capital-labour substitution in manufacturing in a developing country

The case of Cyprus

by

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A constant elasticity of substitution (CES) production function is fitted to cross-sectional data from the 1972 Census of Industrial Production for the large-scale manufacturing sector in Cyprus classified into 32 sub-sectors. For 31 sub-sectors the elasticity of substitution, σ, is calculated to be less than unity and in 27 of these significantly different from zero. These results suggest that an important factor behind the slow growth in employment and rising productivity observed in the manufacturing sector during 1960-1972 may be attributed to capital-labour substitution due to imbalances in the factor markets. Unrestricted forms of the CES production function fit Cyprus manufacturing data better than the restricted forms which assume constant returns to scale.

I. introduction

One of the basic objectives of the Government of Cyprus after independence in 1960 in the pursuance of industrial development has been the creation of more and better employment opportunities. However, one of the most striking characteristics of industrialization in Cyprus has been the relatively slow rate of growth in employment in manufacturing as compared to output. During the period 1960-1972 employment increased on average by 2.4% per annum as compared to an annual increase of 8.5% in output.

The lag in employment as contrasted with the relatively high rates of growth in output and labour productivity is typical of the industrialization process of many developing countries and has been attributed *inter alia* to the use of capital-intensive technology, imperfections in the factor markets, foreign trade policies and the level of wages. These factors tend to make capital relatively cheaper than labour and hence increase the capital intensity in manufacturing.[1]

This study aims in shedding some light on this issue by estimating the elasticity of capital-labour substitution in the manufacturing sector, and from the relative sizes of these elasticities draw some implications about employment creation.

II. the model and method of estimation

From the estimation of various production functions relating output to labour and capital inputs it is reckoned that the production process in the manufacturing sector of Cyprus is characterised by the family of production functions with constant elasticity of substitution (CES) between capital and labour.[2]

The CES production function is typically given by

$$V=\gamma[\delta K^{-\rho} + (1-\delta)L^{-\rho}]^{h/\rho} \qquad (1)$$

where V, K and L represent measures of output, capital and labour; γ,a,ρ are respectively efficiency,

1. See for instance R.S. Eckaus (6), W. Baer and M.E.A. Hervè (2).
2. E. I. Demetriades (4).

capital intensity and factor substitution parameters; h is the degree of homogeneity of the production function. The elasticity of substitution is related to the substitution parameter by

$$\sigma = \frac{1}{1+\rho}$$

If $\sigma=1$, we have a Cobb-Douglas production function and if $\sigma=0$, a Leontief-type fixed proportion production function.

This production function is usually estimated by the regression

$$\log \frac{V}{L} = a + \sigma \log w \qquad (2)$$

where $\frac{V}{L}$ = value added per person employed and w= wage-rate.

This is the Arrow, Chenery, Minhas and Solow[3] equation for estimating the elasticity of substitution between labour and capital. It is derived from the usual profit maximization conditions in which perfectly competitive markets prevail and constant returns to scale are assumed. However estimates of σ from equation (2) have been characterised by serious problems of identification and specification that result in biased estimates of σ unless corrective measures are taken.[4] The identification problems can be overcome and the specification errors reduced by dropping the crucial assumptions of constant returns to scale and perfect competition.[5] By applying a cost minimization procedure to (1) and equating the marginal rate of technical substitution to the ratio of factor prices, we have

$$\frac{\partial V/\partial L}{\partial V/\partial K} = \left[\frac{(1-\delta)}{\delta}\right]\left(\frac{K}{L}\right)^{1+\rho} = \frac{w}{r} \qquad (3)$$

If factor prices are exogenously determined and the level of output is given, then the entrepreneur chooses the least cost factor proportions as given in (3), i.e.

3. K. Arrow, H.B. Chenery, B. Minhas and R.M. Solow (1).

4. P. Dhrymes (5).
5. J.R. Moroney (10).

TABLE 1. *Estimates of the Elasticity of Substitution for the Cyprus Manufacturing Sector, 1972*

Industry Code (ISIC 1958)	Sub-sector	σ	Standard error of σ	R^2	Level of Significance of Equation	Number of Observations
201	Sausages and other meat preparations	0.44	0.16	0.57	0.05	8
202	Dairy products	0.30	0.12	0.25	0.05	22
203	Canning of fruit and vegetables	0.43	0.38	0.11	0.25	12
205	Grain mill products	0.05	0.59	0.01	0.25	7
206	Bakery products	0.57	0.09	0.45	0.01	57
208	Chocolate and sugar confectionery	0.43	0.17	0.45	0.05	10
209–210	Miscellaneous food preparations	0.77	0.16	0.40	0.01	37
211–213	Distilling, rectifying and blending of spirits	0.89	0.15	0.73	0.01	16
214	Soft drinks and carbonated water	0.70	0.11	0.89	0.01	7
220	Tobacco	0.76	0.20	0.83	0.05	5
231	Spinning, weaving and finishing of textiles	0.66	0.21	0.62	0.05	8
232	Knitting mills	0.31	0.08	0.42	0.01	24
241	Footwear	0.72	0.11	0.46	0.01	54
243	Wearing apparel	0.76	0.05	0.62	0.01	138
244	Made-up textile goods	0.10	0.44	0.01	0.25	7
251	Sawmills and wooden flooring	0.21	0.28	0.03	0.25	21
260	Furniture and fixtures	0.69	0.06	0.58	0.01	113
272	Paper and parerboard products	0.96	0.14	0.81	0.01	13
280	Printing, publishing and allied industries	0.71	0.06	0.77	0.01	46
291–293	Tanneries, leather and fur products	0.66	0.15	0.49	0.01	22
300	Rubber products	0.49	0.12	0.69	0.01	9
311–319	Chemicals and chemical products	0.94	0.15	0.60	0.01	30
331–334	Structural clay products and cement	0.35	0.12	0.13	0.01	62
339	Non-metallic mineral products n.e.c.	0.85	0.13	0.73	0.01	18
350	Metal products	0.46	0.09	0.23	0.01	93
360	Machinery	0.55	0.10	0.37	0.01	56
370	Electrical machinery	0.63	0.24	0.30	0.05	18
384–386	Transport equipment	0.61	0.05	0.52	0.01	132
389	Motor car cabinets	0.78	0.17	0.65	0.01	13
394	Jewellery and related articles	0.81	0.15	0.61	0.01	20
399.a	Plastic articles	1.29	0.16	0.84	0.01	14
399.b	Other industries n.e.c.	0.87	0.50	0.50	0.15	5
	All Industries	0.75	0.02	0.56	0.01	1097

$$\frac{K}{L} = \left[\frac{\delta}{1-\delta} \right]^{\sigma} \left(\frac{w}{r} \right)^{\sigma}$$

which can be expressed in logarithms as

$$\log \frac{K}{L} = \sigma \log \left(\delta/(1-\delta)\right) + \sigma \log \frac{w}{r}$$

$$\text{or } \log \frac{K}{L} = a + \sigma \log \frac{w}{r} \qquad (4)$$

We use this equation to estimate the elasticity of substitution in the manufacturing sector.

III. the data

The data utilized in estimating equation (4) were derived from a listing of establishments of the 1972 Census of Industrial Production, and covered all large establishments employing on average 5 or more persons.[6] These establishments were classified into 3-digit industrial groups according to the International Standard Industrial Classification of All Economic Activities (ISIC).

The capital measure (K) was taken to be the fixed assets owned by the firm valued at the initial cost of acquisition and the wage-rate (W) as the total labour costs per person engaged (including direct wages and salaries and other benefits) before deduction of income tax and social security contributions. The labour measure (L) refers to the average number of all persons engaged by the enterprise (including working proprietors). The return to capital was calculated from value added at factor cost, total labour costs and capital assets using the relation

$$r = \frac{V - wL}{K}$$

IV. empirical results

We fitted by ordinary least-squares, data for each industry group into equation (4) and the results are fairly good as can be judged from the goodness of fit of the regressions. Only in five cases (canning of fruit and vegetables, grain mill products, made-up textile goods, saw-milling and miscellaneous industries n.e.c.) the fits are considered statistically poor. The results are presented in Table 1.

The estimates of the elasticity of substitution for the 32 sub-sectors ranged from 0.05 to 1.29. In 5 cases the elasticity of substitution is not different from zero, in 16 cases it is significantly less than unity but significantly greater than zero and in 11 cases it is not statistically different from unity. These results are summarised as follows.[7]

TABLE 2. *Summary of the Estimates of* σ

Number of regressions	$\sigma=0$	$0<\sigma<1$	$\sigma=1$	$\sigma>1$
32	5	16	11	0

where $\sigma=0$ means not significantly different from zero, $0<\sigma<1$ means significantly different from zero but less than unity, and $\sigma=1$ means not significantly different from unity, all taken at the 5% level of significance.

The overall elasticity of substitution for the manufacturing sector is estimated at 0.75. This is comparable to estimates for other developing countries, as shown in the Table below.

TABLE 3. *Elasticity of Substitution for Developing Countries*

Country	Elasticity of Substitution
Cyprus	0.75
Puerto Rico	1.0
Argentina, Brazil, Colombia, Costa Rica and Mexico	0.7
Kenya	0.8
Mexico	0.1
Philippines	0.8

Source: O'Herlihy, C. St. J. (II, pp. 273-277).

V. conclusion

The results of this study indicate a significant relationship between proportions and factor prices in the manufacturing sector in Cyprus. For most industries the elasticity of substitution is less than unity but significantly different from zero. The traditional assumption that in developing countries there exist less possibilities of substitution seems to spring from the belief that since manufacturing processes are imported, the firm's factor combinations are almost fixed into adopting the capital intensity of the process. Perhaps the greater degree of capital-labour substitution exists in ancillary activities of the manufacturing enterprise, such as moving inputs and outputs, packaging and similar activities around the process.

Our results suggest that an important factor behind the slow growth of employment in manufacturing in Cyprus during the period 1960-1972 is capital-labour substitution. This substitution may be attributed to the shortage of skilled labour and imperfections in the labour and capital markets caused by institutional forces. These include labour legislation which increased the labour costs to employers, the provision of incentives for the importation of machinery for the modernization of existing industries and the establishment of new ones, and strong pressure from labour unions resulting in high wages.[8]

6. These firms produced about 75% of the output and employed nearly 70% of the labour force in manufacturing.

7. Equation (2) i.e. $\log V/L = a + \sigma \log w$ was also fitted to the same data. As expected, it gave larger numerical estimates of σ than equation (4). They ranged from 0.26 to 1.88. In 14 sub-sectors out of the 32, σ was greater than unity, in 11 sub-sectors it varied between 0.73 and 0.99, in 4 it ranged from 0.56 to 0.66 and in the remaining 3 sub-sectors it was less than 0.5. For manufacturing as a whole σ was 0.01.

8. For a detailed review of these factors see E.I. Demetriades (3, pp. 251-267).

Moreover, the observed increased labour productivity was to a great extent attributed to the increased capital intensity. Investment during the period 1960-1972 increased at an average rate of 4.3% per annum as compared to a 2.4% rise in employment. Apparently capital investment in order to have noticeable effects on productivity, must be associated with changes in technology and organization.[9] Indeed, significant increases in productivity in manufacturing have arisen from mechanization and more efficient machinery as well as from improved organization and management.[10]

The relatively high elasticity of substitution computed for the Cyprus manufacturing sector indicates that there exists flexibility in the face of external changes such as those which occur in international markets, and that prospects for output growth are relatively good, since the faster growing primary factor can be substituted relatively easily for the slower growing one. Under neoclassical assumptions, if the elasticity of substitution in less than one, decreasing the price of one factor will increase its use but decrease its share in total output.

The relatively slow expansion in employment in manufacturing in Cyprus, confirms other international experiences that under conditions of modern technology and rising productivity, industry is not likely to be a major source of new employment, even if care is taken to use labour-intensive techniques where possible. It would rather generate the effective demand leading to employment expansion in the economy as a whole. The problem of structural unemployment and underemployment in developing countries is therefore best considered as a main objective of economic development in its totality. Modern industry has a low absorptive capacity for labour in relation to the amount of capital invested, and its major contribution to employment is the extent to which it promotes the more rapid development of the economy as a whole.

9. R.M. Solow (12, pp. 76-86).
10. E.I. Demetriades (3, pp. 292-294).

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