CAPITAL-LABOR SUBSTITUTION IN JAMAICAN MANUFACTURING

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ESTIMATES OF THE elasticity of substitution between labor and capital are necessary for many economic decisions, private as well as public.[1] In developing countries interest in the elasticity of substitution stems mainly from the failure of the manufacturing sector to absorb the available labor supply [5] [30]. In his studies of employment in the eastern Caribbean, Harewood [12] [13] noted that labor participation rates in the manufacturing sector had declined between 1946 and 1960. The number of women employed in manufacturing declined in all countries while in Barbados the male labor force in manufacturing declined from 10,800 in 1946 to 9,000 in 1960 [13, pp. 50–51]. Hines [15] also noted the failure of employment to grow to any significant degree in the course of Jamaican industrialization after World War II. He estimated that real GDP grew by more than 125 per cent between 1956 and 1972 while numbers employed in large establishments[2] grew less than 8 per cent and population by almost 25 per cent over the same period [15, p. 5]. The phenomenon of rising unemployment with expanding output in the course of industrialization is extensively reported in the literature on the economic development of the less developed countries since World War II. See Meier [26, pp. 430–40] for a review.

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1 The elasticity of substitution between labor and capital measures the ease with which labor can be substituted for capital (or vice versa) with output remaining constant. It is defined as the proportionate change in the capital-labor ratio divided by a given proportionate change in the marginal rate of technical substitution. Thus:

$$\sigma=\frac{dk}{k}\Big/\frac{ds}{s}, \tag{1}$$

where σ stands for the elasticity of substitution, k stands for the capital-labor ratio (K/L), s stands for the ratio of the marginal product of labor over the marginal product of capital (MP_L/MP_K), dk and ds stand for variations in k and s respectively along a constant product curve. See Allen [1, pp. 340–44]. From (1) after integrating we obtain (2):

$$k=gs\sigma, \tag{2}$$

where g is a constant of integration. If factors are paid their marginal products, we can substitute for s in (2) the ratio of the unit labor cost and the capital rental (w/r) to obtain (3) from which σ is seen as a measure of the responsiveness of K/L to given changes in w/r:

$$k=K/L=g(w/r)\,\sigma. \tag{3}$$

2 A large establishment is defined by Hines as one employing ten or more persons [15, p. 5]. This differs from the Department of Statistics' survey of employment and earnings in large establishments, 1957–62 [17] in which, a large establishment is defined as one employing on the average fifteen or more persons, not including working proprietors and unpaid family workers. The cut-off point was reduced to ten persons after 1962.

In most developing countries policy instruments to influence the relative costs of labor and capital are available; e.g., ad valorem tariffs, rates for amortization of capital expenditure for income tax purposes, minimum wage legislation, central banking policies, etc.[3] Variations in the ratio of unit labor cost to capital rental will result in greater than, less than, or equally proportionate changes in capital per unit of labor employed according as the elasticity of substitution is greater than, less than, or equal to unity. Two well-known cases are (i) the assumption of zero elasticity of substitution, and (ii) the assumption of unit elasticity of substitution. If σ equals zero (input-output production functions) changes in the ratio of unit labor cost to capital rental, w/r, will leave the capital-labor ratio, K/L, unchanged. If σ equals unity (Cobb-Douglas production functions) a given percentage change in w/r will result in an equal percentage change in K/L. Arrow et al. [2] in their pioneering study introduced the more general class of constant elasticity of substitution (CES) production functions in which σ is assumed to be invariant to changes in the capital-labor ratio but free to take any positive value between zero and infinity.

The primary aim of this paper is to present estimates of the constant elasticity of substitution in Jamaican manufacturing industry in 1953, 1960, and 1964. The plan of the paper is as follows: In Section I three estimating procedures are outlined. Section II contains a description of the data and an analysis of the specification and identification problems. Empirical results are presented in Section III. Section IV reports on a test of the assumption that the production functions are linear homogeneous. The paper ends with a summary and a statement of the main conclusions.

I. THEORETICAL FRAMEWORK

Using census data for a cross section of manufacturing industries from nineteen countries Arrow et al. [2] estimated the elasticity of substitution by least squares regression of the following equation (4).

$$\text{Log}\, V/L = \log a + \sigma \log w. \tag{4}$$

V stands for value added, L stands for labor input, w for the money wage rate and $\log a$ is the intercept. Assuming profit maximizing behavior of firms in competitive product and factor markets, the coefficient of $\log w$ in equation (4) was shown by Arrow et al. to be the elasticity of substitution of a linear homogeneous CES production function of the following form (5).

$$V = \gamma[\delta K^{-\rho} + (1-\delta)L^{-\rho}]^{-1/\rho}. \tag{5}$$

K stands for the capital input, γ is the Hicks-neutral efficiency parameter, δ is the distribution parameter, and $\rho = (1 - \sigma)/\sigma$ is the substitution parameter.

To estimate the parameters of (5) directly would require observations on both capital and labor inputs as well as value added. Non-linear estimating procedures would also be necessary. Equation (4), on the other hand, requires observations on the labor input and on the wage rate and can be estimated by ordinary least squares. For these reasons it has become the popular method of estimating the elasticity

[3] For descriptions of some of these policy instruments, see [6] [14] [23].

parameter. See Nerlove [27] for a review of research up to 1967.

If data of acceptable quality on capital input and the rental charge per unit of capital are available an alternative method of estimating the elasticity of substitution is by equation (6):

$$\text{Log } V/K = \log c + \sigma \log r, \qquad (6)$$

where r is the rental charge per unit capital and $\log c$ is the intercept.

Equations (4) and (6) can be shown to be the log-linear forms of the marginal productivity conditions for labor and capital respectively for maximizing a profit function subject to the production function (5). The intercept terms in (4) and (6) can be defined in terms of the parameters of (5).[4] Since equations (4) and (6) are derivable from the same underlying assumptions a comparison of the estimates of σ from the two equations fitted seriatim could provdie a test of the assumptions of linear homogeneity, perfectly competitive markets and profit maximizing behavior (see Dhrymes [7] [8]). Such a test is not conclusive however, due partly to deficiencies in data and partly to least squares bias [25].

The elasticity of substitution may also be estimated from equation (3) (see footnote 1) but this method requires direct observations on K, L, w, and r which are not available. An expression for relative factor payments can, however, be obtained from (3), thus:

$$\text{Log } wL/rK = \log A + \rho \log K/L. \qquad (9)$$

An estimate of σ can be derived from the coefficient of $\log K/L$. The intercept, $\log A$, is $\log (1 - \partial) / \partial$. The relative factor shares method, has been used by Kravis [23], Solow [28], and Bell [3] to estimate the elasticity of substitution.

II. IDENTIFICATION AND SPECIFICATION ANALYSIS

Equations (4), (6), and (9) were fitted to the data by ordinary least squares. An additive error term, $\log u$, with mean of zero and a constant finite variance was assumed for each equation. The main sources of data were the Department of Statistics' survey of establishments, 1954 and 1960 [16] [19] and the survey of costs, output, and investment in large establishments in manufacturing industries, 1964 [20]. The sugar industry was excluded from this study due to difficulties in separating capital and labor inputs used in manufacturing from those used in agriculture.

The 1954 and 1960 surveys provided summary statistics for industry groups in the manufacturing sector. The 1954 survey data referred to the 1953 calendar year and covered seventeen industries, while the 1960 survey covered twenty-three industries (excluding sugar). In the latter survey, data for large establishments (employing an average of fifteen or more persons) and for small establishments were separated and equations were fitted for large, small, and all establishments combined. The 1964 survey provided data on establishments employing ten or

[4] $\text{Log } a = (1-\sigma) \log \gamma - \sigma \log (1-\partial). \qquad (7)$
$\text{Log } c = (1-\sigma) \log \gamma - \sigma \log \partial. \qquad (8)$

more persons. The observations were at the four-digit industry level and equations were fitted for ten two-digit industries in respect of which four or more observations were available.

Fitting equations (4), (6), and (9) to the 1954 and 1960 inter-industry data implies that all industries were on the same linear homogeneous production function and all firms within an industry operated in perfect markets. In theory, the key assumption of linear homogeneity can be relaxed to allow for homogeneity of any degree. The assumption of perfect competition is, however, inconsistent with degrees of homogeneity greater than one. A more general model, outlined in [10], incorporates imperfect as well as perfect markets. The estimation of such a general model would involve simultaneous equation methods since the wage rate and rental charge per unit of capital could no longer be taken as exogenous. Special assumptions about the relationship between average and marginal revenues and costs would also be necessary to handle the case of imperfect markets. Equations (4), (6), and (9) have the advantage of simplicity.

If production functions are not in fact linear homogeneous and markets are imperfect, estimates of the elasticity of substitution derived by the methods of Section I would be biased unless the true value of the elasticity of substitution was unity [10] [27]. Tests of the key assumption of linear homogeneity in total manufacturing in 1953 and 1960 and in 1964 in the two-digit industries are reported in Section IV.

Another possible source of bias is the assumption that the efficiency parameter was identical among industries in 1953 and 1960. Variations in the quality of labor or capital inputs which are not reflected in the measurement of L or K (and which are likely to be positively correlated with the wage rate or the capital rental) will bias estimates of σ from equations (4) and (6) towards unity. If the true value of σ is less than unity the bias will be upwards; if the true value is greater than unity the bias will be downwards [11, p. 289]. A similar bias may arise from variations in the output-mix among industries. Variations in the price of output correlated (positively) with the explanatory variable may bias estimates of σ from (4) and (6) towards unity.

In an attempt to account for both sources of bias $\log V$ and $\log w$ were deflated by an index of labor quality and by an index of output price. Thus in addition to (4) we estimated (4a):

$$\text{Log } V/L = \log a + \sigma \log w + (1-\sigma) \log q + (1-\sigma) \log p, \qquad (4a)$$

where q is the labor quality and p is the output price index. From (4a) it can be seen that if $\sigma = 1$ the coefficient of $\log q$ and $\log p$ will be zero and equation (4) will yield unbiased estimates even when labor quality and the price of output vary among industries. In addition to equation (6) an alternative specification which included $\log p$ on the right hand side was also estimated. Quality differences in the capital input among industries are more intractable. With K measured as horsepower installed, quality differences were probably accounted for in 1953. In 1960 K was measured by book value (undeflated) of plant and equipment and to the extent that book values reflect quality differences there would be no need for further correction.

III. EMPIRICAL RESULTS

A. *Total Manufacturing, 1953 and 1960*

Table I presents estimates of the elasticity of substitution for total manufacturing in 1953. The values of R^2 (adjusted) for the first three equations indicate a high correlation between factor productivities and unit factor costs.

Equation (4) yielded an estimate of the elasticity of substitution of 1.2786 which is significantly greater than one. The introduction of $\log q$ and $\log p$ on the right hand side to measure variations in labor quality and in output price among industries yielded insignificant coefficients, .1301 and .0906 respectively. The adjusted R^2 in equation (4a) is less than in (4) indicating that variations in skill of labor and in output price among industries were not highly correlated with variations in labor productivity among industries in 1953.

TABLE I

ESTIMATES OF THE ELASTICITY OF SUBSTITUTION IN AGGREGATE MANUFACTURING INDUSTRY (1953)

Equation	Elasticity of Substitution	Standard Error	$\bar{R}^2$	*df*
(4)	1.2786	.1351	.84	15
(4a)	1.2251	.1732	.83	13
(6)	.9093	.0579	.94	15
(9)	1.1665	.1496	.04	15

In equation (6) the estimate of the elasticity of substitution is less than one but not significantly so at .95 level. The introduction of $\log p$ on the right hand side did not make a significant difference to the estimate, and this result is not presented.

In theory the results from equations (4) and (6) should not be significantly different. The test for the equality of two means is not valid in this case, however, because $\log r$ is not independent of $\log w$. (See the Appendix for the definition of the rental charge per unit of capital.) However equation (4) yielded an estimate of the elasticity of substitution significantly greater than one while the estimate from (6) is on the opposite side of unity although not significantly different from unity. Among possible explanations for this difference are deficiencies in measurement of the capital input and in the rental charge, differences in the speed of adjustment of inputs to long-term equilibrium levels, etc.

The coefficient of $\log K/L$ in equation (9) was estimated as .1428 with a sampling error of .1098. This estimate of ρ is not significantly different from zero at conventional levels of significance. The estimate of the elasticity of substitution implied by this result is 1.1665 with a sampling error of .1496 approximated by the method outlined in Klein [21, pp. 258–61]. The low value of R^2 (adjusted) indicates that relative income shares between labor and capital are not affected significantly by changes in relative factor costs w/r, due to an elasticity of substitution close to unity.

The results of fitting the equations to 1960 data are presented in Table IIA–C. Results are presented for large and for small establishments in total manufacturing and for all establishments pooled together. In all equations the estimate of the elasticity is greater for large establishment than for small. Small establishments yielded estimates which were consistently less than unity while large establishments yielded estimates which were either significantly greater than or equal to unity.

TABLE II
ESTIMATES OF THE ELASTICITY OF SUBSTITUTION IN AGGREGATE MANUFACTURING INDUSTRY (1960)

A. Equations (4) and (4 a)

	$\hat{\sigma}$	SE ($\hat{\sigma}$)	$\bar{R}^2$	*df*
Large establishments	1.4998	.2392	.71	15
Small establishments	.5521	.1145	.59	14
Total manufacturing	.6352	.0877	.59	35
Large establishments, eq. (4 a)	1.6883	.2597	.73	13

B. Equation (6)

	$\hat{\sigma}$	SE ($\hat{\sigma}$)	$\bar{R}^2$	*df*
Large establishments	.8624	.0850	.87	15
	(.6789)	(.0873)	(.79)	
Small establishments	.7951	.0647	.90	14
	(.7810)	(.0518)	(.94)	
Total manufacturing	.8037	.0477	.89	35
	(.7493)	(.0371)	(.92)	

C. Equation (9)

	$\hat{\rho}$	SE ($\hat{\rho}$)	$\hat{\sigma}$	SE ($\hat{\sigma}$)	$\bar{R}^2$	*df*
Large establishments	−.3781	.1681	1.6082	.4348	.20	15
Small establishments	.2998	.2288	.7693	.1354	.05	14
Total manufacturing	.1156	.1410	.8963	.1132	.01	35

The result from equation (4a) in Table IIA indicates that differences in labor quality and output price among industries in 1960 accounted for some variation in value added per number employed in large establishments. The R^2 (adjusted) increased from .71 to .73, and the estimate of the elasticity of substitution rose from 1.4998 to 1.6883. The increase in the estimate of σ in the presence of $\log q$ and $\log p$ is consistent with the true of σ being greater than one. The coefficient of $\log q$, $(1-\sigma)$, was estimated as −.2949 and of $\log p$ −.5019. The former was significantly different from zero at the .90 level while the latter was not significant at conventional levels. Among the small establishments variations in labor quality and output-price among industries were not significant.

The results in parentheses in Table IIB are alternative estimates of the elasticity of substitution between labor and capital when capital input was measured to include book values of land and buildings, and inventories of raw materials, semi-finished and finished goods as well as book values of plant and equipment. These results are less than those obtained when capital was defined as book values of plant and equipment only. This finding is consistent with expectations that the partial elasticity of substitution between labor and machinery is greater than the partial elasticity between labor and inventories, land, etc.

In Table IIC the estimate of ρ among large establishments is significantly different from zero and is negative. The elasticity of substitution was estimated at 1.6082. The result indicates that increases in the w/r ratio reduce the income share of labor relative to capital due to the more than proportionate reduction in labor employed per unit of capital.

The results in Table I are not strictly comparable with those in Table IIA–C due to differences in the definition of the variables, in the coverage of the samples, etc. between 1953 and 1960.

B. *Two-Digit Manufacturing Industries, 1964*

In Table III two estimates of the elasticity of substitution are presented for ten two-digit manufacturing industries in 1964. The first estimate is derived from equation (4), the regression of $\log V/L$ on $\log w$; the second, from equation (6), the regression of $\log V/K$ on $\log r$. The need, in policy analysis, for estimates of the elasticity of substitution at lower levels of aggregation than the total industry level suggests the results in Table III will be useful despite the small number of observations.

A number of features in Table III are noteworthy. First, estimates on both sides of unity are obtained. Of the ten pairs of estimates, two are greater than unity,

TABLE III

ESTIMATES OF ELASTICITY OF SUBSTITUTION: TWO-DIGIT INDUSTRIES (1964)

ISIC No.	Industry	$\hat{\sigma}$	SE ($\hat{\sigma}$)	$\bar{R}^2$
20	Food (except sugar, rum, molasses) (n=28)	.2506	.3386	.02
		.7783	.1126	.64
22	Beverages (n=6)	.6304	.8405	.00
		.8151	.1163	.90
24	Textiles (n=9)	1.1763	.5228	.36
		1.0023	.2415	.67
26	Wood (except furniture) (n=5)	.2675	.1567	.32
		.6321	.0963	.91
29	Printing, publishing, and allied industries (n=5)	1.2228	.3269	.76
		1.0316	.1862	.88
32	Chemicals and chemical products (n=11)	.5333	.2576	.25
		.9786	.0878	.92
34	Nonmetallic mineral products (n=9)	2.0030	.2628	.88
		.4840	.1021	.73
35	Metal products (except machinery and transport equipment) (n=8)	1.1030	.3046	.63
		.4261	.1711	.44
36	Machinery products and repairs (n=4)	.1675	.5234	.00
		1.0764	1.4314	.00
38	Miscellaneous manufacturing industries and repairs (n=11)	1.0915	.2453	.66
		.7564	.1022	.85

four are less than unity and four others have one estimate greater than and one less than unity.

A second interesting feature is that for the six consumption goods industries (Nos. 20–32) both equations (4) and (6) yielded estimates on the same side of unity. For the four investment goods industries on the other hand, the two equations yielded estimates on opposite sides of unity. In three of the four investment goods industries (Nos. 34, 35, and 38) equation (4) yielded estimates greater than one while equation (6) yielded estimates less than one. The results for No. 36 (machinery products and repairs) depart from this pattern but they are not significantly different from zero.

A possible explanation for the divergence between the two methods of estimating the elasticity of substitution in the investment goods industries in 1964 is the presence of excess capacity in capital stocks. Nineteen sixty-four was a turning point in economic activity after the recession of 1961–63, and book values of fixed assets in the investment goods industries probably overstate capital input in production [29, Table 3].

A third interesting feature in Table III is the large standard errors of the regression coefficient of $\log w$. As a result the estimates are consistent with a number of hypotheses about the true value of the elasticity of substitution. The large standard errors and the low R^2 (adjusted) arise from the narrow range of variation of the explanatory variable, $\log w$, within a two-digit industry. Estimates of the coefficient of variation (the standard error divided by the mean) of $\log w$ ranged from 3.55 per cent in No. 22 (beverages) to 10.79 per cent in No. 26 (wood except furniture).

Compared with $\log w$, $\log r$ (the rental charge per unit of capital) showed considerable variation within a two-digit industry. The narrow range of variation of the wage rate variable and the wide range of the capital rental (a residual) suggests that within a two-digit industry the price of output also varied widely. Variations in the price of output which are positively correlated with the explanatory variable in equations (4) and (6) will lead to a bias towards one in the estimates presented. This possible source of bias could not be investigated due to lack of data.

The pattern of the results in Table III was not altered significantly when the labor input and the wage rate in equation (4) were measured in terms of production workers only and not total employees. Similarly when capital input and capital rental in equation (6) were measured in terms of the sum of fixed capital and inventories of raw materials and finished goods the results were not affected markedly.

In Table IV the results of fitting equation (9) to the two-digit industries are presented. The results reveal the extent to which changes in the ratio of the wage rate over the rental per unit of capital, w/r, affect relative factor shares in an industry. Changes in the w/r ratio operate on relative factor shares through the K/L ratio. Variations in the w/r ratio which are compensated by equally proportionate variations in the K/L ratio leave relative factor shares unchanged.

The R^2 values in Table IV measure the correlation of percentage changes in the K/L ratio with percentage changes in relative factor shares. The F ratio provides a test of the null hypothesis that the R^2 (unadjusted) is equal to zero. Accepting the

TABLE IV

EQUATION (9): RESULTS OF REGRESSION ANALYSIS

ISIC No.	Industry	$\hat{\rho}$	SE($\hat{\rho}$)	$\hat{\sigma}$	SE($\hat{\sigma}$)	R^2	F	Degrees of Freedom n_1	Degrees of Freedom n_2
20	Food (except sugar, rum, molasses)	−.3127	.1938	1.4549	.4103	.09 (.06)	2.60	1	26
22	Beverages	−.2734	.5252	1.3762	.9949	.06 (00)	0.27	1	4
24	Textiles	−.6097	.1536	2.5621	.8903	.69 (.65)	15.7	1	7
26	Wood (except furniture)	.7605	.2631	.5682	.0849	.74 (.66)	8.35	1	3
29	Printing, publishing, and allied	−.3030	.2323	1.4347	.4781	.36 (.17)	1.70	1	3
32	Chemicals and chemical products	−.3043	.2141	1.4374	.4424	.18 (.10)	2.02	1	9
34	Nonmetallic mineral products	−.9096	.2341	11.0561	28.9012	.68 (.63)	15.08	1	7
35	Metal products (except machinery & transport equipment)	−.6649	.2913	2.9841	2.5962	.47 (.38)	5.41	1	6
36	Machinery products and repairs	−.9440	.4622	18.1818	149.0967	.67 (.50)	4.17	1	2
38	Miscellaneous manufacturing industries and repairs	−.2043	.1921	1.2567	.3034	.11 (.02)	1.13	1	9

Note: The figures in parentheses are the adjusted R^2s.

hypothesis that R^2 is zero implies that ρ, the coefficient of $\log K/L$, is also zero and the elasticity of substitution, $\sigma = 1/(1+\rho)$, is not significantly different from one. Rejecting the hypothesis that R^2 is zero implies that ρ is not zero and σ is significantly different from one.

From the F ratios in Table IV we conclude that four industries out of ten, Nos. 24, 26, 34, and 35 have elasticities of substitution significantly different from one at the .90 confidence level. Of these four, No. 26 (wood except furniture) has an elasticity of substitution significantly less than one, the other three have elasticities significantly greater than one.

IV. THE DEGREE OF HOMOGENEITY OF THE CES PRODUCTION FUNCTION

A key assumption underlying the estimates of the elasticity of substitution in Tables I–IV is linear homogeneity of the production function. These estimates will be biased unless:

either (i) the true value of the elasticity of substitution is unity,
or (ii) the degree of homogeneity is unity [10, pp. 387–88].

Among the estimates of σ presented some are consistent with a true value different from unity at conventional levels of significance. A test of the assumption of linear homogeneity is therefore also necessary.

Following the method outlined by Kmenta [22] an attempt was made to estimate the degree of homogeneity by least squares regression of a second order approximation of a CES production function, thus (10):

$$\text{Log}\,V = b + V\log L + \delta\, V \log K/L - \left(\frac{1}{2}\right)\partial(1-\partial)V\rho\,(\log K/L)^2. \quad (10)$$

The coefficient of $\log L$ is the degree of homogeneity and may take any positive value.

Because of "harmful" multicollinearity[5] estimates of the substitution parameter ρ could not be obtained from (10). However, the multiple correlation coefficient between $\log L$ and the other explanatory variables did not suggest that the estimate of V was significantly affected by multicollinearity, except in industry No. 26. Estimates of V with standard errors and degrees of freedom are presented in Table V.

The estimates of V in total manufacturing in 1953 and among large establishments in 1960, although low, were not significantly different from one at the .95 significance level. Among the two-digit industries, except for No. 38 (miscellaneous

TABLE V

ESTIMATES OF THE DEGREE OF HOMOGENEITY OF CES PRODUCTION FUNCTION

		$\hat{V}$	SE ($\hat{V}$)	Degrees of Freedom
Total manufacturing industry				
1953:	all establishments	.6132	.2288	13
1960:	large establishments	.6440	.2051	13
1960:	small establishments	.9512	.1434	12
1960:	all establishments	.9400	.0837	33
ISIC No.	Two-digit manufacturing industries			
20	Food (except sugar, rum, and molasses)	.8843	.1071	24
22	Beverages	1.0235	.1346	2
24	Textiles	1.1503	.1319	5
26	Wood (except furniture)	1.7189	.3383	1
29	Printing, publishing, and allied	1.1311	.6215	1
32	Chemicals and chemical products	1.1486	.1858	7
34	Nonmetallic mineral products	.9289	.2101	6
35	Metal products (except machinery and transport equipment)	1.0132	.1092	4
38	Miscellaneous manufacturing industries and repairs	1.2707	.1280	7

5 A variable is said to be "harmfully multicollinear" only if its multiple correlation with other members of the independent variable set is greater than the dependent variable's multiple correlation with the entire set of independent variables. See [9, p. 98].

manufacturing industries and repairs), the results are consistent with linear homogeneous production functions. In view of the small number of degrees of freedom the results should be considered as suggestive only.

V. SUMMARY AND CONCLUSIONS

Estimates of the elasticity of substitution in manufacturing industry in developing countries are few in number. However, such estimates are necessary for the analysis of a large number of economic issues, particularly the issue of employment, in less developed countries.

Direct estimation of the substitution parameter of the CES production function requires non-linear estimating procedures and observations on both capital and labor inputs which are not often available. None of the indirect methods of estimating the substitution parameter is completely satisfactory, however. They require certain restrictive assumptions, e.g., linear homogeneous production functions, perfect markets, etc.

In this study estimates of the elasticity of substitution in total and in two-digit manufacturing industries in Jamaica were derived by three indirect methods. The assumptions underlying these methods were discussed and tests of some assumptions undertaken.

The main conclusions are as follows:

(1) The elasticity of substitution in large establishments of total manufacturing is found to be greater than one. In small establishments the elasticity was less than one. An average estimate for all establishments combined was about one.

(2) Nine out of ten two-digit manufacturing industries studied were found to have elasticities of substitution of either one or more. Of these, industries No. 24 (textiles), No. 34 (nonmetallic mineral products), and No. 35 (metal products except machinery and transport equipment) were found to have elasticities greater than one. Industry No. 26 (wood except furniture) was found to have an elasticity of substitution less than one.

(3) The assumption that production functions were linear homogeneous could not be rejected at conventional levels of significance for total manufacturing and for nine out of ten two-digit manufacturing industries. Industry No. 38 (miscellaneous manufacturing industries and repairs) showed increasing returns to scale.

(4) Finally the results indicate that variations in relative factor costs are important in determining factor intensities in large establishments in Jamaican manufacturing industry. In small establishments on the other hand factor intensities are not directly related to variations in relative factor costs.

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APPENDIX

Description of Variables

The descriptions of the variables are as follows:

(1) Value added (V) was measured as sales plus change in inventory less cost of materials, fuel, and electricity purchased. It is assumed that the quantity of materials and fuels purchased per unit of output is a constant. For the 1954 study, data on change in inventory was unavailable.

(2) Labor input (L) was measured by total number employed and included managerial, supervisory, clerical and sales workers, craftsmen, technicians, machine operators, and unskilled manual and service workers. Working proprietors and unpaid (family) workers were excluded. The 1954 labor input was the sum of "regular" workers at the end of 1953 and the mean of the maximum and minimum number of "casual" workers employed during 1953.

(3) Payments to labor (wL) was the sum of wages and salaries, social security payments, and the money value of payments in kind.

(4) Unit labor cost (w) was defined as payments to labor (wL) divided by labor input (L).

(5) Capital input (K) was measured differently in 1954, 1960, and 1964. The 1954 data for capital input were horsepower installed at December 31, 1953. The 1960 capital input was measured conventionally as the book value of machinery and equipment at the end of the year. For 1964 capital input was measured as the average of book values of fixed assets (land, structures, machinery and equipment) at the beginning and end of the year.

(6) Payments to capital (rK) was measured as the residual of value added after paying labor's share, i.e., $rK = V - wL$.

(7) Rental charge per unit of capital (r) was measured as payment to capital (rK) divided by capital input K or $(V - wL) / K$.

(8) Index of labor quality (q) was measured in 1954 as the ratio of "regular" to total employees, and in 1960 as one minus the ratio of "unskilled" manual and service workers to total employees during one week in 1960.

(9) Output price index (p) was measured in 1954 and in 1960 as the implicit price deflators of GDP by industrial sectors with the implicit deflator of bread and bakery products taken as unity. The source was Deparmtent of Statistics [18].