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INDUSTRIAL PRODUCTION FUNCTIONS IN THE PHILIPPINES

by

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G.P.S.

Quezon City
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Chapter 1. INTRODUCTION

This is a detailed study of cross-section production functions in the Philippine manufacturing sector. In an early study[1], estimates were made of production functions for the whole manufacturing sector. This study will deal with estimates for different groups of manufacturing industries, classified by two-digit International Standard Industrial Classification (ISIC). Cross-section data for 1960 obtained through a special tabulation from the Bureau of the Census and Statistics are utilized instead of the published Survey of Manufactures data.

The main body of this study is contained in Chapters 3, 4, and 5. In these chapters, the data and the empirical production function estimates are analyzed. Chapter 6 reports earlier estimates of similar production functions based on published Survey of Manufactures data in the Philippines. In a second part of this chapter, an international comparison of Cobb-Douglas estimates is attempted briefly. Chapter 7 represents a very brief summary of the study. In Chapter 2, a review is made of wellknown findings about the specification and estimation of production functions directly relevant to this study.

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[1] G.P. Sicat (1963).

Chapter 2. PRODUCTION FUNCTIONS: SUMMARY OF SPECIFICATION AND ESTIMATION

This chapter summarizes some theoretical and econometric principles which are relevant to this study.

Production Functions: Recent Literature

The production function -- a technical relation of inputs to output -- occupies an important position in economic theory. In recent years, considerable work in this field has been done, in large part as a result of interest in the theory of economic growth and of the development of the less developed regions. The most popular form of the production function is one in which output is dependent on two inputs, capital and labor. The need for a more flexible production function involving inputs which are substitutable in the analysis of economic growth has induced the more recent developments in this area of research. This is a reaction to production functions with fixed coefficients of the Harrod-Domar or of the Leontief types, which dominated earlier growth and development theory.

Much of this new position is due to the resurgence of neo-classical economics in the analysis of economic growth and the relative ease of economic interpretation of the Cobb-Douglas production function.[2] In consequence, the Cobb-Douglas

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[2]See, for instance, Robert M. Solow (1956). For a more recent treatment, see M.C. Kemp and P.C. Thanh (1966); for the importance of production function research for developing countries, see J.G. Williamson (1968).

production function has gained a position in the literature on growth and development.

The second major field of interest in empirical production function estimation is the constant-elasticity-of-substitution (CES production function which was independently discovered by Kenneth J. Arrow and Robert M. Solow (1961). This production function has the added advantage of being more general. It has as special cases both the fixed coefficient production functions and the Cobb-Douglas.

The state of production function studies prior to 1963 is ably reported in a survey by A.A. Walters (1963) about four years ago. Since that time, enormous research had been undertaken, both in theoretical and empirical areas. A testimony to the state of this area of research is found in the collection of papers presented to the October 1965 Conference on Research in Income and Wealth under the auspices of the National Bureau of Economic Research and published in 1967. The major contributions in this volume, which are directly relevant to this study, are those of Solow (1967) and Marc Nerlove (1967) which reviewed the theoretical and empirical studies of production. However, there is a lot of substance to the contribution of many others, including those of Zvi Griliches (1967a).

Earlier than this, two important book-length studies came to the author's attention. These are studies by Marc Nerlove (1965) and by George H. Hildebrand & T.C. Liu (1965). Nerlove's is on the finer problem of estimation and identification, in addition to directly estimating empirical production functions. The Hildebrand-Liu book confines its bulk to a presentation and analysis of massive production function and labor demand function estimates for the United States.

This study of Philippine manufacturing production functions differs from both books in the sense that the estimation technique used is simple least squares. Although most studies of production functions utilize this estimation procedure, there has been a growing sophistication of estimation procedures which are becoming applicable. However, as is often the case, the data constraints determine the estimation techniques that are applicable. In this study, because of the special nature of the data which is based on a single cross-section, only simple least squares appears to be only feasible estimation technique.

Production Functions: Specification

A production function can be generally written as

(2.1) $$Q = f(V_1, V_2, \ldots, V_n)$$

where Q is a measure of output, and V_i $(i = 1, 2, \ldots, n)$, the physical inputs used in production. The standard theory of production, dating back to the more rigorous early formulation of production theory, states that for any input _i_ $(i = 1, 2, \ldots, n)$, holding all other inputs constant,

$$\partial Q/\partial V_i \geqq 0$$

and

$$\partial^2 Q/\partial V_i^2 < 0.$$

The first states that marginal products are non-negative and the second is a statement of the law of diminishing returns as applied to factor _i_. The physical production function, as explicitly stated above, is just one aspect of the workings of the economy. The equilibrium of the firm is an interesting branch of economics in which the production function plays a very significant role.[3] No elaboration will be made here on this point. Since the theory of production cannot be divorced from the theory of distribution, it will be sufficient to say that the rewards of the inputs depend on the value of their respective marginal products. This statement refers in

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[3]See Nerlove (1965), Chapter 2, and P.A. Samuelson (1947), Chapter 4.

short to the theory of marginal productivity as an explanation of distribution theory and of the theory of equilibrium of the production unit.

We may rewrite (2.1) by specifying the inputs.

(2.1a) $$Q = F(L, K, \ldots)$$

where Q refers to a measure of output, L of labor, and K of capital. In general, except for work which has been done in agriculture,[4] empirical production functions have dealt only with two factors in which one primary input is classified simply as labor and the other input, which is reproducible, aggregated as capital. Aggregation is a major problem in the estimation of production functions, especially when it comes to the measure of capital.

A Cobb-Douglas production function based on (2.1a) is

(2.2) $$Q = A\, K^{\alpha_K}\, L^{\alpha_L}$$

where A is a constant, α_K and α_L are non-negative exponents of capital and labor. Non-negative exponents simply means that the marginal products of the inputs are positive, for

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[4]See E.O. Heady & J.L. Dillon (1962).

$$\partial Q/\partial K = \alpha_K \, Q/K$$

and

$$\partial Q/\partial L = \alpha_L \, Q/L.$$

The exponents are therefore given by

$$\alpha_K = \left[\partial Q/\partial K\right] (K/Q)$$

and

$$\alpha_L = \left[\partial Q/\partial L\right] (L/Q),$$

where α_K and α_L are to be interpreted as elasticities of output with respect to capital and labor, respectively.

A problem of production function estimation is to find the values of A, α_K, and α_L. Some estimates of the production function would leave no further restrictions on the values of α_K and α_L. A result showing that $\alpha_K + \alpha_L < 1$ implies diminishing returns to scale; on the other hand $\alpha_K + \alpha_L > 1$ shows increasing returns to scale; and finally $\alpha_K + \alpha_L = 1$, constant returns to scale. In a lot of Cobb-Douglas estimation the last has been assumed, due largely to the evidence that in many estimates, the sum of α_K and α_L did not differ drastically from one. The Cobb-Douglas production function is simply written as

(2.3) $$Q = A \, K^{\alpha_K} L^{1-\alpha_K},$$

since

$$\alpha_L = 1-\alpha_K.$$

The estimation for this case is much simpler. The first estimates of production functions were of this nature, performed by the two persons whose names appear jointly in the adjective.[5] The literature often refers to (2.3) as the Cobb-Douglas production function; estimates of unrestricted elasticities which are linear in their logarithms have also been called by the same adjective.

The special case of (2.3) leads to neat results insofar as the marginal productivity theory of distribution is concerned. If the inputs receive as their renumeration the equivalent of their marginal products, then $\alpha_K Q$ and $(1-\alpha_K)Q$ represent the division of output, since

$$Q = RK + WL$$

$$\frac{Q}{Q} = \frac{K}{Q}\ (\partial Q/\partial K) + \frac{L}{Q}\ (\partial Q/\partial L)$$

$$1 = \alpha_K + (1-\alpha_K),$$

and multiplying by Q again, we have

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[5]For a historical note, it is interesting to read P.H. Douglas (1967); also see Douglas (1948).

$$Q = \alpha_K Q + (1-\alpha_K) Q$$

where R represents rental income to capital and W the wage rate.

A more general specification of the production function is the constant-elasticity-of-substitution (CES) production function of Arrow, Chenery, Minhas, and Solow (ACMS). As pointed out already, this production function includes both the Cobb-Douglas and the fixed coefficients of production functions[6] as specific cases. This production function is written as

$$(2.4) \qquad Q = \gamma \left[\delta K^{-\rho} + (1-\delta) L^{-\rho} \right]^{-1/\rho}.$$

ACMS called γ a neutral efficiency (technological) parameter, since any change in γ changes all the inputs proportionally; δ a distribution parameter, and ρ a substitution parameter. The properties of this production function have been well explored in the original paper on this production function which has now become a classic. And we shall add little to this.

The elasticity of substitution between capital and labor is given by $1/(1+\rho)$, and it is easily estimated from

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[6]That is, production functions of the form $\frac{Q}{L} = \min\left(\frac{K}{L}\right)$.

data on output per labor and wage rates. This elegant result is one of the major reasons why the CES production function has been well-explored, despite its relative youthful age. If $\rho = 0$, the CES production function reduces to a Cobb-Douglas function, $Q = \gamma K^{\delta} L^{1-\delta}$, which is equivalent to function (2.3). In the Cobb-Douglas case, the capital-labor elasticity of substitution is equal to unity.

The CES production function belongs to a family of production functions displaying constant returns to scale. While the fixed coefficient production function of the Leontief-Harrod-Domar type allows for no capital-labor substitution and Cobb-Douglas has a unit elasticity of substitution, the CES production function allows for the possibility of different elasticities of substitution between capital and labor.

A CES production function which is more general than (2.4) is

$$(2.5) \qquad Q/L = \gamma \left[\beta (K/L)^{-\rho} + \alpha (K/L)^{-m\rho} \right]^{-1/\rho}$$

where Q, L, K, γ and ρ are defined as before and β and α take on the role of the distribution parameter, and m is another parameter, which will be defined later. This function is due to Michael Bruno (1962) and independently utilized by Hildebrand and Liu.[7] If m=0, (2.5) becomes equivalent to the CES function given by equation (2.4).

The CES production function may be extended to include more than two inputs. But, extensions based on theoretical studies made by others, notably, Uzawa, McFadden, and Mukherji, have not yielded encouraging results. As Solow points out, "if anyone wants to estimate more-than-three-factor production functions to study substitution possibilities, his choice is pretty limited.[8]

<u>Production Functions: Estimation</u>

The estimation of the Cobb-Douglas and the CES production functions for Philippine manufacturing constitutes the basic work of this study. It is important to describe the experiments on the alternative specifications.

<u>The Cobb-Douglas Production Function</u>. The Cobb-Douglas production function (2.2) is easily estimated as a regression

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[7]See Nerlove (1967) in Brown, ed. (1967), pp. 75-82. The Burno paper is unpublished. See also Hildebrand-Liu (1965). The latter authors did not investigate the properties of this function. Nerlove ties in the Hildebrand-Liu function with Bruno's.

[8]R.M. Solow (1967) in Brown, ed. (1967), p. 46. Solow briefly reviews the attempts at the search for an n-factor CES production function and cites the relevant literature.

linear in logarithms

$$\ln Q = \ln A + \alpha_K \ln K + \alpha_L \ln L + u \tag{2.6}$$

where u is a stochastic random term with zero mean and constant variance. Denoting 2-digit industry groups by an index i for which production functions will be estimated individually, and establishment groups by j, (2.6) can be written for all the estimates made as

$$\ln Q_{ij} = \ln A_i + \alpha_{Ki} \ln K_{ij} + \alpha_{Li} \ln K_{ij} + u_{ij}. \tag{2.6a}$$

In short, with measures of output, labor, and capital, (in accordance with any classification scheme for establishments) transformed into logarithms for any industry group, it is possible to derive estimate of A_i, α_{Ki}, α_{Li} for all the industry groups under consideration.

The estimation for the more special Cobb-Douglas production function shown in equation (2.3) is much simpler. For, consider a production function (2.1) which possesses the property of constant returns to scale. Then

$$Q/L = f(K/L, 1)$$

or in terms of (2.3),

$$Q/L = A(K/L)^{\alpha_K} \tag{2.3a}$$

Thus, the variables entering the production function are expressed simply in terms of per unit of one input, in this case, labor. The estimating equations for the i industries with j observations each are given by the regressions

(2.7) $\ln (Q/L)_{ij} = \ln A_i + \alpha_{Ki} \ln (K/L)_{ij} + v_{ij}$

where v_{ij} is the stochastic residual term. The estimates for α_{Ki} in (2.7) automatically provide the estimates for the coefficients of labor or industry, since these are given by $1 - \alpha_{Ki}$.

In the hope of adding some additional information of production estimates, a third input was added to the production function. This input is an aggregate of intermediate purchases used by the industry. Thus, the production function may be stated as,

(2.1b) $Q = F(K, J, L)$

where J are intermediate inputs of purchases from other establishments and industries. Assuming constant returns to scale

(2.3b) $Q/L = F(K/L, J/L, 1)$.

By a wellknown property of constant returns to scale production function, the Cobb-Douglas production function

(2.3b) $$Q = A\ K^{\alpha K}\ J^{\alpha J}\ L^{1-\alpha K-\alpha J}$$

can be rewritten as

(2.3b) $$Q/L = A(K/L)^{\alpha K}\ (J/L)^{\alpha J}$$

and may therefore be estimated for each <u>i</u> industry by

(2.7a) $$\ln\ (Q/L)_{ij} = \ln\ A_i + \alpha_{Ki}\ \ln\ (K/L)_{ij} + \alpha_{Ji}\ \ln\ (J/L)_{ij} + v_{ij}.$$

This last regression also yields estimates for the exponent of labor for each <u>i</u>, in this case α_{Li}, since this exponent is equal to $(1-\alpha_{Ki} - \alpha_{Ji})$.

<u>The CES Production Function</u>. The constant elasticity of substitution production function (2.4) is estimated by the regression

(2.8) $$\ln\ (Q/L) = \ln\ A + b\ \ln\ W + e$$

where Q/L is output per man, W the average wage rates per man per year, and e a stochastic unexplained term with zero mean and constant variance. For each industry <u>i</u> containing <u>j</u> observations, (2.8) is written as

(2.8a) $$\ln\ (Q/L)_{ij} = \ln\ A_i + b_i\ \ln\ W_{ij} + e_{ij}.$$

As pointed out earlier, b_i is an estimate of the elasticity of substitution between capital and labor in the ith industry. Since, as pointed out from the results of ACMS, $b_i = 1/(1+\rho_i)$, it follows that the substitution parameter $\rho_i=0$ in the strictly Cobb-Douglas case.

The other CES production function (2.5) is estimated by the regression equation[9]

(2.9) $\ln (Q/L) = \ln A + b \ln W + g \ln (K/L) + e$

or, in terms of the per industry i regressions,

(2.9a) $\ln (Q/L)_{ij} = \ln A_i + b_i \ln W_{ij} + g_i \ln (K/L)_{ij} + e_{ij}$,

where b and g no longer represent straightforward estimates of the elasticity of substitution. {For convenience, we eliminate the notation for each i industry in the following .} From (2.8) it would appear that the elasticity of substitution is equivalent to b, but this is now only apparent in view of the appearance of a new variable involving the two inputs. Nerlove has shown that the "true" elasticity of substitution, is (which we may call σ)

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[9]See M. Nerlove (1967), in Brown, ed. (1967), pp. 75-82.