TECHNOLOGICAL ADAPTATION IN UNDERDEVELOPED COUNTRIES: EVIDENCE FROM THE CONSTANT ELASTICITY OF SUBSTITUTION PRODUCTION FUNCTION

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PREFACE

A fundamental problem studied by economists is that of optimizing the mixture of scarce resources used in the production of a given product. This problem may be visualized as that of finding the optimum point on a response surface which describes how the rate of output of the product responds to alternative rates of utilization of the various inputs. Frequently the number of inputs to be considered is reduced by aggregating them into broad "factor" catagories, such as "labor" and "capital."

The optimization is constrained, not only by the relative prices of the inputs or factors, and by the total funds available for their hire, but also by the shape of the response surface itself, which is taken to reflect the "technological" limitations involved. Therefore much recent empirical research in economics has been directed at the estimation of the parameters of mathematical formulas, "production functions," which express the shape of these surfaces.

The research reported in this dissertation was designed to determine whether the shape of production surfaces for various industries differ between the developed and less developed countries. Where a difference is found, an attempt is made to determine whether the difference is "adaptive" in the sense of shifting the optimal input mixture in favor of greater employment of labor, relative to capital, in the underdeveloped countries, where labor is typically more abundant than capi-

tal resources.

I would like to take this opportunity to express my gratitude to Dr. Mohamad Khouja for stimulating my interest in production function estimation, and in the important task of applying econometric tools to the analysis of economic development.

Along with Dr. Khouja, I would like to thank Dr. Michael Edgmand for their thoughtful suggestions and painstaking reviews of the various drafts of this dissertation. I wish also to thank Dr. Robert Sandmeyer and Dr. John Franzmann for their sincere interest in my progress and for patiently giving their time to advise me along the way.

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CHAPTER I

INTRODUCTION

The objective of this dissertation is to test, empirically, the hypothesis that the technologies of industries are adapted, in the underdeveloped countries, to the relative scarcity of capital (compared to labor) resources which is generally assumed to characterize those countries. By "adaptation" it is meant that an industry's technology would be comparatively more labor-using in the underdeveloped countries when, in both the developed and underdeveloped countries, the industry is hypothetically confronted with a factor price ratio reflective of that assumed to prevail in the underdeveloped countries.

For the purpose of this dissertation, such a technological difference will be measured according to the Hicksian definition of "non-neutral" technological change.[1] J. R. Hicks (18) has defined non-neutral technological changes as those which modify the marginal rate of factor substitution (MRS) corresponding to a given factor input combination. Assuming that the MRS tends to be approximately equal to the factor price ratio, this is equivalent to defining non-neutral technological change in terms of a shift in the factor input ratio corresponding to a given factor price ratio.

The hypothesis may therefore be tested by comparing the labor-intensity of an industry in the developed countries with the labor-intensity of its counterpart in the underdeveloped countries at a given factor price ratio. Support for the hypothesis would consist of finding the industry to be comparatively more labor-intensive in the underdeveloped countries when the comparison is made at a factor price ratio similar to that which would typically prevail in those countries -- that is, a high capital rental rate compared to the wage rate.

Such a comparison may be made in terms of estimates of the parameters of two production functions for the industry, fitted respectively to cross-section samples of developed and underdeveloped countries. This procedure is explained in the following chapter. It was applied to fourteen different industries, with the finding that ten of these are characterized by statistically significant adaptive technological differences between developed and underdeveloped countries. The empirical results of this study are presented in Chapter III; certain underlying econometric issues are examined in Chapter IV; then the results are interpreted in Chapter V.

Following the finding that most of the industries examined in this study are characterized by technological adaptation, it is natural to inquire whether there is a meaningful pattern in the differences in degree of adaptation among these industries. Chapter III therefore also proposes a scheme for making such interindustry comparisons. Interestingly, when the industries are ranked according to this scheme, the ranking suggests that "product-centered" industries (such as furniture manufacturing) tend to be more amenable to adaptive innovations than the "process-centered" industries (such as chemical or petroleum refining).[2]

This dissertation thus provides some empirical assessment of the following assertion by Everett Hagen (16, pg. 97):

> Many machines devised in the West incorporate both labor saving features that are wasteful in low income countries and technical features for which there are no feasible labor-intensive alternatives. The mechanization of auxiliary operations such as in-plant transportation can be avoided, but in the fabricating processes themselves, the enterpriser must either use a machine that incorporates expensive labor-saving features or use a non-machine method (producing a somewhat different product.)

In contrast to this statement, the empirical results of the present research suggest that perhaps a stronger distinction should be made between "machines" and fabricating "processes". Where work can be organized as the application of separate machines, it appears that the more labor-saving features of Western technology can be eliminated. But, in those industries where machines loose their separate identity and blur into "refineries" for the continuous processing of a flow of materials, there is evidently less opportunity for capital-saving technological innovations.

This conclusion may be relevant to the planning of industrialization in underdeveloped countries. For example, Eckaus has suggested that under-employment of labor resources may result from the absorbtion of most of the available capital into industries that are not only capital-intensive but also require rigid factor employment ratios. On page 559 of (10) he writes:

> Suppose that the respective demands for output are such that a large part of the available capital is drawn into the capital-intensive and fixed coefficients sector. The amount of labor which can be absorbed in this sector is dependent upon the amount of capital that is available. Since capital is the scarce factor, labor employment opportunities in this sector are limited by its availability rather than by demand for output. The relatively plentiful labor supply is then pushed into the variable coefficients sector and absorbed there as long as the marginal value productivity is higher than the wages it receives.

It should be emphasized that, if only a small amount of capital is left to be combined with labor in the traditional sector, the marginal productivity of labor in that sector may remain quite low, leaving many laborers unemployable at the socially acceptable minimum wage rate. Not only would this result in underutilization of a potential economic resource, but considerable political tension might emerge, further frustrating development planning. The results of the present research suggest, however, that the promotion of product-, rather than process-, centered industrialization may help minimize the development of the dualistic structure of production described by Eckaus.

FOOTONOTES

[1]C. E. Ferguson (12, chapter 11) discusses alternative definitions of non-neutral technological change. He suggests that the Hicksian defition is particularly appropriate where one is concerned with the effect of technological change during a period in which input supplies may be regarded as fixed. Since the present study relies upon cross-section data, the input supplies to the given industry in each country of the sample are effectively "fixed" in the sense that no time variation can be observed in the data.

[2]The distinction between product- and process-centered industries is borrowed from Hirschman (19, pg. 157).

CHAPTER II

METHODOLOGY

The empirical production function underlying this research is the "Constant Elasticity of Substitution (CES)" production function. This function may be written as

$$Q = g\left((1-c)L^{-h} + cK^{-h} \right)^{-1/h} , \qquad (2\text{-}1)$$

where Q is industry output, and where K and L are capital and labor inputs, respectively. The parameters, c, g, and h, are to be estimated. This mathematical model of the production surface was first popularized by Arrow, Chenery, Minhas, and Solow (2); for this reason, it is also often called the "ACMS" function.

This particular specification of the production relationship was selected as the basis of the present research because it permits the value of the elasticity of factor substitution to be estimated rather than requiring it to be (implicitly) assumed. As defined by Hicks (18), the elasticity of factor substitution is the percentage change in the factor employment ratio associated with a one-percent change in the MRS. In the CES function, the elasticity of factor substitution, s, appears implicitly in the parameter h in the following way:

$$s = 1/(1+h) \qquad (2\text{-}2)$$

$$h = (1/s) - 1. \qquad (2\text{-}3)$$

The CES production function is a mathematical generalization of the familiar Cobb-Douglas function. It is shown, for example by Murray Brown (7), that when the value of the elasticity of factor substitution in the CES function is set equal to unity, the latter function collapses to the Cobb-Douglas function as a special case. The importance of <u>estimating</u> this parameter in the present research will be explained after the following brief digression to indicate the meaning of the other CES function parameters.

The parameter, g, in equation (2-1) is effectively a "scale" parameter. Changes in its value would be interpreted as reflecting <u>neutral</u> technological changes, according to the Hicksian criterion discussed in the previous chapter. That is, changes in the value of g will not affect the value of the MRS. This can be seen in the following expression for the MRS (which is derived from the CES function in Appendix A):

$$MRS = MP_L/MP_K = \frac{1-c}{c}(K/L)^{1/s} . \qquad (2\text{-}4)$$

It will be noted that the parameter, g, does not appear in this expression.

It may also be seen in equation (2-4) that the terms (1-c) and c are "distribution" parameters, similar to the exponents of the Cobb-Douglas function. It is interesting, in this respect, that when s equals unity in the CES function, equation (2-4) is identical to an expression for the MRS derived from the following Cobb-Douglas formula:

$$Q = g'L^{(1-c)}K^{c} .$$

(Here, g' is a scale parameter similar to g in the CES function.)

Equation (2-4) provides a means of relating estimates of the CES production function parameters to the intersample comparison of the labor-intensity of a given industry (at a specified factor price ratio). Assuming that the ratio of factor prices tends to be approximately equal to the MRS, one may write:

$$w/r = \frac{1-c}{c}(K/L)^{1/s},$$

$$L/K = \left(\frac{1-c}{c}\right)^{s}(r/w)^{s},$$

$$\ln(L/K) = s\,\ln\left(\frac{1-c}{c}\right) + s\,\ln(r/w). \qquad (2\text{-}5)$$

(In these equations, r represents the pure rental price of capital services, w represents the wage rate per unit of labor services.)

It is useful to consider equation (2-5) as the equation for a straight line in the ln(L/K), ln(r/w) plane. Figure 1 shows how, for an hypothetical industry, the estimates of the CES function parameters might lead to two separate curves for equation (2-5). In Figure 1, the curve for the underdeveloped countries is drawn with a comparatively steeper slope. This would be the result of the industry having a relatively higher elasticity of factor substitution in the underdeveloped countries sampled. The figure demonstrates that, when this is the case, there will be some value of the r/w ratio, above which, the industry would necessarily be more labor-intensive in the underdeveloped countries.

The importance of this latter point is that it implies that the adaptation hypothesis would be supported by a statistically significant intersample difference in the elasticity of factor substitution, pro-

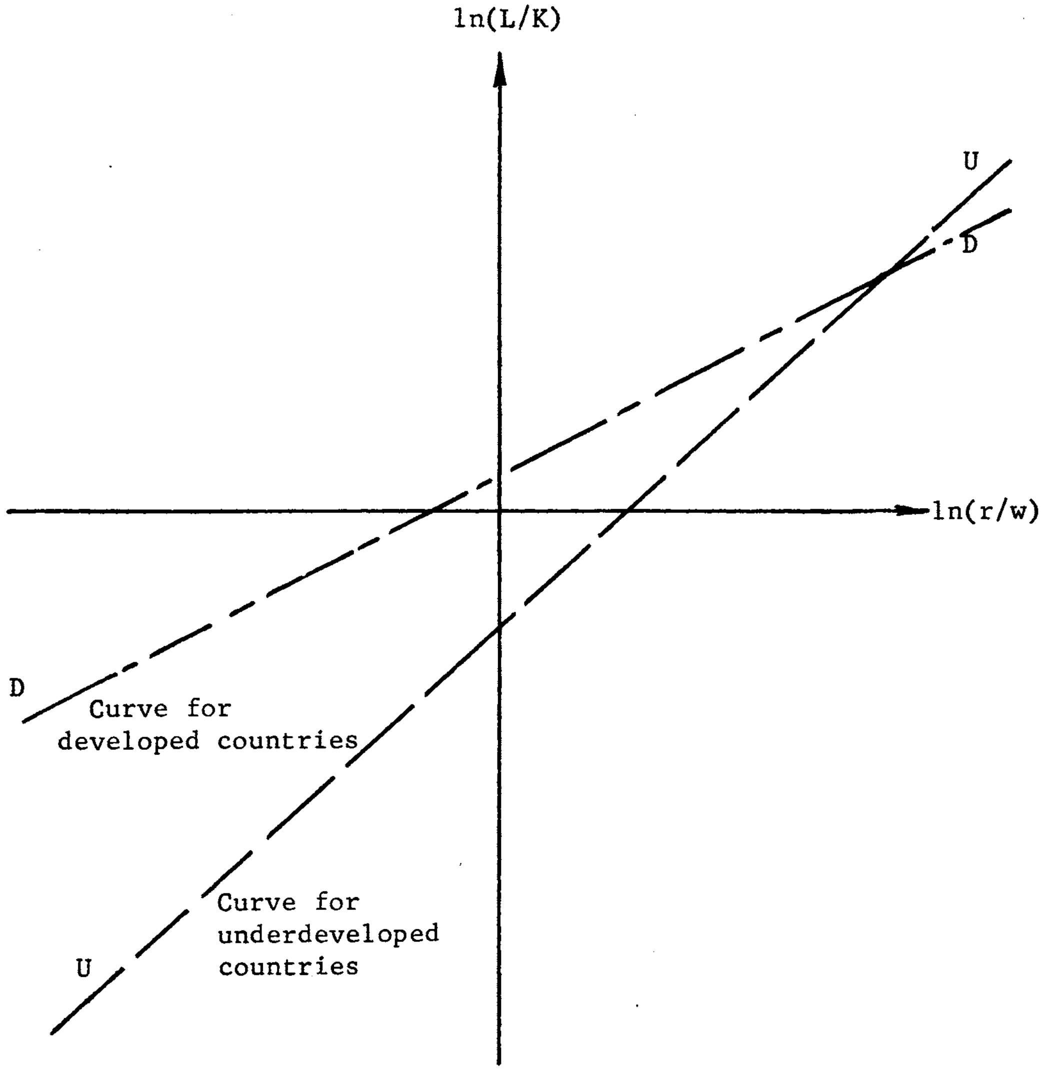

Figure 1. Graphs of Equation (2-5)

viding the estimate of this parameter is higher for the sample of underdeveloped countries. (The hypothesis would also be supported, even if there is no difference in the slopes of the curves in Figure 1, if it can be shown that the curve for the underdeveloped countries lies significantly above that for the developed countries.)

Unfortunately, it is impossible to directly estimate the slope and intercept terms of equation (2-5), even though that equation has the form of a simple regression equation. To do so would require data for K and r, which is difficult to obtain in a consistent form suitable for intercountry cross-section analysis by separate industries. For the underdeveloped countries, such data is essentially unavailable. Instead, the empirical analysis will rest upon regression of an equation derived from assuming an equality between the wage rate and the marginal value productivity of labor (rather than between the MRS and the factor price ratio).

The following expression for the marginal physical productivity of labor is derived from the CES production function in Appendix A:

$$MP_L = dQ/dL = (1-c)g^{-h}(Q/L)^{h+1} . \qquad (2\text{-}6)$$

Substituting a value measure for Q, and setting this expression equal to the wage rate, one obtains:[1]

$$w = (1-c)g^{-h}(V/L)^{h+1} . \qquad (2\text{-}7)$$

It will be convenient to introduce a new parameter, a, such that

$$a = (1-c)g^{-h}. \qquad (2\text{-}8)$$

Further, it may be noted that, according to equation (2-2),

$$h+1 = 1/s. \qquad (2\text{-}9)$$

Then, equation (2-7) may be written as

$$w = a(V/L)^{1/s}. \qquad (2\text{-}10)$$

Taking natural logs and rearranging terms, this becomes

$$\ln(V/L) = -s\ \ln(a) + s\ \ln(w). \qquad (2\text{-}11)$$

Equation (2-11) may be treated as a simple regression equation, in which the elasticity of factor substitution parameter appears as the slope coefficient. From an estimate of the value of this slope coefficient, the value of "a" can be determined as follows. Letting the capital letter A represent the regression estimate of the whole intercept term of equation (2-11),

$$A = -s\ \ln(a). \qquad (2\text{-}12)$$

Then,

$$a = e^{-A/s}. \qquad (2\text{-}13)$$

Regression analysis using equation (2-11)is a fairly standard approach to estimating the elasticity of factor substitution in the absence of adequate data for K and r. See, for example, Arrow et al.(2), Brown and de Cani (6,7), Ferguson and Moroney (13), Fuchs (14), Gupta (15) and Moroney (28).

A special problem arises, however, in using this approach in the context of the present research. It is desired, here, to find not only the slopes, but also the vertical intercepts of the curves shown in Figure 1. Since these curves correspond to equation (2-5), it can be seen that the slope coefficients will be the estimates of the elasticity of factor substitution, which is also the slope term in the regression equation (2-11). But evaluation of the intercept of equation (2-5) requires an estimate of the natural log of (1-c)/c as well. This could be evaluated if, say, the value of (1-c) were known. However, it can be seen from equations (2-8) and (2-13) that the regression of equation (2-11) makes available only an estimate of the combined expression,

$$(1-c)g^{-h} .$$

In particular, it may be shown that

$$\begin{aligned} 1-c &= ag^{h} \\ &= (e^{-A/s})g^{(1/s\ -\ 1)} . \end{aligned} \qquad (2\text{-}14)$$

It appears, therefore, that the vertical location of the curves in Figure 1 depends upon the value of the neutral efficiency, or scale parameter, g. This is a parameter that cannot be estimated without data for K and r. (In a sense, this is the penalty or cost resulting from the lack of that data.) The value of g can be assumed, but then it would be rather meaningless to speak of a statistically significant difference in the vertical position of the curves. If the curves, for a given industry, happen not to have a significant difference in their slopes (with the slope of the curves for the underdeveloped countries being the larger of the two), it will not be acceptable to base a test of the adaptation hypothesis on an intersample comparison of the labor-intensity of the industry.

There is a special circumstance which would, however, relax this restriction. This is the case in which the estimated value of the elasticity parameter happens not to be significantly different from unity. (This is the Cobb-Douglas case.) Equation (2-14) shows that, in that situation, the exponent of g becomes zero, and then (1-c) = a. In that case, the intercept of the curve in Figure 1 can be completely derived from empirical analysis. Of course, in order to use the vertical location of the curves in a statistical test, it would be necessary for s to be effectively equal to unity in <u>both</u> samples of countries.

Except in the event of the special situation just described, this research will not attempt to derive any statistical support for the adaptation hypothesis from a comparison of the vertical location of the curves in Figure 1. However, for the sake of <u>qualitative</u> speculation, it may be interesting to consider the implications of reasonable assumptions about the value of g. A "base-line" for making such assumptions is available in the study by Arrow et al. (2). These authors constructed (time-series) capital and interest rate data for four industries in five countries. Their estimates of the CES parameter g are reported here as Table I.

It was suggested in the previous chapter that, aside from merely testing the hypothesis of (the existance of) adaptive technological differences between developed and underdeveloped countries, it might be useful to make an interindustry comparison of the degree of adaptation. The simplest approach would be to select a value of the r/w ratio rep-

TABLE I

ACMS ESTIMATES OF NEUTRAL EFFICIENCY PARAMETER

Country	Spinning & Weaving	Basic Chemicals	Iron & Steel	Metal Products
U. S.	1.016	1.021	1.733	1.736
Canada	.771	.839	1.378	1.292
U. K.	.880	--	.857	--
Japan	.428	.567	.687	.619
India	--	.441	.657	--

Source: Arrow, Chenery, Minhas, and Solow, "Capital-Labor Substitution and Economic Efficiency", The Review of Economics and Statistics, IVIII (August, 1961), Table 3, pg. 235.

resentive of the factor price environment of the underdeveloped countries, then compare the industries on the basis of the magnitude of the intersample difference in labor-intensity at that factor price ratio.

Consideration of Figure 1 will show, however, that such a comparison might be sensitive to the vertical positions of the curves. Therefore, it will be necessary to perform the comparison for a range of alternative values of the parameter g. Hopefully, at least an ordinal ranking of the industries may be perserved over the range of the most reasonable possibilities for the neutral efficiency parameter's values.

FOOTNOTES

[1]The substitution of a value measure, V , for Q in order to obtain an expression for the marginal value product of labor may have implications for the statistical properties of the parameter estimates based on regression analysis of equation (2-11). This problem is discussed in detail in Chapter IV.

CHAPTER III

EMPIRICAL RESULTS

Fourteen industries are investigated in this study. These are listed in Table II. To a large extent, data availability dictated both the selection of the particular industries to be examined, and the number to be included. While the present investigation differs in important respects from other intercountry investigations employing the CES production function, it was deemed desirable to utilize data as similar as possible to that used in other major studies. (Comparisons are made in Chapter IV.) For this reason, basic data for the empirical analysis was taken from Volume I of the U. N. compilation, The Growth of World Industry: 1967 Edition. This volume provides one of the most complete and recent breakdowns of output, employment, and wage data by country and by industry.

Industries are classified in this source at the three-digit level of aggregation of the International Standard Industrial Classification (ISIC) scheme. The possibility is discussed by Nerlove (30, pg. 68) that a finer classification might decrease the estimated value of the elasticity of factor substitution. However, his conclusion is that the estimate is not sensitive to the aggregation level, at least as between a two-digit and three-digit aggregation.

Given the selection of data source, and its implicit selection of aggregation level, certain industries treated in the source could not

TABLE II

LIST OF INDUSTRIES EXAMINED

ISIC Code	Industry	N_D	N_U
20	Food Products, except beverages	12	15
23	Textiles	14	13
26	Furniture and Fixtures	11	13
27	Paper and Paper Products	13	12
28	Printing and Publishing	13	13
30	Rubber Products	11	15
31	Chemicals and Chemical Products	13	13
32	Products of Petroleum and Coal	9	8
33	Other Non-metalic Mineral Products	13	15
34	Basic Metal Industries	13	14
35	Metal Products, except machinery	10	10
36	Machinery, Non-electrical	11	12
37	Electrical Machinery	11	12
38	Transportation Equipment	11	14

Note: N_D and N_U refer to the number of observations in the samples of developed and underdeveloped countries, respectively. See Table III for the lists of these countries.

be used because data for one variable or another was missing from too many countries. The industries remaining are those listed in Table II. As far as possible, all observations are for the year 1965; but for some countries it was necessary to resort to adjacent years. The countries used in each sample, and the years selected, are listed in Table III.

Division of countries into two samples, one representing developed countries, the other representing underdeveloped countries, is always fairly arbitrary for a few borderline cases. But for the most part, such a division is obvious. All of the countries listed in the "Underdeveloped" group in Table III had a percapita income (GDP) less than $550 in the year 1965, according to the analysis by Hagen and Hawrylyshyn (17). According to the same study, all of the countries listed as "Developed" in Table III had a percapita GDP in that year above $850 - except two countries: Greece ($673) and South Africa ($590).

By "drawing the line" at a slightly higher percapita GDP, these two countries would have fallen into the "Underdeveloped" group. But a pursuasive argument is offered by Hagen and Hawrylyshyn (17, pg. 2) that apartheid makes South Africa's percapita GDP misleading - that the white-dominated sector, which is the locus of most of the economic activity, is more similar to the developed countries. Having so classified South Africa, Greece is the only country with a percapita GDP above that of South Africa and below that of Japan (which clearly belongs in the developed countries group). On the basis that Greece is probably more influenced by Western methods than any of the countries with lower percapita incomes, Greece was included in the developed countries sample.

For each industry, for each of the two samples of countries, ordi-

TABLE III

COUNTRIES INCLUDED IN EACH SAMPLE

Developed Countries	Underdeveloped Countries
Australia (1965)	Brazil (1965)
Belgium (1964)	Burma (1963)
Canada (1965)	Columbia (1965)
Finland (1965)	Honduras (1964)
Germany (1965)	India (1964)
Greece (1964)	Jordan (1966)
Ireland (1965)	Korea (1966)
Israel (1965)	Malaysia (1965)
Japan (1965)	Panama (1965)
Netherlands (1964)	Peru (1965)
New Zealand (1965)	Phillipines (1965)
Norway (1965)	Portugal (1965)
South Africa (1964)	Southern Rhodesia (1966)
United States (1965)	Turkey (1965)
	Zambia (1965)

nary least squares regression analysis was used to fit the following equation:

$$\ln(V/L)_{ij} = A_i + s_i \ln(W/L)_{ij} + u_{ij}$$

$$(\text{for } i = 1,2,\ldots 14;\ j = 1,2,\ldots n). \qquad (3\text{-}1)$$

In this equation, V represents value added at current prices for the i-th industry in the j-th country of the sample, converted into U.S. dollar equivalents. Exchange rates used for the conversion are those given in the United Nations Monthly Bulletin of Statistics (June, 1970) for the year corresponding to the industrial data used (see Table III). The exchange rates given for most countries are "mid-point rates", which are the average of buying and selling rates as of the end of the period. Where mid-point rates are not available, or where the country has multiple exchange rates, the source presents one or more special rates. For all but one of the countries included in the present study (for which mid-point rates were not given), the only rate provided was the "selling rate". This is the rate at which the monetary authorities and authorized banks sell foreign exchange against payment in national currency. The exception is Brazil. For this country, the rate used is a selling rate that also fluctuates in response to sales of foreign exchange by private individuals.

In equation (3-1), L represents thousands of man-years of labor input employed in the given industry for the j-th country. This is measured, normally, as an average of the number of persons engaged during the year. For a few countries, L includes working proprietors, active business partners, unpaid family workers, and homeworkers, as well as persons engaged on a salary or wage basis.

W represents an estimate of all wages and salaries, including all payments in cash or kind, made to employees of the i-th industry in the j-th country during the year.

The results of the regression analysis for the two samples for each of the fourteen industries is shown in Table IV. The values of the parameter $a=\exp(-A/s)$ which are derived from the regression coefficients are presented in Table V.

It was emphasized in the previous chapter, in connection with the discussion of Figure 1, that the empirical test of the adaptation hypothesis requires determining the statistical significance of intersample differences in the elasticity of factor substitution parameter. Recall that, for a given industry, support for the hypothesis would consist of finding that the value of this parameter is significantly higher for the underdeveloped countries sample. Where this is the case, there would necessarily be some value of the r/w ratio, above which, the particular industry would be comparatively more labor-intensive in the underdeveloped countries. Thus, the finding would be that that industry, as it exists in the underdeveloped countries, is better adapted to the factor price environment which is typical of those countries than is the same industry as it exists in the developed countries.

Table VI shows the results of a t-test of the null-hypothesis that there is no difference in the estimated value of the elasticity parameter, s, for the two samples for the indicated industry. The test is the conventional one for testing the statistical significance of a difference between the means of uncorrelated samples. Letting the subscripts, d, and u, indicate the developed and underdeveloped countries samples, respectively, the test employs the following formula:[1]

TABLE IV

RESULTS OF REGRESSION ANALYSIS

Industry & Sample	A	s (st. dev.)	t_s	R^2
20 - D	.97161	.81960 (.09263)	8.84757	.887
20 - U	1.35358	.93077 (.06684)	13.92491	.937
23 - D	.78087	.79033 (.07103)	11.12524	.912
23 - U	.66113	.81204 (.08563)	9.48275	.891
26 - D	.75251	.79110 (.07351)	10.76144	.928
26 - U	.68419	.95605 (.04349)	21.97875	.978
27 - D	.84661	.91858 (.08909)	10.31016	.906
27 - U	1.16555	.97925 (.07134)	13.72589	.950
28 - D	.76684	.85554 (.05978)	14.30963	.949
28 - U	.68460	.94587 (.05038)	18.77195	.970
30 - D	.95389	.76171 (.09694)	7.85754	.873
30 - U	1.23331	.94083 (.09622)	9.77742	.880
31 - D	1.05946	.96116 (.13385)	7.18089	.824
31 - U	1.38759	.90694 (.08012)	11.31976	.921
32 - D	1.63566	.83070 (.27078)	3.06774	.573

TABLE IV Continued

Industry & Sample	A	s (st. dev.)	t_s	R^2
32 - U	2.29783	1.03961 (.50573)	2.05563	.413
33 - D	.86758	.88575 (.06984)	12.68150	.936
33 - U	1.21492	.97725 (.05921)	16.50392	.954
34 - D	.80138	.93512 (.06024)	15.52161	.956
34 - U	1.41065	1.03976 (.09667)	10.75572	.906
35 - D	.80162	.82824 (.06583)	12.58139	.952
35 - U	.86370	1.01158 (.10341)	9.78133	.923
36 - D	.78422	.81717 (.11970)	6.82681	.838
36 - U	.81277	.94156 (.04393)	21.43042	.979
37 - D	1.06812	.62295 (.07877)	7.90758	.874
37 - U	.99384	.89681 (.04975)	18.02350	.970
38 - D	.71154	.85024 (.10592)	8.02655	.877
38 - U	.65891	.89046 (.08041)	11.07381	.911

TABLE V

VALUES OF PARAMETER a

Industry code	a_D	a_U
20	.30560	.23358
23	.37231	.44301
26	.38627	.48888
27	.39786	.30415
28	.40807	.48492
30	.28585	.26958
31	.33212	.21654
32	.13959	.10944
33	.37550	.28846
34	.42444	.25751
35	.37990	.42579
36	.38302	.42180
37	.18003	.33016
38	.43306	.47713

TABLE VI

INTERSAMPLE ELASTICITY OF SUBSTITUTION DIFFERENCES

Industry code	$s_U - s_D$	t	Deg. Frdm.
20	.11117	3.49311	25
23	.02171*	.71405	25
26	16495	6.53690	22
27	.06067	1.88615	23
28	.09033	4.16600	24
30	.17912	4.66939	24
31	-.05422*	-1.25319	24
32	.20791*	1.03803	15
33	.09150	3.70800	26
34	.10464	3.40096	25
35	.18334	4.72954	18
36	.12439	3.25168	21
37	.27386	9.86718	21
38	.04022*	1.04485	23

Note: Starred values are not significantly different from zero at the 80% level of confidence with the indicated degrees of freedom.

$$t = (s_d - s_u) / \left(\frac{var(s_d)}{N_d} + \frac{var(s_u)}{N_u}\right)^{\frac{1}{2}}. \qquad (3\text{-}2)$$

In this formula, N is the number of countries in the sample indicated; the variances of s are variances of the slope regression coefficient, adjusted for degrees of freedom. The degrees of freedom used in interpreting the t-statistic should, in this case, be $N_d + N_u - 2$; these are the values listed in Table VI.

For all but four of the industries, the intersample difference in the parameter, s, is significant at the 80% confidence level, at least. These four industries are: Textiles (23), Chemicals (31), Petroleum and Coal Products (32), and Transportation Equipment (38). For the remaining industries, it is also important to note that, in each case, the elasticity parameter is higher in the underdeveloped than in the developed countries. Thus, it can be concluded that, for ten of the fourteen industries studied, there is evidence of technological adaptation to the local factor constraints. (If industry 27, Paper and Paper Products, is also excluded, this statement can be made at the 98% level of confidence for the remaining nine industries.)

Two of the industries for which the intersample difference in s is not significant, Chemicals, and Petroleum and Coal Products, happen to fall into the special catagory wherein the elasticity of factor substitution is not significantly different from unity for either the developed or underdeveloped countries. (See Table VII.) As discussed in the previous chapter, this implies that the value of the neutral efficiency parameter, g, has no bearing on the vertical location of the curves in

TABLE VII

COMPARISON WITH COBB-DOUGLAS CONDITION

Industry code	$1-s_D$	t	$1-s_U$	t
20	.18040	1.94753	.06923*	1.03576
23	.20967	2.95185	.18796	2.19503
26	.20890	2.84179	.04395*	1.01058
27	.08142*	.91391	.02075*	.29086
28	.14446	2.41653	.05413*	1.07444
30	.23829	2.45812	.05917*	.61495
31	.03884*	.29018	.09306*	1.16151
32	.16930*	.62523	-.03861*	-.07635
33	.11425	1.63588	.02275*	.38423
34	.06488*	1.07703	-.03976*	-.41129
35	.17176	2.60915	-.01158*	-.11199
36	.18283	1.52740	.05844*	1.33030
37	.37705	4.78672	.10319	2.07417
38	.14976	1.41390	.10954	1.36227

Note: Starred values are differences which are not significantly greater than zero at the 80% level of confidence (with N-1 degrees of freedom).

Figure 1. Thus, for these two industries, even if the pairs of curves are parallel, it is still empirically relevant to consider the possibity that the curve for the underdeveloped countries might be above the one for the developed countries. Unfortunately, however, in both cases, calculation shows that it is the curve for the developed countries that has the higher intercept.

The conclusion remains, then, that one can be at least 80% confident that the technological constraints of ten of the fourteen industries studied differ, between developed and underdeveloped countries, in such a manner as to be adaptive to the respective factor endowments of these two types of countries. Of course, this degree of confidence in the <u>existance</u> of some degree of adaptive technological difference does not imply that the difference is necessarily very large.

An analysis of the relative magnitude of the adaptive difference among the various industries requires values to be assumed for the neutral efficiency parameter, g. While this would be inappropriate as the basis for an empirical test of the adaptation hypothesis itself, it turns out that the interindustry comparison is rather insensitive to variations in the values of g (at least within the range of values suggested by the ACMS results reported in Table I.)

Table VIII shows this comparison. It ranks, by increasing degree of adaptation, the ten industries which were found to be characterized by a significant intersample difference in s at the 80% confidence level. Given the assumptions indicated in each part of the table, the respective values of L/K are calculated for each industry, for each sample, using equations (2-5) and (2-14) and the point estimates of A and s reported in Table IV. The industries are then ranked by increasing values

TABLE VIII

INTERINDUSTRY ADAPTATION COMPARISON

Assumptions: $g_D = 1.0$, $g_U = 0.2$

Industry	$(L/K)_U$ / $(L/K)_D$	Industry	$(L/K)_U$ / $(L/K)_D$
@ r/w = 1:		@ r/w = 10:	
34	.48233	34	.61374
20	.56205	27	.71337
33	.61702	20	.72601
27	.62036	33	.76173
30	.69186	30	1.04505
36	.93750	36	1.24843
37	1.07480	28	1.35899
28	1.10379	35	1.74745
35	1.14568	26	1.76782
26	1.20917	37	2.01925
@ r/w = 5:		@ r/w = 100:	
34	.57080	34	.78095
20	.67217	27	.82032
27	.68399	20	.93780
33	.71492	33	.94037
30	.92303	30	1.57854
36	1.14529	36	1.66254
28	1.27651	28	1.67319
35	1.53891	26	2.58457
26	1.57682	35	2.66529
37	1.67013	37	3.79358

TABLE VIII Continued

Assumptions: $g_D = 0.8$, $g_U = 0.2$

Industry	$(L/K)_U$ / $(L/K)_D$	Industry	$(L/K)_U$ / $(L/K)_D$
@ r/w = 1:		@ r/w = 10:	
34	.49455	34	.62928
20	.59523	27	.73508
27	.63924	20	.76887
33	.64251	33	.79319
30	.74459	30	1.12470
36	1.00060	36	1.33245
28	1.16477	28	1.43406
37	1.18925	35	1.85728
35	1.21769	26	1.90475
26	1.30283	37	2.23425
@ r/w = 5:		@ r/w = 100:	
34	.58526	34	.80073
27	.70481	27	.84529
20	.71185	33	.97922
33	.74445	20	.99317
30	.99338	30	1.69886
36	1.22238	28	1.76562
28	1.34703	36	1.77435
35	1.63564	26	2.78476
26	1.69896	35	2.83282
37	1.84795	37	4.19750

TABLE VIII Continued

Assumptions: g_D = 0.8, g_U = 0.4			
Industry	$(L/K)_U$ / $(L/K)_D$	Industry	$(L/K)_U$ / $(L/K)_D$
@ r/w = 1:		@ r/w = 10:	
34	.47622	34	.60596
20	.63264	27	.75025
27	.65244	33	.81076
33	.65674	20	.81719
30	.78639	30	1.18784
36	1.06931	36	1.42395
35	1.20061	28	1.53553
28	1.24718	35	1.83122
37	1.31448	26	2.01558
26	1.37864	37	2.46953
@ r/w = 5:		@ r/w = 100:	
34	.56357	34	.77106
27	.71936	27	.86273
20	.75659	33	1.00090
33	.76093	20	1.05559
30	1.04915	30	1.79422
36	1.30632	28	1.89055
28	1.44234	36	1.89620
35	1.61269	35	2.79306
26	1.79782	26	2.94680
37	2.04256	37	4.63954

of the ratio, $(L/K)_U$ / $(L/K)_D$, which shows the number of times more labor-intensive the industry would be in the underdeveloped than in the developed countries, at the indicated factor price ratio.

It will be noted that, in each case, this value is actually less than unity for several industries. This implies that, at the indicated factor price ratio, the industry is comparatively more labor-intensive in the developed countries. (Since the difference, $s_U - s_D$, was positive and statistically significant for all of the industries treated in Table VIII, the intersample labor-intensity ratio would be greater than unity at a sufficiently high value of the factor price ratio - i.e., to the right of the intersection of the curves in Figure 1. More will be said about the estimated "cross-over" r/w values below.)

The industries which are most consistently "non-adaptive" at the factor price ratios examined in Table VIII are 34 (Basic Metals), 20 (Food Products), 27 (Paper and Paper Products), and 33 (Non-metalic mineral products, other than Petroleum and Coal). In the extreme case, where capital is assumed to be 100 times more scarce than labor, and where the neutral technological difference between developed and underdeveloped countries is assumed to be as narrow as the difference between 0.8 and 0.4, two of these industries, 20 and 33, would be adaptive.

Of course, to this list of industries which are non-adaptive, at the factor price ratios examined, must be added those four industries which cannot be assumed to be adaptive at any factor price ratio. These were: 23 (Textiles), 31 (Chemicals and Chemical Products), 32 (Products of Petroleum and Coal), and 38 (Transportation Equipment).

An alternative way of comparing the various industries is to calculate, for each industry, the location of the point of intersection of the curves in Figure 1. The most adaptive industries would be those for which the intersection is located at comparatively low values of the factor price ratio, r/w. Table IX presents the co-ordinates of these "cross-over" points (converted into their antilog equivalents) for the ten industries found to have significant slope differences at the 80% confidence level.

As in Table VIII, Table IX shows the effect of alternative assumptions regarding the values of g. It will be noted that the cross-over occurs at rather high r/w values for industries 20, 27, 33, and 34. These were the industries shown to be consistently least adaptive in Table VIII. However, Table IX also shows that industries 20 and 33 are considerably more adaptive than industries 27 and 34. (It should be emphasized that a high degree of adaptation corresponds to high numbers in Table VIII, but to low numbers in Table IX. Also note that the ratio $(L/K)_U/(L/K)_D$, in Table VIII, becomes greater than unity for r/w values higher than the cross-over r/w values indicated in Table IX.)

The most interesting aspect of these tables is the great degree of stability in the ordering of the industries. While this regularity is not perfect, it is strong enough to suggest that there is an underlying systematic difference among the industries in some variable that is not explicit in this analysis. Chapter V presents further discussion of this possibility.

TABLE IX

CROSSOVER r/w COMPARISON

Industry code	Industry	Crossover r/w value
For $g_D = 1.0$, $g_U = 0.2$:		
26	Furniture and Fixtures	.27881
28	Printing and Publishing	.28550
37	Electrical Machinery	.33003
35	Metal Products, except Machinery	.36052
36	Machinery, non-electrical	1.03496
30	Rubber Products	2.38472
20	Food Products, except Beverages	35.69920
33	Non-metalic Mineral Products	68.28130
34	Basic Metals	508.30600
27	Paper and Paper Products	942.29900
For $g_D = 0.8$, $g_U = 0.2$:		
28	Printing and Publishing	.16259
26	Furniture and Fixtures	.18093
37	Electrical Machinery	.23695
35	Metal Products, except Machinery	.25755
36	Machinery, non-electrical	.63212
30	Rubber Products	1.62133
20	Food Products, except Beverages	22.08400
33	Non-metalic Mineral Products	44.31490
34	Basic Metals	396.45000
27	Paper and Paper Products	580.82300

TABLE IX Continued

Industry code	Industry	Crossover r/w value
For g_D = 0.8, g_U = 0.4:		
28	Printing and Publishing	.08509
26	Furniture and Fixtures	.13795
37	Electrical Machinery	.18869
35	Metal Products, except Machinery	.27453
36	Machinery, non-electrical	.40862
30	Rubber Products	1.28530
20	Food Products, except Beverages	14.09080
33	Non-metalic Mineral Products	35.84770
27	Paper and Paper Products	426.27400
34	Basic Metals	555.59700
For g_D = 1.2, g_U = 0.2:		
26	Furniture and Fixtures	.40177
37	Electrical Machinery	.43583
28	Printing and Publishing	.45726
35	Metal Products, except Machinery	.47795
36	Machinery, non-electrical	1.56622
30	Rubber Products	3.29496
20	Food Products, except Beverages	53.26540
33	Non-metalic Mineral Products	97.75340
34	Basic Metals	624.06700
27	Paper and Paper Products	1405.83000

FOOTNOTES

[1] This is a conventional test statistic. See, for example, page 16 of Chu (8). It should be noted that, in applying this test to the inter-sample difference in the estimate of the parameter s, it is assumed that the sampling distribution of the slope regression coefficient is normal with a mean value of the estimate equal to the parameter value. With this assumption, the distribution of the estimated values of the regression coefficient may be treated as a distribution of "sample means".

CHAPTER IV

ECONOMETRIC CONSIDERATIONS

The purpose of this chapter is to examine certain econometric problems which arise in connection with studies such as the present one.

Many of the conclusions presented here depend upon estimates of the elasticity of factor substitution. There are certain conditions under which an estimate of this CES production function parameter may be subject to bias (i.e., the expected value of the estimator may be unequal to the population value of the parameter). It has been shown that the estimate of s is biased toward unity whenever the estimate is derived from a regression of ln(V/L) on ln(w), and whenever the wage rate is positively correlated with variations, among the countries of the sample, in the levels of neutral efficiency, the price level, or the quality of the labor force. In all these cases the regression equation, equation (3-1), would involve a specification error resulting from the omission of a relevant variable (efficiency, prices, or labor quality). Appendix B shows how it can be deduced that the resulting bias is in the direction of unity.

It seems reasonable to assume that these correlations have been present in the data used here. Wages would tend to be higher where the price level is high. Higher quality labor would tend to command higher wages. And the social investments which raise the quality of labor would probably have raised the neutral technological efficiency of the economy as well.

Fortunately, however, this possibility would actually strengthen the conclusions presented so far. It implies that the intersample differences in the elasticity of factor substitution may actually be larger than the differences apparent in the estimates. Even if the estimates of s for both samples for a given industry lie on the same side of unity, the parameter difference would be larger than the difference between the estimates of that parameter, if the estimates are known to be biased toward unity.

The possibility also arises that one or more of the four industries found to be characterized by an insignificant intersample difference in s might be found to be adaptive (to some degree) afterall. Table X shows the results of applying equation (3-2) to bias-compensated values of s for these four industries. The table shows that the assumption of a 5% bias is sufficient to produce an intersample difference in s for industry 31 that is significant at the 80% level. However, this is the industry for which the elasticity parameter was found to be higher in the developed than in the underdeveloped countries! This means that, when a comparison is made at r/w values reflective of the high cost of capital relative to labor in the underdeveloped countries, the industry would be found to be more capital intensive in the underdeveloped than in the developed countries. Therefore, if this difference is significant, it is evidence of a technological peculiarity which makes the (Chemical) industry very unsuited to the underdeveloped countries. This peculiarity will be explored further in Chapter V.

For the other three industries, Table X shows that industries 32 (Petroleum and Coal Products) and 38 (Transportation Equipment) will not

TABLE X

BIAS-COMPENSATED INTERSAMPLE s DIFFERENCES

Industry code	Assumed Bias			
	.05	.10	.25	.50
23	.02285* (0.7516)	.02412* (0.7934)	.02895* (0.9521)	.04342 (1.4281)
31	-.05707 (1.3191)	-.06024 (1.3924)	-.07229 (1.6709)	-.10844 (2.5064)
32	.21885* (1.0927)	.23101* (1.1534)	.27721 (1.3840)	.41582 (2.0761)
38	.04234* (1.0998)	.04469* (1.1609)	.05363 (1.3931)	.08044 (2.0897)

Note: Differences shown are for $s_U - s_D$; values in parentheses are (absolute) t-values for the difference. Values starred are not significant at the 80% confidence level.

have a significant intersample elasticity of substitution difference unless the bias in the estimate of this parameter is assumed to be as much as 25%; for industry 23, nearly 50% bias must be assumed.

It might be inappropriate to look again at the adaptation ranking of the industries on the basis of an assumption of, say, 25% bias, because there is no reason to expect that the same degree of estimation bias would have been involved in the treatment of each industry. Even so, it is interesting to find that, in doing so, there is little change in the ordering of the industries. Table XI shows the cross-over r/w values, recalculated on the basis of bias-compensated values of s. The industries found to have a significant intersample difference in s, at the indicated degree of assumed bias, are included. (Industry 31 is omitted because of the reasons discussed above.)

Turning to another issue, the identification of the slope coefficient in the regression of ln(V/L) on ln(W/L) as the estimate of the elasticity of factor substitution required assuming that $MVP_L = w$. But, in order for the regression equation based upon this condition to reveal factor substitution constraints, the MVP_L would have to be viewed as determined by input and output decisions made in response to previous exogenous changes in w.[2] If this adjustment has not been perfectly accomplished at the time of the cross-section observations, the deviation will be subsumed in the value of the stochastic variable, u, in equation (3-1). To be consistent with the assumptions of the Gauss-Markov theorem, these deviations must be random among the countries and have an average value of zero. This condition, in turn, would seem to be satisfied if recent movements of the wage variable were randomly distributed with a mean of zero among the countries of the sample.[3]

TABLE XI

BIAS-COMPENSATED CROSSOVER r/w COMPARISON

Assumed Bias = .10		Assumed Bias = .25	
Industry	Crossover r/w	Industry	Crossover r/w
For g_D = 1.0, g_U = 0.2:			
26	.29949	35	.32266
28	.32996	26	.33231
37	.33846	37	.34959
35	.34393	28	.40432
36	.97305	36	.87977
30	1.87830	32	.98015
20	21.28840	30	1.31212
33	37.85560	20	9.74345
34	210.79700	33	15.63170
27	408.71200	38	25.72630
		34	56.40970
		27	116.64800
For g_D = 0.8, g_U = 0.2:			
28	.18993	26	.22237
26	.19639	35	.23367
37	.24604	28	.23768
35	.24682	37	.26005
36	.60106	36	.55555
30	1.28951	32	.78943
20	13.30780	30	.91791
33	24.69450	20	6.21631
34	164.46000	38	7.88701
27	253.02600	33	10.30060
		34	44.03790
		27	72.83940

TABLE XI Continued

Assumed Bias = .10		Assumed Bias = .25	
Industry	Crossover r/w	Industry	Crossover r/w
For g_D = 0.8, g_U = 0.4:			
28	.10130	28	.13149
26	.15128	26	.17476
37	.19949	37	.21827
35	.26274	35	.24807
36	39439	36	.37525
30	1.03195	38	.70877
20	8.60828	30	.74838
33	20.04760	32	.88405
37	186.40500	20	4.13053
34	230.19400	33	8.42173
		27	54.06650
		34	61.48580
For g_D = 1.2, g_U = 0.2:			
26	.42826	35	.42370
37	.44238	37	.44812
35	.45451	26	.46800
28	.52429	28	.63249
36	1.46018	32	1.17140
30	2.57582	36	1.29843
20	31 50970	30	1.77306
33	53.99540	20	14.19580
34	258.79800	33	22.13360
27	607.87700	34	69.24880
		38	69.96780
		27	172.42000

Hence, unless there is reason to expect a sample-wide trend movement of wages in the period just prior to the observations, there would be no reason to pursue distributed lag estimating techniques. Furthermore, in the context of cross-section data, it would be logical to expect serious multicollinearity involved in any attempt to estimate a distributed lag model with a Koyck-type transformation. Consider, for example, the following (multiplicative) distributed lag model:[4]

$$MVP_L = a(V/L)^{1/s} = w_t w_{t-1}^{q} w_{t-2}^{q^2} \ldots \text{etc.} \qquad (4\text{-}1)$$

A Koyck-type transformation applied to this model leads to:

$$\ln(V/L)_t = -s(1-q)\ \ln(a) + q\ \ln(V/L)_{t-1} + s\ \ln(w)_t . \qquad (4\text{-}2)$$

The lag parameter q and the elasticity of factor substitution can be identified in (4-2) as the slope regression coefficients. However, it is reasonable to expect that the value of $(V/L)_{t-1}$ would be highly correlated with w_t from country to country within the cross-section sample. The result of such multicollinearity would be high sampling variances (and low t-values) for the regression coefficients.

Indeed, this was confirmed in an attempt to estimate the coefficients of equation (4-2) for the 14 industries (for each of the two samples of countries) treated in this study. It was found that the t-values for the regression coefficients were so low as to preclude any meaningful intersample comparisons. Thus, cross-section analysis seems neither to require distributed lag estimation techniques on theoretical grounds, nor to support these techniques from the practical standpoint of regression mechanics.

A final issue to be discussed has to do with the assumed stability of the structural relationship (the production function) being estimated. A wide range of variation of the variables involved in regression analysis is desirable in that this leads to smaller confidence intervals for the estimates of the parameters. But it must be noted that, in the present case, if the ratio of factor prices varied extremely from country to country within a sample, it might be inappropriate to view the associated variation in factor employment ratios as a response pattern manifest within the context of a common perception of the technological constraints of production. This is, in fact, specifically the theoretical motivation for the present study. It is felt that the extreme variation of factor prices between developed and underdeveloped countries precludes pooling intercountry data for both types of countries. The hypothesis of technological difference between the production functions of an industry in the developed and underdeveloped countries is essentially an hypothesis that the structural relationship to be estimated is not stable across such a wide variation in factor prices.

This issue was confronted by Fuchs (14) in his estimations of the elasticity of factor substitution for several industries from intercountry data. He introduced into his regression analysis a "shift" or "dummy" variable in order to separate the observations from the developed countries. However, while this may remove a source of bias in the estimate of that parameter (which was his intention), it still assumes that the value of the parameter is the same for both types of countries. The coefficient of his shift parameter permits only an adjustment (two estimates) of the <u>intercept</u> of the regression of $\ln(V/L)$ on $\ln(w)$.[5]

The Fuchs study uses data from the 1950-55 period for industries classified at the three-digit ISIC level (His objective was to produce estimates that could be compared with the Arrow, Chenery, Minhas, and Solow study.) This means that Fuchs' results cannot be directly compared with those reported here. The most comparable study, in terms of data period and aggregation level, is that by Murata and Arrow (1965) which is unpublished, but which is reviewed in Nerlove (29). The Murata-Arrow estimates of the elasticity of factor substitution are reported here as Table XI. These investigators use 1957-59 data from the 1963 edition of the same UN document which provided the basic data for the present study. Therefore, their definitions of variables would be consistent with those used here.

The Murata-Arrow study, however, pools the observations from both developed and underdeveloped countries, and therefore provides a single estimate of the elasticity of factor substitution for each industry. Table XII presents these results, along with the estimates of s from the present study. It may be interesting to notice that the Murata-Arrow estimates do not always fall between the separate estimates of s_U and s_D, as one might initially expect. This may be explained by the fact that the observations from the developed and underdeveloped countries are clustered in separate parts of the ln(V/L)-ln(w) plane. Figure 2 shows how regression lines fitted to these separate clusters may have slopes which, in both cases, are higher (or lower) that the slope of a regression line fitted to a pooled sample using all observations at once.

TABLE XII

COMPARISON WITH MURATA-ARROW RESULTS

Industry code	s_D	$s_{(M-A)}$	s_U
20	.8196	.725	.9308
23	.7903	.827	.8120
26	.7911	.919	.9561
27	.9186	.788	.9793
28	.8555	.926	.9459
30	.7617	.768	.9408
31-32	na.	.834	na.
34	.9351	.873	1.0398
35	.8282	.922	1.0116

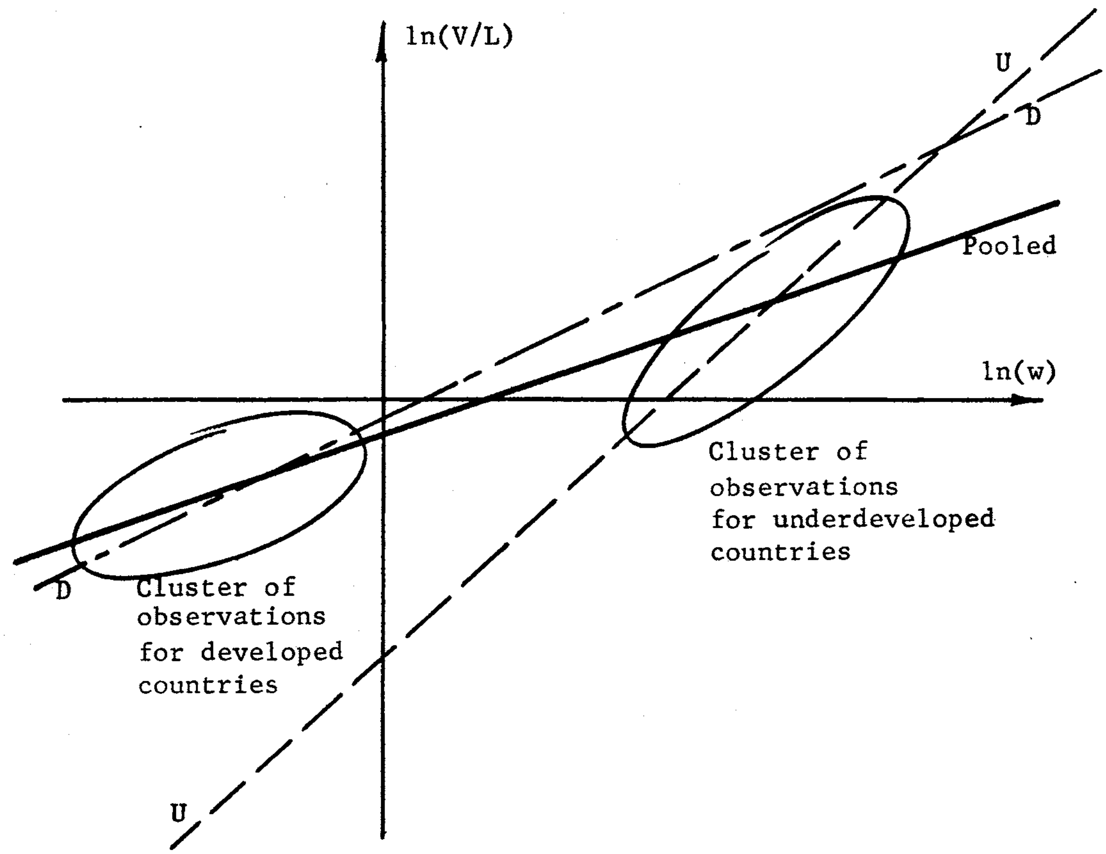

Figure 2. Pooled and Separate Regression Lines

FOOTNOTES

[1]See Moroney (27), pg. 291, or Lucas (23), pg. 237.

[2]See Lucas (23) for a detailed discussion of this point.

[3]The assumptions required by the Gauss-Markov theorem are given in most standard econometrics texts. For example, see Wonnacott and Wannacott (34).

[4]The Koyck transformation is applied to this multiplicative distributed lag model by Brown and de Cani (6), pg. 295.

[5]On dummy variables, see Wonnacott and Wonnacott (34).

CHAPTER V

CONCLUSIONS

The basic conclusion of this research is that the production functions of several industries do differ between developed and underdeveloped countries in a way that can be interpreted as technological adaptation to the dissimilar factor endowments of these two groups of countries. Tables VIII and IX, however, show that there are wide differences among these industries in their relative degree of technological adaptation. The ranking of the industries in these tables is interpreted as showing the relative degree to which they are amenable to technological innovations which would make them more suitable to the prevailing factor supply constraints.

This interpretation of the ranking implicitly assumes that plant managers, foremen, economic planners, and others are continually striving, in the underdeveloped countries, to remove whatever technical production limitations prevent the substitution of labor for capital. The ranking then shows how successful this "innovative pressure" has been in the various industries investigated.

This interpretation, however, raises further conceptual issues. For example, the range of factor substitutions actually permitted by the technical requirements of a given industrial procedure may already be wider than the range that is perceived by decision makers who are conditioned by traditional practices in their own country. Thus if the managers of a particular industry in the underdeveloped countries are predominantly Western educated (perhaps even expatriates from the U.S. or U.K.) it might be argued that their Western preconceptions would prejudice the nature of the technology of the industry in those countries.[1] One would then observe less difference between the developed and underdeveloped countries in the technology of that particular industry. This may, for example, be part of the explanation for the small intersample technological differences found to characterize the Chemical industry and the Petroleum and Coal Products industry.

In as much as the underdeveloped countries import a large amount of industrial equipment from the West, the design of equipment used in the underdeveloped countries will also partially reflect the objectives of Western capital goods producers. Engineering decisions made within the capital goods sector have a profound effect in limiting the range of operating decisions that may be made by users of those capital goods. W. E. G. Salter (31, pg. 14) writes:

> In even the simplest designing process there are numerous alternatives that must be decided on the basis of cost: whether a machine should be powered by electricity or diesel power, whether a control should be automatic or manual, whether bearings should be of bronze or of steel, or whether the flow of materials should be mechanized or not. These, and countless other everyday decisions are essentially cost decisions.

The particular ranking of the industries in Tables VIII and IX seems to suggest, in both cases, that industries which are process-oriented are much less adaptive than industries which are product-oriented. These terms are borrowed from Albert O. Hirschman (19, pg. 147) where he explains that,

> In some industries, the technology consists of a basic process around which work falls into place almost naturally; examples are smelting, petroleum refining, cement, brewing, and many

> others. In other industries, such as construction and much of metalworking, as well as in most service industries, work is not patterned around one or several key technical processes. As a result, sequences are far less rigidly compelled, it is impossible to identify any one process as central, and tasks are typically defined in terms of their direct contribution to the achievement of the goal - the final product - rather than in terms of the roles performed in different phases of the production process. In these "product-centered" industries technology therefore makes much less of a contribution to the coordination of efforts unless it succeeds, by organizing "flow," in imitating the conditions prevailing in the "process-centered" industries. Thus, the efficiency-enhancing and coordination-promoting property of modern technology tends to be much more pronounced in process-centered than in product-centered industries.
>
> It is possible to classify a plant (or industry) into one or the other catagory by asking the question whether its physical assets have a definite capacity. If a positive answer can be given, as is the case with a blast furnace, a refinery, or a brewery, we have a process centered situation...

It seems reasonable to expect that the individual tools and machines used in product-oriented industries are easier to produce within the underdeveloped countries than are the heat-exchangers, pumps, distillation columns, and similar equipment typically required in the process-oriented industries. Industrial processes, such as steel making and chemical refining, impose severe materials requirements; metals, for example, must withstand high temperatures and corrosive agents. The high degree of equipment integration involved in industrial "flow" processes must also impose severe reliability standards for equipment components. All of these considerations imply that industrial process equipment is likely to be imported by the underdeveloped countries from the capital goods sectors of the Western economies - where cost decisions reflected in the design of the equipment would have been made in response to the factor supply constraints of the more developed countries.

By way of contrast, the simpler mechanical implements used in the product-centered industries may more easily be redesigned so that they can be produced as well as used economically in the underdeveloped countries. This is substatiated, for example, by case-study evidence collected by W. Paul Strassman in Mexico and Puerto Rico. On pages 187-8 of (31) he relates that,

> Mexican firms redesign machinery to allow cheaper production. A foreign subsidary making agricultural equipment systematically examined imported parts and subassemblies to see if they could be redesigned for production with machinery on hand. They had learned that in Mexico welding was cheaper than hot upsetting, and that flame cutting costs less than shearing, contrary to United States practice...Another machinery builder made savings by replacing imported stainless steel shafts in his product with shafts made of ordinary steel. The crucial part exposed to wear was filed down, chromium plated and polished: a highly-labor intensive substitution.
>
> Still more interesting, however, are changes in machinery that affect operation as well as construction. Foreign machines are still the prototype from which departures are made, with or without patent permission. Usually the working mechanism is kept intact but control mechanisms are simplified or eliminated. Levers may be substituted for electric relays and buttons.

Strassman's case studies support the impression that technological adaptation proceeds in a piecemeal fashion. But in the process-centered industries where work is organized around the flow of materials (which often cannot be handled directly), this flow dictates a high degree of organizational integration which probably does not lend itself to piecemeal innovations. In order to make significant labor-saving changes, it would be necessary to tamper with the basic organization of production. Not only would this require a highly developed engineering capability, it would also require a large enough market to justify extensive investment in plant (rather than merely machine) redesign.

These various arguments, supported by the findings of the present research, seem to strongly suggest that the distinction between process-centered and product-centered industries is relevant to the planning of industrialization in the underdeveloped countries. Hirschman's purpose in emphasizing this distinction was to suggest that process-centered industries may stimulate development, the technical process itself imposing a highly efficient pace and order to the organization of production. However, the value of the developmental stimulus must apparently be carefully weighed against the consequences of the possible development of a dualistic structure of production, as described by Eckaus and discussed in Chapter I.

Naturally, the present research also suggests additional lines of inquiry. For example it would be interesting to attempt to operationalize the distinction between process-centered and product-centered industries in a manner that would permit an empirical ordering of industries between these two poles. Correlation analysis could then be used to quantitatively evaluate the impression that the least adaptive industries in Tables VIII and IX are the more process-oriented industries.

It would also be interesting to determine the extent of adaptive technological change which takes place within a country, between high and low labor cost areas. Applying such an analysis to industries within the United States, for example, would permit the use of much more refined data and econometric procedures. Furthermore, it would be possible to compare the cross-section results for two or three time periods in order to study the evolutionary pattern of technological adaptation.

FOOTNOTES

[1] I am grateful to Dr. Mohamad Khouja for emphasizing this point.

BIBLIOGRAPHY

(1) Allen, R. G. D. Macro-Economic Theory: A Mathematical Treatment. New York: St. Martin's Press, 1967.

(2) Arrow, J. K. et al. "Capital Labor Substitution and Economic Efficiency." The Review of Economics and Statistics, Vol. 43 (August, 1961), 225-47.

(3) Bodkin, R. G. and L. R. Klein. "Non-Linear Estimation of Aggregate Production Functions." The Review of Economics and Statistics, Vol. 49 (February, 1967), 28-44.

(4) Brown, Murray. On the Theory and Measurement of Technological Change. New York: Cambridge University Press, 1966.

(5) Brown, Murray (ed.). The Theory and Empirical Analysis of Production. New York: Columbia University Press (for the National Bureau of Economic Research), 1967.

(6) Brown, Murray and John S. de Cani. "Technological Change and the Distribution of Income." International Economic Review, Vol. 4 (September, 1963), 289-309.

(7) Brown, Murray and John S. de Cani. "A Measure of Technological Unemployment." The Review of Economics and Statistics, Vol. 45 (November, 1963), 389-94.

(8) Chu, Kong. Principles of Econometrics. Scranton, Pa.: International Textbook Company, 1968.

(9) Daniels, M. R. "Differences in Efficiency among Industries in the Developing Countries." The American Economic Review, Vol. 59 (March, 1969), 159-71.

(10) Eckaus, Richard S. "The Factor Proportions Problem in Underdeveloped Areas." The American Economic Review, Vol. 45 (September, 1955), 539-65.

(11) Ferguson, C. E. "Cross-section Production Functions and the Elasticity of Substitution in American Manufacturing Industry." The Review of Economics and Statistics, Vol. 45 (August, 1963), 305-18.

(12) Ferguson, C. E. The Neoclassical Theory of Production and Distribution. New York: Cambridge University Press, 1969.

(13) Ferguson, C. E. and John R. Moroney. "The Source of Change in Labor's Relative Share: A Neoclassical Analysis." The Southern Economic Journal, Vol. 35 (April, 1969), 308-22.

(14) Fuchs, Victor R. "Capital Labor Substitution: A Note." The Review of Economics and Statistics, Vol. 45 (November, 1963), 436-38.

(15) Gupta, S. B. "Some Tests of the International Comparisons of Factor Efficiency with the CES Production Function." The Review of Economics and Statistics, Vol. 50 (November, 1968), 470-75.

(16) Hagen, Everett E. The Economics of Development. Homewood, Ill.: Richard D. Irwin, Inc., 1968.

(17) Hagen, Everett E. and Oli Hawrylyshyn. "Analysis of World Income and Growth 1955-1965." Economic Development and Cultural Change, Vol. 18, Part II (October, 1969), 1-89.

(18) Hicks, John R. The Theory of Wages. New York: Cambridge University Press, 1932.

(19) Hirschman, Albert O. The Strategy of Economic Development. New Haven: Yale University Press, 1958.

(20) Klein, L. R. Textbook of Econometrics. Evanston, Ill.: Row-Peterson, Inc., 1953.

(21) Kmenta, J. "On Estimation of the CES Production Function." International Economic Review, Vol. 8 (January, 1967), 180-89.

(22) Leontief, Wassily. "An International Comparison of Factor Costs and Factor Use: A Review Article." The American Economic Review, Vol. 54 (June, 1964), 335-45.

(23) Lu, Yao-chi and L. B. Fletcher. "Generalization of the CES Production Function." The Review of Economics and Statistics, Vol. 50 (November, 1968), 449-512.

(24) Lucas, Robert E. Jr. "Labor Capital Substitution in U. S. Manufacturing." Harberger and Martin (eds.) The Taxation of Income from Capital. Washington, D. C.: Brookings Institution, 1969, 223-267.

(25) Maddala, G. S. and Joseph B. Kadane. "Some Notes on the Estimation of the Constant Elasticity of Substitution Production Function." The Review of Economics and Statistics, Vol. 48 (August, 1966), 340-44.

(26) Marcus, Matiyahu. "Capital-Labor Substitution Among States: Some Empirical Evidence." The Review of Economics and Statistics, Vol. 46 (November, 1964), 434-37.

(27) Minsol, Archen. "Some Tests of the International Comparison of Factor Efficiency with the CES Production Function: A Reply." The Review of Economics and Statistics, Vol. 50 (November, 1968), 477-79.

(28) Moroney, J. R. "Identification and Specification Analysis of Alternative Equations for Estimating the Elasticity of Substitution." The Southern Economic Journal, Vol. 36 (January, 1970), 287-99.

(29) Nerlove, Marc. Estimation and Identification of Cobb-Douglas Production Functions. Chicago: Rand McNally Company, 1965.

(30) Nerlove, Marc. "Recent Empirical Studies of the CES and Related Production Functions." Murray Brown (ed.) The Theory and Empirical Analysis of Production. New York: Columbia University Press (for the National Bureau of Economic Research), 1967, 55-122.

(31) Salter, W. E. G. Productivity and Technological Change. 2nd. ed. New York: Cambridge University Press, 1966.

(32) Strassman, W. Paul. Technological Change and Economic Development: The Manufacturing Experience of Mexico and Puerto Rico. Ithica, New York: Cornell University Press, 1968.

(33) United Nations. The Growth of World Industry: 1967 Edition. Vol. 1, "General Industrial Statistics, 1953-1966." New York, 1969.

(34) Wonnacott, Ronald and Thomas Wonnacott. Econometrics. New York: John Wiley and Sons, Inc., 1970.

(35) Zarembka, Paul. "On the Empirical Relevance of the CES Production Function." The Review of Economics and Statistics, Vol. 52 (February, 1970), 47-53.

APPENDIX A

MATHEMATICAL DERIVATIONS

Given the CES production function,

$$Q = g\left((1-c)L^{-h} + cK^{-h} \right)^{-1/h} , \qquad \text{(A-1)}$$

where $s = 1/(1+h)$, let $a = (1-c)g^{-h}$ and $b = cg^{-h}$, then:

$$Q = \left(aL^{-h} + bK^{-h}\right)^{-1/h} \qquad \text{(A-2)}$$

The Marginal Products of Labor and Capital can now be derived as follows. First, rewrite (A-2) as,

$$Q^{-h} = aL^{-h} + bK^{-h} . \qquad \text{(A-3)}$$

Then, differentiate both sides of (A-3) with respect to L,

$$-hQ^{-h-1} (dQ/dL) = -haL^{-h-1} .$$

Or,

$$MP_L = dQ/dL = a(L/Q)^{-h-1} ,$$

$$= a(Q/L)^{h+1} ,$$

$$= a(Q/L)^{1/s} ,$$

$$= (1-c)g^{-h} (Q/L)^{1/s} .$$

Similarly,

$$MP_K = dQ/dK = b(Q/K)^{1/s},$$

$$= cg^{-h}(Q/K)^{1/s}.$$

Defining the MRS as the ratio, MP_L/MP_K, then provides,

$$MRS = \frac{a}{b}(K/L)^{1/s},$$

$$= \frac{(1-c)}{c}(K/L)^{1/s}.$$

APPENDIX B

ANALYSIS OF ESTIMATING BIAS OF s

Given the results of Appendix A,

$$MP_L = (1-c)g^{-h}(Q/L)^{1/s},$$

setting the real wage rate (w) equal to the marginal value product of labor (MVP_L) implies that,

$$w = p(MP_L) = MVP_L,$$

$$= pg^{-h}(1-c)(Q/L)^{1/s}.$$

Or, $$(Q/L)^{1/s} = wp^{-1}g^{h}(1-c)^{-1}.$$

And, $$Q/L = w^{s}p^{-s}g^{sh}(1-c)^{-s}. \qquad (B-1)$$

Since, by definition, $s = 1/(h+1)$, it follows that $h = (1-s)/s$. Employing this result, and recognizing that the regression requires current value added per unit labor input (V/L) to be the dependent variable, rather than simply Q/L, equation (B-1) becomes,

$$V/L = (pQ)/L = w^{s}p^{1-s}g^{1-s}(1-c)^{-s}. \qquad (B-2)$$

If p and g are constants, the regression equation may be written as,

$$\ln(V/L) = \ln(p^{1-s} g^{1-s} (1-c)^{-s}) + s \ln(w). \qquad \text{(B-3)}$$

Or, letting A = the constant intercept term, this is the regression,

$$\ln(V/L) = A + B \ln(w), \qquad \text{(B-4)}$$

where B is the slope regression coefficient. And, by the Gauss-Markov theorem, E(B) = s.

However, if p, for example, varies from country to country within the sample, taking this variable into account explicitly would require estimation of the multiple regression equation,

$$\ln(V/L) = \ln(g^{1-s} (1-c)^{-s}) + s \ln(w) + (1-s) \ln(p). \qquad \text{(B-5)}$$

In this case, (B-3) would be an incorrect specification. If p is correlated with w, the Gauss-Markov theorem would not hold, and neither would the condition that E(B) = s, for equation (B-4). Instead, the relationship between B in (B-4) and s in (B-5) could be determined as follows.

For simplicity, let,

$$X = \ln(w)$$

$$Y = \ln(V/L)$$

$$Z = \ln(p).$$

Then (B-5) implies that,

$$Y = f(X,Z).$$

Taking the total derivative with respect to X,

$$dY/dX = f_X + (dZ/dX) f_Z \, . \qquad \text{(B-6)}$$

The partial derivatives, f_x and f_z, correspond to the slope coefficients in the multiple regression equation (B-5). Similarly, the derivative, dY/dX, corresponds to the slope coefficient in the simple regression equation (B-4). Therefore,

$$E(B) = s + \frac{dZ}{dX}(1-s). \qquad \text{(B-7)}$$

In terms of standardized measurements, a positive, but less than perfect correlation between p and w would imply a value of dZ/dX which is positive, but less than unity. Assuming this value in equation (B-7), it can be seen that E(B) will be between unity and the actual value of the parameter s. That is, the estimate of s provided by the regression of ln(V/L) on ln(w) will be biased toward unity. Exactly the same line of argument would also hold if g (the neutral efficiency parameter) is a variable rather than a constant among the countries of the sample.

If labor quality is a variable, let $L = L'q$, where L' is the measured labor input (e.g., man-years) and q is a quality weighting variable. The equation (B-2) becomes,

$$V/(L'q) = (W/(L'q))^{s}\, p^{1-s}\, g^{1-s}\, (1-c)^{-s},$$

given that the wage rate (w) is to be measured by the ratio of the total wage bill (W) to the measured labor input (L). The regression equation is then,

$$\ln(V/L') = \ln(p^{1-s}\, g^{1-s}\, (1-c)^{-s}) + s\,\ln(w) + (1-s)\,\ln(q).$$

Thus, in this case, too, the omission implies the relationship given in equation (B-7), and the conclusion, again, would be that (B-4) provides an estimate of s that is biased toward unity (if labor quality is positively correlated with wage rates).

This analysis follows that given by Moroney (28, pg. 291), or Lucas (24, pg 237).

VITA 2

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