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

Production Function Analysis in the Manufacturing Sector of Barbados:

An Econometric Approach*

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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.

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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.

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]

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

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:

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

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.

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 (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

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.

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

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 (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, Chemicals	16	0.355[a] (0.301)	0.03	1.39	0.62
	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

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.

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.

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