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A TEST OF THE NEO-CLASSICAL CONCEPT OF CAPITAL-LABOR SUBSTITUTION

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The motivation for this study developed from observation of the fact that practitioners in the field of economic development have, almost unanimously, rejected conventional economic theories as bases for policy decisions and have accepted a number of ideas, having no theoretic bases, as guides for development. One of these ideas is the concept of Appropriate Technology introduced by Schumacher (1973).[1] This concept places emphasis on the use of "labor intensive" technologies even where the conventional model would indicate a need for "capital intensity".

Part of the argument for Appropriate Technology is based on the, often observed, fact that the introduction of high technology capital into an economy, whose labor force is primarily unskilled, causes unemployment. A theoretical explanation for this can be developed, if the basic assumptions of the neoclassical production model can be modified. Specifically, it is important to assume that factors are heterogeneous (rather than homogeneous) and that there is strict (rather than variable) factor proportionality.[2]

Because these assumptions are contrary to the conventional wisdom of the discipline, it was decidcd that it would be wise to first determine whether or not the heterogeneity and strict factor porportionality assumptions fit the real world better than the conventional assumptions.

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I. The Null Hypothesis

The null hypothesis to be tested is the conventional one that, as an economy grows, substitutability between capital and labor increases, or at least remains constant. Rejection of this hypothesis would support the alternative hypothesis that, as an economy grows, substitutability decreases.

The rationale for the alternative hypothesis is as follows : In early stages of economic development less developed countries are engaged in peasant agriculture with other activities limited to handicrafts and very small industries requiring only simple technology. Workers are generally self employed and are not equipped with much physical capital and that of a very primitive nature. Thus the level of information (i.e. technological design of capital and skill level of labor) is very low. Products can be produced with a fairly large number of alternative combinations of capital and labor; in short the idea of variable proportions fits the situation quite well. Therefore, elasticity of substitution between capital and labor can be expected to be quite large.

As the economy develops over time, the increase in per capita income, size of market and capital stock encourage entrepreneurs to invest in more advanced technologies and to improve the skill levels of themselves and their workers in order to increase productivity.

These changes in technology and skill levels, cause capital and labor inputs to move from one input space to another. The capital and labor in each input space are specific in the sense that they can only be used in production of certain commodities or groups of commodities. Thus, the capital and labor being utilized in one input space are so different from those used in another that if capital from one input space were substituted for labor in another nothing would happen. Both would be redundant. In this case, the assumption that inputs are homogeneous (neoclassical model) is not realistic and practical.

As technologies advance and are manifested in capital design, they require particular amounts of labor, with specific skills to work with fixed amounts of capital of particular types. Therefore, there is strong complementary relationship between capital and labor at the same general level of information, A change of factor coefficients should be regarded as a dynamic transition from one set of coefficients to another, rather than a smooth substitution along the neo-classical isoquant.

All of this implies that, as an economy is developed over time, the degree of substitution between capital and labor declines. Eventually it declines to zero and the production function is then characterized by fixed proportions. Specifically, then, if the assumption of a fixed proportions productions function which

serves as a theoretical basis for Appropriate Technology is valid, elasticity of substitution between capital and labor should decline in the course of economic growth of a developing economy.

It is the purpose of this research, then, to test the neoclassical hypothesis that the elasticity of substitution between capital and labor remains constant, in the course of economic growth, by concentrating on the alternative hypothesis that it declines. This test uses statistical data for Taiwan. The choice is made in part because of the availability of data and in part because Taiwan has been experiencing a remarkably high rate of econmic growth and rapid rate of structural change during the past several decades.[3]

II. The Statistical Model

In testing the hypotheses concerning elasticty of substitution, it is assumed that the CES production function (Arrow, Chenery, Minhas and Solow, 1961) appropriately describes the production process in a country. The function is of the form :

$$Y = f(K, L) = A\,[\sigma K^{-\sigma} + (1-\sigma)\,L^{-\sigma}]^{-n/\sigma} \qquad (1)$$

where Y, K and L represent output, capital and labor respectively, and A, σ, σ, n are defined as parameters denoting efficiency, distribution, substitution and homogeneity,

By differentiating equation (1) and performing appropriate algebraic manipulation, the elasticity of substitution between capital and labor (σ) is given by

$$o = \frac{1}{1+\sigma} \qquad (2)$$

To use this CES production function in statistical analysis, the following assumptions, made by Arrow, Chenery, Minhas and Solow, have been adopted :

1. Constant returns to scale (ie., $n=1$)
2. A unitary technical progress index (ie., $\sigma=1$)
3. Profit maximizing behavior
4. Perfect competition in both product and factor markets.

The assumption of profit maximizing behavior implies that there is equality between marginal factor productivities and factor rewards. Thus, by dropping the assumption of constant returns to scale, setting partial derivatives of equation (1) with respect to L and K equal to wage (w) and rent (r) respectively and performing appropriate algebraic manipulations a suitable equation for estimating the elasticity of substitution is obtained as follows :

$$\ln (K/L)_t = b_0 + \sigma \ln (w/r)_t + u_t$$

where b_0 is an intercept and u_t is assumed to be a normally and independently distributed disturbance term.

To test the hypothesis concerning elasticity of substitution between capital and labor in the process of economic growth, we relate elasticity (σ) to the economic growth index D_i as :

$$\sigma_i = b_{1i} D_{it} \tag{4}$$

Substituting equation (4) into equation (3) yields :

$$\ln (K/L)_t = b_0 + b_{ix} D_{it} \ln (w/r)_t \tag{5}$$

where the subscript (t) represents time and i = 1, 2, 3 (a sequence) as shown below :

D_1 = relative share of agricultural income

D_2 = relative share of agricultural employment

D_3 = relative share of agricultural population.

It is commonly accepted among economists that the agricultural population and labor force and agriculture's share of national income can be expected to decline in the course of economic growth,[4] as resources shift from agricultural to nonagricultural sectors. Therefore, the statistical measures D_1, D_2 and D_3 above can be expected to decline in the course of economic growth. If, the coefficients of D_1, D_2 and D_3 were positive, the results would support the alternative hypothesis that elasticity of substitution between capital and labor decline in the course of economic growth.

III. Description of Data

Data employed in this research were taken from four sources : (1) *Taiwanese Statistical Data Book*, Council for Economic Planning, Executive Yuan, Republic of China; (2) *Statistical Year Book of the Republic of China*, Directorate-General of Budget, Account and Statistic, Executive Yuan, Republic of China; (3) Liu, Pual K.C., "A Study on the Allocation of Manpower and Capital Between Industries in Taiwan" *Academic Economic Papers : 2* (September, 1974) pp. 151–211, edited by the Institute of Economics, Academia Sinica, Nankang, Taipei, Taiwan, Republic of China; (4) Thorbecke, Erik, "Agricultural Development," In *Economic Growth and Structural Change in Taiwan*, edited by Walter Galenson, Ithaca and London, Cornell University Press, 1979 pp. 132–205. All monetary data are in terms of (1966) constant Taiwanese dollars.

To test the hypothesis that elasticity of substitution between capital and labor declines in the course of economic growth, equation (5) is calculated for the agricultural and non-agricultural sectors of Taiwan utilizing time series data for Taiwan during 1951 through 1972. The capital-labor ratio (K/L) is derived for each sector by dividing the capital stock (NT$) by the number of employed persons in that sector. The wage-rent ratio (ω/r) is derived by dividing the wage rate by

the rental rate in each sector. The wage rate in each sector is obtained by dividing annual labor income (NT$) by the number employed. The rental rate is obtained by dividing annual capital income (NT$) by the value of capital (NT$).

Calculation of the D values is as follows : D_1 (relative share of agricultural income) is the ratio of agricultural income to national income; D_2 (relative share of agricultural employment) is the ratio of agricultural employment to total employment; and D_3 (relative share of agricultural population) is the ratio of agricultural population to total population.

IV. Analysis of Statistical Results

The elasticity estimates from equation (5), using the three indices of economic growth, are presented in Tables 1 and 2. The coefficients were estimated after corrections had been made for serial correlation.[6] In table 1, the coefficients ($\hat{b}_j$'s) obtained for the agricultural sector display the hypothesized signs. All t statistics are significant. The coefficients for D_1 (relative share of agricultural income) and D_3 (relative share of agricultural population) are significant at the 5 per cent level. The coefficient for D_2 (relative share of agricultural employment) is significant at the 10 percent level. The results, then, support the alternative hypothesis that the elasticity of substitution between capital and labor in the agricultural sector declined during the course of economic growth in Taiwan.

In Table 2 the coefficients ($\hat{b}_j$'s) also display expected signs for the nonagricultural sector of the economy and are significant at the 1 percent level. These results are consistent with the alternative hypothesis that elasticity of substitution between capital and labor in the nonagricultural sector declined in the course of economic growth in Taiwan.

In Figures 1 & 2 the values of $b_j D_{jt}$ are graphically represented. The figures show that the results obtained in this study reject the null hypothesis that elasticity of substitution between capital and labor remains constant as the economy progresses over time. The reason for this is that as information levels increase both capital and labor move gradually from the original input space (where the neoclassical assumptions hold) to different input spaces. The quality of capital and labor in different input spaces is so different that substitution among spaces is impossible. Further, the amount of labor required per unit of capital in each input space is particularly defined. Thus, the degree of substitution between capital and labor declines in the course of economic growth. In the extreme case, it will decline to zero and the production function will be characterized by a fixed proportions production process.

Table 1

The Estimated Regression Coefficients of the Economic Growth Indices of the Agricultural Sector

D_i	$\hat{b}_i$	DF	MSE	$\hat{p}$	R^2
D_1	0.01619**	19	0.00015	0.524	0.235
	(2.417)				
D_2	0.01434***	19	0.00016	0.519	0.173
	(1.998)				
D_3	0.00024**	19	0.00014	0.567	0.225
	(2.346)				

Table 2

The Estimated Regression Coefficients of the Economic Growth Indices of the Non-Agricultural Sector

D_i	$\hat{b}_i$	DF	MSE	$\hat{p}$	R^2
D_1	0.10053*	19	0.00146	0.630	0.537
	(4.696)				
D_2	0.13582*	19	0.00037	0.748	0.833
	(9.748)				
D_3	0.00162*	19	0.00121	0.588	0.658
	(6.041)				

t values shown in parentheses
* significant at 1 percent
** significant at 5 percent
*** significant at 10 percent

Figure 1

Values of Elasticity of Substitution
Between Capital and Labor
For the Agricultural Sector of Taiwan
22 year period 1951 through 1972

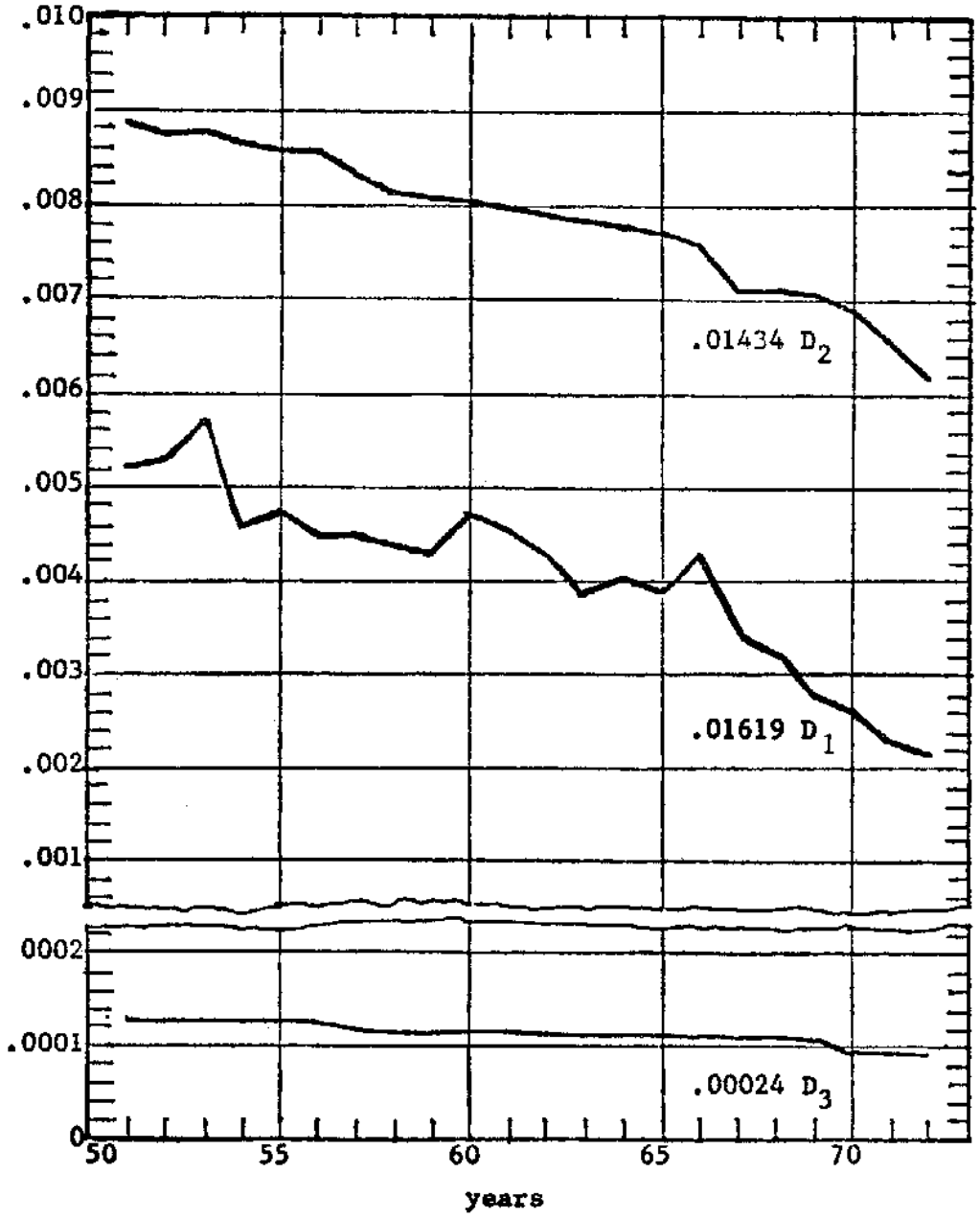
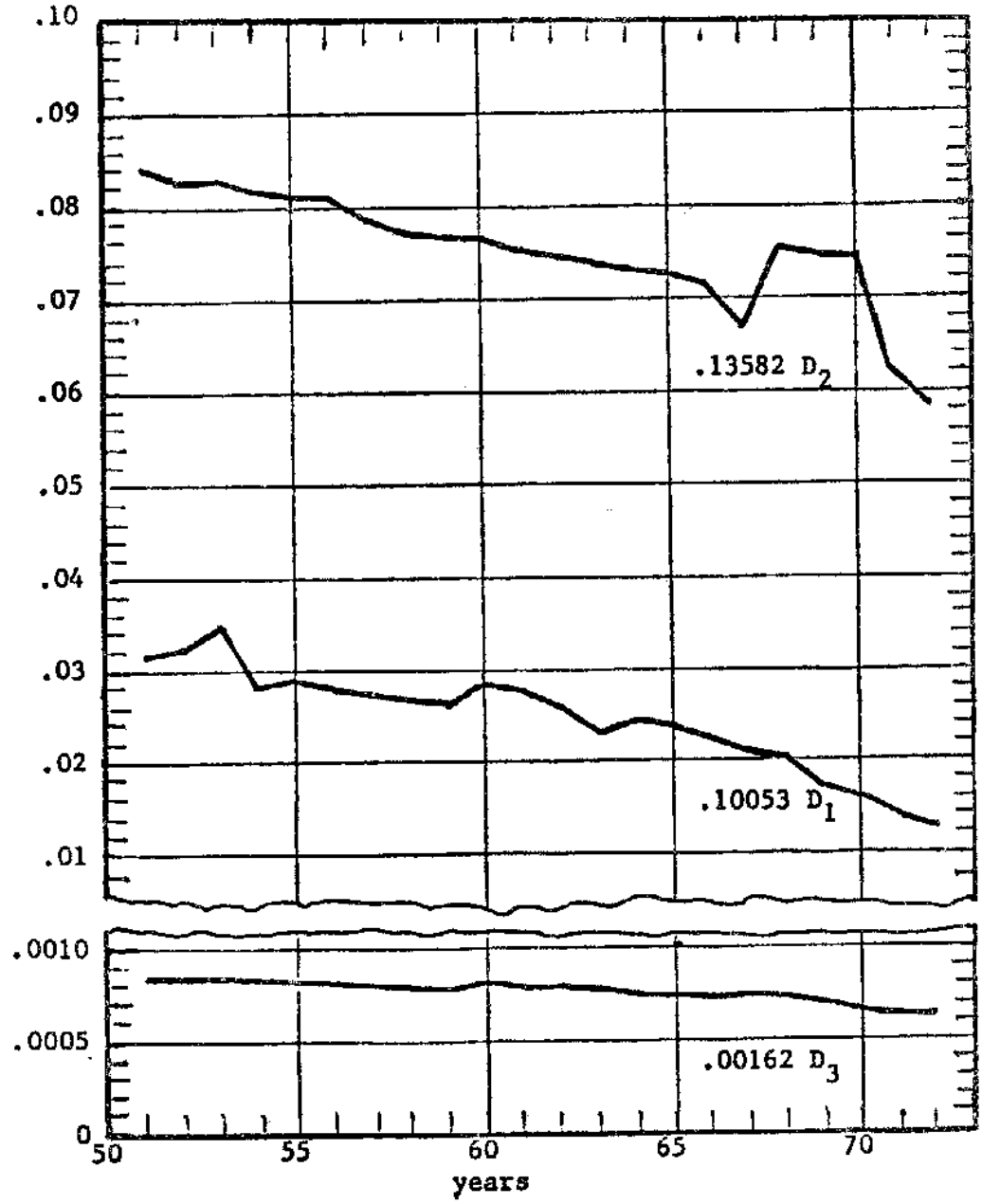


Figure 2

Values of Elasticity of Substitution
Between Capital and Labor
For the Non Agricultural Sector of Taiwan
22 year period 1951 through 1972



FOOTNOTES

1. See Schumacher (1973), Eckaus (1955, 1977), Stewart. (1972. 1978) Gurley (1974), Ranis (1979) and White (1979).
2. See Lee and Harmston (1983).
3. The detail of economic growth in Taiwan can be seen in Fei, Ranis and Kuo (1979).
4. See Johnston (1970)
5. Since Durban-Watson statistics indicate the presence of positive serial correlation in all equations, the AUTOREG procedure of SAS, which is similar to the method of Cochrane-Orcutt, is applied to correct the presence of the serial correlation.

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