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RETURNS TO SCALE IN BRANCHES OF NEW ZEALAND MANUFACTURING INDUSTRY: A Cross-Section Production Function Study, 1983/84

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Abstract. This paper is concerned with estimating the degree of returns to scale in seven major branches of New Zealand manufacturing industry using different production functions. The results obtained reveal that different production function specifications give very similar, if not identical, results. The estimated production functions consistently suggest constant returns to scale in all major branches of New Zealand manufacturing industry.

I. INTRODUCTION

This paper is concerned with estimating the degree of returns to scale in seven major branches of New Zealand manufacturing industry. For this purpose cross-section data for 1983/84 are used and different production function specifications are tried.

The outline of the paper is as follows. In Sections II and III various production function specifications and the data used are discussed. Section IV presents the results and Section V compares them to the results from similar international studies. Finally, in Section VI, the results and the conclusions are summarized.

II. ESTIMATION OF CES AND OTHER FUNCTIONAL FORMS

Econometric application of the aggregate production functions are variants of the general type:

$$Q = f(E, K, t) \tag{1}$$

where Q, E, K are the levels of output, employment and capital stock, respectively and t is a time trend.

This general function is homogeneous to degree v (returns to scale) and the time variable is included in order to allow for effects of quality change over time. In this study cross-section data are used for estimation purposes (see Section III) and, therefore, t is zero. However, even when $t=0$, equation (1) can not be estimated

* This study is one in a series of analyses by the author and Assoc. Prof. J. M. Howells based on New Zealand manufacturing data. The research is supported by a University of Otago research grant. The author would like to thank Dr. Ross Cullen and Mrs. Sue Cathro for their helpful comments. Of course, responsibility for remaining errors is his own.

unless an explicit assumption is made about the functional relationship between the two inputs and output.

In recent years the Constant Elasticity of Substitution (CES) production function has gained a great degree of popularity mainly because it subsumes a number of more specialized production functions [Bairam (1988)]. This can be seen from the conventional CES specification:

$$Q = A[(1-\omega)E^{-\rho} + \omega K^{-\rho}]^{-(v/\rho)} \tag{2}$$

where $A > 0$; $1 \geqslant \omega \geqslant 0$; $\rho \geqslant -1$ and $\rho = [(1/\sigma) - 1]$.

As before Q, E and K represent output, employment and capital stock, respectively. A is the scale parameter denoting the efficiency of the technology and units of measurement, ω indicates the degree to which the technology is capital-intensive, v is the returns to scale parameter and σ is the elasticity of substitution between labour and capital which is derived from the substitution parameter ρ. [$\sigma = 1/(1+\rho)$, therefore, σ is defined in the range $0 < \sigma < \infty$.]

The degree of generality of the CES is achieved through the substitution parameter ρ. The CES production function is equivalent to the Cobb-Douglas for $\rho = 0$ and to the fixed proportion production function for $\rho \rightarrow \infty$. That is to say with $\sigma = 1$, the Cobb-Douglas can be obtained as a special case of (2):

$$Q = AE^{\alpha}K\beta \tag{3}$$

where $\alpha = (1-\omega)v$, $\beta = \omega v$ and, hence, $v = \alpha + \beta$ is the degree of returns to scale.

Fitting the CES is not an easy task. This is because equation (2) is non-linear in parameters. Consider the logarithmic transformation of equation (2):

$$\ln Q = \ln A - (v/\rho)\ln[(1-\omega)E^{-\rho} + \omega K^{-\rho}] \tag{4}$$

The problem is to obtain an estimate of the parameters A, v, ρ and ω, given the data on output, employment and capital stock. As is obvious from (4), a simple least-squares procedure can not be applied, since the equation is still non-linear. Estimation of the parameters of the CES production function is only possible by the following two methods.

The parameters of (4) can be estimated by non-linear methods. The likelihood function can be set up in the usual way and maximum-likelihood estimates of the parameters can be obtained with a computer. However an alternative, and considerably simpler, estimation of the parameters of the CES production function is also possible if (4) is replaced by its approximation that is linear with respect to ρ. Kmenta (1967, 1971) used OLS to estimate the parameters of the CES by replacing it with the following function:

$$\ln Q = \ln A + \mu_1 \ln E + \mu_2 \ln K + \mu_3(\ln K - \ln E)^2 \tag{5}$$

where $\mu_1 = (1-\omega)v = \alpha$, $\mu_2 = \omega v = \beta$ and $\mu_3 = 0.5[\omega(1-\omega)\rho v]$.

Therefore, the parameters of (4) are related to the coefficients of (5) as follows:

$$\omega = [\mu_2/(\mu_1 + \mu_2)] \quad (6)$$

$$v = (\mu_1 + \mu_2) \quad (7)$$

$$\rho = [2\mu_3(\mu_1 + \mu_2)/(\mu_1\mu_2)] \quad (8)$$

Equation (5) is derived from (4) by using Taylor's series of expansion around $\rho = 0$ [$\sigma = 1$] and disregarding the terms of third and higher order. It is clear that the right-hand side of (5) can be conveniently separated into two parts; one corresponding to the Cobb-Douglas production function and one representing a 'correction' due to the departure of ρ from zero. The latter part is given by $[\mu_3(\ln K - \ln E)^2]$ which disappears if $\rho = 0$. Consequently, a μ_3 estimate can be used to test the Cobb-Douglas hypothesis. If the estimated coefficient obtained is not significantly different from zero the CES production function can be rejected in favour of the Cobb-Douglas production function.

If, however, as suggested by Griliches and Ringstad (1971) and Sargan (1971) the squared term is replaced by an unconditional quadratic then the Translog production function of Brendt and Christensen (1973) is obtained:

$$\ln Q = \Pi + \pi_1 \ln E + \pi_2 \ln K + \pi_3(\ln E)^2 + \pi_4(\ln K)^2 + \pi_5(\ln E)(\ln K) \quad (9)$$

This is clearly a flexible general form that is easy to estimate. Unfortunately, in general, output is not homogeneous in the inputs, and estimates of marginal products and elasticity of substitution again requires the calculation of functions of the coefficients. It can be seen from (9) that if π_3, π_4 and π_5 are not statistically significantly different from zero, (9), is also reduced to the log-linear Cobb-Douglas production function. Hence, (9) can be used to test the Cobb-Douglas specification against one more possible alternative, the Translog production function.

In Section IV both (5) and (9) are used for guidance in determining the appropriate production function specification for the data and period covered in this study.

III. DATA

The data used for estimation purposes are cross-section (cross-group) statistics for seven divisions (branches) of New Zealand manufacturing industry. The titles of the nine NZ-SIC divisions and number of groups (sub-branches) included in each are reported in Table 1. Two of the divisions D37 (Basic Metal Industries) and D39 (Other Manufacturing Industries) are excluded from this study. This is because for D37 and D39 the available samples are too small (4 and 6, observations, respectively) furthermore D39, unlike any other division, is not homogeneous.[1]

[1] The groups included in this division are as follows: Jewelry and Related Articles; Musical Instruments; Sporting and Athletic Goods; Brushes and Brooms; Toys and Games; Manufacturing Industries, n.e.c.

TABLE 1. New Zealand Manufacturing [Major Division 3] Standard Industrial Classification (SIC)

Division code (D)	No of groups in 1983/84 census	Division title
31	26	Food, beverages and tobacco
32	17	Textile, wearing apparel and leather goods
33	12	Wood and wood products
34	9	Paper and paper products
35	16	Chemicals and related products [including petroleum, coal and plastic products]
36	10	Non-metalic mineral products [excluding petroleum and coal products]
37	4	Basic metal industries
38	34	Fabricated metal products, machinery and equipment
39	6	Other manufacturing industries

Note: For details see *Census of Manufacturing, 1983/84*, Department of Statistics, Wellington, 1986, pp. 67–84.

The data on the seven major divisions were taken from the *Census of Manufacturing Bulletin, 1983–84*, Series C, Numbers 1–9, published by the New Zealand Department of Statistics. Output (Q) is value added and employment (E) consists of total number of full-time persons engaged plus half of the part-time persons engaged. The capital stock (K) statistics used are the total book value of fixed tangible assets.

It should be noted that these statistics may not be entirely consistent or reliable. Measurement errors, especially in employment and fixed assets statistics, are very likely. This is mainly because from the input side there is a common tendency to assume that there are no significant variations in the degree of utilization of input factors over time and/or across-industries.[2] However, it should be also emphasized that the data used show wide variations between groups included in each division, therefore, minor inaccuracies are hopefully of little significance. Nevertheless the results reported in the next section must be interpreted in this light.

IV. EMPIRICAL RESULTS

In the literature it is widely recognized that a researcher can not rely on economic theory for guidance in the appropriate choice of production function specifications [Bairam (1987b)]. Consequently, he/she has to allow data to determine the form by employing statistical tests. This researcher initially estimated both Kmenta's approximation of the CES [equation (5)] and the Translog production function [equation (9)] for the seven major branches of New Zealand

[2] A detailed discussion of measurement errors and their consequences can be found in Bairam (1986 and 1988).

manufacturing industry using cross-section (sub-branch) data available on each division. These specifications were tested because it seemed plausible to prefer the two less restricted production functions to the more specialized Cobb-Douglas production function. However, all the estimated CES and Translog production functions yielded μ_3 or π_3, π_4 and π_5 coefficient estimates which are not significantly different from zero at conventional test levels.[3] Consequently, the CES and Translog hypotheses were rejected in favour of the Cobb-Douglas hypothesis.

Since the Cobb-Douglas production function is the appropriate specification for the data and the period covered by this study, the results reported in Table 2 are estimates of the following logarithmically transformed Cobb-Douglas production function:

$$\ln Q = \ln A + \alpha \ln E + \beta \ln K \qquad (10)$$

It can be seen from the table that for a cross-section study adjusted R^2s are very high. In the estimated equations the value of $\bar{R}^2$ ranges between 0.896 and 0.996, which indicates that at least 90% of the sample variation of the dependent variable, output, can be attributed to the estimated effect of employment variation and variation in capital stock. Turning to the t-statistics, the estimates of α and β are statistically significantly greater than zero at conventional test levels in all equations but one (the value of β obtained for D36 is not significantly different from zero).

The results in Table 2 suggest that constant returns to scale prevail in *all* branches of New Zealand manufacturing. The estimated degrees of returns to scale ($v = \alpha + \beta$) are between 0.96 and 1.11 and, at the 0.95 confidence level, they are not significantly different from unity. The Machinery Industry (D38) indicates some economies of scale ($v = 1.11$), however, the estimated economies of scale are still small and statistically insignificant.[4] It is worthwhile noting that these branch estimates of v imply that the *average* degree of returns to scale in *total* manufacturing is not significantly different from unity. This suggests that a constant returns to scale Cobb-Douglas can be justified as the underlying model of New Zealand aggregate manufacturing production.

Finally, since for all divisions $v = \alpha + \beta = 1$ the Cobb-Douglas used [equation (10)] is constrained to linear homogeneity and the following specification is also estimated:

[3] In order to save space these coefficient estimates and their standard errors are not reported here. They are available upon request from the author.

[4] The hypothesis H_0: $v = \alpha + \beta = 1$ can be tested by noting:

$$[(v-1)/SD(v)] \cdots t_{n-k}$$

where n = number of observations

k = number of explanatory variables included

$[SD(v)]^2$ = Variance (v) = Variance (α) + Variance (β) + 2 Covariance (α, β).

TABLE 2. THE COBB-DOUGLAS PRODUCTION FUNCTION ESTIMATES FOR BRANCHES OF NEW ZEALAND MANUFACTURING INDUSTRY

$\ln Q = \ln A + \alpha \ln E + \beta \ln K$
Cross-section Data, 1983/84

Division No.	$\ln A$	α	β	$\bar{R}^2$	SEE	n	$v=\alpha+\beta$
31	6.35	0.70	.34	0.942	0.227	26	1.04⁺
		(8.51)	(4.49)				
32	6.97	0.68	0.32	0.986	0.137	17	1.00⁺
		(14.48)	(7.30)				
33	6.07	0.71	0.35	0.974	0.279	12	1.06⁺
		(4.81)	(3.02)				
34	7.76	0.72	0.26	0.996	0.089	9	0.98⁺
		(11.63)	(5.60)				
35	8.07	0.76	0.23	0.956	0.206	16	0.09⁺
		(10.44)	(3.98)				
36	8.55	0.77	0.19	0.869	0.254	10	0.96⁺
		(3.91)	(1.56)*				
38	4.59	0.61	0.50	0.943	0.285	34	1.11⁺
		(4.57)	(3.70)				

Source: See text.
Variables: $\ln Q$, $\ln E$ and $\ln K$ are logarithmic values of output, employment and capital stock, respectively.
Notes: Figures in parentheses are t-statistics and $v=\alpha+\beta$ is the degree of returns to scale. * indicates a coefficient not significantly different from zero and + denotes a degree of returns to scale not significantly different from unity in a one tail test at the 0.95 confidence level.

$$\ln(Q/E) = \ln A + \beta \ln(K/E) \tag{11}$$

The results obtained using this specification and the same data are reported in the Appendix. It can be seen from the estimated equations that the estimated β coefficients are very similar, if not identical, to those reported in Table 2. They reveal that the marginal productivity of capital (or capital's share in total earnings) range between 0.190 in D36 (Non-mineral Products) to 0.485 in D38 (Fabricated Metal Products, Machinery and Equipment). It is also worthwhile to note the decrease in the standard errors of most estimated β coefficients reported in the Appendix. This occurs because multicollinearity between $\ln E$ and $\ln K$ in equation (10) is avoided by the transformation, so increasing the accuracy of the estimates.

V. DISCUSSION AND COMPARISON TO OTHER SIMILAR STUDIES

In this section the estimated scale parameters (v) for New Zealand manufacturing branches are compared to similar estimates for US [McCombie (1985)], Soviet [Bairam (1987a, 1988)] and European Comecon [Bairam (1986)] manufacturing branches obtained using the Cobb-Douglas or the CES production functions.

A major difficulty that is encountered in comparing the results from different studies is that the scope of the individual branch which comparisons are made is often left unclear. Here, this is not a problem, as all the results reported in Table 3 are in terms of the International Standard Industrial Classification (ISIC). Nevertheless, it should be emphasized that this is not the only problem. Comparing the present estimates to the estimates from the four other studies is still difficult for a number of reasons. First, three of these studies used gross-output [Bairam (1986, 1987a, 1988)] rather than value added used in this study as the dependent variable, Q. Second, all four studies for estimation purposes employed *pooled* cross-section and time-series data covering the period 1960–75 [as opposed the pure cross-section data for 1983/84 used here]. Third, the cross-section units used differ among the studies. Bairam (1986) used pooled *cross-country* data drawn from the seven European Comecon countries,[5] while McCombie (1985) and Bairam (1987a, 1988) employed pooled *cross-regional* data drawn from American States and Soviet Republics, respectively. However, despite these differences, it is interesting to compare the findings. A comparison of the present results with the recent literature is also important to show whether the estimated v parameters reported in this paper are reasonable and consistent with the established wisdom.

The summary results in Table 3 clearly show that the degree of returns to scale, v, in similar Soviet/Comecon and American manufacturing branches differ *less than many suppose*. The estimates reveal that similar, if not identical, degrees of return

TABLE 3. THE DEGREE OF RETURNS TO SCALE (v) IN NEW ZEALAND, AMERICAN, SOVLET AND COMECON MANUFACTURING INDUSTRIES

Industry title	NZ	USA	Comecon	USSR	
	[CD]	[CD]	[CD]	[CD]	[CES]
Food, beverages, tobacco	1.04^+	0.81	0.72	0.49	0.41
Textile, wearing apparel and leather goods	1.02^+	0.99^+	0.91^+	1.02^+	0.84^+
Wood and wood products	1.07^+	0.96^+	n.a.	0.83^+	0.88^+
Paper and paper products	0.98^+	0.99^+	n.a.	n.a.	n.a.
Chemicals and allied products	0.99^+	0.79	0.78	0.69	0.72
Non-metalic mineral products	0.96^+	0.79	n.a.	0.98^+	0.86^+
Fabricated metal products machinery and equipment	1.11^+	0.97^+	0.92^+	0.92^+	0.90^+
Unweighted average	1.02	0.90	0.83	0.82	0.77

Sources: US: McCombie (1985); Comecon: Bairam (1986); USSR [CD]: Bairam (1987a); USSR [CES]: Bairam (1988).

Notes: CD and CES indicate whether the Cobb-Douglas or the CES production function is used for estimation purposes. + denotes a degree of returns to scale not significantly different from unity in a one tail test at the 0.95 confidence level.

[5] These seven European Comecon countries are Bulgaria, the CSSR, the GDR, Hungary, Poland, Rumania and the USSR.

to scale prevail in similar branches of Soviet, Comecon and US manufacturing industries. These estimates consistently refute the hypothesis of increasing returns to scale. The results further reveal the estimates of v for *both* Soviet/Comecon and American Chemicals and Allied Products and Food, Beverage and Tobacco branches are statistically significantly less than unity at conventional test levels. Therefore, suggesting that the same manufacturing branches suffer from decreasing returns to scale in countries with different economic systems.

However, comparing these findings with those reported in this study for New Zealand manufacturing also reveals that diseconomies experienced by Soviet and American Chemical and Food industries is not a universal problem. As explained before, none of the New Zealand manufacturing industry branches is characterized by economies of scale either, nevertheless, unlike the other countries discussed here, no New Zealand branch suffers from diseconomies of scale. It can be seen from Table 3 that constant returns to scale prevail in New Zealand Chemical and Food Processing Industries. This is a quite important finding because these two branches are very important for the New Zealand economy. Food Processing is the leading branch of the economy and Chemicals and Allied Products are very important, and they generally receive priority treatment, because their progress affects the growth of the related branches and sectors such as Construction Materials and agriculture.[6]

Finally, the estimates summarized in Table 3 give unweighted averages of the value of returns to scale of 1.02 for New Zealand branches, 0.90 for US branches, 0.77–0.82 for Soviet branches and 0.83 for Comecon branches. These averages clearly suggest that, if economies of scale are found largely at the individual branch level of aggregation rather than at that of total manufacturing [see Bairam (1986, 1987b)], constant returns to scale prevail in New Zealand total manufacturing but not in USSR/Comecon and US total manufacturing. The latter, especially Soviet total manufacturing, suffer from diseconomies of scale.

VI. SUMMARY AND CONCLUSION

In this paper the author primarily attempted to provide estimates of the degree of returns to scale (v) experienced by the seven major branches of New Zealand manufacturing. The results obtained reveal that different production function specifications [Cobb-Douglas, Translog and Kmenta's approximation of the CES] give very similar, if not identical, results. It therefore follows that the estimates of v for the seven branches are not sensitive to changes in production function specification. This is mainly because the elasticity of substitution between labour and capital is not statistically significantly different from unity at conventional test levels. Consequently, the Cobb-Douglas production function can be accepted as

[6] This comparative advantage, implied by the New Zealand Chemicals and Food Industry estimates, deserves further investigation, as they have important implications for the country's export potentials. The present author will examine these two branches in detail in a forthcoming paper.

the underlying production function of all the New Zealand manufacturing branches.

The estimation of the conventional Cobb-Douglas production function consistently refutes the hypothesis of increasing returns to scale in branches of New Zealand manufacturing. The results consistently suggest constant returns to scale. Nevertheless, the results also imply that, at least in two major branches, namely Chemicals and Food Processing, New Zealand manufacturing has a comparative advantage over larger developed countries both in the East and the West. This is because these two major branches of the developed countries considered suffer from diseconomies of scale.

APPENDIX. THE CONSTANT RETURNS TO SCALE COBB-DOUGLAS PRODUCTION FUNCTION ESTIMATES FOR BRANCHES OF NEW ZEALAND MANUFACTURING INDUSTRY

$\ln(Q/E) = \ln A + \beta(K/E)$
Cross-section Data, 1983/84

Division No.	$\ln A$	$\alpha(=1-\beta)$	β	$\bar{R}^2$	*SEE*	*n*
31	6.77	0.67	0.33 (4.46)	0.431	0.270	26
32	6.93	0.68	0.32 (7.76)	0.787	0.133	17
33	6.13	0.60	0.40 (3.52)	0.509	0.284	12
34	7.76	0.76	0.24 (5.91)	0.809	0.087	9
35	7.95	0.77	0.23 (4.22)	0.582	0.199	16
36	8.37	0.82	0.18 (1.63)*	0.172	0.238	10
38	5.48	0.51	0.49 (3.95)	0.265	0.303	34

Source, Variables and Notes: See Table 2.

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