \tag{5b}$$

where the α's and β's are fixed parameters and time subscripts have been added.

A second lag enters our model of the investment process because, for a given change in the determinants of K^*, we assume that it takes time before the decision to invest is made and the capital good can be delivered. Furthermore, it may take time until a delivered piece of capital can be usefully incorporated into the production process. These considerations lead to the following specification of net investment (I^N) as a distributed lag of current and past changes in the "desired" capital stock,

$$I_t^N = \sum_{j=0}^{J} \gamma_j \Delta K^*_{t-j}, \tag{6}$$

where Δ represents a first-difference and the γ's are fixed parameters.

To complete the investment model, we note that gross investment (I_t) equals the sum of net (6) and replacement components, and assume that the latter is simply a fixed proportion of the existing capital stock (δK_{t-1}).[5] Combining this assumption for replacement investment with those on expectations and delivery lags, we can specify an investment function, expressed in terms of observable variables and fixed parameters, that can be estimated econometrically. The derivation is greatly simplified if the model is stated in terms of natural logarithms[6] (denoted by a "ˆ"), and we thus obtain the following Neoclassical investment model,

$$I_t = \phi \sum_{h=0}^{H_1} a_h \Delta\hat{Y}_{t-h} - \sigma \sum_{h=0}^{H_2} b_h \Delta(\widehat{C/P})_{t-h} + \delta K_{t-1}, \qquad (7)$$

where $a_h = \alpha_i * \gamma_j$, $H_1 = I_1 * J$, $b_h = \beta_i * \gamma_j$, and $H_2 = I_2 * J$. The rather cumbersome equation (7) has been presented to highlight that the lag coefficients in Neoclassical investment models are an amalgam of production function, expectations, and delivery lag parameters (Eisner, 1969a; Nerlove, 1972). Given the number of coefficients to be estimated in (7), the econometrician must impose some additional assumptions in order to identify the individual α's, β's, γ's, ϕ, and σ.[7]

B. *Key Assumptions and Caveats*

A number of important assumptions are needed in order to estimate the Neoclassical investment model (7). Questions have arisen in defining the user cost of capital (C) and the marginal product of capital (f_K), and they, in addition to the assumption of extrapolative expectations, will be examined in the following three sub-sections.

1. The User Cost of Capital. The definition of the user cost of capital is of crucial importance for policy since all tax parameters affect investment through C. Furthermore, a misspecified user cost variable may bias the estimated coefficients in the econometric equation. Each component of C in (3) has been the subject of controversy, and each is reviewed below.

q (purchase price of a unit of capital)

This variable is usually measured by published price indices that are based on production costs and may suffer from an upward bias. In the presence of quality changes in new capital goods not proportional to the added cost of production, the published series may overstate price increases (or understate decreases) relative to an index based on the value to capital goods users (Gordon, 1983). While the methodology underlying the construction of price series may be open to debate, systematic bias in the plant and equipment investment goods deflator is not apparent over a long time horizon. For the period 1953–1981, the ratio of the plant and equipment deflator to the GNP deflator, scaled to 1.0 in 1953, reaches a peak in 1957 (1.050), generally falls for the ensuing 17 years, and bottoms-out in 1973 (.942). The ratio rises sharply between 1973 and 1975. From 1975–1981, the series exhibits a dampened oscillatory pattern and, in 1981, equals its 1953 value. While there would appear to be no long-run bias in the investment goods deflator, it remains an open question whether the serial correlation adversely affects econometric estimates or whether significant differences exist between equipment and structures deflators considered separately.

ρ (financial cost of capital net of inflation)

Traditional corporate finance suggests that ρ be a weighted average of the costs of debt and equity to the firm, where the weights reflect the firm's leverage (the ratio of total debt to the total value of the firm). The nominal cost of debt is usually taken as a corporate interest rate adjusted downward for the deductibility of interest payments (i.e., multiplied by $1 - \tau_c$); in order to convert this into a real rate, the rate of inflation, stated in terms of aggregate or capital goods prices, is subtracted. The real cost of equity is measured by an earnings-share price ratio or by a dividend-share price ratio plus some measure of expected real capital gains accruing to shareholders. Given the divergence between reported and economic earnings stemming from the historical cost basis for calculating depreciation allowances, first-in, first-out (FIFO) accounting conventions for inventories, and changes in the value of debt, the earnings-price ratio must be adjusted, though this correction need not result in a downward revision even in inflationary times for heavily levered firms. The problem with using the dividend-share price plus expected capital gains measure is that estimating the latter term usually proves to be difficult.

Empirically, defining ρ partly in terms of an adjusted earnings-price ratio (or dividend-price ratio cum capital gains) can lead to a serious bias in an estimated investment equation. The adjusted earnings-price ratio is a misspecification of the true cost of equity because the numerator reflects current conditions, while the denominator incorporates expected, future conditions. A spurious relation between ρ, hence C, and investment can be seen to exist if a fall in the earnings-price ratio reflects high expected future profits, which would be positively related to investment and yet not be indicative of lower equity cost, accurately measured as the ratio of *expected* earnings to share price. As shown by Eisner and Nadiri (1968) and Chirinko and Eisner (1982, 1983), the implied impact of tax parameters on investment (through large estimated values of σ and b's in (7)) are much larger when ρ is defined as a weighted-average of equity and debt costs rather than just the latter term.

Theoretically, the definition of ρ depends on the objective of the firm. If the firm chooses policies to maximize the value of both debt and equity claims, then ρ should be specified as a weighted average of debt and equity costs (Brock and Turnovsky, 1981). Alternatively, if the firm maximizes the value of equity and treats debtholders as suppliers of a factor of production, then ρ should equal the cost of equity (Chirinko and King, 1983); in this latter case, the user cost will have to include a term for the net cost of debt finance (D, to be discussed below).

Regardless of the definition of ρ, two key assumptions in most investment models are that the financial and investment decisions can be made independently and that the firm's managers have well-defined objective functions. We thus ignore, among other considerations, the interactions between risky investments and financing rates (Gordon and Malkiel, 1981), the role of personal taxes (Auerbach, 1983a; Poterba and Summers, 1983), and the divorce of ownership from management characterizing most large firms (Jensen and Meckling, 1976).

δ *(rate of depreciation of the capital good)*

In deriving the Neoclassical model, it was assumed that capital depreciated at a geometric rate, thus justifying the treatment of replacement investment as a fixed proportion of the existing capital stock. The validity of the geometric depreciation assumption has been the subject of some empirical investigations that can be classified into three general approaches.

The first method is to examine directly the relationship between replacement investment and the capital stock. The evidence of Feldstein and Foot (1971) and Eisner (1972), while not in agreement on the relationship between replacement and expansion investments, is united in rejecting the geometric depreciation hypothesis. The problem with their approach is that we do not have independent and accurate measures of replacement investment and the capital stock. In both studies, replacement investment is inferred from McGraw-Hill survey responses, whose subjective components may vary systematically from firm to firm. As argued by Jorgenson (1971), the Feldstein and Foot study is marred because the capital stock data obtained from the Commerce Department is constructed using non-geometric depreciation patterns; hence these results against the hypothesis are not surprising. Eisner uses the value of gross fixed assets, presumably taken from balance sheets, as his measure of the capital stock and, while this is an independent measure of the capital stock, it is based on book value, which may not accurately reflect the productive stock needed for the regression analysis.

The second approach is to examine prices of used durable goods, which are governed by the pattern of depreciation. A recent survey of this large literature is given by Hulten and Wykoff (1981), and the majority of studies seem to support the geometric hypothesis. However, observed asset prices in secondary markets may be misleading because of a "sample selection" problem: the goods that are traded, hence the asset prices we observe, may not be representative of all assets in a particular category. This bias may be brought about because of asymmetric information between sellers and buyers or because of an unexpected development making some assets in a particular category relatively obsolete and more likely to be traded at unrepresentative prices.[8]

Coen (1975) has developed a third approach by estimating a series of investment equations based on alternative depreciation patterns and choosing the pattern that provides the highest $\bar{R}^2$ and reasonable parameters. For two-digit industries, he found infrequent support for a geometric pattern, although it and straight-line depreciation were most common for equipment. The "one-hoss-shay pattern," under which there is no depreciation until the end of the service life (e.g., a lightbulb), was evident for structures in a majority of industries.

This variety of results is not surprising because, like other decisions facing the firm, the rate at which capital is allowed to depreciate is based on economic considerations such as tax, interest, and inflation rates.[9] Feldstein (1983, Chapter I) speculates that ignoring the endogeneity of depreciation may result in unknown biases in the reported impacts of tax rules, but econometric evidence bearing on this point has yet to be generated.

k (rate of the investment tax credit)

Measuring the impact of the investment tax credit should presumably follow directly from the tax code. For equipment with a given tax life, the statutory rate is known, and the composite rate for assets with various tax lives can be computed as a weighted average of these statutory rates.

Three caveats must be noted. First, the user cost of structures should include a partial credit because of the special tax status afforded public utility structures. Second, insufficient taxable profits in a given year can preclude firms from using the total amount of their credits. This loss is mitigated by carryback and carryforward provisions, whose value to the firm would need to be discounted, but it has been estimated by the Treasury that between 5 percent to 10 percent of the value of available credits are never claimed.[10] Third, variations in the investment credit have sometimes been preannounced and retroactive, thus complicating the specification of the value applicable to investment undertaken in a particular time.[11]

τ_c (rate of income taxation)

Most investment studies measure τ_c by the readily available series for the federal corporate income tax rate. However, noncorporate businesses, whose rates are probably lower, own approximately 27 percent of equipment and structures stocks.[12] State and local governments also levy corporate income taxes and, in 1980, their average collections amounted to 17 percent of total corporate income taxes. As with all business taxes, allowance may have to be made for firms with zero or negative profits.

z (discounted value of depreciation allowances)

To calculate z, we need to know the tax service life for a given asset, the pattern of tax depreciation and the rate of income taxation applicable over the asset's life, and a nominal rate to discount these future deductions back to the current period. The tax life can be obtained by referring to the tax code, but it is not necessarily in the firm's best interest to choose the lowest possible service life because, over certain ranges, lower service lives result in lower investment credits. It might also be suspected that the profit maximizing firm would choose the most accelerated depreciation schedule available. However, evidence presented by Ture (1967) and Vasquez (1974) indicates that, for the period 1954 to 1959, only one-half of producers' durable equipment was being depreciated with one of the accelerated methods introduced in 1954; the latter author also presents similar evidence for the Asset Depreciation Range System enacted in 1971. Slow adoption of the more favorable methods may reflect a learning lag that is not relevant currently, but a correct measure of depreciation practices for this period remains important if we are to obtain unbiased econometric estimates. Lastly, the choice of the *nominal* discount rate will be affected by the same consideration surrounding the specification of ρ.

D (net cost of debt finance)

This term is not found in standard derivations of the user cost and, as derived in Chirinko and King (1983), follows from a model where the firm maximizes with respect to the interests of shareholders. Debtholders are viewed as supplying a factor of production (debt) for which they are compensated (interest plus principal), and D is defined as

$$D = b\left[\frac{(1-\tau_c)i+\eta}{\rho+\pi+\eta} - 1\right], \quad (8)$$

b = proportion of a new investment financed with debt;
i = rate of nominal interest;
η = rate at which debt is retired (assumed to be geometric);
π = rate of inflation.

For an additional dollar of new investment, the firm will raise b percent through debt issue, and hence will have its user cost lowered by $-b$. However, the firm will have to incur interest and retirement payments $-b((1-\tau_c)i+\eta)$ and, since these costs will occur over time, they need to be discounted by $\rho+\pi+\eta$. In the event that net-of-tax interest costs equal the nominal discount rate $(\rho+\pi)$, the "subsidy" associated with debt finance is zero. The impact of this term on econometric estimates has yet to be assessed.[13]

2. The Marginal Product of Capital. A second set of key assumptions concerns the definition of the expected marginal product of capital in terms of an underlying production function and a key parameter, the elasticity of substitution between labor and capital (σ). The two alternative production technologies view capital as either

—putty-putty: both before and after installation, capital can be combined with inputs in any desired proportions; the model developed in (7) is based implicitly on a putty-putty technology;
—putty-clay: before installation, capital can be combined with inputs in any desired proportions; however, after installation, the proportion is fixed until the capital good is retired.

The desired factor proportions will depend on the relative prices of inputs. The force of the putty-clay assumption is that the response of investment to a change in the desired capital stock may not be independent of the source. Changes in output, for example, would lead to more rapid investment in new capacity than changes in relative prices, which lead to new investment only as old capital depreciates.

Much attention has been focused on the value of σ,[14] which is not only the elasticity of substitution between labor and capital, but also the elasticity of K^* with respect to (C^e/P^e) (see (4)). Since all tax parameters are embedded in the user cost, the potency of tax policies are directly linked, ceteris paribus, to the value of σ. Direct estimates of σ are mixed, with cross-section studies finding values near unity and time-series analyses generating much lower estimates.[15] Indirect estimates by means of investment functions tend to be quite low (Coen (1969) estimated σ's of .20 for equipment and .40 for structures).

However, in the context of investment studies, this debate is misdirected because knowledge of σ alone does not tell us anything about the critical elasticity of investment with respect to the user cost (Eisner, 1974). Rather, this latter elasticity depends in a complicated way on production function, delivery lag, and expectation parameters (cf., (7)). Only if it is assumed that expectations are static and the delivery lag parameters sum to one can the value of σ have an unambiguous effect on investment expenditures. A similar criticism applies to the importance of putty-putty versus putty-clay technologies. Even if putty-clay considerations contribute to relative price effects that are lower than output effects, the value of the expectation parameters can lead to an elimination or reversal of the roles of (C/P) and Y in econometric equations.[16]

3. *Extrapolative Expectations.* While the assumption that Y^e and (C^e/P^e) can be represented as distributed lags of past observations is easy to implement empirically, it does have some serious drawbacks. First, such extrapolative expectations schemes treat all changes, perhaps brought about by tax policy, as though they were permanent. For example, the variation in the investment tax credit in 1966 that was announced to be temporary would have the same impact on C^e as changes that were to be permanent. Second, preannounced changes in tax parameters would have no effect on investment expenditures in the Neoclassical model, yet firms would be expected to alter their plans so as to benefit from the future policy. Such a scenario was presented by the phase-in provisions for depreciation allowances in the 10-5-3 program, where firms had an incentive to delay current investment expenditures in anticipation of more generous tax write-offs in later years. Third, firms form their expectations based on whatever information is available, and the assumption that firms utilize a single expectation lag (cf., 5) with the same set of parameters for a significant period of time may be restrictive. These parameters will reflect basic characteristics of the economy that may themselves be subject to change (Lucas, 1976). For example, the behavior of interest rates pre-1979, when the Federal Reserve used them as a target, may have changed radically after the October 1979 policy switch to monetary aggregates. A fourth and related point is that, by utilizing (5b), we are constraining all of the variables embedded in the user cost of capital to have the same set of expectations coefficients. Yet it is quite conceivable that expected interest rates follow a regressive pattern (a high rate today to be followed by a lower rate) but that expected tax rates are nearly constant.[17] The ramification of unstable expectations, from whatever causes, is that the estimated coefficients in an investment function will be unstable over time and unreliable in assessing alternative tax policies. The first of these implications can be tested econometrically, and a failure to pass this test would render the investment function suspect as a tool for policy analysis.

C. *Empirical Results*

Studies utilizing variants of the Neoclassical framework are much too voluminous to describe in any detail here. Rather, given the focus of this survey on economic policy, we will concentrate on a selection of those papers comparing different models or dealing explicitly with the response of investment to output and user cost.

Critical to the results is the manner in which ΔY and $\Delta(C/P)$ enter the regression. The version of the Neoclassical model tested by Jorgenson and his collaborators contains the $\Delta(Y(P/C))$ term entered as a distributed lag. As we saw above, such a formulation is justified under the restrictive assumptions that σ equals ϕ and that the expectation parameters for both output and the user cost are identical. The estimated coefficients on this composite term will reflect a mixture of the effects of ΔY and $\Delta(C/P)$ on investment, and can have important ramifications on tax policy analysis. Consider a situation where the relationship between the output term (ΔY) and net investment is stronger than that between the relative "price" term ($\Delta(C/P)$) and net investment. Estimated coefficients from a regression using the composite term $\Delta(Y(P/C))$ will exceed coefficients on the relative "price" variable from a regression where ΔY and $\Delta(C/P)$ have been entered separately. Thus, the version of the Neoclassical model with a composite term, often used in policy analysis, will overstate the effects of tax parameters, operating through the user cost, on investment.[18]

Models that have been tested relative to the Neoclassical relate investment to a distributed lag of changes in output or sales (the flexible accelerator, obtained as a special case of (7) when $\sigma = 0$) or the level of or changes in liquidity—profits, cash flow, or internal funds. These liquidity variables have been considered a determinant of investment spending insofar as they serve as a proxy for expected profits or permit the firm to avoid imperfections in capital markets.[19] Liquidity may constitute an additional channel through which tax policy affects investment.[20]

There have been a number of studies comparing these alternative theories based on the goodness-of-fit ($\bar{R}^2$), structural stability, and predictive performance. For firms, Jorgenson and Siebert (1968a) found that their version of the Neoclassical model performed best, followed by the Expected Profits and Accelerator models. The Liquidity theory was decidedly inferior to all of the above models.[21] For manufacturing industries, Jorgenson, Hunter, and Nadiri (1970a) found that the Neoclassical model with $\Delta(Y(P/C))$ as the principal regressor dominated the Accelerator model cum current profits in terms of goodness-of-fit and lack of autocorrelated errors. The roles were reversed, however, when the models were evaluated in terms of their predictive performance (Jorgenson, Hunter, Nadiri, 1970b).[22] Using aggregate data and Neoclassical (with a composite term) and Accelerator models, among others,[23] Peter Clark (1979) concluded that "output is clearly the primary determinant of nonresidential fixed investment" (p. 103).[24] Of course, these results do not vitiate the importance of user cost, but warn that Y and (C/P) may have differing effects on investment expenditures and, as suggested by our development of the Neoclassical model, should be entered separately.

Estimates of the effects of tax policy on investment have varied widely, as demonstrated in papers presented at a Brookings Conference (Fromm, 1971). The model of Hall and Jorgenson enters output and user cost in constrained form; Bischoff presents a putty-clay model where σ is estimated freely and found to be close to one; and Coen estimates a model with separate lags for output and user cost variables, and also tests for the importance of cash flow on the speed with which firms adjust to the desired capital stock. Given their estimated investment equations, the authors then quantify, in a partial equilibrium setting, the added investment resulting from tax depreciation changes in 1954. For 1954–1962, Hall and Jorgenson's constrained Neoclassical model implies that, on average, investment was raised 6.89 percent. A much lower response of 1.46 percent is forthcoming from Bischoff's putty-clay framework. Coen finds that investment was 3.87 percent higher as a result of the change in tax policy when cash flow does not enter the model; when cash flow influences both the estimated parameters and policy simulation, he finds a much smaller increase in investment of only 2.02 percent. However, Coen's results depend crucially on the assumed method of tax depreciation (double-declining-balance or sum-of-the-years-digits) and lag length for user cost, and can vary by as much as 80 percent.[25]

As an aside, it should be noted that Coen's results for cash flow provide a striking example of when a priori reasoning can lead to misleading conclusions concerning investment spending. It might have been expected that the model with cash flow effects would indicate that investment is more responsive to a given tax stimulus than the model excluding cash flow; however, the simulation results run in the opposite direction. This seeming paradox is resolved by noting that, since *both* the estimated parameters and simulations are affected by the variables in the model, the ultimate impact of tax policy on investment can only be determined through a complete econometric analysis.

Disparities similar to those found by Bischoff, Coen, and Hall and Jorgenson were evident in the study by Chirinko and Eisner (1982), who analyzed the investment equations in six quarterly macroeconometric models: Bureau of Economic Analysis, Chase Econometrics, Data Resources Inc. (DRI), University of Michigan, MIT-PENN-Social Science Research Council (MPS), and Wharton Econometrics. In one partial equilibrium simulation, it was found that a doubling of the investment credit for equipment and the institution of a 10 percent credit for structures led to increases in investment, after five years, of between 1.4 and 15.8 billions of constant dollars. The mean increase for all six models was $7.1 billion.

A number of these models contained overly restrictive constraints, and the investment equations were reestimated with more general specifications. For most of the models, dividend-share price or earnings share price variables entering the financial cost of capital were removed to avoid the potential upward bias in the coefficients on C.[26] In particular for the DRI model, which resembles that of Hall and Jorgenson, the combined (Y(P/C)) term was replaced by separate output and relative price variables; for the MPS model, based on Bischoff's putty-clay framework, a constant term was added to allow for the possibility that the mean of variables omitted from the equation was non-zero. The combined effects of these modifications were dramatic. The response of investment to the same investment credit stimuli fell in DRI from $15.8 to $6.0 and in MPS from $15.1 to $5.9 billion. The mean increase in business fixed investment for all six revised models was $4.0 billion. In either set of equations, but a fortiori in the revised set, it may be noted that a 10 percent increase in the investment credit brought about considerably less than 10 percent in added investment. The mean results from the original equations suggest that each dollar of federal tax loss would result in about $.84 of added investment. The revised equations offer a comparable figure of only $.47.[27] All of these results, it must be remembered, are dependent on the applicability of investment equation coefficients, estimated from historical data, to the current situation with a modified tax code.

It should also be noted that none of the above results consider general equilibrium effects, as the price level and interest rates, among other variables, will react directly or indirectly to the tax stimulus. Similar differences between models remain when tax policies are analyzed with all of the equations in large-scale macroeconometric models. Green (1980) found that, for a two percentage point increase in the investment credit, the ratio of increased nonresidential fixed investment to the Treasury's revenue loss was 3.1 in DRI and only .60 in Wharton (twenty quarters after the policy was initiated).[28] The variety of results in the original model equations and the smaller range exhibited in the revised equations found by Chirinko and Eisner (1982) were essentially duplicated in full model simulations (Chirinko and Eisner, 1983), though the results were occasionally affected by the specification of the monetary sectors in some models. For all six models under the tax credit scenario, the mean increase in total, constant dollar, fixed investment was $11.7 billion and the net federal budget deficit increased by $10.2 billion. For the modified equations, the comparable figures were $8.7 and $10.0 billion.

IV. Tobin's Q Model

A. *Theory*

As discussed above, a serious shortcoming in the Neoclassical model is the treatment of expectations. In response, a number of investigators have recently based their analyses of investment on Tobin's (1969) Q theory, which is appealing in its explicit consideration of forward-looking expectations. These enter the econometric specification directly through the market value of the firm taken from financial market data, incorporating, in principle, the expectations of future variables relevant to the investment process. Rather than being buried in the lag coefficients, the effects of expectations are reflected by a variable in the regression equation.[29]

As with all of the theories examined in this survey, the firm's decision on acquiring capital is determined by the balancing of the expected marginal benefit and cost. In Q theory, the expected marginal benefit (λ^e) is defined as the sum of the value of all expected future marginal products at time s, ($P^e f^e_{K,s}$) flowing from an additional unit of capital, discounted by the financial cost of capital (ρ) and the rate at which this unit of capital will depreciate (δ). This forward-looking definition should be contrasted with the static concept utilized in the Neoclassical model. When making the investment decision, the firm knows the marginal cost, comprising the marginal purchase cost ($\bar{q}_t$), net of tax and debt financing considerations, and marginal adjustment cost ($G'(I_t)$) associated with the additional unit of capital. The latter arises as the firm formulates plans and then installs new capital goods into the production process. This internal cost can be viewed as the movement of real resources (e.g., labor) from producing output toward incorporating new capital goods, and such costs are assumed to increase at an accelerating rate as investment exceeds replacement needs.[30] These considerations lead to the following decision rule for Q theory (cf., (1) and (2)),

$$\lambda^e_t = \bar{q}_t + G'(I_t),$$

$$\lambda^e_t = \sum_{s=t}^{\infty} [(1-\delta)/(1+\rho)]^{(s-t)} P^e F^e_{K,s},$$

$$\bar{q}_t = q_t(1 - k_t - \tau_{c,t} z_t)(1 + D_t), \qquad (9)$$

$G'(I_t)$ = adjustment cost associated with an additional unit of capital.

The two key variables in this investment theory are marginal Q (Q^M) and average Q (Q^A). Marginal Q is defined as the ratio of the increase in the value of the firm from acquiring an additional unit of capital to its net-of-tax purchase cost, less one.

$$Q^M_t = (\lambda^e_t/\bar{q}_t) - 1. \qquad (10)$$

With some additional manipulations (Abel, 1979; Hayashi, 1982), we can derive the following investment function,

$$I_t/K_t = d_0 + d_1 Q^M_t + d_2(I_{t-1}/K_t), \qquad (11)$$

where the d's are parameters to be estimated. In (11), positive values of Q^M_t lead to more investment (per unit of capital), and the lagged term is included to capture the effect of delivery lags. As more investment is undertaken, the return to additional units declines until Q^M_t equals zero. Owing to the forward-looking λ^e_t, Q^M_t is unobservable, and hence (11) is not a testable econometric specification. This problem has been overcome in empirical work by replacing marginal Q with average Q, defined as "the ratio of the market value of firms to the replacement cost of their assets" (von Furstenberg, 1977, p. 347).

$$Q^M_t = Q^A_t = (V_t/\bar{q}_t K_t) - 1. \qquad (12)$$

V_t = financial value of the firm (equity shares and bonds).

The theoretical justification for this key link has been developed by Hayashi (1982).[31] Whenever Q^A_t, is positive, financial investors believe that the firm's future prospects are sufficiently favorable to warrant further investment. As more capital is accumulated, K_t increases until Q^A_t equals zero. The importance of (12) should not be underestimated for it allows us to equate a forward-looking variable with one that is readily observed (in one sense, the importance of Q^A_t is that the variables defining it do not contain an "e" superscript). Given Q^A_t, we have a great deal of information about future variables relevant to investment without having to make any specific assumptions on expectations formation or future conditions of supply and demand.[32]

B. *Key Assumptions and Caveats*

A number of the same assumptions and caveats (e.g., data definitions) associated with the Neoclassical model pertain here as well. In this subsection, we consider two additional caveats pertaining to the measurement of Q_t^A and the equality of marginal and average Q's.

The greatest source of variability in Q_t^A emanates from V_t, the value of the firm as evaluated in financial markets. Clearly, short-term fluctuations in V_t will not be related to the investment decisions of the firm and, for quarterly data, we need some way to "filter-out" the noisy part of Q_t^A from that part containing an accurate signal of the firm's fortunes. (The problem will weigh less heavily when using annual data.) One method is to use band spectrum regression, a sophisticated econometric technique that is designed precisely as a filter and that has been used with some success in a Q model (Engle and Foley, 1975). A second procedure is to use the standard instrumental variable method. The latter was employed by Chirinko (1984b) and, while any application of this procedure is always dependent upon the choice of suitable instruments, regression results based on either actual Q_t^A or instrumented Q_t^A differed little.

The above measurement problem views Q_t^A as being a correct indicator of the Q_t^A that matters to the firm except for random noise due to a too variable V_t. An additional measurement problem concerns a possible systematic bias stemming from a mismeasured K_t in the denominator. This capital stock (when multiplied by $\bar{q}_t$) represents the replacement cost to the firm, and is calculated by a perpetual inventory method with a fixed set of straightline depreciation rates. These rates may have become highly inaccurate in the face of the major structural shifts that have occurred since the early 1970s. The rapid rise in energy prices may have made part of the existing capital stock obsolete, forcing firms to retire machines designed initially to work best with low energy costs. Some of these machines may have been modified to be more economical under prevailing relative prices but, nonetheless, the published capital stock series with fixed depreciation rates will overstate the replacement value of the existing capital stock. During the 1970s, Q_t^A had been persistently below its long-run equilibrium value of zero, indicating to some authors (e.g., Baily, 1981) that observed Q is plagued by a systematic bias. However, when measured over a longer time horizon, the mean value of Q_t^A approximately equals its equilibrium value (Chirinko, 1984a). In any event, there does not appear to be any available technique for handling this problem.

A second general problem confronting Q theory is that observed Q_t^A may diverge from unobserved Q_t^m in at least three plausible situations. First, conditions of imperfect competition or non-constant returns to scale may prevail, thus violating the assumptions underlying (12). Second, capital may not be safely considered homogeneous because adjustment costs vary between capital goods (Chirinko, 1982; Wildasin, 1984) or, as mentioned above, sudden shifts in relative prices result in part of the existing stock becoming obsolete. Third, in contrast to the original presentation of the Q model by Tobin, the formal development has not recognized that the firm actively participates in a number of financial markets. When financial policy is endogenous, Q_t^A is likely to be an uninformative, and possibly misleading, signal for investment expenditures (Chirinko, 1985). In either of these three cases, the conventional formulation of the Q model is misspecified; however, with suitable modification, an estimatable structural equation can be preserved.[33]

C. *Empirical Results*

Relative to the Neoclassical model, substantially less empirical work has been undertaken with the Q framework. Most studies have been primarily concerned with fitting the model to various datasets and, with the exception of Summers (1981), have not focused on the effects of alternative tax policies.

The empirical results with the Q model

are less than satisfactory. The early studies by Ciccolo (1975) and Engle and Foley (1975), the latter using data through 1968, found Q to play a significant role.[34] Using more recent data, von Furstenberg (1977) concluded that including Q in regression equations "must be regarded as optional." When investment equations were estimated with industry data (at the two-digit SIC level), von Furstenberg, Malkiel, and Watson (1979, 1980) found that insignificant Q's were concentrated in a few, although capital-intensive, industries, but that for the majority of industries Q possessed significant explanatory power. This tendency for Q to emerge as significant at a lower level of aggregation was not sustained in an analysis of firm data by Chappell and Cheng (1982); however, the Q variable was a significant determinant of investment for approximately one-half of the firms studied by Salinger and Summers (1983) and Rukstad (1985). Studies by Oulton (1979), Jenkinson (1981), and Poterba and Summers (1983) using aggregate data for the United Kingdom and by Hayashi (1983) using aggregate and industry data for Japan generated mixed results. Hayashi also found some evidence of a structural shift in the Q equation after 1975, a result consistent with a systematic bias caused by the rapid increase in energy prices and subsequent obsolescence of part of the capital stock. Recent work by Summers (1981) with aggregate U.S. data revealed that giving careful consideration to tax variables was important but that the overall explanatory power of the tax-adjusted Q specification was low with $\bar{R}^2$ ranging from .30 to .40. Relative to alternative investment equations estimated with U.S. data, Q models have not performed adequately in terms of either within sample or out-of-sample statistics (Clark, 1979).[35]

Given the direct treatment of expectations, the disappointing empirical performance of Q models is puzzling. One important assumption in these studies is that the value of the firm and its production technology depend on a single (or composite) capital input. The misspecification of the Q model following from this critical assumption has been substantiated in Chirinko (1984b), whose empirical results suggest that capital inputs should be modeled separately. A second possible problem discussed in Section IV.B concerns the financing of investment expenditures. When the conventional Q model was modified to allow for an endogenous financial policy but capital was treated as a composite input, the empirical performance of the Q model improved little.

Analyzing the effects of tax policy within the Q framework takes place in a two-step process, by relating changes in tax parameters to changes in Q_t^A, which, in turn, affect investment expenditure through the estimated coefficients in the econometric equation. The first step is particularly difficult for we have to quantify the response of equity values to alternative tax parameters. Summers (1981) accomplishes this task by solving for investment, the capital stock, and the value of Q_t^A simultaneously over an infinite horizon. His work suggests that the level of taxes, raised by the interaction of inflation with a non-neutral tax code, can have significant effects on investment. However, this result follows from the large tax increases generated from his specification of the tax code. Using the per dollar of tax loss as a basis for comparison, Chirinko (1984b) has shown that, after five years, the cumulative increase in investment ranges between $.12 to $.39 in Summers' model, which treats equipment, structures, and inventory as a composite capital good. When differences in adjustment costs among these three capital inputs were recognized explicitly, the largest comparable impact was $.09 per dollar of tax loss with over half due to inventory accumulation.

V. Two Additional Models

A. *Unobserved Shadow Price Model*

1. Theory. The decision rule governing investment in the Unobserved Shadow Price (USP); (Mussa, 1977; Abel, 1979; Sargent, 1979) model is identical to that in the Q model (cf., (9)),

$$\lambda_t^e = \bar{q}_t + G'(I_t), \tag{13}$$

but the two theories differ in how the unobservable expectations are related to observable variables. In the USP model, the problem of unobservable expectations has been solved by either two-step, one-step, or transformation (or Euler equation) procedures. The two-step procedure decomposes the investment problem into expectations formation and, given these expectations, the decision to acquire investment goods. Expectations are assumed to be formed by some set of lagged variables, including the variable to be forecast and others that may sharpen the prediction. The one-step procedure follows a similar decomposition of the investment decision rule, but estimates all of these parameters simultaneously. The third procedure indirectly attacks the unobservable expectations problem by transforming the investment decision rule (13) to eliminate all but one of the future variables and then replacing this unknown with its realized value.

2. *Empirical Results.*[36] The response of investment to tax policy has varied widely in estimated USP models. Using the Transformation method, Abel (1979, 1980) obtained estimated elasticities of investment with respect to λ_t^e ranging between −.50 and −1.10, and Pindyck and Rotemberg (1983a) found capital to be highly responsive to its own price (elasticity of −2.90) and output (1.50). In a later study based on the same translog cost specification, Pindyck and Rotemberg (1983b) obtained significantly lower elasticities of −.13 and .73, respectively. When equipment and structures were entered separately, price and output elasticities were −.52 and 1.06 for equipment and −.16 and .53 for structures, respectively.

The One-Step procedure was used by Messe (1980) in estimating the demand for labor and capital, and the relative price terms proved insignificant. Bernanke (1983) estimated a One-Step model for purposes of tax policy analysis, and reported that a 10 percent increase in the investment credit "raises net equipment investment 1.9 percent and net structures investment 0.3 percent in the first year" (p. 74). In a model with multiple inputs and adjustment costs, Schramm (1970) found that user cost effects were important but that liquidity played little role in influencing investment.

Using the Two-Step procedure, Craine (1975) found significant relative price terms. The elasticity of investment with respect to the supply price of capital was .94, but may not be useful for tax policy analysis since tax parameters were not included in the definition of the price variable. User cost of capital and output elasticities for both the intermediate-run and long-run capital stocks, of −.20 and .60 were generated by Nadiri and Prucha (1983b) in a study of factor demands by American Telephone and Telegraph. Schiantarelli (updated) reports long-run elasticities for investment that vary widely between positive and negative values depending on the choice of the discount rate. The elasticity for the investment credit is more stable, taking on values between 0.0 and .10.

B. Feldstein's Effective Tax Rate and Return-Over-Cost Models

In the Fisher-Schultz Lecture presented at the Fourth World Congress of the Econometric Society in 1980, Martin Feldstein examined the effect of taxes on investment by estimating two new econometric models, Effective Tax Rate and the Return-Over-Cost, as well as the familiar Neoclassical model. Based on the econometric results from three different models, he concluded that "the rising rate of inflation has, because of the structure of existing U.S. tax rules, substantially discouraged investment in the past 15 years" (Feldstein, 1982, p. 860). Since the Neoclassical model has already been discussed, we focus on the Effective Tax Rate and Return-Over-Cost specifications.

1. Theory. In the first model, Feldstein examines the degree to which net investment is affected by the net-of-tax real return to capital, RN_t, defined as the average yield adjusted for taxes and depreciation to bondholders and shareholders. The following econometric specification for the Effective Tax Rate (ETR) model was estimated,

$$I_t^n/Y_t = e_0 + e_1 UCAP_{t-1} + e_2 RN_{t-1}. \quad (14)$$

The term $UCAP_{t-1}$ is the Federal Reserve Board's Index of Capacity Utilization for Total Manufacturing, and is entered presumably to capture the effects of the business cycle. Both explanatory variables are entered lagged one period to reflect delays in decision making, production, and delivery of capital goods, and to avoid econometric difficulties (Feldstein, 1982, p. 839). Expectations parameters are incorporated implicitly into the e's (cf., eqn. 7). It should be noted that (14) is a savings schedule determined by the equality of benefits (RN_t) and costs (the decline in utility from foregone current consumption) at the margin.

The second new model presented by Feldstein quantifies investment incentives by contrasting the maximum potential net return ($MPNR_t$) on a standard investment project with the cost of funds (COF_t). In this Return-Over-Cost (ROC) framework, the basic marginal-benefit-equal-marginal-cost decision rule governing investment becomes,

$$MPNR_t = COF_t. \quad (15)$$

The $MPNR_t$ depends positively on a hypothetical marginal return, and will be raised by tax stimuli such as more generous investment credits and depreciation allowances. Whenever the maximum potential net return exceeds the cost of funds, firms have an incentive to acquire more capital, and this relationship is embedded in the following econometric equation,

$$I_t^N/Y_t = f_0 + f_1 UCAP_{t-1} + f_2(MPNR_{t-1} - COF_{t-1}). \quad (16)$$

As in the Neoclassical and Effective Tax Rate models, the estimated coefficients represent, in part, expectations parameters.

2. *Key Assumptions, Caveats, and Empirical Results.* All three of the models analyzed by Feldstein in his Fisher-Schultz Lecture have been critically examined in Chirinko (forthcoming). Based on a number of independent criticisms, that study concludes that none of the models, when properly specified and evaluated, support Feldstein's conclusion that taxes have exerted a significantly depressing effect on business net investment during the recent episode of inflation.[37]

VI. Summary and Conclusion

This paper has reviewed the theory, key assumptions, caveats, and empirical results associated with four classes of investment models. To aid in the exposition, the survey has been organized around two elements common to all four classes of models—the formulation of the expected marginal benefits and expected marginal costs of acquiring capital, and the relationship between these unobservable expectations and observable variables. Significant disparities in the implied response of investment expenditures to tax policy were evident in the reported empirical results, but a number of these larger responses were based on assumptions that arguably lead to upward biases. While investment *may* respond significantly to variations in tax parameters, it appears to this author that the supporting empirical evidence has yet to be generated. Whether this conclusion is robust to further econometric work remains an open question for future research.

FOOTNOTES

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[1]Chirinko and Eisner (1983, p. 139).

[2]This view of investment studies parallels that found in Feldstein (1982).

[3]See Jorgenson (1963, 1967), Hall and Jorgenson (1967, 1969, 1971), Jorgenson and Siebert (1968a, 1968b), and Jorgenson and Stephenson (1967a, 1967b, 1969a, 1969b). The formula presented in (3) differs from the conventional expression by the term (1 + D), and has been derived in Chirinko and King (1983).

[4]As noted by Coen (1969) and Gould (1969), a se-

rious problem with (4) is that the profit-maximizing firm will choose both the capital stock and output simultaneously. Under cost minimization the expression for K* would differ somewhat from (4) (see Coen, 1969, p. 378, fn. 12), but would not alter the key points pertaining to the investment function to be discussed in this Section.

[5]This assumption is justified if capital depreciates at a geometric rate (or an exponential rate if the model is stated in continuous time). See Jorgenson (1963, 1967) and Feldstein and Rothschild (1974) for further discussions.

[6]Most investment models are estimated in level form. While the differences in ease of exposition are considerable, the differences in estimation results are fortunately trivial (Eisner and Nadiri, 1970, Table I).

[7]A set of assumptions sufficient for identifying these parameters is that expectations depend solely on last period's value (i.e., static expectations) and the γ's sum to one. If, following Jorgenson, we further assume that the production function is Cobb-Douglas ($\phi = 1 = \sigma$), then the distributed lags in (7) contain identical coefficients.

[8]See Hulten and Wykoff (1981, pp. 96–99) for a further discussion of this "sample selection" (or "lemons") problem.

[9]See Feldstein and Rothschild (1974), Auerbach (1979), and Abel (1981b) for models with endogenous depreciation.

[10]See Auerbach (1983b) and Cordes and Sheffrin (1983) for recent analyses of the carryover of tax credits.

[11]See Klein and Taubman (1971), Abel (1982), and Auerbach and Hines (1985) for analyses of temporary and anticipated tax policies.

[12]A complete analysis of this tax rate differential would recognize the different degrees of risk associated with the corporate and noncorporate forms of organization (Gravelle, 1983).

[13]Simulation results with assumed parameters indicate that the (1 + D) term reduces the sensitivity of the user cost to variations in the rates of inflation and leverage (Chirinko and King, 1983).

[14]See Eisner and Nadiri (1968), Coen (1969), Eisner (1969b), Hall and Jorgenson (1969), and Jorgenson (1972).

[15]A critical review and reconciliation of these disparate direct estimates is provided by Berndt (1976), whose results depend on, among other factors, the specification of the user cost.

[16]Abel (1981a) offers an alternative reason why the estimated response of investment to changes in relative prices and output may not provide any evidence on the nature of the production technology.

[17]Feldstein and Flemming (1971) and Feldstein (1982) modify the Neoclassical model by permitting components of (C/P) to have different elasticities, which can be interpreted as allowing for different expectations patterns.

[18]This result has been established by Eisner and Nadiri (1968, 1970), Eisner (1969b), and Chirinko and Eisner (1982, 1983). Hall and Jorgenson (1969) have commented on the first and third studies; Sinai and Eckstein (1983) on the fourth and fifth studies.

[19]Eisner and Strotz (1963, p. 124). However, after examining sources of finance for small businesses, David Cohen (1981) concluded that "Market mechanisms for the distribution of capital to small and growing firms, while not problem free, do not exhibit any debilitating structural flaws" (p. 263).

[20]Models based on liquidity variables receive less attention in this study than in previous surveys (e.g., Jorgenson, 1971) because, relative to most of the models considered here, the theoretical basis is less developed. Except for personal taxes, the Effective Tax Rate model of Feldstein (Section V.B) can be interpreted as a model of liquidity.

[21]Liquidity variables have not generally performed well. In reviewing the results from a number of models, Jorgenson (1971) concluded that "Variables associated with internal finance do not appear as significant determinants of desired capital in any model that also includes output as a significant determinant" (p. 1133). Further results for liquidity variables are contained in the comparative studies cited in fn. 23 and in the Q models cited in fn. 35.

[22]Gould and Waud (1973) found that a reduced form investment model (i.e., one in which output had been substituted out; cf. fn. 4) performed as well or better than the Neoclassical model of Jorgenson and Stephenson (1967b).

[23]Bischoff (1971b) and Kopcke (1985, and previous studies cited in his fn. 11) also analyze a series of models with aggregate data.

[24]The dominant role of output may stem from a definition of output that includes investment, possibly resulting in a spurious correlation between investment and output variables (mentioned to the author by Robert Gordon). Spurious correlation could also arise because investment and output both trend upward over time, but can be eliminated by dividing investment and output by a variable with a significant trend component (e.g., potential GNP as in the Clark study).

[25]None of the results are strictly comparable owing to a number of differences in constructing and estimating the models, especially with regard to the sector under study. The data of Hall and Jorgenson pertain to manufacturers' equipment, those of Bischoff to aggregate equipment, and those of Coen to manufacturers' equipment and structures.

[26]On average, replacing the dividend-share price or earnings-share price ratios resulted in, ceteris paribus, a 25% reduction in the investment increase under the tax credit scenario. More extreme effects were found by Eisner (1969b, Tables 3 and 4).

[27]In a recent study, Hendershott and Hu (1981) present evidence of a strong link between the user cost and equipment investment, but the relevant t-statistics are unacceptably low by conventional standards.

[28]In their simulations with the Wharton model, Klein and Taubman (1971) found that, if tax incentives had not been reinstated in March 1967, investment spending in 1967 would have declined by 2.3 billion constant (1958) dollars, approximately half of which was due to feedbacks from the non-investment sectors of the model.

[29]A further advantage of Q theory is that, unlike the Neoclassical model, it incorporates the simultaneous determination of output and capital (cf., fn. 4).

[30]Adjustment costs were initially introduced by Eisner and Strotz (1963) as representing external adjustment costs due to a rising supply curve for capital goods. See Lucas (1967a), Gould (1968), Treadway

(1969) for models of internal adjustment costs.

[31]The key conditions are that the firm's production technology is homogeneous of degree one, markets are perfectly competitive, and capital depreciates at a geometric rate. Furthermore, Hayashi's derivation indicates that the numerator of Q_t^A must be lowered by the present value of tax depreciation allowances to be claimed in the future on existing assets.

[32]A caveat is that, in order to specify Q_t^A, we need to make some assumptions about future discount rates and tax rules that will affect z_t, hence $\hat{q}_t$.

[33]See Hayashi (1982) and Rukstad (1985) for the case of imperfect competition, Chirinko (1985) for non-constant returns to scale and endogenous financial policy, and Chirinko (1984b) for multiple capital inputs.

[34]Grunfeld (1960) appears to have been the first to use market value data as a regressor in an investment equation.

[35]When liquidity variables have been entered with Q, the results have been mixed; see Grunfeld (1960), von Furstenberg (1977), Chappell, Cheng, and Richards (1984), and Chirinko (1985).

[36]A discussion of the key assumptions and caveats associated with the USP model is precluded because of space limitations and a desire to avoid some technical issues beyond the scope of this survey.

[37]Feldstein will be presenting a reply.

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