JOURNAL OF ECONOMIC DEVELOPMENT
Volume 12, Number 2, December 1987

Production Function Analysis in the Manufacturing Sector of Barbados:

An Econometric Approach*

Andrew S. Downes**

This paper examines the substitution, returns to scale and technical change parameters of production functions in the manufacturing sector of Barbados over the 1970-1977 period using a CES production function. Subject to the limitations of the data and assumptions of the analysis, there is evidence of labour-saving technical change and 'increasing returns to scale.' The elasticity of input substitution appears to be low.

I. Introduction

The purpose of this paper is to examine some of the characteristics of production functions in the manufacturing sector of Barbados, a small developing country in the Caribbean. Production function analysis is important for several reasons. First, the extent of factor substitution in the production process has implications for employment generation, the functional distribution of income and wage policy. Secondly, the "effects of varying factor

*This paper is based on part of Chapter 7 of the author's Ph.D. thesis "Industiral Growth and Employment in a Small Developing Country: The Case of Barbados 1955-1980," Department of Economics, University of Manchester, July 1985. The author would like to thank Dr. N. Lee and Dr. G. Joseph for their guidance and comments. An anonymous referee also provided useful comments. The author, however, accepts full responsibility for the interpretation of the results.

**Lecturer, Department of Economics, University of the West Indies, Cave Hill Campus, Barbados.

endowments in international trade hinge on the shape of particular production functions" (Arrow, et al., p. 225). Thirdly, the nature of the production function determines the type of index number formula used to measure industrial production. For example, the widely used Laspeyres index of industrial production assumes that the underlying production function is linearly homogeneous and additive in inputs.

Although there has been an ongoing research program in production function analysis in developing countries, very little study has been undertaken on the nature of the production process in the manufacturing sector of the Caribbean (see for example, Williams; Sackey; Downes). While manufacturing operations have increased rapidly in the 'more developed countries' of the Caribbean — Barbados, Guyana, Jamaica and Trinidad and Tobago — since the 1950's, little is known about the extent of factor substitution in the production process, the nature of economies of scale and technical change in the manufacturing sector. One reason for the lack of research into these matters stems from the unavailability of suitable data. In recent years, however, several countries have conducted surveys of industrial establishments which provide the basic data source for an econometric analysis of production functions.

The organization of the paper is as follows: first, the analytical framework used in the study is presented. This framework assumes that establishments in a 'manufacturing group' are cost minimizing subject to a given production constraint.[1] While several functional forms of the production process exist in the literature, such as, the Cobb-Douglas, the Constant Elasticity of Substitution (CES) and the translog (see Denny) this paper utilizes the CES functional form. Secondly, the results of the estimation process are analyzed. Cross-sectional estimation for three years, 1970, 1973 and 1977 is used to determine the extent of factor input substitution, scale economies and technical change in ten 'manufacturing groups.' Finally, some limitations and implications of the research findings are discussed.

[1] A 'manufacturing group' refers to a collection of establishments producing goods under a three-digit industrial classification. In some cases, a small number of establishments exist in a given classification, so that for confidential reasons, some heads are grouped together.

II. The Analytical Framework

The analytical approach adopted in this study is based on the assumption that establishments within a 'manufacturing group' seek to minimize the costs of producing a target level of output. This cost minimization approach has three main advantages which are relevant in an analysis of production fucntion characteristics (see Brechling, p. 9). The first advantage relates to the non-specification of assumptions regarding the competitive nature of the output market. As Brechling (p. 9) indicates, by "letting output be exogenous, errors ensuing from a misspecification of the structure of the output market are avoided." A second advantage is that cost minimization is compatible with decreasing long-run marginal (average) costs. Although output price is not relevant to the cost minization approach, it is consistent with average cost pricing which is practised in a number of manufacturing operations.[2] This separation of scale and substitution effects permits easy estimation and testing of the parameters of the production function.

Under the assumption that establishments within a 'manufacturing group' seek to minimize the cost of producing some level of output which they will sell at an 'administered' price, the production technology is given by the CES functional form:

$$(1)\ V = \gamma \{\delta K^{-\varrho} + (1-\delta)L^{-\varrho}\}^{-\mu/\varrho}$$

where V is real net output or value added (assuming that the Leontief separation theorem holds), K is utilized capital services, L is labour services employed. The parameters of the function are γ (an efficiency parameter) which is less than infinity; δ (a distribution parameter) lying between zero and one, ϱ (a substitution parameter) which is greater than or equal to minus one but less than or equal to infinity, and μ (a returns to scale parameter) representing the degree of homogeneity of the function and is greater than zero. Since equation (1) is a flow equation, then on the assumption of constant utilization rates, the capital and labour services flows can be proxied by the stock concepts of labour and capital.

2 See BIDC.

There are two main reasons governing the choice of the CES functional form in this study. First, the CES function permits any value of the eleasticity of substitution between factors of production to be determined although this value is constant along the isoquant. While other functional forms have been developed which place no a priori restrictions on the production parameters (e.g. translog, generalized Leontief and generalized Box-Cox and variable elasticity of substitution (VES)), the estimation of these functions require more information than is readily available from many industrial surveys in developing countries. A second reason for the choice of the CES function is that the 'indirect' method of estimation of production parameters can be used by invoking the first order optimization conditions of the constrained problem. This estimation process does not necessarily require the use of capital data which is usually difficult to obtain (see Arrow, et al.).

Assuming an average cost pricing formula, then for given factor input prices

$$(2)\ P = m \left\{ \frac{WL}{V} + \frac{rK}{V} \right\}$$

where P is the 'price' of output, W is the nominal price of labour services (the wage rate or average labour costs), r is the nominal price of capital (the user cost or rental price of capital) and m is an assumed constant mark-up factor ($m>1$).

Minimizing the cost of production subject to the production function (1) yields the first order optimality condition

$$(3)\ \frac{W}{r} = \frac{1-\delta}{\delta} \cdot \frac{K^{1+\varrho}}{L^{1+\varrho}}.$$

Rearranging (3) gives

$$(4)\ rK = \frac{\delta}{1-\delta}\ WL^{1+\varrho} K^{-\varrho}.$$

Also from (2)

$$(5)\ rK = \frac{PV}{m} - WL.$$

Combining equations (4) and (5) yields:

$$(6)\ \frac{PV}{m} - WL = \frac{\delta}{1-\delta}\ WL^{1+\varrho}K^{-\varrho}$$

Using the first order optimality condition based on the Lagrangian multiplier, $K^{-\varrho}$ can be replaced by the relation[3]

$$(7)\ K^{-\rho} = \frac{\hat{V}^{-\varrho/\mu}}{\delta\gamma^{-\gamma/\mu}} - \left(\frac{1-\delta}{\delta}\right) L^{\rho}$$

where $\hat{V}$ is the target level of output. Substituting (7) into (6) and carrying out a series of simple manipulations and then taking natural logarithms, a demand for labour function results in the following form:

$$(8)\ \ln L = \frac{1}{1+\varrho} \ln\left(\frac{1-\delta}{m\gamma^{\rho/\mu}}\right) - \frac{1}{1+\varrho} \ln \frac{P}{W} + \frac{\mu+\varrho}{\mu(1+\varrho)} \ln\hat{V}$$

or more simply

$$(9)\ \ln L = \theta_1 + \theta_2 \ln\frac{W}{P} + \theta_3 \ln\hat{V}$$

where $\theta_2 = \frac{-1}{1+\varrho} < 0$, $\theta_3 = \frac{\mu+\varrho}{\mu(1+\varrho)} > 0$, and θ_1 is a constant.

For the purpose of statistical estimation, a stochastic term, ε, can be added to equation (9) on the assumption that it is exponential and multiplicative in equation (1), that is, e^{ε}. Hence the statistical equation is:

$$(10)\ \ln L = \hat{\theta}_1 + \hat{\theta}_2 \ln\frac{W}{P} + \hat{\theta}_3 \ln\hat{V} + \varepsilon_1$$

where ε_1 follows a normal distribution with zero mean and constant variance.

In equation (10), $\hat{\theta}_2$ represents an estimate of the elasticity of

[3] This is one way of by-passing the problem of the unavailability of capital data for the manufacturing sector of Barbados.

substitution parameter, while $\hat{\theta}_3$ can be used to provide an estimate of the scale parameter. If a parameter restriction is placed on $\hat{\theta}_3$ such that $\mu = 1$, the degree of homogeneity of equation (1) is unity. In effect, equation (10) can be written in the restriction form as

$$(11)\ \ln \frac{V}{L} = \hat{\theta}_1 + \hat{\theta}_2 \ln \frac{W}{P} + \varepsilon_2$$

where $\hat{\theta}_2 > 0$.[4] Since $\frac{V}{L}$ is a measure of labour productivity, the role of factor substitution in the productivity of labour can be assessed through an estimate of θ_2.

The cost minimization framework employing the CES functional form permits the estimation of parameters of the production function, namely, the elasticity of input substitution and the extent of scale economies. Furthermore, it has been pointed out by Nadiri (p. 1141), and Yotopoulos and Nugent (pp. 145-151), that technical change can result in factor input substitution so that a fall in the elasticity of substitution between capital and labour may be due to labour-saving technical change.[5] In the following section, a discussion of these production characteristics is presented for the manufacturing sector of Barbados during the 1970's.

III. Empirical Results

Before presenting the empirical results, it should be noted that there are statistical problems associated with the use of the CES function in examining the parameters of production functions. These problems have been surveyed by Morawetz; Nadiri; Mayor; and O'Herlihy among others. Briefly, these problems, which are also encountered in this study, include the assumption of additive separability of capital and labour from each other and from inter-

4 This assumes that the target level of output $\hat{V} = V$.

5 This is based on the Hicksian notion of technical change. Technical change or progress is labour-saving, neutral or labour using whether the marginal rate of technical substitution of capital for labour decreases, remains constant or increases for the original capital-labour ratio (See pp. 420-422).

mediate inputs, bias in the estimates associated with the absence of labour quality and 'management' input in the production function, the assumption of homogeneous labour (i.e. an aggregation problem), measurement errors in the data, the use of different vintages of capital stock in the plant and excess capacity. Since the data are not available to fully assess the effect of these problems, they must be taken into consideration when interpreting the results.

The 'unrestricted' equation (10) and the 'restricted' equation (11) are applied to 10 'manufacturing groups' on a cross-establishment basis for the years 1970, 1973 and 1977. The labour variable (L) is defined as the total number of employees at the end of the year, the wage variable (W) is the ratio of total wages and salaries to the total number of employees at the end of the year, and the output variable (V) is net output or census value added. It is assumed that theoretically, all establishments within a group charge the same output price through a tacit oligopolistic agreement or statistically, the standard deviation of the price distribution within each group is very small. These assumptions are made to overcome the problem of unavailability of price data across establishments.

The results of estimating the unrestricted equation (10) indicate that, in general, the output variable has a greater statistical effect on the demand for labour than the wage variable. For the three years, the output variable is only statistically insignificant at the 5% level in three 'groups' — beverages (1970), machinery and electrical apparatus (1970) and other manufacturing (1977). In these cases, the wage variable is also statistically insignificant at the 5% level (see Table 1). For the overall or total manufacturing sector, both variables are statistically significant at the 5% level, but these overall results rest on the assumption that all establishments are on the same production function and are in 'long-run' equilibrium. To the extent that cross-establishment estimation reflects a 'long-run' situation, the relative importance of the output variable suggests that measures to increase output would have a greater 'long-run' impact on employment growth than measures to reduce wages.

In the unrestricted equation, the wage variable is significantly different from zero in food products (1970, 1973), textiles and

Table 1

CROSS-ESTABLISHMENT LABOUR DEMAND EQUATION FOR THE MANUFACTURING SECTOR
UNRESTRICTED EQUATION
$(\ln L = \hat{\theta}_1 + \hat{\theta}_2 \ln W/P + \hat{\theta}_3 \ln \hat{V} + \varepsilon_1)$

Industrial Branch	1970					
	n	$\hat{\theta}_2$	$\hat{\theta}_3$	$\bar{R}^2$	F	SEE
Food Products	16	0.754 (0.300)*	0.846 (0.078)*	0.91	73.18	0.39
Beverages, Tobacco[b]	10	0.583 (2.078)	0.684 (0.298)	0.53	6.00	0.80
Textiles, Wearing Apparel, Leather Products	24	0.677 (0.205)*	0.808 (0.113)*[1]	0.69	26.43	0.50
Wood Products, Furniture, Fixtures	12	0.151 (0.278)	0.597 (0.231)*[1]	0.36	4.07	0.47
Paper Products, Printing, Publishing	13	0.450 (0.423)	0.605 (0.122)*	0.72	16.31	0.63
Chemicals	12	0.463 (0.322)	0.774 (0.193)*[1]	0.60	9.38	0.49
Non-metallic Mineral Products	12	0.663 (0.362)	0.827 (0.162)*[1]	0.75	17.58	0.49
Metal Products, Transport Equipment of Metal	12	0.242 (0.365)	0.421 (0.187)*	0.22	2.56	0.56
Machinery, Electrical Equipment	6	1.005 (1.047)	0.690 (0.549)	-0.07	0.83	1.01
Other Manufacturing	5	0.943 (0.543)	0.833 (0.186)*[1]	0.86	13.65	0.45
TOTAL MANUFACTURING	122	0.712 (0.100)*	0.771 (0.045)*	0.71	148.07	0.57

Table 1 (continued)

Industrial Branch	1973 n	$\hat{\theta}_2$	$\hat{\theta}_3$	$\bar{R}^2$	F	SEE
Food Products	19	1.217 (0.235)*	1.055 (0.072)*[1]	0.94	143.54	0.30
Beverages, Tobacco[b]	10	1.333 (1.060)	0.553 (0.157)*	0.64	9.04	0.81
Textiles, Wearing Apparel, Leather Products	30	0.625 (0.250)*	0.741 (0.073)*	0.78	52.20	0.54
Wood Products, Furniture, Fixtures	13	0.365 (0.366)	0.656 (0.113)*	0.74	17.67	0.37
Paper Products, Printing, Publishing	16	0.644[a] (0.220)*	0.716 (0.071)*	0.91	72.87	0.43
Chemicals	14	0.415 (0.325)	0.727 (0.134)*[1]	0.70	15.88	0.37
Non-metallic Mineral Products	16	1.340 (0.333)*	0.917 (0.113)*[1]	0.83	36.05	0.49
Metal Products, Transport Equipment of Metal	16	0.826 (0.175)*	0.705 (0.010)*	0.80	30.82	0.39
Machinery, Electrical Equipment	9	1.600 (0.386)*	1.176 (0.327)*[1]	0.76	13.83	0.56
Other Manufacturing	5	0.714 (0.695)	0.695 (0.127)*[1]	0.85	15.50	0.55
TOTAL MANUFACTURING	149	0.803 (0.091)*	0.771 (0.034)*	0.78	265.29	0.56

Table 1 (continued)

Industrial Branch	n	1977 $\hat{\theta}_2$	$\hat{\theta}_3$	$\bar{R}^2$	F	SEE
Food Products	24	0.266 (0.301)*	0.778 (0.111)*[1]	0.81	58.73	0.73
Beverages, Tobacco[b]	9	0.147[a] (0.143)	0.564 (0.111)*	0.81	18.51	0.31
Textiles, Wearing Apparel, Leather Products	34	0.151 (0.262)	0.726 (0.073)*	0.78	62.57	0.67
Wood Products, Furniture, Fixtures	21	0.011[a] (0.207)	0.702 (0.079)*	0.88	72.50	0.36
Paper Products, Printing, Publishing	19	0.126[a] (0.317)	0.666 (0.114)*	0.84	48.60	0.52
Chemicals	16	0.406 (0.517)	0.540 (0.155)*	0.43	6.68	0.59
Non-metallic Mineral Products	17	0.693 (0.174)*	0.694 (0.098)*	0.77	27.74	0.48
Metal Products, Transport Equipment of Metal	18	0.176 (0.253)	0.643 (0.114)*	0.66	17.19	0.61
Machinery, Electrical Equipment	8	1.337 (0.844)	0.491 (0.180)*	0.56	5.47	0.71
Other Manufacturing	5	0.195[a] (0.635)	0.725 (0.251)	0.94	29.99	0.42
TOTAL MANUFACTURING	171	0.411 (0.084)*	0.763 (0.033)*	0.78	300.44	0.63

Notes:

n	Number of establishments used in estimation.
$\hat{\theta}_2$, $\hat{\theta}_3$	Estimates of the 'wage' and 'output' variables, respectively. The numbers in brackets indicate the standard errors of the estimates.
$\bar{R}^2$	The coefficient of determination adjusted for the number of degrees of freedom.
F	F-test statistic.
SEE	Standard error of the estimated regression.
a	Indicates a positive value for the 'wage' variable, when it should theoretically be negative.
b	Refers to beverages only.
*	Indicates that the estimate is statistically significantly different from zero at the 5% level of significance.
1	Not significantly different from unity at the 5% level of significance using a two-tail test.

wearing apparel (1970, 1973), non-metallic mineral products (1973, 1977), metal products and machinery (1973). The results for machinery and other manufacturing should be treated with caution since the small number of observations does not give enough 'degrees of freedom' to adequately undertake tests of significance. One of the problems with cross-establishment econometric estimation which can affect the significance of the wage variable is the low variability in wage rates across establishments. Low variability in an explanatory variable has the effect of increasing the standard of the coefficient of that variable and hence produce an insignificant result. If wage contracts are set at approximately the same level for most establishments within an industrial branch, then very little variation would be observed in wage variable.

In order to test the hypothesis that the output coefficient is equal to unity, a generalized t-test is used.[6] If the coefficient is not significantly different from unity, then it is likely that production takes place under constant returns to scale. Furthermore, if the restriction of a unity output coefficient holds, then the restricted equation (11) can be used to represent labour demand in the manufacturing sector. The empirical results indicate that while the restriction of a unitary output coefficient held in 6 'groups' for 1970, the restriction only held for 5 'groups' in 1973 and 1 'group' in 1977 (see Table 2). In food products, constant returns to scale (i.e. $\theta_3 = 1$ or $\mu = 1$), held for all three periods. A value of the output coefficient other than unity provides a partial measure of the retuns to scale parameter.[7] If the output coefficient is less than unity ($\theta_3 < 1$), then 'increasing returns to scale' exist (i.e. $\mu > 1$ if $\varrho > 0$). The results indicate that the scale parameter is greater than unity in paper products, printing and publishing and metal products for all three years. It seems that production was gradually taking place under 'increasing returns to scale' over the 1970s, since in 1970, six of the ten 'groups' had an output coefficient approximately equal to unity (i.e. $\mu = 1$), while in 1977, eight of the ten 'groups' had an output coefficient between zero and unity (i.e.

6 The F test statistic which can also be used to test the validity of the restriction yields the same result as the t test statistic.

7 Since the capital variable is not explicity used in the analysis, a more accurate interpretation of the coefficient is 'returns to labour.'

Table 2

SUMMARY OF THE STATISTICALLY APPROXIMATE VALUES OF THE OUTPUT VARIABLES AT THE 5% LEVEL OF SIGNIFICANCE*

Industrial Branch	1970	1973	1977
Food Products	1	1	1
Beverages, Tobacco**	0	>0, <1	>0, <1
Textiles, Wearing Apparel, Leather Goods	1	>0, <1	>0, <1
Wood Products, Furniture, Fixtures	1	>0, <1	>0, <1
Paper Products, Printing, Publishing	>0, <1	>0, <1	>0, <1
Chemicals	1	1	>0, <1
Non-metallic Mineral Products	1	1	>0, <1
Metal Products, Transport Equipment of Metal	>0, <1	>0, <1	>0, <1
Machinery, Electrical Equipment	0	1	>0, <1
Other Manufacturing	1	1	0
Total Manufacturing	>0, <1	>0, <1	>0, <1

Notes: * The values are based on test of significance from zero and unity.
** For beverages only.

$\mu > 1$). The results of estimating the unrestricted equation (10) suggest that the elasticity of substitution across 'manufacturing groups' was 'low' and production may have been taking place under increasing returns to scale over the period.

Since the restriction of a unitary output coefficient is not universally valid for all manufacturing groups for the three years, the estimation of equation (11) to determine the value of the elasticity of substitution will yield biased estimates. The estimated values of the elasticity of substitution for both the restricted and unrestricted equatons are presented in Table 3. The estimates from the unrestricted equation (10) suggest that the elasticity of substitution is low in most 'groups' (i.e. the estimate is not significantly different from zero at the 5% level). The estimates of the restricted equation (11) indicate, however, that the elasticity of substitution is not statistically different from unity in half of the groups over the three years. The food products, textile and wearing apparel, chemicals and non-metallic mineral products 'groups' yield consistently 'high' values of the elasticity of substitution for the three years. However, the values of the elasticity of substitution from the restricted equation only provide 'reliable' results as long as the restriction is valid. As indicated previously, the assumption of a unitary output coefficient is generally untenable for 1977, and, to a lesser extent, for 1973.

A supplementary test of unitary elasticity of substitution in the restricted equation (11) is undertaken. Since the t-distribution asympotically approximates a standard normal distribution, then the test statistic T,
where

$$(12)\ T = \sum_{i=1}^{10} \left\{ \frac{\theta_{2i} - 1}{S_{\theta_{2i}}} \right\}^2$$

follwes a χ^2 distribution with 10 degrees of freedom (i.e. the 10 'manufacturing groups'). $S_{\theta_{2i}}$ is the standard error of θ_{2i} for $i = 1$, 2.... 10. Given the 'null' or 'maintained' hypothesis that the elasticity of substitution, θ_2, is equal to unity for all 'manufacturing groups' in the restricted equation, the calculated values of T for 1970, 1973 and 1977 are 9.8354, 29.7845 and 36.5146 respectively. As the critical value of the χ^2 for 10 degrees of freedom at the 5% level of significance is 18.31, the unitary elasticity holds, in general, for all 'groups' in 1970, while the elasticity of substitution is, in general, not equal to unity for all 'groups' in 1973 and 1977. A comparison of the estimates of the elasticity of substitution for 1973 and 1977 indicates that the 1977 values are lower than the 1973 values in 8 'groups' (see Table 4). To the extent that a fall in the elasticity of factor substitution indicates that there is labour-saving technical change taking place, then within the restricted framework, it seems that such a change took place in the manu-

Table 3

ESTIMATES OF THE ELASTICITY OF SUBSTITUTION IN THE MANUFACTURING SECTOR 1970, 1973, 1977

Industrial Branch	1970		1973		1977	
	UR	R	UR	R	UR	R
Food Products	0.754*[1]	1.123*[1]	1.217*[1]	1.084*[1]	0.266	0.739
Beverages, Tobacco	0.583	2.344*[1]	1.333	0.451	-0.147	0.077
Textiles, Wearing Apparel, Leather Goods	0.677*[1]	0.890*[1]	0.625*[1]	0.852*[1]	0.151	0.649*[1]
Wood Products, Furniture, Fixtures	0.151	0.435	0.365	0.784	-0.011	0.513[3]
Paper Products, Printing, Publishing	0.450	1.340*[1]	-0.644*	-0.355	-0.126	0.599*[1]
Chemicals	0.463	0.713*[1]	0.415	0.740*[1]	0.406	1.174*[1]
Non-metallic Mineral Products	0.663	0.954*[1]	1.340*[1]	1.516*[2]	0.693*[1]	0.823*[1]
Metal Products, Transport Equipment of Metal	0.242	0.678	0.826*[1]	0.925*[1]	0.176	0.483
Machinery, Electrical Equipment	1.005	1.354	1.600*[1]	1.580*[1]	1.337	1.101
Other Manufacturing	0.943	0.842	0.714	0.688	-0.195	0.440
Total Manufacturing	0.712*[3]	0.981*[1]	0.803*[3]	1.003*[1]	0.411*[1]	0.733*[3]

Notes:
UR Indicates estimates from the unrestricted equation.
R Indicates estimates from the restricted equation.
* Indicates that the estimate is statistically different from zero at the 5% level of significance.
1 Indicates that the estimate is not statistically different from unity at the 5% level of significance.
2 Indicates that the estimate is statistically greater than unity.
3 Indicates that the estimate is statistically less than unity.
The estimates without superscripts indicate that these estimates are not different from zero at the 5% level of significance.

Table 4
Cross-Establishment Estimates of the Elasticity of Substitution Restricted Equation ($\ln(V/L) = \hat{\theta}_1 + \hat{\theta}_2 \ln(W/P) + \varepsilon_2$)

Industrial Branch	1970: n	$\hat{\theta}_2$	$\bar{R}^2$	F	SEE
Food Products	16	1.123 (0.256)*	0.55	19.28	0.43
Beverages, Tobacco[b]	10	2.344 (1.256)*	0.21	3.49	0.80
Textiles, Wearing Apparel, Leather Products	24	0.890 (0.169)*	0.56	27.70	0.53
Wood Products, Furniture, Fixtures	12	0.435 (0.247)	0.16	3.10	0.52
Paper Products, Printing, Publishing	13	1.340 (0.439)*	0.41	9.30	0.86
Chemicals	12	0.713	0.41	8.48	0.50
Non-metallic Mineral Prod.	12	0.954 (0.241)*	0.57	15.71	0.49
Metal Products, Transport Equipment of Metal	12	0.678 (0.458)	0.10	2.19	0.77
Machinery, Electrical Equipment	6	1.354 (0.771)	0.29	3.09	0.92
Other Manufacturing	5	0.842 (0.514)	0.30	2.69	0.44
TOTAL MANUFACTURING	122	0.981 (0.092)*	0.48	112.67	0.63

Table 4 (continued)

Industrial Branch	1973				
	n	$\hat{\theta}_2$	$\bar{R}^2$	F	SEE
Food Products	19	1.084 (0.156)*	0.72	48.01	0.29
Beverages, Tobacco[b]	10	0.451 (1.391)	-0.11	0.11	1.11
Textiles, Wearing Apparel, Leather Products	30	0.852 (0.288)*	0.21	8.74	0.64
Wood Products, Furniture	13	0.784 (0.449)	0.15	3.05	0.49
Paper Products, Printing,	16	0.355[a] (0.301)	0.03	1.39	0.62
Chemicals	14	0.740 (0.318)*	0.25	5.43	0.42
Non-metallic Mineral Products	16	1.516 (0.227)*	0.74	44.60	0.39
Metal Products, Transport Equipment of Metal	16	0.925 (0.214)*	0.54	18.62	0.48
Machinery, Electrical Equipment	9	1.580 (0.365)*	0.69	18.75	0.55
Other Manufacturing	5	0.688 (1.028)	-0.12	0.45	0.81
TOTAL MANUFACTURING	149	1.003 (0.098)*	0.41	103.99	0.64

Table 4 (continued)

Industrial Branch	1977				
	n	$\hat{\theta}_2$	$\bar{R}^2$	F	SEE
Food Products	24	0.739 (0.212)*	0.33	12.14	0.78
Beverages, Tobacco[b]	9	0.077 (0.229)	-0.12	0.11	0.54
Textiles, Wearing Apparel, Leather Products	34	0.649 (0.268)*	0.13	5.86	0.80
Wood Products, Furniture, Fixtures	21	0.513 (0.199)*	0.22	6.67	0.47
Paper Products, Printing, Publishing	19	0.599 (0.238)*	0.23	6.34	0.63
Chemicals	16	1.174 (0.558)*	0.19	4.40	0.74
Non-metallic Mineral Products	17	0.823 (0.212)*	0.47	15.20	0.70
Metallic Products, Transport Equipment of Metal	18	0.483 (0.291)	0.09	2.76	0.76
Machinery, Electrical Equipment	8	1.101 (1.237)	-0.03	0.79	1.04
Other Manufacturing	5	0.440 (0.268)	0.30	2.68	0.43
TOTAL MANUFACTURING	171	0.733	0.33	83.59	0.72

Notes:

- n — Number of establishments used in estimation.
- $\hat{\theta}$ — Estimate of the 'wage' variable or the elasticity of substitution.
- $\bar{R}^2$ — Coefficient of determination adjusted for the number of degrees of freedom.
- F — The F-test statistic.
- SEE — Standard error of the estimated regression.
- a — A negative value for the 'wage' variable, when it should be theoretically positive.
- b — Refers to Beverages only.
- * — Indicates that the estimate is statistically significantly different from zero at the 5% level using a one-tail test.

facturing sector of Barbados over the 1970-1977 period.

The conclusions of the above exercise depend critically upon the assumptions employed and the limitations of the data and estimation technique. The assumptions of labour homogeneity, little cross-establishment output price variation, exogeneity of output and the absence of a capacity utilization variable can result in omitted variable and simultaneous equation bias in the estimates. But given the data availability constraints in the manufacturing sector of Barbados, these problems are a by-product of the exercise.

Subject to the qualifications relating to the limitations of the exercise, the following conclusions have been reached: first, the 'real price' of labour had a small effect on the demand for labour across manufacturing groups for the years 1970, 1973 and 1977. Second, the declining value of the elasticity of substitution suggests that labour-saving technical change occurred resulting in a fall in employment growth. Third, the 'output effect' on employment growth dominated the 'price effect' across branches over the 1970s. Fourth, the estimate of the output coefficient suggests that production took place under conditions of increasing returns. Fifth, under the assumption that all establishments in the manufacturing sector lie on the same production function, the results indicate that the 'price' variable was significant at the 5% level for all three years. Finally, under the assumption that production takes place under constant returns to scale (which is not generally supported by the results), the elasticity of substitution is approximately equal to unity in half of the 'manufacturing groups' for the three years.

IV. Conclusion

This paper has explored the characteristics of production functions in the manufacturing sector of Barbados over the 1970-1977 period. Subject to the limitations of data and assumptions of the analysis, the empirical results shed some light on the degree of capital-labour substitution, the nature of technical change and the extent of 'returns to scale.' The results are in effect tentative since the availability of more time series data and other variables would permit more definitive conclusions to be reached. It seems therefore, that over the study period, the existence of labour-saving technical change and the relatively low level of the substitution parameter, meant that employment generation in the manufacturing sector was limited. Measures to increase output (e.g. export promotion), would have a more significant effect on employment generation than measures to reduce wages. The extent to which employment increases depends on the relative influence of labour-saving technical change and output expansion.

References

Arrow, K.J., et al., "Capital-Labour Substitution and Economic Efficiency," *Review of Economics and Statistics,* 43, 3, Aug. 1961, 225-250.

Barbados Industrial Development Croporation (BIDC), *Survey of Manufacturing Costs in Barbados,* BIDC, Bridgetwon, Barbados, 1985.

Barbados Statistical Service (BSS), *Survey of Industrial Establishments,* BSS, Bridgetown, Barbados, 1970, 1973, 1977.

Brechling, F., *Investment and Employment Decisions,* Manchester University Press, Manchester, 1975.

Denny, M., "The Relationship between Functional Forms for the Production System," *Canadian Journal of Economics,* 7, 1, Feb. 1974, 21-31.

Downes, A.S., "Capital-Labour Substitution in the Barbadian Industrial Sector: Some Cross-Sectional Econometric Results," *Journal of Caribbean Studies,* 4, 1, Fall 1984, 1-10.

Ferguson, C.E., *Microeconomic Theory,* 3rd ed., Richard, D. I., ed., Illinois.

Mayor, T., "Some Theoretical Difficulties in the Estimation of the Elasticity of Substitution from Cross-Section Data," *Western Economic Journal,* 6, 3, June 1968, 153-163.

Morawetz, D., "Elasticities of Substitution in Industry: What Do We Learn From Econometric Estimates," *World Development,* 4, 1, Jan. 1976, 11-15.

Nadiri, M.I., "Some Approaches to the Theory and Measurement of Total Factor Productivity: A Survey," *Journal of Economic Literature,* 8, 4, Dec. 1970, 1137-1177.

O'Herlihy, C. St. J., "Capital-Labour Substitution and the Developing Countries: A Problem of Measurement," *Bulletin of the Oxford University Institute of Economics and Statistics,* 34, 2, 1972, 269-30.

Sackey, J.A., "Elasticity of Substitution and Employment Generating Capacity of a Bauxite Firm in Guyana," *Social and Economic Studies,* 30, 2, June 1981, 45-70.

Thomas, J.J., *An Introduction to Statistical Analysis for Economists,* 2nd ed., Weidenfeld and Nicolson, London, 1983.

Williams, R., "Capital-Labour Substitution in Jamaican Manufacturing," *The Developing Economies,* 12, 2, June 1974, 169-181.

Yotopoulos, P.A. and J.B. Nugent, *Economics of Development: Empirical Investigations,* Harper and Row, New York, 1976.