Working Paper 73-3

THE COST OF CAPITAL, THE DESIRED CAPITAL STOCK,

AND A VARIABLE INVESTMENT TAX CREDIT

AS A STABILIZATION TOOL

Glenn C. Picou   Roger N. Waud

November 16, 1973

THE COST OF CAPITAL, THE DESIRED CAPITAL STOCK, AND A VARIABLE INVESTMENT TAX CREDIT AS A STABILIZATION TOOL

Glenn C. Picou* and Roger N. Waud**

This study considers the potential of a variable investment tax credit to relieve the pressure of a contracyclical monetary policy on the housing and State and local government sectors. In particular, it examines the potential of such a policy instrument to affect business capital expenditures in the United States manufacturing sector at the two-digit SIC (Standard Industrial Classification) level of aggregation. If a variable investment tax credit can affect investment expenditures with sufficient force and speed, the active use of such a policy instrument could reduce the stabilization burden now borne by the housing and State and local government sectors.

Perhaps the best known recent works in this area are those by Hall and Jorgenson (11, 12 13) and Bischoff (2). The model used by Hall and Jorgenson assumes that the elasticity of the desired capital stock with respect to the implicit rental rate on capital is unity, that is, it is an assumed rather than an estimated value. In addition, their model has a theoretical difficulty which recent re-

---

* Economist, Federal Reserve Bank of Richmond.
** Professor of Economics, University of North Carolina, Chapel Hill; Senior Economist, Board of Governors of the Federal Reserve System. Cathy Gaffney, Federal Reserve Bank of Richmond, provided considerable programming assistance.

search [6] has found to be of empirical consequence. Essentially this

difficulty stems from attempting to explain the demand for an input,

capital, by use of output in a single equation model. Bischoff's

model is more general than that used by Hall and Jorgenson in that

it assumes a CES production function, instead of Cobb-Douglas, and

is a putty-clay model as opposed to a putty-putty model. Bischoff's

model still has the same theoretical difficulty alluded to above how-

ever. Furthermore, his model must be estimated by nonlinear estimation

techniques the statistical properties of which have not as yet been

established except to a limited extent in certain asymptotic cases.

Bischoff's as well as Hall and Jorgenson's empirical investigations

of tax effects on investment behavior were conducted at a much more

aggregative level than that undertaken in this study. Our model differs

from both of these models in that: output specific to the industry is

not used as an explanatory variable; the effects of labor costs on the

demand for capital are explicitly taken into account. Our model dif-

fers from the Hall-Jorgenson model in that the elasticity of the de-

sired capital stock with respect to the implicit rental rate on

capital is a parameter to be estimated, rather than assumed to equal

one. Our model differs from the Bischoff model in that ours is a putty-

putty model assuming a Cobb-Douglas production function. Because of

this we are able to use a linear estimation procedure whereas Bischoff's

model must be estimated by nonlinear techniques. Undeniably, this gain

is obtained by giving up some generality of specification. However, as

regards the Cobb-Douglas assumption, Jorgenson's survey [14, pp. 1131-1133] of findings on this issue concludes that it is a tenable assumption.

In Section I we summarize the case that is commonly put forward for a variable investment tax credit scheme. Section II details the framework of analysis used in this study. Section III discusses estimation and related data problems, and presents our estimation results. In Section IV the policy implications of our findings are considered.

I. Monetary Policy and the Case for a Variable Investment Tax Credit

A major, often heard, complaint against heavy reliance on monetary policy to stabilize the economy is that its effectiveness places the major burden of adjustment on those sectors most sensitive to changes in general credit conditions. In particular, the housing and State and local government sectors appear among the most severely, some argue inequitably, penalized. Given the existing political and economic institutions, these sectors will continue to bear the cutting edge of monetary policy unless measures are instituted that will increase the responsiveness of other sectors to monetary stabilization policies.[1]

---

[1] A compendium of papers which examines possible measures to alleviate the problem in housing in particular, plus extensive bibliographies on the problem in general, may be found in [3].

There are a number of potential ways to reduce the burden of cyclical stabilization currently borne by the housing and/or the State and local government sectors. Most have some severe drawbacks associated with them however. For example, the notion of pursuing a more active contracyclical fiscal policy has not turned out to be very feasible in the United States. Allocation considerations have typically taken precedent over stabilization objectives in making Federal expenditure decisions, and the instigation and implementation of changes in general tax rate schedules has usually been a protracted process. Schemes designed to insulate the housing sector from the effects of changes in credit conditions would only serve to further exacerbate the effects of such changes on the State and local government sector, and schemes designed to insulate the latter would similarly worsen the burden on the housing sector. Schemes designed to buffer both sectors from the effects of changing credit conditions would reduce the impact of monetary policy on aggregate demand and therefore would require larger, probably unpalatable, fluctuations in interest rates and monetary aggregates to obtain the same effect on aggregate spending. Hence, extensive insulation of the housing and State and local government sectors would considerably compromise the efficacy of monetary policy as a stabilization tool.

Largely because of the above considerations, attention has been given to the design of policy instruments intended to affect business fixed investment in a contracyclical manner. Whatever the sources

of fluctuations in aggregate economic activity, changes in the rate of
business fixed investment have been a large and volatile component. If
this component could be stabilized, reliance on conventional monetary
policy could be reduced and this would help alleviate the burden of
cyclical adjustment that is now borne by housing and State and local
government construction activity. It appears that conventional monetary
policy as conducted since the Treasury-Federal Reserve accord has found
it difficult to exercise either a rapid or sizeable influence over busi-
ness fixed capital spending. This suggests that attempts to induce
contracyclical movements in business fixed investment may require larger
movements in interest rates and monetary aggregates than monetary policy
has heretofore envisioned. But this would place an even more severe
burden of adjustment on the housing and State and local government sec-
tors. These considerations have motivated the search for a policy in-
strument specifically designed to directly affect business fixed invest-
ment expenditure while minimizing their impact on other sectors.

Such an instrument could be designed by using a system of
business investment taxes and subsidies to pursue desired stabilization
goals. Various traditional types of taxes could be imposed on invest-
ment during periods deemed excessively expansionary while investment
tax credits might be offered during recessionary periods. Because it
is typically difficult to get rapid congressional approval of such
discretionary measures, it would be necessary that such a scheme be
endowed with formula flexibility, with circumscribed discretionary

authority vested either in the executive branch of government or the
Federal Reserve System in order that the primary function and purpose
of the scheme may be to pursue stabilization goals. For lack of a
better name, such a policy instrument may be called a variable invest-
ment tax credit.[2/]

In the context of a neoclassical theory of factor demand,
such as developed by Haavelmo [10] and Jorgenson [15], it can be shown
that a variable investment tax credit (VITC) can change the effective
factor demand for capital equipment by altering the implicit rental
rate or own price of capital. If a VITC scheme is to be a useful
stabilization tool, two conditions must be satisfied to some reasonable
degree: first, the demand for capital should be sensitive to changes
in the implicit rental rate of capital; second, the full impact of such
changes must occur within a reasonable time after a change in the im-
plicit rental rate occasioned by a change in the VITC. It is the purpose
of this study to provide an empirical examination of both of these issues
for twelve out of twenty of the two-digit SIC industries comprising total

---

2/ An alternative approach has been suggested by Pierce and Tinsley [3,
pp. 345-355]. They propose the establishment of a business investment
fund (BIF) having a unit deposit or withdrawal rate geared to the level
of aggregate fixed investment expected relative to the expenditure level
deemed necessary for economic stabilization; the BIF rate would amount
to a mark-up or rebate on the purchase price of new capital goods. A
positive BIF rate would be applied to gross fixed investment expenditures
during periods of excess aggregate demand, thereby effectively raising
the price of new capital goods and discouraging investment demand. During
periods of deficient aggregate demand the BIF rate would be negative, the
outpayments serving to effectively lower the price of new capital goods
to investing firms. A similar scheme has been used in Sweden: see
Lindbeck's paper in this volume.

U.S. manufacturing (see Table 1): with regard to the sensitivity of

the desired capital stock to changes in the implicit rental rate of

capital, elasticity estimates are obtained; with regard to lag lengths,

distributed lags are estimated to attempt to ascertain how long it

takes for the impact of a change in the implicit rental rate of capital

to be fully realized.

TABLE 1

STANDARD INDUSTRIAL CLASSIFICATION

SIC #	INDUSTRY
20	Food and Beverages
22	Textile Mill Products
26	Paper and Allied Products
28	Chemical and Allied Products
29	Petroleum and Coal Products
30	Rubber Products
32	Stone, Clay, and Glass
33	Primary Metals
34	Fabricated Metals
35	Nonelectrical Machinery
36	Electrical Machinery and Equipment
38	Instruments

If the lags appear to be "too long," a case can be made for

administering the VITC scheme in such a way as to encourage business

investment decision makers to speed up their attempts to put new capital

in place. For example, if the policy maker publicly announces that an

investment tax credit will be granted on all projects started between

say time t and t + 4 (a period of four months for example), decision makers would presumably try to take advantage of such a credit while it lasted. The closer the termination date is to t , the more "bunching" of investment expenditures would presumably occur in the time interval from t to t + j , where j is the termination date. By varying j the policy maker could in this way have an effect on the length of the lag between the change in the implicit rental rate of capital, caused by a change in the variable investment tax credit, and the point in time by which the impact of such a change on the desired stock of capital would be fully realized.

The purpose of a VITC scheme is to stabilize business fixed investment which, by virtue of its multiplier effects on aggregate demand, would serve to help stabilize the economy. Increased stability of the economy would in turn make the task of stabilizing investment that much easier by reducing the fluctuations in the feedback effects from the economy on investment -- the well-known accelerator effect which aggregate economic fluctuations have on investment. This study obtains estimates of the strength of these feedbacks and the distributed lag lengths over which their impact on investment is fully realized. Hopefully this will shed some light on just how much the feedback effects of increased stability in the economy might aid a VITC scheme's task of stabilizing fluctuations in fixed business investment.

II. The Framework of Analysis -- A Neoclassical Reduced Form Model

The model used in this study is derived from a microtheoretical analysis of a monopolistic producer. The model can then be extended to imperfectly competitive and perfectly competitive industries. The interpretation of the parameters is the same on an industry or firm level; and the market structure of the industry will not affect the interpretation of the results. The model has been used to analyze investment behavior by Gould and Waud [6], and a variant has been used by Waud [24] to study the demand for labor.

The Reduced Form

The following symbols are used in the derivation of the model to follow:

P = unit price of output Q;

Q = quantity of output;

s_1 = total cost per production worker hour;

s_2 = total cost per overhead worker hour;

L_1 = production worker hours;

L_2 = overhead worker hours;

q = price of capital goods;

K = capital stock employed;

$K*$ = capital stock desired;

I = gross capital formation;

T = corporate profit taxes;

R = time rate of discount;

u = corporate tax rate;

v = proportion of depreciation cost chargeable against net taxable income;

w = proportion of cost of capital chargeable against net taxable income;

x = proportion of capital gains on assets subject to taxation;

r = cost of capital;

δ = rate of depreciation.

In this version of the neoclassical model, it is assumed that the firm chooses its capital and labor inputs in such a manner as to maximize its net worth, or the present value of all future net receipts. It is also assumed that replacement investment is directly proportional to the capital stock of the firm.[3/] Net investment is thus constrained by the relation

(1) $\dot{K} = I - \delta K$ $(\dot{f} = df/dt)$

The firm's output is also constrained by the production possibilities embodied in the firm's production function

(2) $F(K, L_1, L_2, Q) = 0$.

Net receipts at time t are equal to the algebraic sum of gross receipts, labor costs, capital costs, and taxes, where taxes are equal to the tax rate times the firm's net taxable income:

3/ For a discussion of this assumption, see Jorgenson [17, p. 139] .

(3) $\qquad T = u[PQ - s_1L_1 - s_2L_2 - vq\delta K - wqrK + x(\dot{q}/q)qK]$.

In (3), $vq\delta K$ is the amount of depreciation chargeable against net income, $wqrK$ is the amount of capital cost chargeable against net income, and $x\dot{q}K$ is the amount of capital gains chargeable to net income. The unit cost of capital is assumed to be invariant with respect to the rate of investment. The cost of investment at the rate I is simply equal to the amount of capital investment per unit of time multiplied by the unit cost of capital goods. The labor inputs L_1 and L_2 are assumed to be sufficiently elastic so that the desired labor inputs can be realized in each period without any costs of adjustment.[4] Thus the cost functions for labor are simply equal to the labor inputs multiplied by their unit costs.

The firm will thus act so as to maximize

(4) $\qquad V = \int_o^\infty e^{-Rt}[PQ - s_1L_1 - s_2L_2 - qI - T] dt$

subject to the constraints (1) and (2). We assume a Cobb-Douglas production function. Neutral technological change is introduced into the production function by assuming that the effective input from each factor is the product of that input and a proportionality factor which is a function of time. The proportionality factor in the production function is also a function of time. In this case, the proportionality

---

4/ It will be presumed that the demand for labor inputs for a two-digit industry constitutes a relatively small proportion of the total labor demand. Consequently, labor inputs can be adjusted to the desired level in each period with little cost of adjustment. Such an assumption is made by Waud [24].

factors are assumed to be exponential functions of time: $A_i(t) = A_i e^{g_i t}$ $(i = 0, \ldots, 3)$. Thus the production function can be expressed as

$$(5) \qquad Q = A_o(t) \; \bar{A}_1(t)\bar{K}^{-a} \; \bar{A}_2(t)L_1^{-b} \; \bar{A}_3(t)L_2^{-d}$$

$$= A e^{gt} K^a L_1^b L_2^d \qquad a,b,d \geq 0$$

where $A = A_o A_1^a A_2^b A_3^d$ and $g = ag_1 + bg_2 + dg_3$; it is assumed $g > 0$.

Substituting (3) and (5) into (4) and then obtaining the Euler first order conditions for a maximum, we get the following comparative static equilibrium values for capital and labor:[5]

$$(6) \qquad K = K^* = \frac{aQP}{c} \; ;$$

$$(7) \qquad L_1 = L_1^* = \frac{bQP}{s_1} \; ;$$

$$(8) \qquad L_2 = L_2^* = \frac{dQP}{s_2} \; ;$$

where c in (6) is the implicit rental on a unit of capital services, or the own price of capital, which from the Euler conditions can be shown to be

$$(9) \qquad c = q \left[\left(\frac{1 - uv}{1 - u}\right) \delta + \left(\frac{1 - uw}{1 - u}\right) r - \left(\frac{1 - ux}{1 - u}\right) \dot{q}/q \right] \; .$$

---

[5] The details of this derivation may be obtained from the authors on request.

Following Jorgenson [16, p. 59], it is assumed that the firm views all

capital gains and losses on its capital stock as transitory. This

assumption may be justified on the grounds that the manufacturing

firm does not generally buy capital goods with the intention of realizing

any capital gain which might arise due to changes in the prices of capital

goods. The firm views all such capital gains as transitory and of no

consequence in determining its cost of capital so that $(\dot{q}/q)$ can be

equated to zero. From (6) and (9) it is now apparent how tax and credit

schemes imposed on the firm enter into the determination of the desired

capital stock through the own price of capital c , that is, by virtue

of the presence of such policy determined tax parameters as u , v , and

w in (9). It is through changes in just such parameters as these that

a VITC scheme would work by changing c .

It is important to emphasize that (6) defines the long run

equilibrium value of capital, since the cost of adjustment of capital

has been constrained to zero. In a dynamic situation, however, the

desired capital stock will not equal (and will generally exceed) the

actual stock. The actual output level, Q , which is constrained by

the actual capital stock, will generally fall short of the long run

optimal output level. Gould [9] has shown that the use of actual out-

put in determining optimal capital when output is constrained by the

nonequilibrium stock of capital K will lead to a bias in the estima-

tion of the long run value K^{*} . This occurs if the level of output

which can be produced under the constraint imposed by the production

function is less than that which the firm would wish to produce given the demand for its product. It is therefore necessary to formulate long run desired capital in terms of variables which are not influenced by the capital investment decision and the adjustment processes of the firm.[6/] To obtain the necessary reduced form model, it will be assumed that a monopolist firm faces the following demand function:[7/]

$$(10) \qquad P = \lambda_o Q^{\gamma_1} Y^{\gamma_2} \qquad \gamma_2 \geq 0 , \quad \gamma_1 < 0 ..$$

The shift variable Y is real GNP, and $\gamma_1 = (1/\eta)$, where η is the firm's price elasticity of demand.[8/] For the nonmonopolist industry, η is the elasticity of demand for the industry as a whole.

Using the equilibrium values of capital and labor, as given by (6), (7), (8), the demand function (10), the production function (5), and the first order conditions, it can be shown that the desired capital stock can be expressed as a function of technological change, the own price of capital, the costs of labor, and the shift variable, real GNP:[9/]

6/ Gould and Waud [6] have found that this consideration, to some a seemingly theoretical nuance, appears to be an important consideration when estimating investment functions from real-world data, and then using the estimated investment functions to forecast future levels of investment expenditures.
7/ This procedure also eliminates another source of endogeneity present in the desired capital stock specification of (6), i.e., the price-quantity relationship implicit in the demand function. It is assumed that the firms in the industry make a decision with respect to either quantity or price. In this study the firm is presumed to be a price taker and a quantity adjuster. In either case, quantity and price cannot both be considered exogenous to the firm, or the industry.
8/ This follows Gould and Waud [6].
9/ The rather lengthy and involved details of this derivation will be provided on request of the authors.

(11)
$$K^* = \lambda_o e^{\lambda_1 t} c^{\lambda_2} s_1^{\lambda_3} s_2^{\lambda_4} Y^{\lambda_5} .$$

or in log-linear form

(12) $\ln K^* = \ln\lambda_o + \lambda_1 t + \lambda_2 \ln c + \lambda_3 \ln s_1 + \lambda_4 \ln s_2 + \lambda_5 \ln Y .$

Equation (12) expresses the capital demand function for a monopolist firm. Gould [7] has shown that the model can be extended to the analysis of any industry organization without any change in the interpretation of the demand elasticities λ_i . The only change in the model occurs in the constant term.[10]

Analysis of the raw data showed very high correlations between s_1 and s_2 . It is therefore assumed for all industries that $s_2 = \theta s_1$.[11] In order to avoid serious multicollinearity problems this relationship is used to substitute s_2 out of the derivation which leads to the reduced form (11) and (12). The reduced form model can then be rewritten as

---

[10] Gould [7, pp. 35, 36] demonstrates that ". . . these coefficients $[\lambda_i]$ are the elasticities of K^* with respect to each of these variables and hence this result can be interpreted as meaning that a change in the price of productive factors, a shift in demand, or a neutral technological change will have the same proportionate effect on the demand for capital irrespective of whether the industry is monopolistic or competitive in structure. This identity of coefficients has empirical advantages, since the interpretation of the estimated parameters (except the intercept) stays the same even if the organization of the industry is ambiguous."

[11] Simple regression of $\ln s_2 = \ln\theta + \ln s_1$ produced R^2's of more than .90 for all industries except SIC 34, in which the R^2 was quite small. To maintain uniformity in the results, the assumption $s_1 = \theta s_2$ was also made in SIC 34, although the possibility of specification bias is thereby introduced.

(13) $\quad \ln K_t^* = \ln \lambda_o + \lambda_1 t + \lambda_2 \ln c_t^* + \lambda_3 \ln s_{1t}^* + \lambda_4 \ln Y_t^*$

where the coefficient on $\ln Y_t^*$ is now called λ_4 instead of λ_5.
The asterisks on c , s , and Y indicate that these are the values
expected to hold in the "long run," the permanent values of c , s ,
and Y ; we shall discuss this at greater length below.

Cost of Adjustment

The desired capital stock K^* appearing on the left side of
(13) refers to the amount of capital which is desired at the present
time t given the values on the right side of (13). This model,
however, like almost all others which have been used in the empirical
analysis of investment behavior,[12] has been derived on the assumption
that the unit cost of capital goods is invariant with respect to the
rate of capital formation. This assumption is no doubt an inaccurate
characterization of the capital stock adjustment process since clearly
the more rapidly a firm, or industry, tries to purchase and put capital
stock in place, the more expensive each unit of capital will become.

The firm's cost of capital adjustment reflects both internal
and external cost factors. An internal cost is associated with the
introduction of new equipment to a firm's production process. One
example of such a cost might be the overtime payments required for
the installation of capital equipment in a relatively short period
of time. The more rapid the rate of installation for a given unit of

---

12/ See Jorgenson [14] for an extensive survey.

capital, the greater these internal costs. The external cost is the purchase price of a unit of capital. For a single firm in a competitive market for capital equipment, external costs of adjustment may well be zero. However, if the firm's desire to accumulate capital more rapidly is held in common with other firms in the market, their common attempt will tend to raise the supply price of capital. For an industry as a whole, regardless of the market structure of the capital goods producing industry, an attempt to increase the rate of capital investment would tend to push up the purchase price of capital.[13/] Taking both factors into consideration, a realistic cost of investment function for a manufacturing industry should reflect these nonzero costs of adjustment. Hence it is inconsistent to speak of profit maximizing behavior without recognizing that the rate of investment will be a determinant of the unit cost of capital, and this cost will have an effect upon the profits of the firm. But if costs of investment affect profits, they also affect the desired capital stock variable. That is, the desired capital stock and the rate of investment are determined simultaneously, with the cost of adjustment a factor in their mutual determination.[14/]

When it is assumed that the unit cost of capital goods is invariant with respect to the rate of capital formation, the first order conditions for maximization of the present value of all future

---

13/ For a detailed discussion of adjustment cost function characteristics, see Eisner and Strotz [5].
14/ See Gould [8] for an extensive discussion of these issues.

net cash flows, i.e., maximization of equation (4), do not yield an

investment equation but rather the equilibrium value of the capital

stock since investment is either zero or infinite, as Haavelmo [10]

has demonstrated. This is precisely what is given by the reduced form,

equation (13). The typical investment study, having arrived at some

expression for K^* by a maximization procedure under the assumption

that the unit cost of capital goods is invariant with respect to the

rate of capital formation, then attempts to relax this assumption and

give explicit recognition to the real world fact that firms cannot

adjust their actual capital stock to the desired level instantaneously

without incurring exorbitantly prohibitive costs of adjustment. They

do this by substituting for K^* the equation defining K^*, such as

(13), into some kind of ad hoc adjustment scheme which defines how the

actual capital stock is adjusted through time to the desired level K^*.

Such a scheme is then shown to give rise to an expression defining

investment expenditure as a distributed lag function of all the vari-

ables defining the desired capital stock.[15]

The only theoretically correct way of dealing with the cost

of adjustment problem is to directly incorporate cost of adjustment

functions, for both labor and capital, into the objective function,

such as (4), and then carry out the maximization procedure.[16] This

---

15/ For a more complete description of this procedure and a survey
of the studies which adopt it, see Jorgenson [14].
16/ See Gould [8] for an extensive discussion of this procedure and
the issue in general.

explicitly recognizes the fact that the rational firm must take explicit account of adjustment costs in the profit-maximizing process. When such costs are included in the objective function, the resulting first order conditions yield the optimum capital stock and the corresponding investment path for the firm. However, the investment functions are nonlinear forms not amenable to linear estimation techniques, and this limits their usefulness in empirical analysis. This is the main reason such a procedure was not followed in this study.

Given that (13) was derived on the assumption that the unit cost of capital is invariant with respect to the rate of capital formation, and given that we know that the unit cost of capital typically rises with the rate of capital formation -- contrary to assumption, it must be recognized that at any point in time t the desired capital stock K^* defined by (13) is not likely to be equal to the actual capital stock K in place at t in a world continually adjusting to change. Only in some long run, static, steady state might we expect K^* to equal K .[17/] Recognizing therefore the need for characterizing

---

17/ Even this would only be approximately true because, in a real world characterized by nonzero adjustment costs, the desired long-run steady state level of the capital stock would be lower than that desired in a world where adjustment costs are zero. This is because nonzero adjustment costs would make any amount of capital more expensive than would be the case if adjustment costs were zero, and these costs would effectively drive up the implicit rental rate on capital thereby reducing the size of the desired capital stock below what it would be if adjustment costs were zero and the implicit rental rate of capital were therefore lower. Hence, even in a long run steady state, K^* as defined by (13) would tend to overstate the amount of capital desired in a world characterized by nonzero costs of adjusting to that steady state.

the process by which the actual capital stock K is adjusted to the

desired capital stock K^* through time, we could adopt the rather

general, though ad hoc, adjustment process specified by Jorgenson [15].

Substituting K^* as defined by (13) into that scheme gives rise to a

distributed lag investment function.[18/] Unfortunately, the function

is nonlinear and must be estimated by nonlinear estimation techniques.

One of the main requirements of this study is to be able to make state-

ments regarding the statistical significance of the estimated relation-

ships between K^* and the explanatory variables on the right-hand side

of (13). Unfortunately, the theory of statistical inferences for non-

linear estimators is not as yet sufficiently developed to allow us to

do this. Another serious drawback of the Jorgenson scheme is that it

would constrain us to the assumption that the distributed lags on the

independent variables in (13) are all of the same length. We have no

a priori reason for believing this to be the case.

Given all of these considerations the approach taken in this

study is to construct ex post measures of the desired capital stock

K^* for each industry and substitute these measures for K^* into (13).

Then we may use linear estimation techniques and, in addition, we are

not constrained to assume that the independent variables in (13) all

have the same distributed lag lengths.

_____

18/ This has in fact been done elsewhere: see Gould and Waud [6].

Measuring the Desired Capital Stock

Given that the costs of capital stock adjustment rise with the rate at which the firm adjusts its actual capital stock to its desired or target level, it follows that at any point in time t the firm envisions making this adjustment to its notion of the desired level, held at time t , over several periods n . Presumably, the more (less) rapidly costs of adjustment rise with the speed of adjustment the lower (larger) will be the rate of adjustment of the actual capital stock to the desired level. It is maintained that the firm's plans for capital accumulation are embodied in its capital appropriation decisions. Given the firm's actual stock of capital in period t and the stock of capital which it desires to have in place in period t + n assuming its anticipations are realized, it is assumed that the firm adjusts its capital appropriations backlog so that the backlog represents the amount of capital expenditures necessary to bring the actual capital stock up to the desired level in period t + n .[19] These expenditures will include replacement investment necessary to maintain the current capital stock plus expenditures for replacement of any net capital formation which occurs over the n periods. Let o_t be that proportion of the appropriation backlog B_t which the firm anticipates will be directed toward net capital formation.

---

[19] This notion of the desired capital stocked is based on an assumption made by Jorgenson [17, p. 177]. ". . . We assume that the desired level of capital is equal to the actual level of capital plus the backlog of incompleted investment projects."

Assuming that the firm forecasts its expenditure pattern accurately over the n period horizon, o_t can be estimated ex post, as described below. Subsequently, it can be shown that the desired capital stock for period $t + n$, as of period t , can be expressed as the sum of current capital stock depreciated at the rate δ over the subsequent n periods, and the depreciated gross investment stream over the same period. We will now develop this notion of the desired capital stock more explicitly.

The concept of desired capital stock employed in this study assumes that in period t , the capital stock desired for period $t + n$, K^*_t , is equal to the current stock of net depreciable capital assets plus some proportion of the current backlog:

$$(14) \qquad\qquad K^*_t = K_t + o_t B_t .$$

K_t is the stock of net depreciable assets at the end of period t , B_t is the backlog, in real terms, at the end of period t , and o_t is the proportion of the current backlog planned for net capital formation over the investment "horizon" (which is discussed below). The remaining proportion of the backlog, $(1 - o_t)$, is planned either for maintaining the existing stock of capital over the n period horizon, or for maintaining the new capital stock which is put in place in periods $t + 1$ through $t + n - 1$.

The proportion o_t of the backlog intended for net capital expansion over the horizon is estimated ex post. Net capital expansion

over n periods is the sum of depreciated (determination of δ , the depreciation rate, is described below) gross investment over the n periods less the depreciation over n periods of the capital stock in place at the beginning of the n periods (end of period t). Thus:

$$(15) \qquad o_t = \frac{\sum_{i=1}^{n} (1 - \delta)^{n-i} I_{t+i} - K_t - K_t (1 - \delta)^n}{B_t} \ .$$

Examination of (15) reveals that it defines the proportion of the back-log intended for net capital expansion over the horizon. Since $K_t (1 - \delta)^n$ represents the amount of capital K_t presently in place which will still be in existence in period $t + n$, $K_t - K_t (1 - \delta)^n$ represents the amount of capital presently in place which will no longer be in existence in period $t + n$. $\sum_{i=1}^{n} (1 - \delta)^{n-i} I_{t+i}$ represents that part of gross investment taking place between t and $t + n$ which will still be in existence as capital stock in period $t + n$. Hence the numerator of (15) represents the net addition or growth of the capital stock between t and $t + n$. The numerator of (15) divided by B_t , the total backlog in existence in period t , gives o_t , the proportion of the backlog intended for net capital expansion over the horizon n . The resulting desired capital stock can be expressed as:

(16) $\quad K_t^* = K_t + {}_oB_t$

$$= K_t + \sum_{i=1}^{n} (1 - \delta)^{n-i} I_{t+i} - [K_t - K_t(1 - \delta)^n.$$

$$= \sum_{i=1}^{n} (1 - \delta)^{n-i} I_{t+i} + K_t(1 - \delta)^n .$$

The assumption of perfect forecasting is made for the simple reason that the true desired capital stock variable is an ex ante variable which is a function of the expected investment stream over time. Such a simplifying assumption is necessary to allow any estimation whatsoever of desired capital stock. Perhaps the strongest justification for this assumption is provided by the rational expectations hypothesis due to Muth [19]. Basically, that hypothesis asserts that rational economic actors will use forecasting schemes which have the property that they are correct on average, i.e., that they are unbiased predictors. Unfortunately, even if this is true on average, it is still possible of course for the forecaster to be systematically wrong over some finite number of periods. For example, suppose the actual investment stream through period $t + n$ in fact exceeds the planned investment stream based upon conditions in period t. Given the conditions in period t, the firm may accurately forecast what the investment path would be over n periods, were nothing to change after period t. Only if the firm were also accurate in its anticipation of the future values of the explanatory variables in (13) would actual

investment over n periods tend to coincide with the expected n

period stream from period t to t + n . If however, the economic

series under consideration were subject to some exogenous shift in-

troducing a positive time trend for example, it is possible that

over time the firm would be revising its desired capital stock up-

ward. This would mean that in period t + i, $0 < i \leq n$, the actual

rate of investment would include a component resulting from changes

in desired capital after period t . If I^*_{t+i} is the expected in-

vestment expenditure due to conditions in period t , and if the de-

sired capital stock is revised upward after period t and before

t + i , then it is possible that $I_{t+i} > I^*_{t+i}$. Such a situation

would introduce a systematic error into measurement of the dependent

variable K^*_t , which might give rise to serial correlation.

The planning horizon of the firm is the number of periods

n over which the current appropriations backlog is expected to be

translated into actual capital formation. The procedure to be used

in the estimation of the length of the horizon is that suggested in

the NICB Survey of Capital Appropriations.[20] The backlog rate is the

ratio of the backlog of capital appropriations outstanding at the end

of each quarter, divided by the amount of actual capital expenditures

during that quarter. The backlog rate indicates the number of quarters

over which the current backlog would be worked off, were it to be

spent at the current rate of investment. The high, low and average

---

20/ See Cohen [4, p. 318] .

length of the planning horizon over the period 1954 to 1967 is given

for each industry in Table 2. The horizon was computed by taking the

rounded value of the backlog rate for each quarter from 1953 to 1967.

TABLE 2

LENGTH OF PLANNING HORIZON*

SIC #	HIGH	LOW	MEAN
20	4	1	2
22	9	2	5
26	7	3	4
28	7	3	4
29	5	1	3
30	6	1	4
32	8	2	4
33	9	3	6
34	10	3	6
35	6	1	3
36	9	3	5
38	5	1	3

* Rounded.
Source: Computed from NICB Survey on Capital
Appropriations.

The procedure used to estimate the rate of depreciation δ

for each industry is that developed by Jorgenson [16, pp. 38-40].

The estimates of the depreciation rates for each industry are shown

in Table 3. A description of all the data used in calculating the

desired capital stock series for each industry is given in the

appendix.

TABLE 3

ESTIMATED RATE OF DEPRECIATION

SIC #	δ
20	.01235
22	.02015
26	.01302
28	.01942
29	.01316
30	.01839
32	.02051
33	.01919
34	.02079
35	.03123
36	.01165
38	.01067

Expectations and Distributed Lags

In a world of perfect knowledge and positive costs of adjust-
ment, K^*_t would be the capital stock which, given the future paths
of the explanatory variables c , s , and Y as of period t , the
firm desires for period $t + n$. This capital stock would in fact be
realized in period $t + n$. But knowledge of the future is not certain,
and future values of the explanatory variables will not be known with
certainty. As it stands, the formulation of desired capital depends upon
variables unknown at time t . To characterize the way the firm handles
this problem we assume that the decision maker in the firm has an
"anticipation" function. This function transforms ex post data into
ex ante data which in this case are the expected, long run equilibrium

values of c , s , and Y prevailing over some specified period of
time.[21/] These expected long run, or "permanent," values c^* , s^* ,
and Y^* , at time t are each assumed to be functions of their past
values.[22/] The permanent value is incorporated in the form of a
distributed lag function of each of the independent variables in (13).
(The asterisks indicate these long run or permanent values of the
variables.) The permanent values of the three independent variables
are assumed to be exponential functions of past values of each of the
respective variables. These anticipation functions can be expressed
in log linear form as

$$\text{(17)} \qquad \ln c_t^* = \sum_{i=0}^{\theta_2} a_{2i} \ln c_{t-i}$$

$$\text{(18)} \qquad \ln s_{1t}^* = \sum_{i=0}^{\theta_3} a_{3i} \ln s_{1t-i}$$

$$\text{(19)} \qquad \ln Y_t^* = \sum_{i=0}^{\theta_4} a_{4i} \ln Y_{t-i}$$

where θ_2, θ_3, and θ_4 are the respective lag lengths on c , s ,
and Y . Substituting (17), (18), and (19) into (13), the final form
of the reduced form model to be estimated is:

21/ The entire future path of the independent variables will not in
general be needed for purposes of optimum decision making. Beyond
some future date, values of the independent variables will become
irrelevant to the current optimum decision. See Modigliani and Cohen
[18, pp. 34-36].
22/ Alternatively, the anticipation functions could be interpreted as
expressing a relationship between past values of the variables and the
relevant future paths of P , s , and c .

$$(20) \qquad \ln K_t^* = \ln \lambda_o + \lambda_1 t + \lambda_2 \sum_{i=0}^{\theta_2} a_{2i} \ln c_{t-i}$$

$$+ \lambda_3 \sum_{i=0}^{\theta_3} a_{3i} \ln s_{1t-i} + \lambda_4 \sum_{i=0}^{\theta_4} a_{4i} \ln Y_{t-i} + u_t$$

where u_t is a disturbance term.

Long run equilibrium is defined to occur when the permanent values of the variables do not change over their respective anticipation formation periods.[23/] This equilibrium condition implies that:

$$(21) \qquad \sum_{i=0}^{\theta_j} a_{ji} = 1 \qquad (j = 2, 3, 4)$$

The sum of the coefficients for each of the three variables estimated will thus be equal to the long run elasticities λ_2, λ_3, and λ_4. The signs which can be associated with λ_1, λ_3, and λ_4 cannot be established unambiguously on a priori grounds.[24/] The sign of λ_2, the elasticity of the desired capital stock with respect to the own price or implicit rental rate of capital, can be said a priori to be unambiguously negative.

23/ This approach to the anticipation function is discussed in detail by Tinsley [23].
24/ For an extensive theoretical discussion of the a priori statements which can be made about the signs of λ_1, λ_2, λ_3, and λ_4 in models of this type see Gould [7].

III. <u>Estimation of the Model</u>

<u>Sample Period and Level of Aggregation</u>

The analysis is based upon quarterly data covering the period

1954I to 1967IV. The level of aggregation was dictated by the source

of the data on capital backlogs: the National Industrial Conference

Board's (NICB) <u>Quarterly Survey of Capital Appropriations: Historical</u>

<u>Statistics, 1953-1967</u> [1970]. The NICB's survey universe consists of

the 1,000 largest manufacturing corporations in terms of total assets.

These 1,000 firms are broken down into 15 sub-universe corresponding

to 15 industrial categories established by the Standard Industrial

Classification (SIC). Capital backlog estimates for the sub-universe

are obtained through a sample drawn from each of these 15 sub-universes.

This study examines the demand for capital in 12 of these 15 sub-universes.[25]

The 12 industries included in the study are listed in Table 1.

It is presumed that the demand for capital in the sub-universe

under consideration is representative of the demand for capital in each

of the corresponding industries as a whole. This assertion is made on

the basis of the ratios of sub-universe total assets to industry total

assets. Except for the textile industry, SIC 22, and the fabricated

metal industry, SIC 34, the sub-universe firms hold more than half of

---

25/ Four of the industries are actually three-digit industries.
Primary Iron and Steel and Primary Non-Ferrous Metals are combined
to obtain SIC 33, Primary Metals. The other two, Transportation
Equipment and Motor Vehicles and Equipment form SIC 37, Transporta-
tion and Equipment. Because of the 1957 changes in the Standard
Industrial Classification cited by Waud [24, p. 424], SIC 37 is
omitted from the analysis.

the assets in each of the corresponding industries as a whole. These
ratios for the years 1954, 1957, and 1967 are given in Table 4.[26]/

TABLE 4

PERCENTAGE OF TOTAL INDUSTRY ASSETS HELD
BY FIRMS IN NICB SUB-UNIVERSE
1954, 1957, 1967*

SIC #	1954	1957	1967
20	62.3	57.2	66.4
22	34.6	41.7	58.8
26	55.9	67.5	76.1
28	81.7	80.3	86.2
29	100.0	100.0	95.5
30	84.4	82.2	72.4
32	63.9	66.1	73.4
33	83.7	87.0	85.0
34	43.2	45.9	46.3
35	59.4	56.4	79.2
36	87.7	80.9	79.5
38	62.8	83.5	77.4

* Figures are for the 4th quarter in each year.
Source: Quarterly Financial Reports for U.S.
         Manufacturing Corporations; Quarterly
         Survey of Capital Appropriations

While the sample period for the dependent variable, the
desired capital stock, covered the 56 quarters from 1954I through
1967IV, the time series for the independent variables were extended
further back to reduce the degrees of freedom lost in estimating the
distributed lags. Labor costs and real GNP were constructed for the

---

26/ A more complete description of capital backlogs and the NICB
Survey can be found in Cohen [4].

period 1951I through 1967IV. The own price of capital variable could
only be extended back through 1952I. Wherever the own price of capital
variable was lagged more than 8 quarters, the sample period for the
dependent variable was accordingly reduced. The data and sources are
described in the appendix.

Multicollinearity and Estimation of the Distributed Lags

When two or more explanatory variables are highly correlated,
it is often very difficult to distinguish the separate effects of these
variables on the dependent variable. In the presence of such multi-
collinearity, estimation of the regression coefficients by ordinary
least squares will still yield unbiased estimates, but relatively
large sampling variances of these coefficients may be obtained, thus
potentially understating the actual significance of the explanatory
variables implied by the theory. Because of the distributed lag for-
mulation of the model to be estimated here, the reduced form (20),
there are a large number of highly intercorrelated explanatory vari-
ables which give rise to rather severe multicollinearity. In an
attempt to increase the efficiency of our estimation of (20) in
the face of this problem, we resorted to the Almon lag procedure
[1].

The Almon technique allows indirect estimation of distri-
buted lag weights by a procedure which yields more efficient estima-
tors than direct ordinary least squares (OLS) estimation. Discussing
lagged variables, Almon points out that for long lags, ". . . or when

successive observations are too collinear for this straightforward (OLS) treatment, as will frequently be the case with quarterly data, it becomes necessary to make some reasonable, restrictive assumption about the pattern of the weights" [1, p. 179]. The assumption made is that these weights lie on a polynomial function. Use of the Almon procedure is not a solution to the problem of multicollinearity among lagged variables. However, through indirect OLS estimation, it yields unbiased estimates of the distributed lag coefficients which are more efficient than those obtainable through direct OLS estimation which imposes no a priori restrictions upon the shape of the lag distribution. This procedure thus reduces the chance of understating the significance of the estimated coefficients due to multicollinearity.[27]

Autocorrelation

Incorrect specification of functional forms and/or of the variables to be included in the functions to be estimated can give rise to autocorrelation. Systematic measurement errors in the dependent variable can also contribute to autocorrelation. If these errors in specification or measurement give rise to a systematic relationship among the disturbances over time, autocorrelation occurs. The disturbance term becomes a proxy for the effects of these specification errors on the dependent variable. Consequently, a necessary assumption for ordinary least squares estimation is violated. OLS estimation

---

[27] For an extensive discussion of the Almon lag technique and its uses and misuses see Schmidt and Waud [20].

of a model with autocorrelated disturbances will still yield unbiased

regression coefficients. In general, however, the OLS estimate of the

disturbance variance and the sampling variances of the coefficients

will be biased; the direction of these biases is difficult to establish.[28]

In preliminary estimations of the model, the Durbin-Watson

coefficient consistently indicated the presence of positively auto-

correlated disturbances. Subsequent estimation of the model was

therefore based on the assumption that the disturbances were related

by a first order regressive scheme of the type:

$$(22) \qquad u_t = \rho u_{t-1} + \epsilon_t \qquad \rho < 1$$

The disturbance term ϵ_t is assumed to be identically and independently

distributed with zero mean and constant variance. The autoregressive

coefficient ρ is estimated and then used to transform all of the

variables according to the scheme $x_t = (X_t - \hat{\rho}X_{t-1})$. Estimation

of ρ is carried out using the Cochrane-Orcutt iterative procedure.

The initial step is the estimation of the model's parameters by OLS,

as if no serial correlation were present. The residuals $\hat{u}_t$ are

computed, and then used to estimate the autoregressive coefficient,

$\hat{\rho}_1$. The raw data are then transformed by $\hat{\rho}_1$, and the parameters

are estimated again, using the transformed data. The residuals are

recomputed, and a second estimate $\hat{\rho}_2$, and the procedure continues.

In the computer program used for this study, the procedure continues

until either:

28/ See Theil [21], pp. 254-257.

i) two successive estimates of ρ differ by less than .001;

ii) the number of iterations exceeds 20;

iii) ρ exceeds .975, in which case first differences are indicated as necessary.

Generalized least squares (GLS) estimation of the model, using the transformed data, will yield unbiased estimates of the disturbance variance if ρ is correctly estimated; unbiased estimates of the sampling variances of the regression coefficients will also be obtained. However, the Cochrane-Orcutt procedure yields a local minimum for the sum of the square of transformed residuals, which is not necessarily the global minimum. However, even if ρ is incorrectly estimated, GLS estimation will generally reduce the bias in OLS estimation of the disturbance variance as well as the biases in the sampling variances of the regression coefficients.[29]

Minimum Standard Error Criterion and Selection of Lag Lengths

The choice of an approprirate specification of the lengths of the distributed lags on each of the independent variables in (20) is a complex decision problem for which no formal statistical procedure is available. However, in regression problems with fixed independent variables, such as ours, Theil [22, p. 211-215] has suggested a justification for the criterion of minimizing the estimated standard error of regression. This is the criterion used in this study. There is no reason to suppose that this criterion will be satisfied when

---

[29] See Theil [21] p. 256.

ln c , ln s , and ln Y all have the same lag length. Certainly a much more general search is necessary to allow for the sizeable probability that the lag lengths on ln c , ln s , and ln Y which satisfy the minimum standard error criterion are all different. For each industry studied here, searching over all possible lag combinations on ln c , ln s , and ln Y for as many as up to twelve periods in some instances, this was found to be the case.

When searching the lag space beyond four quarters the Almon technique is used; a fourth degree polynomial is assumed and no endpoint constraints are imposed. Of course in the case of a fourth degree polynomial, any lag length less than or equal to four periods is simply estimated by ordinary least squares. Imposing endpoint constraints by constraining the weights at these points to be zero is not warranted unless it can be established that such constraints are valid. In the absence of validation, no such constraints should be imposed -- otherwise there will be misspecification errors. Using the Almon technique without imposing endpoint constraints allows the data to tell whether such constraints are valid.[30/]

Estimation Results

Searching all possible lag lengths on ln s , ln c , and ln Y in each industry up through three years, the estimates of the reduced form (20) which give the minimum standard error of regression are reported in Tables 5 through 16. In each industry the lag

_____

30/ For a more extensive discussion of the use of the Almon technique see Schmidt and Waud [20].

space was always searched through twelve quarters including the current quarter. This required examination of approximately 500 equations in each industry. In several industries the minimum standard error of regression occurred when one of the independent variables had a lag length of eleven quarters. This means it is possible that the lag lengths in those cases on those variables may be longer. Nonetheless this was quite an exhaustive search procedure and indicates that further search might reveal an even longer lag length in these instances. As discussed above, since the disturbance terms always seemed to be auto-correlated, we used generalized least squares (GLS) and estimated the autoregression coefficient ρ by the Cochrane-Orcutt procedure. Since the reduced form (20) is expressed in logarithms, the regression co-efficients may be interpreted as elasticities.[31]

31/ In the presence of autocorrelated disturbances the minimum standard error criterion is only justified asymptotically.

TABLE 5

SIC 20

GLS Regression Estimates of Equation (20)*
(t-statistics)

Period	s		c		Y	
t	0.1331	(0.2251)	0.0057	(0.0938)	-0.1966	(1.4144)
t-1	-0.2415	(0.4031)	-0.0165	(0.2675)	0.0235	(0.1633)
t-2	-0.4023	(0.6491)	-0.0491	(0.7481)	0.0644	(0.4900)
t-3	-0.2854	(0.5035)	-0.0712	(1.1636)	0.0997	(0.7220)
t-4	-0.8149	(1.2585)	0.0582	(0.9997)	0.1855	(1.4143)
t-5					0.2607	(1.9512)
t-6					0.1465	(1.3118)
Σ	-1.6109	(2.1361)	-0.0729	(0.5531)	0.5838	(1.1845)
λ_1	0.0219	(1.9731)				
Cons.	6.1010	(2.4826)				
$\bar{R}^2$	0.9911					
SE	0.0142					
DW	1.7755					
ρ	0.8643					

* Data transformed into logarithms. Coefficients estimated using Almon lags. $\bar{R}^2$ is R^2 adjusted for degrees of freedom. S.E. is the standard error of regression. D.W. is the Durbin-Watson statistic. ρ is the autoregression coefficient on the disturbance terms estimated by the iterative Cochrane-Orcutt procedure.

TABLE 6

SIC 22

GLS Regression Estimates of Equation (20)[+]
(t-statistics)

Period	s	c	Y
t	0.4635 (0.9704)	-0.2469 (2.4216)	0.5424 (2.1774)
t-1	-0.1287 (0.2697)	-0.0893 (1.4128)	0.0274 (0.1017)
t-2	0.7766 (1.7230)	-0.0495 (0.6998)	-0.1408 (0.5544)
t-3	0.0141 (0.0301)	-0.0729 (1.1334)	0.0166 (0.0645)
t-4	0.5399 (1.0689)	-0.1176 (2.1593)	-0.4566 (1.7153)
t-5		-0.1541 (3.0412)	
t-6		-0.1654 (3.4302)	
t-7		-0.1470 (3.5159)	
t-8		-0.1070 (2.9467)	
t-9		-0.0657 (1.7678)	
t-10		-0.0562 (1.6240)	
t-11		-0.1239 (2.1790)	
Σ	1.6054 (1.5812)	-1.3954 (3.1385)	-0.0111 (0.0107)

λ_1 0.0112 (0.6386)

Cons. 2.9224 (0.7119)

$\bar{R}^2$ 0.9837

SE 0.0193

DW 2.0051

ρ 0.9415

+ See * Table 5.

TABLE 7

SIC 26

GLS Regression Estimates of Equation (20)[+]
(t-statistics)

Period	s	c	Y
t	0.6169 (1.8269)	0.0521 (0.7413)	-0.0657 (0.7171)
t-1	0.4754 (0.5879)	-0.0509 (1.9216)	-0.1214 (0.7936)
t-2	-0.0750 (0.0888)	-0.0672 (1.7887)	0.0105 (0.0912)
t-3	-0.6126 (1.2229)	-0.0421 (1.6081)	0.1659 (2.6378)
t-4	-0.8628 (2.2814)	-0.0084 (0.3727)	0.2447 (2.2663)
t-5	-0.6951 (1.2153)	0.0132 (0.4315)	0.2100 (1.8067)
t-6	-0.1238 (0.2087)	0.0142 (0.4738)	0.0888 (1.1467)
t-7	0.6928 (1.5683)	-0.0014 (0.0576)	-0.0287 (0.2878)
t-8	1.4517 (2.7290)	-0.0175 (0.6954)	0.1115 (0.0368)
t-9	1.7058 (2.0463)	-0.0058 (0.2384)	0.4270 (4.3313)
t-10	0.8634 (1.0982)	0.0074 (1.5250)	
t-11	-1.8115 (4.3904)		
Σ	1.6280 (0.8468)	-0.0393 (0.2947)	0.9426 (3.4824)

λ_1	0.0094 (2.0040)	
Cons.	3.8518 (2.5858)	
$\bar{R}^2$	0.9926	
S.E.	0.0149	
D.W.	1.8393	
ρ	0.0451	

+ See * Table 5.

TABLE 8

SIC 28

GLS Regression Estimates of Equation (20)[+]
(t-statistics)

Period	s		c		Y	
t	-0.6222	(0.7310)	-0.1923	(2.8054)	-0.0955	(0.7172)
t-1	-0.7942	(1.0469)	-0.0186	(0.3343)	-0.0135	(0.0674)
t-2	0.7091	(0.9365)	-0.0839	(1.7822)	0.1032	(0.5804)
t-3	0.0488	(0.0641)	-0.1671	(2.8179)	0.2246	(1.6052)
t-4	-0.4905	(0.5158)	-0.1680	(3.2353)	0.3282	(2.2755)
t-5			-0.1079	(1.8215)	0.3984	(2.8063)
t-6			-0.1289	(2.0959)	0.4270	(3.5626)
t-7					0.4128	(3.1282)
t-8					0.3620	(2.4457)
t-9					0.2877	(2.8036)
Σ	-1.1490	(0.8622)	-0.8666	(4.2454)	2.4349	(3.2134)

λ_1	0.0012	(0.0631)
Cons.	-2.9072	(0.7269)
$\bar{R}^2$	0.9936	
SE	0.0158	
D.W.	2.2359	
ρ	0.8596	

[+] See * Table 5.

TABLE 9

SIC 29

GLS Regression Estimates of Equation (20)[+]
(t-statistics)

Period	s	c	Y
t	0.2147 (0.8458)	-0.0801 (1.7007)	0.2996 (3.1536)
t-1	-0.2289 (0.7201)	-0.0253 (0.5952)	0.5038 (4.9658)
t-2	-0.2029 (0.6020)	0.0552 (1.4051)	0.2726 (2.7521)
t-3	0.0343 (0.1485)	0.0312 (0.8134)	-0.0208 (0.1832)
t-4	0.2895 (1.5099)	-0.0755 (1.7198)	-0.1569 (1.2475)
t-5	0.4351 (1.8044)	-0.0919 (2.3034)	-0.0703 (0.5488)
t-6	0.4089 (1.6989)		0.1504 (1.1820)
t-7	0.2145 (1.1384)		0.2625 (2.5268)
t-8	-0.0795 (0.3537)		
t-9	-0.3386 (1.0151)		
t-10	-0.3630 (1.1319)		
t-11	0.1126 (0.4560)		
Σ	0.4967 (0.4120)	-0.1863 (1.5612)	1.2409 (2.9135)

λ_1 -0.0089 (1.3196)

Cons.   3.3491 (1.4136)

$\bar{R}^2$ 0.9912

SE   0.0115

DW   2.1189

ρ 0.5835

+ See * Table 5.

TABLE 10

SIC 30

GLS Regression Estimates of Equation (20)[+]
(t-statistics)

Period	s	c	Y
t	-0.0635 (0.1446)	-0.5584 (6.0047)	-0.4750 (2.9728)
t-1	1.4487 (2.6254)	-0.0733 (2.6164)	0.6572 (4.5781)
t-2	-0.1138 (0.1918)	0.0877 (2.9520)	1.0075 (6.5983)
t-3	0.2160 (0.3745)	0.0709 (2.9772)	0.8677 (7.4683)
t-4	0.5677 (1.0265)	-0.0121 (0.6143)	0.4947 (5.1478)
t-5		-0.0838 (3.0207)	0.1101 (1.2078)
t-6		-0.1006 (3.1780)	-0.0998 (1.0954)
t-7		-0.0537 (2.0054)	0.0161 (0.1459)
t-8		0.0320 (1.5144)	0.5736 (3.2152)
t-9		0.0970 (3.9290)	
t-10		0.0477 (2.0036)	
t-11		-0.2435 (5.5705)	
Σ	2.0552 (4.1924)	-0.7902 (3.7237)	3.1520 (8.2358)

λ_1 -0.0331 (4.2092)

Cons. -9.7346 (4.2700)

$\bar{R}^2$ 0.9915

SE   0.0192

DW   2.1346

ρ -0.4694

+ See * Table 5.

TABLE 11

SIC 32

GLS Regression Estimates of Equation (20)[+]
(t-statistics)

Period	s	c	Y
t	0.6221 (0.8174)	-0.0380 (0.4615)	0.2235 (1.3778)
t-1	-0.3209 (0.5160)	0.0355 (0.8532)	0.4641 (2.7579)
t-2	-0.2075 (0.2942)	0.0459 (1.0062)	0.3419 (2.2475)
t-3	-0.8430 (1.2360)	0.0026 (0.6636)	0.0965 (0.6514)
t-4	-0.9194 (1.3047)	-0.0120 (0.4039)	-0.1040 (0.7363)
t-5		-0.0426 (1.2753)	-0.1634 (1.3295)
t-6		-0.0613 (2.0709)	-0.0569 (0.4306)
t-7		-0.0672 (2.7718)	0.1686 (1.0787)
t-8		-0.0669 (2.0868)	
t-9		-0.0739 (2.2733)	
t-10		-0.1092 (2.0770)	
Σ	-1.6687 (3.0849)	-0.3671 (2.0987)	0.9704 (2.8429)
λ_1	0.0134 (1.7794)		
Cons.	3.6093 (1.9246)		
$\overline{R}^2$	0.9820		
SE	0.0193		
DW	1.9177		
ρ	0.1959		

+ See * Table 5.

TABLE 12

SIC 33

GLS Regression Estimates of Equation (20)[+]
(t-statistics)

Period	s	c	Y
t	0.3245 (1.0616)	0.0088 (0.1351)	0.3191 (2.0805)
t-1	0.1520 (0.4763)	0.0348 (0.7775)	0.2585 (1.8708)
t-2	0.2397 (0.7102)	0.0169 (0.3901)	0.2365 (1.6131)
t-3	0.4454 (1.4965)	-0.0014 (0.0340)	0.2881 (1.7673)
t-4	0.6603 (2.1570)	0.0046 (0.1124)	0.4043 (2.0822)
t-5	0.8093 (2.3634)	0.0401 (1.0855)	0.5316 (2.5939)
t-6	0.8504 (2.5213)	0.0916 (2.4901)	0.5727 (2.8635)
t-7	0.7756 (2.7153)	0.1261 (2.5875)	0.3860 (2.1953)
t-8	0.6101 (2.3785)	0.0918 (1.8993)	-0.2144 (1.2341)
t-9	0.4128 (1.4199)	-0.0826 (1.1313)	
t-10	0.2759 (0.9987)		
t-11	0.3254 (1.2466)		
Σ	5.8813 (2.4383)	0.3308 (1.7549)	2.7825 (4.1272)

λ_1 -0.0410 (2.7577)

Cons. -4.0628 (1.0743)

$\bar{R}^2$ 0.9690

Se   0.0156

DW   2.0088

ρ 0.6779

+ See * Table 5.

TABLE 13

SIC 34

GLS Regression Estimates of Equation (20)[+]
(t-statistics)

Period	s	c	Y
t	0.1688 (0.6415)	-0.0321 (0.4649)	0.0821 (0.5913)
t-1	0.4399 (1.1201)	0.0558 (1.5466)	0.3179 (3.0043)
t-2	-0.2180 (0.5298)	0.1055 (2.4767)	0.2496 (2.4061)
t-3	-0.0055 (0.0143)	0.1097 (3.0917)	0.0519 (0.4968)
t-4	-0.1289 (0.5265)	0.0704 (1.9031)	-0.1443 (1.2958)
t-5		-0.0006 (0.0166)	-0.2512 (2.1704)
t-6		-0.0822 (2.1491)	-0.2249 (2.0773)
t-7		-0.1437 (2.9874)	-0.0650 (0.7066)
t-8		-0.1449 (3.0189)	0.1853 (2.1842)
t-9		-0.0360 (0.5319)	0.4395 (4.5987)
t-10			0.5671 (5.4849)
t-11			0.3943 (3.1470)
Σ	0.2563 (1.2214)	-0.0982 (0.6718)	1.6022 (6.4750)

λ_1 -0.0081 (5.6612)

Cons. -0.0558 (0.0546)

$\overline{R}^2$ 0.9760

SE 0.0201

DW 1.9343

ρ -0.1429

+ See * Table 5.

TABLE 14

SIC 35

GLS Regression Estimates of Equation (20)[+]
(t-statistics)

Period	s	c	Y
t	7.5425 (5.3193)	-0.3871 (3.9435)	-0.3973 (2.4081)
t-1	-1.6001 (0.6122)	0.0878 (1.7673)	-0.3161 (1.6131)
t-2	-2.8669 (1.0334)	0.0919 (1.8100)	-0.0944 (0.6171)
t-3	-0.4595 (0.3011)	-0.0886 (2.9081)	0.2012 (2.3570)
t-4	2.4895 (2.2731)	-0.2535 (6.0529)	0.5117 (4.5142)
t-5	3.9173 (2.1182)	-0.2886 (5.7095)	0.7864 (6.1668)
t-6	2.8303 (1.5440)	-0.1654 (3.3081)	0.9824 (9.6515)
t-7	-0.6952 (0.7187)	0.0583 (0.9667)	1.0648 (8.9190)
t-8	-5.5138 (4.0412)	0.2390 (4.3674)	1.0067 (6.9836)
t-9	-9.4104 (3.4276)	0.1474 (1.6832)	0.7892 (4.9294)
t-10	-9.1104 (3.3112)		
t-11	-0.2299 (0.2118)		
$\sum$	-13.0966 (1.9365)	-0.5590 (3.0449)	4.5346 (17.9194)

λ_1 -0.0470 (5.5730)

Cons. -15.4342 (9.7946)

$\bar{R}^2$ 0.9932

SE   0.0238

DW   1.9163

ρ -0.2756

+ See * Table 5.

TABLE 15

SIC 36

GLS Regression Estimates of Equation (20)[+]
(t-statistics)

Period	s	c	Y
t	-3.3508 (4.4839)	-0.1102 (1.3411)	-0.7150 (4.9473)
t-1	1.6587 (1.3915)	-0.1748 (3.8035)	-0.4205 (2.3644)
t-2	-1.8384 (1.4352)	-0.1947 (3.9607)	-0.6742 (3.9865)
t-3	-1.3266 (0.9819)	-0.2213 (5.4038)	-1.0630 (6.9237)
t-4	-2.0911 (2.2068)	-0.2801 (6.1361)	-1.3002 (7.5403)
t-5		-0.3701 (7.5684)	-1.2252 (6.5704)
t-6		-0.4644 (9.4806)	-0.8038 (4.8483)
t-7		-0.5097 (8.8559)	-0.1281 (1.0237)
t-8		-0.4267 (7.6627)	0.5837 (5.0857)
t-9		-0.1098 (1.5227)	0.9870 (8.1672)
t-10			0.6180 (4.8934)
Σ	-6.9482 (9.7444)	-2.8616 (10.4534)	-4.1486 (5.9487)
λ_1	0.0997 (9.0103)		
Cons.	24.3705 (7.5357)		
$\bar{R}^2$	0.9872		
SE	0.0270		
DW	1.9605		
ρ	0.1118		

+ See * Table 5.

TABLE 16

SIC 38

GLS Regression Estimates of Equation (20)[+]
(t-statistics)

Period	s	c	Y
t	2.5955 (1.5099)	0.0878 (0.5834)	0.0084 (0.0303)
t-1	2.2404 (1.1913)	-0.0575 (0.3803)	0.3569 (1.3507)
t-2	-3.6129 (1.8400)	-0.2853 (1.8800)	0.4705 (1.8914)
t-3	-1.1552 (0.6104)	0.2339 (1.4455)	0.4423 (2.0677)
t-4	0.1890 (0.1003)	-0.1342 (0.8315)	0.3477 (1.6380)
t-5			0.2441 (1.0376)
t-6			0.1711 (0.7109)
t-7			0.1507 (0.7008)
t-8			0.1868 (1.0462)
t-9			0.2657 (1.5991)
t-10			0.3557 (2.0452)
t-11			0.4074 (1.7139)
$\sum$	0.2567 (0.1762)	-0.1552 (0.5059)	3.4070 (2.4702)

λ_1 -0.0100 (0.4206)

Cons. -9.4545 (1.3484)

$\bar{R}^2$ 0.9878

SE   0.0368

DW   2.0340

ρ 0.6568

+ See * Table 5.

A comparison of the sums (Σ) of the estimated distributed
lag regression coefficients associated with ln s , ln c , and ln Y
and the t-statistics associated with these sums (Tables 5 through 16)
indicates that all three of these variables appear to have a signifi-
cant influence in SIC 30, 32, 33, 35, and 36 (Tables 10, 11, 12, 14,
and 15). It is noteworthy that four of these industries, SIC 32, 33,
35, and 36 are durable goods industries and that all five of these
industries are among the most cyclically variable of the 2-digit SIC
industries in U.S. manufacturing. As noted above, multicollinearity
is a major difficulty in a study of this nature and the problem is
more acute in those industries where there is less cyclical variability
in the data, such as is the case in the nondurable goods sector of U.S.
manufacturing. Since multicollinearity causes the estimated standard
errors associated with estimated regression coefficients to "blow up,"
i.e. pushes the estimated t-statistics toward zero, the apparent in-
significance of many of the sums (Σ) of the estimated distributed
lag coefficients of the nondurable goods industries SIC 20, 22, 26,
28, and 29 (Tables 5, 6, 7, 8, and 9) may well be a reflection of
this problem and not necessarily an indication of the true influence
of these variables in these industries. It is suspected that a major
factor contributing to the multicollinearity problem is the presence
of the time variable t in these regressions; unfortunately there
didn't appear to be any other tractable way of controlling for tech-
nological change. Experimentation with some of the industries indi-

cated a notable increase in the t-statistics when time was dropped
from the regressions.

In six of the twelve industries the sum of the estimated
regression coefficients associated with s , the hourly cost of a
production worker manhour, appears to be significant: SIC 20, 30,
32, 33, 35, and 36 (Tables 5, 10, 11, 12, 14, and 15 respectively).
The signs of these sums are negative in four of these industries,
SIC 20, 32, 35, and 36 (Tables 5, 11, 14, and 15 respectively) and
positive in two, SIC 30 and 33 (Tables 10 and 12 respectively). As
was noted above, it is not possible to specify on a priori grounds
what the sign of the coefficient of hourly labor costs should be.
This is because it is not possible to say a priori whether substitu-
tion effects or scale effects will dominate when there is a change
in relative factor prices. When hourly labor cost increases (falls),
labor becomes more (less) expensive relative to capital. The sub-
stitution effect alone dictates that more (less) capital be used
relative to labor. However, the increase (decrease) in the hourly
labor cost causes the industry supply schedule to shift up (down)
and this causes a reduction (an increase) in industry output which
by itself has the scale effect of reducing (increasing) the use of
both inputs. If the demand schedule facing the industry is elastic
enough the scale effect causing a reduction (an increase) in the
demand for manhours and the demand for capital services, may more
than offset the increase (decrease) in the demand for capital services

stemming from the substitution effect. The net result is that an increase (a decrease) in hourly labor costs leads to a reduction (an increase) in the demand for capital services as well as in the demand for labor services. Hence, depending on the elasticity of the demand schedule facing the industry, the sign of the regression coefficient associated with the hourly cost of a production worker manhour may be either positive or negative.[32/]

The sum of the estimated regression coefficients associated with c , the implicit rental rate or own price of capital, appears significant in eight out of the twelve industries: SIC 22, 28, 29, 30, 32, 33, 35, and 36 (Tables 6, 8, 9, 10, 11, 12, 14, and 15 respectively). In seven out of these eight the signs of the sums are negative as we would expect on a priori grounds. The positive sign in SIC 33 (Table 12), the one exception, is contrary to theoretic considerations. If the own price of capital rises (falls), then the substitution effect dictates that less (more) capital and more (less) labor be used. The scale effect, resulting from the upward (downward) shift in the supply schedule due to the increased (decreased) cost of capital, dictates that less (more) of both inputs be used. Hence, both the substitution and the scale effect operate to reduce (increase) the use of capital in response to a rise (fall) in the own price of capital.

The sizes of the negative sums of the significant estimated regression coefficients associated with c (Tables 6, 8, 9, 10, 11, 14,

---

32/ For a more technical discussion see Gould [7].

and 15) are the magnitudes of the elasticities of the desired capital

stock in each industry with respect to the own price of capital.

Examination of these estimates suggests that a one percent fall in

c will cause a rise in the desired stock of capital ranging anywhere

from about 0.19 percent after five quarters in the case of SIC 29

(Table 9), to as much 2.86 percent after nine quarters in the case

of SIC 36 (Table 14). The lengths of the distributed lags on c in

these industries range from a low of 5 quarters in SIC 29 (Table 9)

to a high of 11 quarters in SIC 22 (Table 6) and SIC 30 (Table 10).

Given our lag length search procedure described above, the true maxi-

mum lag length in some instances may be even longer. In order to get

an estimate of the total distributed lag length from the point in time

of the change in c and the point at which the actual investment

expenditures have brought the actual capital stock to the desired

level in any industry, the mean length of the planning horizon

given in Table 2 must be added to the corresponding industry lag length

given in one of the Tables 6, 8, 9, 10, 11, 14 or 15. The variability

of the lengths of the planning horizons shown in Table 2 should be

kept in mind when assessing these lags. These results are summarized

in Table 17 for the seven industries having significant negative

estimated sums of regression coefficients, or elasticities, associated

with c , the own price of capital.

In all industries except SIC 20 and 22 (Tables 5 and 6) the

estimated sum of the regression coefficients or elasticities associated

TABLE 17

ESTIMATED DISTRIBUTED LAG LENGTHS
BETWEEN CHANGE IN OWN PRICE OF CAPITAL
AND TOTAL CHANGE IN DESIRED STOCK OF CAPITAL ΔK^*
AND TOTAL CHANGE IN ACTUAL CAPITAL STOCK ΔK
FOR SIC 22, 28, 29, 30, 32, 35, 36

Industry	ΔK^* lag length[+] (1)	n Mean Planning[≠] Horizon (variation) (2)	ΔK lag length equal (1)+(2) (3)	Σ Elasticity[+] (t-statistic) (4)
SIC 22	11	5 (2-9)	16	-1.3954 (3.1385)
SIC 28	6	4 (3-7)	10	-0.8666 (4.2454)
SIC 29	5	3 (1-5)	8	-0.1863 (1.5612)
SIC 30	11	4 (1-6)	15	-0.7902 (3.7237)
SIC 32	10	4 (2-8)	14	-0.3671 (2.0987)
SIC 35	9	3 (1-6)	12	-0.5590 (3.0449)
SIC 36	9	5 (3-9)	14	-2.8616 (10.4534)

+ From Tables 6, 8, 9, 10, 11, 14 and 15.
≠ From Table 2.

with Y , gross national product, appear significant. Among the ten

industries for which this sum elasticity appears significant, only

one of them has a negative sign -- SIC 36 (Table 15), Electrical

Machinery and Equipment. While the sign of the sum elasticity asso-

ciated with Y cannot be specified on a priori grounds, since an

industry may move cyclically or contracyclically, we are suspicious

of the negative sign in SIC 36 simply because it is hard to believe

that this industry responds negatively to movements in general economic

activity as measured by GNP. For the nine industries with significant

positive estimated sum elasticities, a one percent change in Y would

appear to cause an increase in the desired capital stock ranging any-

where from about 0.94 percent in the case of SIC 26 (Table 7), with a

distributed lag of 9 quarters, to as high as 4.53 percent in SIC 35

(Table 14), also with a 9 quarter distributed lag. The lengths of

these distributed lags range from 7 quarters for SIC 29 (Table 9) and

SIC 32 (Table 11) up to 11 quarters for SIC 34 (Table 13) and SIC 38

(Table 16). Again, given our description of the lag length search

procedure, it is possible in some instances that the true maximum

lag length may be longer. The estimated sums of the regression co-

efficients or elasticities on Y and their distributed lag lengths

are summarized in Table 18 for the ten industries where they appear

significant. The accelerator-type effects of changes in GNP on the

desired capital stock in each of these industries appears to be quite

strong. Again, an estimate of the total length of the distributed lag

between a change in GNP and the point at which the actual investment
expenditures have brought the actual capital stock to the desired
level in any industry requires that the mean length of the planning
horizon in Table 2 be added to that shown in Table 18.

Regarding the individual regression coefficients which add
up to the sums in Tables 5 through 16, there are instances where the
signs switch, or "flip-flop," at some point in the distributed lag.
It appears that this happens with statistical significance in: SIC 26
(Table 7) in the case of s ; SIC 30 (Table 10) in the case of c and
Y ; SIC 34 (Table 13) in the case of c and Y ; SIC 35 (Table 14) in
the case of s , c , and Y ; and SIC 36 (Table 15) in the case of Y .
The significant switching of signs among these distributed lag weights
cannot be ruled out as theoretically implausible on a priori grounds.
Gould [8] has shown in a dynamic theory of investment of the firm that
in some instances there is reason to expect the true distributed lag
weights to switch sign.[33]

In eight of the twelve industries, SIC 20, 26, 30, 32, 33,
34, 35, and 36 (Tables 5, 7, 10, 11, 12, 13, 14, and 15 respectively),
the estimated regression coefficient associated with t , time, appears
to be significant. It will be recalled that time was introduced in
order to control for technological change. A priori, it is not possible
to specify what the sign of the coefficient λ_1 on time should be.

---

[33] However it is also possible that this phenomena is an artifact
of attempting to estimate distributed lags by use of higher order
polynomials. See Schmidt and Waud [20].

TABLE 18

ESTIMATED SUMS OF REGRESSION COEFFICIENTS OR ELASTICITIES
ON GNP AND THEIR DISTRIBUTED LAG LENGTHS
FOR SIC 26, 28, 29, 30, 32, 33, 34, 35, and 36

Industry	GNP Elasticity[+] (t-statistic)	Lag length
SIC 26	0.9426 (3.4824)	9
SIC 28	2.4349 (3.2134)	9
SIC 29	1.2409 (2.9135)	7
SIC 30	3.1520 (8.2358)	8
SIC 32	0.9704 (2.8429)	7
SIC 33	2.7825 (4.1272)	8
SIC 34	1.6022 (6.4750)	11
SIC 35	4.5346 (17.9194)	9
SIC 36	-4.1486 (5.9487)	10
SIC 38	3.4070 (2.4702)	11

[+] From Tables 7 - 16.

It is conventional to presume that it should be negative on the assumption that technological progress will diminish the size of the desired stock of capital. This presumption is not necessarily correct however. In an industry facing an elastic demand schedule for its product, it is possible for λ_1 to have a positive sign. A positive λ_1 indicates that firms will increase their desired stock of capital in response to technological improvement. If the industry demand schedule is sufficiently elastic, an increase in productivity will cause the industry supply schedule to shift rightward causing a relatively large increase in equilibrium industry output. The increase in productivity by itself, as reflected in normal replacements, would not be sufficient to permit the increased production without an increase in the total stock of capital.$\underline{34/}$ In this case λ_1 would have a positive sign. Of the eight industries having significant estimates of λ_1, the sign on λ_1 is positive in four of them: SIC 20, 26, 32, and 36 (Tables 5, 7, 11, and 15).

IV. <u>Implications for a Variable Investment Tax Credit Scheme as a</u>

<u>Stabilization Tool</u>

Before drawing any policy implications from the estimates presented here, it should be reemphasized that there are many caveats

---

34/ This argument is similar to those regarding scale and substitution effectis. Again, for a more technical and rigorous treatment of the signs on parameters like λ_1, λ_2, λ_3, and λ_4 in reduced from neoclassical models see Gould [7].

which dictate reservation and caution in interpreting our results. The model we have used, like others which have characterized empirical research in this area, does not adequately incorporate the dynamic considerations of adjustment cost in its explicit derivation from the profit maximization process. Rather, adjustment costs and expectations formation are tacked on ad hoc by imposing a distributed lag scheme ex post the explicit profit maximization derivation; again, this has been the common practice of other well-known econometric research efforts in this area. Ours is a putty-putty model and assumes a Cobb-Douglas production function. Jorgenson's [14, pp. 1131-1133] survey of the research on the tenability of the Cobb-Douglas assumption concludes that overall this assumption is not inconsistent with the findings of empirical investigations of this issue. However, some might justifiably feel more comfortable if the more general CES specification had been used in this study. Also, there is little doubt but that a putty-clay model is a more accurate characterization of the world than a putty-putty model.

Statistically, multicollinearity was a major problem in the data used here and this may account for the lack of evidence of statistical significance among several of the nondurable goods industries. Perhaps even more worrisome are the many approximations and heroic assumptions which were needed in the process of constructing the data -- both by us and the various agencies which collect the raw data by sampling procedures. No doubt this gives rise to not insignificant

errors in variables problems. These problems are common to any

econometric investigation, but when drawing policy implications for

the consideration of policy makers and others not often so aware of

econometric and statistical nuances it is especially important that

they be emphasized. All of these problems aside, there is still the

usual imprecision inherent in any interpretation of statistical esti-

mates. With these reservations in mind, the following tentative con-

clusions are offered.

As indicated at the outset, a VITC scheme would operate by

changing the implicit rental rate or own price of capital. Our estimates

of the elasticity of the desired capital stock with respect to the own

price of capital suggest that the own price of capital is a significant

determinant of the desired capital stock level, particularly in the

durable goods industries. Hence a VITC scheme would appear to be a

potential stabilization policy tool insofar as changes in the own

price of capital could be expected to have a significant, and predict-

able, effect on the desired capital stock and thus on investment

expenditures. However our results (summarized in Table 17) suggest

that these effects occur with rather lengthy distributed lags,

requiring anywhere from five to eleven quarters for the full effects

of a change in the own price of capital on the desired stock of capital

to be realized, and on average another three to five quarters for

actual investment expenditures to finally bring the actual level of

the capital stock into line with the desired level. In view of our

description of the lag length search procedure above, it is possible

that in some instances the lag lengths may be even longer. These

findings lend support to the suggestion that a VITC scheme be adminis-

tered in such a way as to encourage the bunching of investment expendi-

tures, as described in Section I above, with the intention of shortening

the lag lengths which would otherwise appear to be inordinantly long

from a policymaker's standpoint.

Finally, as was pointed out in Section I, to the extent there

are multiplier-accelerator-type feedbacks from investment expenditures

to general economic activity (as measured by GNP) and back to investment

expenditures, any increase in the stability of investment expenditures

brought about by a VITC scheme would, by virtue of this accelerator-

multiplier feedback linkage, reduce fluctuations in investment expendi-

tures even more. This itself would make the stabilization task of a

VITC scheme easier, once it is properly initiated. Our estimates

(summarized in Table 18) suggest that this feedback is significant

and quite strong -- as proponents of an accelerator theory of investment

would predict. Again, however, the distributed lag lengths of these

effects appear quite long, ranging between seven and eleven quarters,

possibly longer, for the full realization of their impact on the desired

capital stock, plus on average another three to five quarters for actual

investment expenditures to fully bring the actual level of the capital

stock into line with the desired level. Nonetheless, any initial

stabilization of investment expenditures and thus GNP, brought about

by a VITC scheme, could be expected to receive substantial subsequent
reinforcement from the accelerator effects of GNP on investment ex-
penditures -- at least according to the estimates we have presented.

The stabilization potential of a VITC scheme depends crucially
on yet another factor which has not been a subject of investigation in
this study. Namely, the ability of the policymaker, vested with the
authority to administer the VITC scheme, to forecast sufficiently well
so that his stabilization efforts are appropriately timed. Otherwise,
the administration of a VITC scheme will only aggravate the instability
it is designed to alleviate. To the extent our estimates suggest that
it can be a powerful tool for increasing economic stability, it can
also be a destabilizing force in the hands of a policymaker lacking
sufficient prescience.

References

[1] Almon, S., "The Distributed Lag Between Capital Appropriations
and Expenditures," _Econometrica_, January 1965, 33, pp. 178-196.

[2] Bischoff, C.W., "The Effect of Alternative Lag Distributions"
in Fromm, G., ed. _Tax Incentives and Capital Spending_. Washington, D.C.: Brookings Institution, 1971.

[3] Board of Governors of the Federal Reserve System, _Federal Reserve
Staff Study: Ways to Moderate Fluctuations in Housing Construction_, Washington, D.C., 1972.

[4] Cohen, M., "The National Industrial Conference Board Survey of
Capital Appropriations" in _The Quality and Economic Significance
of Anticipations Data: A Conference_. Princeton: Princeton
University Press, 1960.

[5] Eisner, R. and Strotz, R.M., "Determinants of Business Investment"
in _Impacts of Monetary Policy_, Commission on Money and Credit.
Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1963.

[6] Gould, J.P., and Waud, R.N., "The Neoclassical Model of Investment
Behavior: Another View," _International Economic Review_, February
1973, 14 (1), pp. 33-48.

[7] Gould, J.P., _A Microeconomic Approach to the Demand for Physical
Capital_. Unpublished Ph.D. dissertation, University of Chicago,
1966.

[8] _____, "Adjustment Costs in the Theory of Investment of the
firm," _Review of Economic Studies_, January 1968, 35, pp. 47-55.

[9] _____, "The Use of Endogenous Variables in Dynamic Models of
Investment," _Quarterly Journal of Economics_, November 1969, 83,
pp. 580-600.

[10] Haavelmo, T., _A Study of the Theory of Investment_. Chicago:
University of Chicago Press, 1960.

[11] Hall, R.E., and Jorgenson, D.W., "Tax Policy and Investment
Behavior," _American Economic Review_, June 1967, 57 (3), pp. 391-414.

[12]   _____, "Tax Policy and Investment Behavior: Reply and Further Results," _American Economic Review_, June 1969, _59_ (3), pp. 388-401.

[13]   _____, "Application of the Theory of Optimum Capital Accumulation" in Fromm, G., ed. _Tax Incentives and Capital Spending_. Washington, D.C.: Brookings Institution, 1971.

[14]   Jorgenson, D.W., "Econometric Studies of Investment Behavior: A Survey," _Journal of Economic Literature_, December 1971, _9_ (4), pp. 1111-1148.

[15]   _____, "Capital Theory and Investment Behavior," _American Economic Review_, May 1963, _53_ (2), pp. 247-260.

[16]   _____, "Anticipations and Investment Behavior," J.S. Duesenberry, E. Kuh, G. Fromm, and L.R. Klein, eds., _The Brookings Quarterly Econometric Model of the United States_. Chicago: Rand McNally, 1965, pp. 35-94.

[17]   _____, "The Theory of Investment Behavior," R. Ferber, ed., _Determinants of Investment Behavior_. New York: Columbia University Press, 1967.

[18]   Modigliani, F. and Cohen, K.J., _The Role of Anticipations and Plans in Economic Behavior and Their Use in Economic Analysis and Forecasting_. Urbana, Illinois: University of Illinois, 1961.

[19]   Muth. J.F., "Rational Expectations and the Theory of Price Movements," _Econometrica_, July 1961, _29_, pp. 315-335.

[20]   Schmidt, P., and Waud, R.N., "The Almon Lag Technique and the Monetary versus Fiscal Policy Debate," _Journal of the American Statistical Association_, March 1973, _68_, pp. 11-19.

[21]   Theil, H., _Principles of Econometrics_. New York: John Wiley and Sons, Inc., 1971.

[22]   _____, _Economic Forecasts and Policy_. (2nd ed.) Amsterdam: North-Holland Publishing Company, 1961.

[23]   Tinsley, P.A., "An Application of Variable Weight Distributed Lags," _Journal of the American Statistical Association_, December 1967, _62_, pp. 1277-1289.

[24]   Waud, R.N., "Manhour Behavior in U.S. Manufacturing: A Neoclassical Interpretation," _Journal of Political Economy_, May/ June 1968, _76_ (3), pp. 407-427.

APPENDIX

SOURCES, DESCRIPTION, AND DERIVATION OF DATA

Capital Stock, Backlogs, and Investment

Net Depreciable Capital Assets. For the period 1952 through
1968, quarterly estimates of net fixed capital assets for two digit
manufacturing industries are obtained from the Quarterly Financial
Reports for U.S. Manufacturing Corporation. The estimates reported
are obtained from a sample selected from all U.S. corporations filing
a corporate tax return.

The net fixed capital asset data reported are estimates of
land plus net depreciable assets plus net depletable assets. In order
to get an estimate of the stock of net depreciable assets, it is
necessary to first obtain quarterly estimates of the ratio of net
depreciables to net fixed capital assets. Annual ratios of net de-
preciables to net fixed capital assets can be computed directly from
the Statistics of Income: Corporate Income Tax Returns for the period
1954 to 1967.[1] Net fixed capital stock for each industry is obtained
by taking the sum of depreciable assets less accumulated depreciation,
depletable assets less accumulated depletion, and land. For the years

---

[1] In 1962, the categories of balance sheet data published in the
Statistics of Income did not correspond to the categories published
prior to and after 1962. Neither were they available from the Source
Book, the comprehensive source from which the Statistics of Income data
are taken. All of the series obtained from the Statistics of Income
were linearly interpolated in order to obtain figures for 1962.

1952 and 1953, the fixed capital estimate is not broken down into depletable and depreciable assets; the data is not available for 1968. Thus the ratio of depreciables to total fixed capital cannot be directly computed for these years. Based upon the stable pattern of these ratios over time, it was assumed that the average ratio for the period 1954 to 1967 could be used for the years 1952, 1953, and 1968. The mean, high, and low values of the ratios for each industry are presented in Table A-1. The annual ratios are interpolated linearly to obtain quarterly ratios for each industry. Net depreciable capital assets are obtained by multiplying, for each quarter, net fixed capital assets by the ratio of net depreciables to net fixed capital assets.

TABLE A-1

RATIO OF NET DEPRECIABLE ASSETS TO NET
FIXED CAPITAL ASSETS

SIC #	HIGH	LOW	MEAN
20	.946	.921	.933
22	.981	.959	.973
26	.913	.887	.898
28	.994	.945	.953
29	.881	.787	.844
30	.991	.951	.964
32	.943	.914	.928
33	.043	.913	.927
34	.944	.937	.939
35	.957	.947	.952
36	.971	.950	.961
38	.969	.949	.956

Source: Statistics of Income, various annual issues.

For the years 1955 through 1967, the ratios of net depreciable assets to net fixed assets were computed from data for all active corporations filing income tax returns, as published by the Internal Revenue Service in the _Statistics of Income_. In 1954, the ratios were computed from the returns of all active corporations who also filed a balance sheet; of the 722,805 corporations filing returns in 1954, 667,856 (92.4%) filed returns with balance sheets.

At the time the data were being compiled, the 1967 income tax data had not yet been published. The 1967 data were directly obtained from the Internal Revenue Service.

In 1958, changes were made in the _Standard Industrial Classification Manual_ [1967]. For most industries, the changes were minor and appear to have had no significant effect on the data. In the category of nonelectrical machinery (SIC 35), however, a number of three digit industries previously included in nonelectrical machinery were reallocated to other two digit industries. The result was a reduction in the net capital stock series of approximately 5%. For the year 1958, overlapping data were presented in the _Quarterly Financial Reports_; the percentage reduction for each of the four quarters was: I - 5%; II - 5%; III - 6%; IV - 5%. In order to standardize the series, therefore, the data for the 24 quarters previous to 1958 were multiplied by a factor of .95 to make the pre-1958 series compatible with the post-1958 series.

Deflation of Net Depreciable Capital Assets. Annual deflators for net depreciable assets at the two digit industry level were obtained

from the National Industrial Conference Board. These deflators represent the ratio of the book value of net depreciables to their 1958 prices. The data are available for the years 1953 to 1965 (except for SIC 34, fabricated metals, where the deflator is available only through 1963). In order to obtain estimates of the deflators for 1952 and through 1968, it was assumed that the capital stock deflators for two digit industries were closely related to that for all manufacturing. The net depreciable capital stock deflator for all manufacturing was obtained from the Office of Business Economics, Department of Commerce. The annual values of the two digit industry deflators for the period 1953 to 1965 (1963 for SIC 34) were regressed onto the corresponding values of the deflator for all manufacturing. The resulting relationships, shown in Table A-2, were used to extrapolate the two digit industry deflators to 1952, and through 1968. These annual estimates were then interpolated linearly to obtain quarterly deflators of net depreciable capital stock at the two digit industry level.

   Reduction of Net Depreciable Capital to NICB Universe Level. The capital appropriations data compiled by the NICB are estimates for a universe consisting of the 1000 largest manufacturing corporations, ranked according to total assets. In the years 1954, 1957, and 1967, the NICB computed estimates of total year end assets, by two digit industries, of all firms in the 1,000 corporation universe. These total asset figures are divided by total year end assets for all corporations in each two digit industry, which data are obtained

TABLE A-2

REGRESSION OF INDUSTRY CAPITAL STOCK DEFLATOR
ON ALL MANUFACTURING DEFLATOR

SIC #	R^2	CONS. (t)	COEF. (t)
20	.987	-10.0583 (- 3.497)	1.0253 (29.677)
22	.973	- 4.5046 (- 1.163)	0.9761 (20.983)
26	.998	- 1.5888 (- 1.533)	0.9700 (77.908)
28	.988	-14.8295 (- 4.963)	1.1177 (31.142)
29	.998	- 0.1554 (0.155)	0.8808 (72.906)
30	.992	- 6.6356 (- 2.911)	1.0655 (38.917)
32	.998	-20.2170 (-14.988)	1.1698 (72.198)
33	.993	0.6041 (0.307)	0.9393 (39.793)
34	.994	- 2.6875 (- 1.312)	1.0070 (39.696)
35	.997	0.4982 (0.412)	0.9853 (67.785)
36	.939	28.1811 (8.227)	0.5581 (13.564)
38	.996	2.6986 (1.884)	0.9620 (55.920)

from the Quarterly Financial Reports. These ratios are interpolated

linearly to provide quarterly estimates of the ratios, for each in-

dustry, of the assets of the corporations in the NICB universe to

the assets of all corporations in the total universe for the period

1955 to 1967. For 1952 to 1954, the 1954 value of the ratio was

used for each quarter; for 1968, the 1967 value was used. Finally,

these ratios were multiplied by the quarterly net depreciable capital

stock estimates to obtain the net depreciable assets corresponding to

the NICB universe data on capital backlogs and appropriations.

Capital Backlog and Investment Data. For the period 1953 to

1967, quarterly estimates of the capital backlog and investment ex-

penditures are obtained from the NICB Quarterly Survey of Capital

Appropriations. These series are estimates of expenditures and backlogs for the NICB universe of the 1,000 largest manufacturing corporations, by industry.

The investment data and the backlog data are converted to real terms by means of the deflator for gross private domestic fixed nonresidential investment (GPDI). This quarterly series, which is seasonally adjusted, is obtained from Table 8.1 of the National Income and Product Accounts of the United States (NIPA) 1967.

Estimation of Rate of Depreciation (δ). The net depreciable capital stock series used in the estimation of δ is that obtained from the Quarterly Financial Reports, which has been deflated and reduced to the NICB population level (see the description above). Capital expenditures are obtained from the NICB Quarterly Survey of Capital Appropriations: Historical Statistics, 1953-1967. These data are deflated by the investment deflator q. The data cover the period from the 4th quarter of 1954 to the 4th quarter of 1967.[2]

Total Hourly Compensation Per Production Worker

See the appendix in [24] for a description of how this data

---

[2] Subsequent to the analysis of the model, an error was found in the algorithm used in estimating δ. The error in δ exceeded .001 in only 2 industries (.00108 in SIC 20, and .00219 in SIC 35); in five of the industries, the error was .00001 or less. These errors should have only negligible effects on the estimated own price variable, and also on the final regression results. The cost of re-estimating all equations does not seem justified on the basis of the very minor potential gains in accuracy. Table 3 contains the original estimates of δ.

was constructed.$\underline{3,4}$/

Implicit Rent Per Unit of Capital Services (Own Price of Capital)

The concepts and methods used in the determination of the user cost of capital will be the same as those used by Jorgenson '1965'. Assuming, as Jorgenson does, that capital gains from price changes of capital equipment are considered transitory by the firm, and thus do not affect the user cost of capital, the user cost can be written as:

$$c = q \left[\left(\frac{1 - uv}{1 - u} \right) \delta + \left(\frac{1 - uw}{1 - u} \right) r \right]$$

Investment Deflator (q). The investment deflator used in this formulation of user cost is the deflator for gross private domestic fixed nonresidential investment. This deflator is obtained on a quarterly, seasonally adjusted basis from the NIPA.

Corporate Tax Rate (u). The tax rate is the ratio of corporate profit taxes to corporate profits before tax. The data are available on an annual basis, for two-digit industries, from the NIPA. Federal and state corporate profits tax liability data by industry are

---

3/ BLS Data for 1954-1967 are obtained from the Employment and Earnings Statistics for the United States, 1909-1969 [Bureau of Labor Statistics, 1969'; data for 1968-1969 are obtained from various monthly issues of Employment and Earnings and Monthly Report on the Labor Force.

4/ OBE data for 1954-1965 are obtained from the National Income and Product Accounts of the United States, 1929-1965 [Office of Business Economics, 1969'; data for 1966-1969 are obtained from various monthly issues of the Survey of Current Business.

taken from the NIPA, as are corporate profits before tax data by industry. Since there is no reason to believe that tax rates are viewed as variable over the year by the firm, the tax rate computed for each year is used for the four quarters in each year.

Proportion of Depreciation Chargeable Against Net Taxable Income (v). The variable v is the ratio of the capital consumption allowance to the current replacement cost of capital. Corporate capital consumption allowance by industry is obtained annually from the NIPA. Current replacement cost is computed as the product of the rate of depreciation (δ) (see below) times the value of the net stock of depreciable assets. For the period 1954 to 1967, the value of the net stock of depreciables is directly obtainable from the Statistics of Income, as described under "Net Depreciable Capital Assets." For the period 1951 to 1953, these data are not available. However, the value of net fixed capital assets can be computed. Because the ratios of net depreciable assets to net fixed capital assets are relatively constant over the period 1954 to 1967, it is assumed that they can be extrapolated backwards for the period 1951 to 1953. Multiplying these estimated ratios by the value of net fixed capital stock, estimates of the value of net depreciable assets for the years 1951 to 1953 were obtained. The mean and range of these ratios, for each two-digit industry, for the period 1954 to 1967 have been given in Table A-1 above. Again, the variable v computed on an annual basis is used for all four quarters of the corresponding year.

Proportion of Cost of Capital Chargeable Against Net Taxable Income (w). The variable w is the ratio of net monetary interest to the cost of total capital. Net monetary interest is the difference between interest paid and interest received, and is obtained annually from the Statistics of Income for each two-digit industry. The cost of total capital is computed as the product of the cost of capital (r) (see below) times the value of total capital (net fixed capital plus working capital) in current prices. The value of net fixed capital is obtained annually from the Statistics of Income, as described under "Net Depreciable Capital Assets." Working capital is in general the sum of cash, net notes and accounts receivable, government investments, inventories, and other current assets, less accounts payable, bonds, notes, and mortgages payable in less than one year, and other current liabilities. The yearly breakdown by specific item included in working capital is given in the following table. The data is obtained on an annual basis from the Statistics of Income. The variable v is also computed on an annual basis.

Cost of Capital (r). The cost of capital is defined by

$$r = \frac{\text{corporate profits after tax} + \text{net monetary interest}}{\text{value of securities}}$$

The value of securities is equal to the value of equity plus the value of debt. The value of equity is given by the ratio of corporate profit after tax to the earnings price ratio. The value of debt is equal to the ratio of net monetary interest to the bond yield. Cor-

porate profits after tax are obtained annually for each industry from the NIPA. The bond yield is a quarterly average of the monthly composite average of yields on industrial bonds; the price earnings ratio (the reciprocal of the earnings price ratio) is a quarterly average of the monthly end of the month average price earnings ratio for industrial common stocks. Both are obtained from Moody's Industrial Manual ˙1970˙. Quarterly estimates for net monetary interest and corporate profits after tax are obtained by a linear interpolation of the annual data.

TABLE A-3

ITEMS INCLUDED IN WORKING CAPITAL

YEAR	ITEM NUMBER										
	1	2	3	4	5	6	7	8	9	10	11
1951	x	x	x		x		x	x			
1952	x	x	x		x		x	x			
1953	x	x	x		x		x	x			
1954	x	x	x	x	x		x	x	x		
1955	x	x	x	x	x		x	x	x		
1956	x	x	x	x	x		x	x	x		
1957	x	x	x	x	x		x	x	x	x	
1958	x	x	x	x	x		x	x	x	x	
1959	x	x	x		x	x	x	x		x	x
1960	x	x	x		x	x	x	x		x	x
1961	x	x	x		x	x	x	x		x	x
1963	x	x	x		x	x	x	x			x
1964	x	x	x		x	x	x	x			x
1965	x	x	x		x	x	x	x			x
1966	x	x	x		x	x	x	x			x
1967	x	x	x		x	x	x	x			x

ITEMS:
1. Cash
2. Net Notes and Accounts Receivable
3. Inventories
4. Prepaid Expenses and Supplies
5. Government Investments
6. Other Current Assets, including short term marketable instruments
7. Accounts Payable
8. Bonds, Notes, Mortgages, Payable in Less Than 1 Year
9. Accrued Expenses
10. Deposits and Withdrawable Shares
11. Other Current Liabilities

SPECIAL STUDIES PAPERS

The following may be obtained on request from:

Special Studies Section
Division of Research and Statistics
Federal Reserve Board
Washington, D.C. 20551

1. James L. Pierce — Some Simple Rules for the Conduct of Monetary Policy

2. William Poole — Optimal Choice of Monetary Policy Instruments in a Simple Stochastic Macro Model

3. Edward M. Gramlich and John H. Kalchbrenner — A Constrained Estimation Approach to the Demand for Liquid Assets

4. P. A. Tinsley — On Polynomial Approximation of Distributed Lags

5. Robert T. Parry — The Application of Quadratic Programming to the Portfolio Selection Problem: A Review

6. Richard Puckett — Chance Constrained Programming with Applications to Portfolio Problems in Commercial Banking

7. P. A. Tinsley — Capital Structure, Precautionary Balances, and Valuation of the Firm: The Problems of Financial Risk

8. Roger Craine — On the Specification of a Distributed Lag Adjustment Model

9. P. A. Tinsley — On Optimal Dynamic Adjustment of Quasi-Fixed Factors

10. P. A. Tinsley — On Distributed Lag Specification of Optimal Factor Adjustment Paths

11. P. A. Tinsley — A Variable Weight Distributed Lag Model of Labor Demand

12. Roger Craine — On the Service Flow from Labor