ΣΠΟΥΔΑΙ

Τριμηνιαία Επιστημονική Έκδοση της Ανωτ. Βιομηχανικής Σχολής Πειραιώς

ΕΤΟΣ 1988 ΙΑΝΟΥΑΡΙΟΣ - ΙΟΥΝΙΟΣ 1988 ΛΗ' ΤΟΜΟΣ ΑΡΙΘΜ. ΤΕΥΧΟΥΣ 1 2

ESTIMATION OF THE ELASTICITY OF SUBSTITUTION BETWEEN EQUIPMENT AND STRUCTURES FOR THE UNITED STATES MANUFACTURING

By
Dr SPIROS C. HANDRINOS *
University of Manchester and KEPE (Athens)

INTRODUCTION

The substitution between factors of production or between commodities is the primary point emphasis of neoclassical economics since its laws are based on the degree or ease of substitution of the relevant variables. A measure of the ease of substitution between commodities or between factors of production is the elasticity of substitution. It is well - known that in the case of the Cobb - Douglas production the elasticity of substitution (σ) takes the value of unity[1].

In the case of a C.E.S. production σ is not restricted a *priori* to the value of unity (or to zero in the special case of a Leontief type production function) but is constant (constant in the sense that σ is not altered by changes in

* I am indebted to M. T. Sumner for his constructive suggestions, comments, advice and encouragement during the preparation of this paper. Errors and omissions of the final product must be blamed on me.

1. See R. C. D. Allen (1962).

the relative factor inputs and prices). It is determined by the underlying technology and its range can be any number between 0 and ∞. Clearly the Cobb-Douglas and Leontief production functions are special cases of the C.E.S. relation.

The literature on empirical estimation of the elasticity of substitution between labour and capital is vast[2],while empirical work in estimating the elasticity between components of a single factor of production (especially for capital) is negligible. It is taken for granted in empirical work that σ is infinite.

Sato [1967] presented estimates of the elasticity of substitution between the two main components of the capital stock, equipment (E) and structures (S) for the U.S. privately - owned manufacturing establishments. His objective was the construction, as a first step, of a consistent aggregate capital stock which was going to be an argument in a generalised C.E.S. production function. Although Sato' s formula has derived from a constrained minimisation problem, the desired equipment - structures ratio which he derived, was a function of the relative prices of the investment goods rather that the rentals of the services of the stocks. This would be correct in the absence of any tax considerations and in the case when the required rate of return ratio ($\frac{r + \delta E}{r + \delta S}$)[3], is costant for whole period (only the constant of the functions would then be affected).

Our objective in this paper is threefold. (a) To correct Sato's estimates of σ for US manufacturing ; (b) to test the appropriateness of the partial adjustment model in this specific context, comparing the partial adjustment hypothesis with two alternatives and (c) to extend the period of estimation : various tax incentives were introduced in the US especially after 1962.

Section (1) deals with (a) the description of the variables and (b) the derivation of the model (determination of the desired capital stock ratio).

There are a number of very different reasons why one may wish to introduce lagged values of the dependent variable in the model. We test the correctness of

2. See D. W. Jorgenson (1971) and M. Nerlove (1967).

3. A. A. Kintis (1968) tried to estimate the elasticity of substitution between equipment and structures for Greek manufacturing industry. For rental ratio, he considered only the required rate of return ratio (see section two below). Since this ratio was constant for the whole period no estimates of σ could derived. See also Kintis (1973) esp. pp. 92 - 95.

the partial adjustment model by comparing this hypothesis with two alternatives (section 2). Section 3 deals with the results. Data sources and the various tax incentives introduced in the US corporate sector are presented in the appendix.

1. (a) DESCRIPTION OF THE VARIABLES

The variables are defined as follows :

$$Z_t = \frac{q_E(t)}{q_S(t)}$$ where q_E, q_S are price of the investment goods

$$x_t = \frac{K_E(t)}{K_S(t)}$$ where K_E, K_S are capital stocks

$$C_t = \frac{C_E(t)}{C_S(t)}$$ where C_E, C_S are rentals (user costs).

The rental of the K_i component of the capital stock is given by [4]

$$C_i \quad q_i (r+\delta_i) . \frac{1-k-uL_i + k' L_i}{1-u}$$

4. See Hall and Jorgenson (1967).

Then the ratio of the rentals of equipment and structures becomes

$$C = \frac{q_E}{q_S} \cdot \frac{(r+\delta_E)}{(r+\delta_S)} \cdot \frac{1-k-uL_E+k' uL_E}{1-uL_S}$$

(k and k' are zero for structures) where,

k = rate of investment credit

k' = the proportion of the investment credit that must be deducted from the depreciable base of assets on which the credit is claimed.

L = the present value of the stream of depreciation for tax purposes stemming from one dollar of current investment

r = the cost of capital

δ_E, δ_S = physical depreciation rates.

The rental ratio is decomposed into three rat'sio namely :

$C_t = Z_t W_t T_t$, where $T = \frac{1-k-uL_E+k' uL_E}{1-uLS}$ tax adjustment ratio.

Two alternative hypotheses concerning the cost of capital have been assumed ; firstly, we assume as Hall and Jorgenson [1971] did that the pre - tax rate of return is constant. Hence the after tax rate of return is given by the formula,

$r_{it} = (1 - u_{it})\, p$ where = u_t corporate tax rate and

ρ = .20 (fixed pre-tax rate).

Secondly, we assume the net rate of return r_2 to be constant at .15 level (after tax rate of return constant).

The first hypothesis, according to Harberger [1971], is implausible for the United States. An indirect rejection of this hypothesis could be based on our estimates [5].

$\gamma_t = \dfrac{\gamma_E(t)}{\gamma_S(t)}$ γ_E, γ_S telhnical improvements in equipment and structures respectively.

1. (b) DERIVATION OF THE MODEL

We proceed in the analysis by assuming that the production function is of the C.E.S. form with arguments n factors of production or n components of a given factor or a combination of the two [6]. We further assume for simplicity that returns to scale are constant and that facior markets are competitive.

Since our objective is the estimation of σ between components of the capital stock, we assume that an aggregate index of capital can be written as,

$$k_t = \sum_{i=1}^{n} [b_i k_{it}^{-\rho}]^{-1/\rho} \qquad (1)$$

where

$\rho = \dfrac{1-\sigma}{\sigma}$, $-1 < \rho < \infty$, and σ is the elasticity of substitution[7]. The assumptions underlying (1) are (a) that there exists a certain degree of substitubility between different types of capital goods and (b) that σ is the same between any pair of the capital stock.

5. See section 3.

6. See Coen R. M. (1969).

7. Equation (1) corresponds to one of Sato's (1967) lower level (first level C. E. S. functions).

In the special case in which the arguments of (1) are the stocks of equipment and structures we get,

$$k(t) = [b_E k_{E(t)}^{-b} + b_S\, k_{S(t)}^{-b}\ ]^{-1/\rho} \qquad (2)$$

The constrained cost minimisation function will be of the form,

$$H = C_E\, k_E + C_S\, k_S - \mu[k - b_E k_E{}^{-\rho} + b_S k_S{}^{-\rho}]^{-1/\rho} \qquad (3)$$

The first order conditions for cost minimisation are,

$$\frac{\partial H}{\partial k_E} = C_E - \mu b_E Y^{1+\rho}\, k_E{}^{-\rho-1} = 0 \qquad (4.a)$$

$$\frac{\partial H}{\partial k_S} = C_S - \mu b_S Y^{1+\rho}\, k_S{}^{-\rho-1} = 0 \qquad (4.b)$$

$$\frac{\partial H}{\partial \mu} = k - [b_E\, k_E{}^{-\rho} + b_S k^{-\rho}]^{-1/\rho} = 0 \qquad (4.c)$$

Dividing equation (4.a) by (4.b) and rearranging we get :

$$\frac{k_{E(t)}}{k_{S(t)}} - \left[\frac{b_E}{b_S}\right]^{\sigma} \left[\frac{C_{E(t)}}{C_{S(t)}}\right]^{-\sigma} \quad \text{or}$$

$$x_t^* \quad b^{\sigma} \; C_t^{-\sigma} \tag{5}$$

where

x^* is the equilibrium stock ratio. If allowance for technological improvements is made[8] in the construction of the stock of capital, e.g. (5) becomes,

$$x_t^* = b^{\sigma} \; C_t^{-\sigma} \gamma_t^{\sigma - 1} \tag{6}$$

where

$$\gamma_{(t)} = \frac{\gamma_{E(t)}}{\gamma_{S(t)}} \text{ and}$$

γ_i is the efficiency level of factor k_i [9].

Equations (5) and (6) are estimated for the United States manufacturing industry. Data sources are given in the Appendix.

2. SEARCH FOR THE CORRECT STATISTICAL MODEL

It has been shown that the equilibrium ratio is of the form of equation (5) or (6). A random term is added in (5) or (6) in view of the stochastic nature of observations. Then we get,

$$x_t^* = b^{\sigma} \; C_t^{-\sigma} \, 10^{u_t}. \tag{7}$$

8. See Sato (1967) p. 206.

9. Equation (6) can be easily derived where k_i is substituted with $S_i = \gamma_{i(t)} k_{i(t)}$.

Equation (7) in logarithmic form is written as,

$$\log x^* = \sigma \log b - \sigma \log C_t + u_t. \qquad (8)$$

The disturbances u_t are distributed with zero mean and constant variance.

A naive approach to the estimation of equation (8) would be to assume that the desired composition of capital is achieved instantaneously, e.g. $x_t = x^*_t$ for all t. Then (8) becomes,

$$\log x_t = \sigma \log b - \sigma \log C_t + v_t. \qquad (9)$$

Estimation of equation (9) showed the existence of serially correlated residuals. (Durbin -Watson test). Since nothing is known about the serial correlation properties of u_t in (8) only assumption can be made about the reasons that caused the serial correlation in the residuale of (9).

Two alternative assumptions can perhaps be made about the correlation properties of the disturbances u_t in equation (8); either (a) the u_t are serially independent or (b) they are serially correlated.

In the former case, the partial adjustment hypothesis can be offered as an explanation of the correlated residuals of equation (9). The partial adjustment mechanism is of the form[10].

$$\left[\frac{x_t}{x_{t-1}}\right] = \left[\frac{x^*_t}{x_{t-1}}\right]^{\gamma} \qquad 0 < \gamma < 1 \qquad (10)$$

Substitution of equation (8) in equation (10) gives,

$$\log x_t \quad \sigma\lambda \log b - \sigma\lambda \log C_t + (1-\lambda) \log x_{t-1} + \lambda u_t. \qquad (11)$$

10. The strong assumption of equal adjustment rates of equipment and structures to their optimum is implicit in equation (10).

Since the disturbances u_t are serially independent (by assumption) then the disturbances in (11) are also serially independent. The serial correlation in the residuals of equation (9) can be explained through the omission of the lagged dependent variable (x_{t-1})

The alternative assumption is that the disturbances u_t are serially correlated. In such a case the serial correlation in the residuals of (9) is explained by a serial correlation model. We assume that the disturbances follow a first - order autoregressive scheme of the form,

$$v_t = \rho v_{t-1} + e_t \tag{12}$$

where the e_t are randomly distributed with zero mean, constant variance and zero convariance.

Substitution of equation (9) into equation (12) yields

$$\log x_t = \sigma(1-\rho)\log b - \sigma \log C_t + \rho \log x_{t-1} + \rho\sigma \log C_{t-1} + e_t \tag{13}$$

Discrimination between equation (11) and equation (13) could be a very difficult task. The partial adjustment model may work (it may yield significant and sensible coefficients and it may reduce the serial correlation) although it is the wrong model. Grilliches [1961] points out that as long as there are some exogenous variables in the model, we can distinguish (with great difficulty) between the two hypotheses. The criterion, he suggests, is to add in equation (11) the variable C_{t-1} : if the coefficient of C_{t-1} is significant, has an opposite sign to C_t and is approximately equal to the product of the coefficients of C_t and x_{t-1}, then we may conclude that the partial adjustment specification is the wrong one.

Table (1) presents the coefficients of the lagged independent variable for the period 1929 - 1963.

TABLE 1

Coefficients of the lagged one period independent variable

(a) Z_{t-1}	(b) C_{1t-1}	(c) C_{2t-1}
—.0932	—.0765	—.11863
(.06719)	(.06883)	(.06372)

(a) price ratio.

(b) rental ratio calculated on the assumption that the pre-tax rate of return is constant (r_1).

(c) rental ratio calculated on the assumption that the after-tax rate of return is constant (r_2).

The coefficient of the lagged one period independent variable— independently of how we specify the independent variable — has a wrong sign and is insignificant. We may conclude that partial adjustment is the correct hypothesis. Estimates of equation (11) are given in the following section.

3. RESULTS

We have stressed before that Sato' s estimates of the elasticity of substitution (σ) between equipment and structures are incorrect. They have been derived with the ratio of prices of the investment goods as the independent variable. Since the rental ratio of the capital stocks is the correct variable (the price ratio is only part of the rental ratio) his estimates are biased.

We have reproduced Sato's results (Table 2A) for two reasons : (a) for comparison purposes and (b) in order to be sure that we use the same set of data. The differences in the reproduction of Sato' s results are very small.

It must be noted at the beginning that the estimates of σ vary around Satosl estimates. The overestimation or underestimarticn (in relation to Sato's resu's-depends on the way in which rental ratio is defined, that is on the assumptions made about the rate of return, the tax rate ut, the rate of replacement (δ) and the lifetime of capital goods allowable for tax purposes. If the pre-tax rate of return is constant then the two additional components of the rental ratio work in opposite directions e.g. the tax adjustment ratio is increased by every decrease in the tax rate ut while the required rate of return ratio is decreased. If the after tax rate of return is assumed constant then this ratio is constant and the tax adjustment ratio works in the same direction as the price ratio. In such a case the elasticity of substitution is lower than Sato's estimate while in the former case it may be higher or lower depending on the net effect of the two ratios. Table 2A presents estimates of σ and of the adjustment elasticity (λ) for composite variables, that is variables that have been constructed through the addition of the various components of the user cost to the price variable.

Since we have assumed two alternative rates of return, two sets of results are presented.[11] Because the variability of rit (by assumption) depends on the tax rate we obtained results based on the effective tax rate and on the statutory rate. In order to conserve space we present results based on the effective rate.[12] (There were no basic differences in the results). When r2 (after tax constant rate of return) is assumed the statutory corporate tax rate is used. Results are given separately when the technological ratio is added as a separate independent variable".

It is clear that the results differ signifilcantly. The estimates are constrained by the period of consideration, the specification of the independent variable, the treatment of the technological change ratio and the specification of the cost of capital. It can be seen that σ varies between 1.5 and 3.6 for the period 1929 - 1963 and between .74 and 2.48 for the sub - period 1947 -1963. With the rental ratios as explanatory variables the range of σ is between 1.5 and 2.9 for the 1929 - 1963 period and between 1.8 and 2.0 for the sub - period 1947 -1963 (with a tendency of σ to be around 2.0 for this sub-period).

The values of the adjustment elasticity also vary with the above mentioned

11. Variables in the tables take the subscript (1) when the constant pre-tax rate of return assumption is used and (2) when the after-tax constant rate of return is considered.

12. Complete regression results and summary tables based on the statutory rate are vailable on request.

13. For estimation purposes, we assume that the differential in the rates of technical improvements is constant e.g. γ (t) = 10γt. See Sato (1967) esp. p· 211.

TABLE 2A

Estimates of the elasticity of substitution (σ), partial adjustment elasticity (λ), and the Technical improvement differential ($10\hat{\gamma}$) for various specifications of the rental variables.

	Period 1929-1963				Period 1947-1963			
	σ	λ	$10^{\hat{\gamma}}$	Durbin Statistic	σ	λ	$10^{\hat{\gamma}}$	Durbin Statistic
Z_t	2.7409	.0958	-	-.11206	2.4819	.1008		-.97178
	1.6366	.1487	1.0249	-.48512	2.1199	.1235	1.006	-.87304
Z_t+W_{1t}	3.5755	.0717		1.88271	.7436	.1292		-.25475
Z_t+T_{1t}	2.4291	.0969		-.5663	1.7951	.1190		-1.34453
$W_{1t}+T_{1t}$	negative	.0200		3.46666	negative	.1590		-.76954
	2.9111	.0899		.42952	2.0378	.0996		-1.32544
C_{1t}	1.5393	.1580	1.0342	- 23953	1.8652	.1092	1.0003	-1.28410
Z_t+W_{2t}	2.7409	.0958		-.11077	2.4819	.1008		-.97178
Z_t+T_{2t}	2.2973	.1128		-.41798	1.8543	.1269		-1.05819
W_2t+T_{2t}	1.6014	.0753		4.29214	1.6705	.1877		-.85742
C_{2t}	2.2976	.1126		-.42219	1.8597	.1266		-1.07056
	1.6067	.1503	1.0193	-.53997	1.8038	.1304	1.0117	-1.06415

factors. It can easily be seen that a trade off exists between the values of σ and λ. The higher the σ the lower the λ.

The introduction of the technical improvement ratio lowers the elasticity of substitution and increases the adjustment elasticity. The technical improvement differential is found to vary between 1.002 and 1.034 depending on the period of examination. The differential varies between 2.0 and 3.4 per cent for the period 1929 -1963 and between zero and 1.2 per cent in the period 1947 - 1963.[14] Since the estimates of σ are higher than unity it can be said that technical change is structure - saving and equipment using among capital inputs.

The R^2 is very high in all the estimated equations. No equations can be selected on the basis of the R^2 criterion, since in all cases its value is about the same (around .99).

All the equations offer plausible results except the regressions where the price component (variable) of the user cost was omitted. Either negative values of σ or very high and unacceptable Durbin - statistics were found. This is not true for the two sub-periods 1947 -1963 and 1947 -1973 or for the constant after - tax rate of return assumption; the estimated σ' s and λ' s are plausible. (The required rate of return ratio is constant, so the variable is the tax adjustment ratio. One would expect these results since numerous tax changes took place during 1954-1969 in order to promote capital spending. It seems that fiscal measures can change the composition of the capital stock[15]).

Tables 2B and 2C present the coefficients of the estimating equations for different combinations of the components of the rental ratio where these components are entered in the estimating equation as separate explanatory variables.

The coefficient of the Wit was found to be positive and significant for the periods 1929-1963 and 1947- 1973. This result means that an increase in the required rate of return ratio will increase the equipment- structures stock ratio: an increase in the former ratio can occur either through a decrease in the cost of capital (r) because 5B > 5s or a suitable change in the depreciation rates (change in the useful lifetimes of the capital goods). Therefore a decrease in r will increase the equipment - structures stock ratio. This result is contrary to our expectation. We would expect a decrease in r to have a greater effect on the longer lived asset viz. buildings. The explanation that seems most obvious is that the constant

14. The maximum differential used by Solow (1962) was 2 per cent.

15. See Appendix Table A1.

TABLE 2B

Estimated Coefficients of the components of the rental ratio when they are introduced a separate explanatory variables

Period 1929-1963						
$\log C_{1t}$	$\log Z_t$	$\log W_{1t}$	$\log T_{1t}$	$10^{\gamma t}$	$\log X_{t-1}$	Durbin Statistic
-.26269 (.03247)					.91007 (.01529)	.42952
.24320 (.02999)				.001243 (.00043)	.84201 (.02711)	-.23953
	-.22668 (.03274)	.17776 (.08521)			.90373 (.01377)	.45369
	-.22319 (.03198)		-.30907 (.13011)		.90425 (.01352)	-.52629
	-.22451) (.03268)	-.08656) (.25436)	-.43591) (.39542)		.90450 (.01374)	-.56289
		.12048 (.39855)	-.59989 (.62284)		.96936 (.01574)	3.17775

TABLE 2B (contd)

Period 1929-1963

$\log C_{2t}$	$\log Z_t$	$\log W_{2t}$ = constant	$\log T_{2t}$	$10^{\gamma t}$	$\log X_{t-1}$	Durbin Statistic
-.25880 (.02743)					.88736 (.01531)	-.42219
-.24154 (.02830)				.000756 (.000427)	.84967 .02599	-.53997
	-.24952[1] (.02913)		-.56117[16] (.30631)		.86964 (.02346)	-.52591

16. The t test indicates no statistical difference between the coefficients of log Z_t and log T_{2t}.

TABLE 2C

			Period 1947-1963			
$\log C_{1t}$	$\log Z_t$	$\log W_{1t}$	$\log T_{1t}$	$10^{\gamma t}$	$\log X_{t-1}$	Durbin Statistic
-.20293 (.09008)					.90042 (.03101)	-1.32544
20374 (09339)				.000137 (.00063)	.89077 (.05482)	-1.28410
	-.23916 (.11072)	.10065 (.12725)			.88990 (.03258)	-1.35825
	-.23137 (.11121)		-.17001 (.19096)		.88701 (.03317)	-1.32298
	-.23203 (.11592)	.02211 (.23865)	-.14217 (.36034)		.88696 (.03451)	-1.34829
		-.00721 (.26431)	-.25471 (.39494)		.83121 (.02261)	-1.21172
$\log C_{2t}$	$\log Z_t$	$\log W_{2t}$ = constant	$\log T_{2t}$	$10^{\gamma t}$	$\log X_{t-1}$	Durbin Statistic
-.23539 (.09564)					.87343 (.02110	-1.07056
-.23522 (.09929)				.000530 (.00061)	.86960 (.04975)	-1.06415
	-.23881 (.11168)		-.21486 (.31140)		.87588 (.04555)	-1.07236

TABLE 3A

Estimates of the statisticaly of substitution (σ), partial adjustment (λ) and the technical improvement differential $10\hat{\gamma}$ for various specifications of the rental variable.

	Period 1929-1973				Period 1947-1973			
	σ	λ	$10^{\hat{\gamma}}$	Durbin Statistic	σ	λ	$10^{\hat{\gamma}}$	Durbin Statistic
Z_t	3.2628	.0667		2.11029	3.0192	.0552		2.81675
	1.2816	.1534	1.0803	1.73207	.8294	.1963	.8796	2.98346
Z_t+W_{1t}	3.9621	.0547		2.87944	3.1575	.0558		2.64006
Z_t+T_{1t}	2.6282	.0809		.76815	2.4664	.0778		1.69811
$W_{1t}+T_{it}$	negative	negative		4.82810	5.3931	.0528		2.95132
	2.9632	.0796		1.17646	2.6611	.0728		1.17122
C_{1t}	1.3897	1.527	1.0502	1.04007	1.3229	.1368	1.0461	1.45107
Z_t+W_{2t}	3.2628	.0667		2.11029	3.0192	.0552		2.81675
Z_t+T_{2t}	2.5248	.0887		.91803	2.2741	.0824		1.83863
$W_{2t}+T_{2t}$	negative	.0096		4.66330	4.4020	.0613		2.99695
	2.5254	.0887		.91472	2.2760	.0823		1.83448
C_{2t}	1.2805	.1583	1.0652	.65621	.8386	.2190	8886	1.50804

TABLE 3B

Estimated coefficients of the components of the rental ratio when they are introduced as separate explanatory variables

Period 1929-1973

$\log C_{1t}$	$\log Z_t$	$\log W_{1t}$	$\log T_{1t}$	$10^{\gamma t}$	$\log X_{t-1}$	Durbin Statistic
-.23596 (.03252)					.92037 (.01485)	1.17646
-.21227 (.03114)				.001266 (.00044)	.84725 (.02890)	1.04007
	-.19601 (.03865)	.10627 (.09941)			.93576 (.01464)	2.21516
	-.19481 (.02978)		-.31289 (.08639)		.91827 (.01342)	.61412
	-.20018 (.03451)	-.03110 (.09751)	-.32561 (.09603)		.91694 (.01419)	.52656
		.24523 (.11403)	-.30576 (.12861)		.97943 (.01239)	3.87325
$\log C_{2t}$	$\log Z_t$	$\log W_{2t}$ = constant	$\log T_{2t}$	$10^{\gamma t}$	$\log X_{t-1}$	Durbin Statistic
-.22403 (.02854)					.91129 (.01486)	.91472
-.20269 (.02734)				.001218 (.00042)	.84172 (.02769)	.65621
	-.21748 (.03016)		-.29015 (.09460)		.90779 (.01559)	.80294

TABLE 3C

Estimated coefficients of the components of the rental ratio when they are introduced as separate explanatory variables

			Period 1947-1973			
$\log C_{1t}$	$\log Z_t$	$\log W_{1t}$	$\log T_{1t}$	10^{Yt}	$\log X_{t-1}$	Durbin Statistic
-.19366 (.03910)					.92722 (.01699)	1.1722
-.18179 (.04074)				.00088 (.00085)	.86317 (.06480)	1.45107
	-.14961 (.05325)	-.40859 (.19126)			.94997 (.01865)	2.64502
	-.17378 (.05090)		-.26703 (.10365)		.91772 (.02070)	1.50618
	-.15972 (.04785)	-.37161 (.17187)	-.24965 (.09659)		.92419 (.01945)	1.54867
		-.46067 (.20382)	-.22329 (.11556)		.95409 (.02072)	2.88833
$\log C_{2t}$	$\log Z_t$	$\log W_{2t}$ = constant	$\log T_{2t}$	10^{Yt}	$\log X_{t-1}$	Durbin Statistic
-.18739 (.04290)					.91767 (.01973)	1.83448
-.18364 (.03975)				.001812 (.00081)	.78101 (.06379)	1.50804
	-.16424 (.04927)		-.26499 (.09098)		.91166 (.02071)	1.65160

pre - tax rate of return assumption is not the correct assumption in this specific context.

The coefficients of the tax adjustment variables are significant and negative when the tax variables are included in the estimating equation as separate independent variables (except for the sub-period 1947- 1963). Their coefficients are higher than the relevant coefficients of the price variables. Fiscal incentives tend to influence the structure of the capital stock in a significant degree.

When the three components of the rental ratio are inserted as separate explanatory variable the coefficients of the Wit and Ttt are insignificant. The coefficients of the Tit ratios for the periods 1929- 1973 and 1947-1973 are high and significant.

When the price variable was omitted the coefficients of the Wit and Tit were either insignificant or a high value of the Durbin - statistic was obtained.

The results (Tables 3A, 3B and 3C) for extended period 1929 -1973 and sub-period 1947 -1973 are about the same with a tendency of an increased σ especially in the sub-period 1949-1973. The tax adjustment variables (Tit) have a significant and negative coefficient when they are added as separate variables. The Durbin - statistics of these equations are within the acceptable range.[17]

It seems that tax incentives played an important role in the composition of the capital stock through their effect on the demand of the various capital goods.[18]

The Durbin - statistics are very high for the price variables in the extended period and sub - periods. The relevant Durbin - statistics for the rental variables are inside the acceptable range.

4. SUMMARY AND CONCLUSIONS

The results presented in this paper lead to the following conclusions.

a) The elasticity of substitution is much less than infinite. The estimates of σ

17. See Durbin J. (1970).

18. See Table Al in the Appendix where the effects of selective tax incentives on the rental ratio are presented.

differ significantly (variation ranges between .84 and 2.92) and are constrained by the period of consideration, the specification of the rental ratio, the addition of the ratio of technical change and the constant pre-tax or after - tax rate of return· σ is higher for longer periods than for shorter periods of consideration. Its value decreases significantly when the ratio of technical change is added as an explanatory variable. With the constant pre - tax rate of return assumption we got results contrary to our expectations. The coefficient of the required rate of reurn ratio tends to be positive and significant. Estimates of σ are higher than esti. mates based on the constant after - tax rate of return assumption.

b) The relative rentals play an important role in explaining the observed change in the composition of the capital stock.

c) Tax incentives seem to have affected considerably the composition of the capital stock.

d) Technical improvement found to be more rapid for equipment than structures. (Technical change equipment using).

e) The estimated low coefficients of adjustment suggest limited ex post-substitutability of the components of the capital stock.

APPENDIX

Data Sources

The data have been taken from US national income statistics (Department of Commerce) and from various issues (mainly July issues of the survey of Current Business. The Capital stock is calculated as

$$k_i(t) \quad I_i(t) + (1 - \delta)\, k_{it-1} \tag{1}$$

Ii (t) is deflated gross investment in period t (1954 prices). For the period 1963 - 1973 gross investment is given in 1958 in 1958 prices. Investment at 1958 prices is transformed to 1954 prices through the use of a linear regression on data for the common years.

$$\frac{\text{I current prices}}{\text{I 1954 prices}} = Q + b \quad \frac{\text{I current prices}}{\text{I 1958 prices}}$$

The capital stock for extended period 1963 - 1973 has been calculated according to (1).

Double declined depreciation pattern has been followed both for equipment and structures. The average life of equipment is assumed[19] to be 17 years ($\delta_E =$ ·1176) and for that of structures 40 years ($\delta_S = .05$)

Two alternative measures for the corporate tax rate were used. (a) an effective rate defined as the ratio of the Federal and State tax liability to gross corporate profits in manufacturing and (b) the statutory tax rate[20].

---

19. See G. Jaszi, R. C. Wassom and L. Grose (1962) esp. Table 7, p. 18.
20. The statutory tax rate is taken from J. A. Pechman (1971), Table A3. pp. 258 - 259.

Tax Incentives

a) Accelerated Depreciation

The adoption of accelerated methods for computing depreciation in **1954** involved a change from straight line depreciation to either sum of the years' digits on double declining balance formulas. Since the sum of the years' digits offers a slight advantage over double decline, we have assumed that accelerated depreciation was taken in the form of the sum of the years' digits.

b) Investment Tax Credit and Long Amendment 1962

An effective rate of tax credit of 6 per cent was taken for manufacturing equipment (3 per cent for 1962).

The imposition and subsequent repeal of the Long Amendment first eliminated the tax credit from the depreciation base in 1962 and 1963 (k'=k) and then restored it in 1964 and subsequent years (k' = 0).

c) Investment Credit Suspension 1966

We have ignored the investment Credit Suspension since the suspension was η effect only from October 10 1966 to March 9 1967.

d) End of the investment Credit for 1969.

e) Service Lives

Estimates of the lifetimes of assets allowable for tax purposes were **taken** from Hall and Jorgenson [1971] p. 31 and are as follows :

	Asset Lifetimes (years)	
Period	Equipment	Structures
1929 - 54	17.5	27.8
1955	16.3	25.3
1956 - 61	15.1	22.8
1962 - 73	13.1	22.8

Indicatively the effects of selective tax incentives on the rental ratio are given in Table Al.

TABLE A1

YEAR	C_{1t}			C_{2t}		
	with the tax incentive	without	change (percent)	with	without	change (percent)
1954: accelerated depreciation	1.330	1.333	-.2	1.229	1.245	-1.3
1962: change in the Life of Equipment and structures	1.349	1.384	-2.6	1.227	1.241	-2.9
1963: investment credit	1.206	1.282	-6.3	1.238	1.316	-6.3
1964: reduction in tax rate	-	-	-	1.071	1.060	+1.0

REFERENCES

Allen R. G., 1962, «Mathematical Analysis for Economists» MacMiJlan, London.

Coen R. M., 1969, «Tax Policy and Investment Behaviour : Comments» American Economic Review June pp 370 - 379.

Durbin J., 1970, «Testing for Serial Correlation in Least Squares Regression when some of the Regressors are Lagged Dependent Variables» Econometrica vol. 38 pp 410-421.

Griliches Z., 1967, «Distributed Lags : A Survey». Econometrica vol. 35, January, pp 16- 1961, «A Note on the Serial Correlation Bias in Estimates of Distributed

Lags». Econometrica vol. 29, January.

Hall R. E. and Jorgenson D. W., 1967, «Tax Policy and Ingestmeni Behaviour». American Economic Review, June pp 391 - 414.

——— 1971, «Application of the theory of Optimal Capita! Accumulation» in G. From (ed) Tax Incentives and Capital Spending, The Brooking Institution Washington. D. C.

Harberger A. C, 1971, «Discussion» in G. Fromm (ed) op. cit.

Jorgenson D. W., 1971, «Investment Behaviour and the Production Function» Discussion paper No 202 September, Harvard Institute of Economic Research, Harvard University, Massachusetts.

Jaszi G., Wassom R. C. and Grose L., 1962, «Expansion of Fixed Business Capital in the United States : Survey of Current Business (42) pp 9 - 18.

Kintis A. A., 1968, «An Econometric Analysis of the Growth Process in Greek Manufacturing» PhD Thesis, Manchester.

——————1973, «The Demand for Labour in Greek Manufacturing» Center of Planning and Economic Research.

Nerlove M., 1967, «Recent Empirical Studies of the CES and Related Production Functions» in H. Brown (ed) The Theory and Empirical Analysis of Production studies in Income and Wealth, vol 32, Columbia University Press, New York pp 55 - 122.

Pechman J. A., 1971, «Federal Tax Policy» The Brooking Institution, Washington D. C.

Sato K., 1967, «A two level Constant - Elasticity of Substitution Production Function» Review of Economic Studies (34).

Solow R. M., 1962, «Technical Progress, Capital Formation and Economic Grouwh» American Economic Review, Papers and Proceedings, 52.

Summer M. T., 1973, «Announcement Effects of Profits Taxation» in Parkin M. (ed) Essays in Modern Economics : Proceedings of the Association of University Teachers of Economics, Longmans.

Survey of Current Business, Washington : U. S. Government Printing Office, various issues.

U. S. Department of Commerce, U. S. Income and Output, Washington 1958.