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INSTITUTIONAL REFORM AND THE INFORMAL SECTOR PROJECT

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RELATIVE EFFICIENCY, SELF-CONTAINMENT AND COMPARATIVE COSTS OF LESS DEVELOPED COUNTRIES

April, 1991

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IRIS Reprint No. 2

Prepared for

Institutional Reform and the Informal Sector Project (IRIS)
AID Contract No. DHR-0015-A-00-0031-00

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Reprinted from *Economic Development and Cultural Change*, 39(3), April, 1991

Prime Contractor: University of Maryland at College Park

Relative Efficiency, Self-Containment, and Comparative Costs of Less Developed Countries*

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I. Introduction

International differences in comparative costs can in principle be attributed to three kinds of forces: factor proportions, economies of scale, and relative efficiency. To take a specific example, the low relative price of certain services in less developed countries might be attributed to the fact that the services in question are not at all intensive in either physical or human capital (the factor proportions account), that economies of scale are unimportant in these services, or that LDCs are relatively efficient in producing these services (as compared to their efficiency in producing, say, manufactured products).

While it is obvious that differences in relative efficiency can affect comparative costs (and trade patterns), economists have tended to emphasize the factor proportions theory and economies of scale in their explanations. Part of the reason for this emphasis is that the relative efficiency explanation is rather empty, unless one can come up with explanations for the patterns of relative efficiency.

The present article attempts to address these issues by looking at some data on relative product prices in a sample of less developed countries (LDCs) and more developed countries (MDCs). The data are taken from the purchasing-power parities collected by the International Comparison Project.[1] In the course of the research project it was discovered that neither the factor proportions theory nor the economies of scale phenomenon could account for more than a rather small part of the observed variation in relative product prices. The research was then directed toward explaining the remaining variation in relative product prices by looking at some product characteristics that were thought to affect relative efficiency.

There are many characteristics of goods that may be hypothesized to affect the relative efficiency of LDCs compared to MDCs. These

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0013-0079/91/3903-0034$01.00

include the degree of technological progress, the complexity of the production process, and the degree to which operations can be machine-paced rather than operator-paced. A number of different variables will be used to capture various aspects of goods, but particular attention will be paid to the hypothesis that LDCs are especially deficient in managing large organizations and interdependent production processes; this hypothesis suggests that LDC efficiency should be relatively high in goods that can be produced in small organizations and in a self-contained manner. This self-containment hypothesis will be described in the next section of the article.

This article is organized in the following way. Following the explanation of the self-containment hypothesis in Section II, Section III presents the theory of predicted relative prices according to the factor proportions theory and the economies of scale account and explains how the deviations of actual from predicted prices are calculated. Section IV describes the empirical calculation of factor shares and relative factor prices. The adjustment for economies of scale is presented in Section V, and Section VI describes the variables reflecting hypotheses about relative efficiency. Results are presented in Section VII, and some concluding observations appear in Section VIII.

II. The Self-Containment Hypothesis and Relative Efficiency

As explained above, differences in efficiency levels across countries are interpreted here as deviations of actual relative prices from those predicted by the factor proportions theory and economies of scale account. Consequently efficiency differences across countries can have many sources, including technological secrets or other barriers to technological diffusion, and differences in operational efficiency within and between organizations. The hypothesis to be explained here will focus on the process of technological diffusion and on differences across countries in the efficiency of large organizations.

In the process of technological diffusion, it is obvious that the profits of importing foreign technology (with or without local adaptation) will tend to be greater where the activity that is being transferred is largely self-contained. That is, the innovation is more likely to fail if its success depends on new kinds of performances by actors over whom the innovator has no control. Hence, technological differences between MDCs and LDCs should be relatively small in activities with a high degree of self-containment and relatively great in activities with a high degree of interdependence.

Where successful technological innovation requires coordination of a large number of different activities, one might ask, why doesn't the innovator internalize the externalities by organizing all the necessary activities himself? A major part of the answer to this question would

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seem to lie in the difficulties and inefficiencies encountered in LCDs in the operation of large-scale organizations.[2]

In the process of development, MDCs have developed the skills and the culture to make large organizations function comparatively effectively. In some activities, such as mining, organizations based in the MDCs have been able to set up rather self-contained activities (in the sense that there is little reliance on new types of performance by people in the LDC who are not part of the organization), and they often achieve technological levels not very different from the operations in their home countries. Much more typically, foreign-dominated hierarchies are not permitted to endure in LDCs today.

The hypothesis has two components, one relating to self-containment and the other to the efficiency of large organizations. The two are connected, in that activities could become more self-contained if they were incorporated into a larger organization. But the arguments are also distinct. The hypothesis predicts that efficiency levels in poor countries will be relatively low in (*a*) activities that require large-scale organizations in the private sector, (*b*) activities that require extensive support services from the government, and (*c*) activities that require high-quality inputs from other sectors of the economy. Conversely, efficiency levels in poor countries will be relatively high in activities that can be carried out in small organizations in a self-contained manner.

The self-containment/interdependence hypothesis is related to some ideas recently presented in the development literature. In a thought-provoking lecture, R. E. Lucas has presented a model of development emphasizing the external effects of human capital;[3] in his model the productivity of labor of a given skill is positively related to the average skill level of the labor force. Lucas stresses the notion that one learns by interacting with other people, but his model also derives justification from the observation that a particular factory will be more productive if it can count on timely and high-quality inputs from its suppliers. The remarkable books by Jane Jacobs describe in vivid detail the productive interactions of producers in the specialized districts of cities.[4] The notion of technological mastery presented by L. E. Westphal clearly involves skills in supplying companies as well as in the particular factory.[5] This idea is also present in the product cycle model and other technology-based theories of trade.[6]

The hypothesis is consistent with the observed comparative advantage of LDCs in primary as opposed to manufactured products. The production process of primary products tends to be much more self-contained than that of manufacturing products. The latter typically requires quality-controlled inputs from other sectors and relies much more than the primary sector on the economy's transportation and

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communications network. These observations are not meant to suggest that the LDC comparative advantage in primary products is unrelated to factor endowments of land, labor, and capital. However, the factor-proportions theory has confronted a puzzle as to why densely populated LDCs (e.g., Pakistan, Bangladesh, Philippines) have exported mainly primary products that are less labor intensive (in terms of capital-labor ratios) than some manufactured products.

The hypothesis also has implications for the relative efficiency of services, construction, and manufacturing in poor countries, and these implications can be tested with our data. The final product services included in this study tend to be provided by very small establishments, and they are relatively self-contained (in that the ratios of purchased inputs to sales is quite low).[7] Manufacturing activities, by contrast, are highly interdependent, requiring inputs from many different locations and requiring the coordination of actions of many different individuals. Construction occupies an intermediate position between services and manufacturing in terms of size of establishment and ratio of purchased inputs to sales.

Apart from the comparison of manufacturing services and construction, the hypothesis suggests some other product characteristics that might be used to explain the deviations of actual from predicted relative prices. Some of the characteristics mentioned below are also suggested by the technology gap theories, especially the product cycle version. These theories suggest measures of technological progress, such as the ratio of research and development expenditures to sales and the rate of total factor productivity growth in the MDCs. Technological progress is probably also correlated with the share of professional workers and the share of college graduates on the payroll. On the other hand, the presence of highly trained employees is probably also an indication of the industry's need to process information, which may come from other sectors or from within an organization.

Variables that are more specifically related to the self-containment hypothesis rather than the technology gap theories are establishment size as measured by the number of employees and input-output table measures of the degree of interaction of a sector with the rest of the economy. These variables are the number of input sectors into an industry and a measure of the dispersion of the input shares. These input-output variables, which emphasize the reliance of an industry on a well-functioning transportation and communications system, are suggested quite directly by the self-containment hypothesis.

III. The Deviation of Actual Prices from Predictions Based on the Factor Proportions Theory and Economies of Scale

In this section I explain the relationship, according to the factor proportions theory, between the relative prices of goods, on the one hand,

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and the relative costs of factors and the factor intensities of goods, on the other. For simplicity, I shall assume a Cobb-Douglas production function and for convenience of exposition I shall illustrate the case of two factors of production, but the results generalize readily to the case of five factors, which is actually used in the empirical implementation (the five factors are raw labor, skilled production labor, nonproduction labor, equipment, and structures).

The exposition begins by assuming constant returns to scale. Then I introduce an economies of scale adjustment in a preliminary way, leaving the more detailed explanation of this adjustment to Section V. Finally, I derive an expression for the deviations of actual prices from the predictions.

Under a Cobb-Douglas production function, there is also a Cobb-Douglas cost function that relates the price of the product to factor prices and factor shares. For the MDC the production function and the cost function are as follows:

$$Y = a^{\mathrm{MDC}} x_1^{T} x_2^{1-T},$$

$$E^{\mathrm{MDC}} = (1/a^{\mathrm{MDC}})(W_1)^{T}(W_2)^{1-T},$$

where Y is output, x_1 and x_2 are factor inputs, W_1 and W_2 are factor prices in the MDC, T is the share of factor 1, a^{MDC} is the Hicks-neutral efficiency parameter in the MDC, and E^{MDC} is the cost of producing one unit of output.[8]

For the LDC the unit cost would be

$$E^{\mathrm{LDC}} = (1/a^{\mathrm{LDC}})(w_1)^{T}(w_2)^{1-T},$$

where w_1 and w_2 are the factor prices in the LDC.

According to the factor proportions theory the predicted relative price for product i would be

$$\mathrm{PRP}_i = (E_i^{\mathrm{LDC}}/E_i^{\mathrm{MDC}}) = A^* \,\mathrm{WFPI}_i,$$

where A^* is the ratio of the efficiency parameters $(a^{\mathrm{MDC}}/a^{\mathrm{LDC}})$, assumed to be uniform across products, and WFPI_i is the weighted factor price index, or

$$\mathrm{WFPI}_i = (w_1/W_1)^{T_i}(w_2/W_2)^{1-T_i}.$$

Departing now from the assumption of constant returns to scale, let RS_i represent the relative size of factories in the LDC compared to the MDC and let $\phi(RS_i)$ be the function determining the proportional increase in costs due to operating at a scale smaller than in the MDC.

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Then predicted relative price in the LDC becomes

$$\mathrm{PRP}_i = A^*\mathrm{WFPI}_i\phi(RS_i).$$

The actual relative price in the LDC may be written

$$\mathrm{PRICE}_i = A_i\mathrm{WFPI}_i\phi(RS_i) + e_i,$$

where e_i is a random error term and A_i is allowed to vary across products. The deviation of the actual price from the predicted price is then

$$\mathrm{PDEV}_i = \mathrm{PRICE}_i - \mathrm{PRP}_i = (A_i - A^*)\mathrm{WFPI}_i\phi(RS_i) + e_i.$$

Dividing by PRP_i gives

$$\mathrm{RDEV}_i = \mathrm{PDEV}_i/\mathrm{PRP}_i = [(A_i - A^*)/A^*] + e_i/\mathrm{PRP}_i, \qquad (1)$$

where RDEV_i is the proportional deviation of the observed price from the predicted price, which according to (1) is equal to the proportional deviation of A_i from A^*. The efficiency parameter A_i is considered to be a function of the product characteristics mentioned in the previous section (R&D intensity, establishment size, professional share, etc.). Thus in the empirical work RDEV_i will be regressed on these and other product characteristics.[9]

For reasons explained below I shall assume that the error term is heteroscedastic of the form $\mathrm{var}(e_i) = s^2\,\mathrm{VAR}_i$, where VAR_i is an exogenous variable. Hence $\mathrm{var}(e_i/\mathrm{PRP}_i) = s^2(\mathrm{VAR}_i/\mathrm{PRP}_i^2) = s^2v_i$, where $v_i = \mathrm{VAR}_i/\mathrm{PRP}^2$. To correct for heteroscedasticity the observations in the regression will be weighted by $1/v_i$.

IV. Empirical Calculation of Price Deviations

The International Comparison Project (ICP) provides purchasing-power parities (PPPs) vis-à-vis the U.S. dollar for 34 countries and some 150 categories of goods. For example, the PPP for tires, tubes, and accessories in India is 11.06 rupees per dollar. Dividing this PPP by the exchange rate of 8.376 rupees per dollar gives 11.06/8.376 = 1.32, which is the relative price of tires in India. For a given commodity category these relative prices have been averaged across countries of similar per capita income to reduce noise. In the present study the countries have been divided into four groups according to real per capita income, as follows:

I. India, Pakistan, Sri Lanka, Thailand, Philippines, Korea
II. Malaysia, Colombia, Jamaica, Syria, Brazil, Mexico, Iran, Uruguay

III. Ireland, Italy, Spain, United Kingdom, Japan, Austria
IV. Netherlands, Belgium, France, Luxembourg, Denmark, Germany, United States.

Group I consists of low-income countries in Asia. Group II is composed of higher-income LDCs. Group III includes industrial countries below the top level of income, and Group IV contains the highest income countries. Three African countries were not included in this group because it was thought that their pattern of relative prices might be quite different. It turned out, however, that exclusion of the African countries had practically no effect on the results. The correlation of group I relative prices with and without the three African countries was 0.98.[10]

A proper test of the hypotheses would be conducted with value-added prices, but since the ICP provides only the final product prices and not any data on the prices of raw materials and intermediate goods, the final product prices have been used as proxies for the unknown value-added prices. The absence of prices of raw materials and intermediate goods inevitably reduces the precision of the tests but does not invalidate them because the final product prices are probably fairly highly correlated with the value-added prices.

In order to obtain the factor shares and other characteristics of the production process, it is necessary to match the ICP product categories with the categories in censuses of business establishments. Considerable effort has gone into matching the ICP categories with U.S. establishment data, and reasonably good matches have been obtained for 63 of the ICP's 151 detailed categories. This set will form the sample for the present study. The sample includes seven service categories, 11 construction categories, and 45 manufactured products.

Details of the calculation of the factor shares and of the selection of the sample categories are available in a working paper.[11] The appendix to the working paper contains a printout of the factor shares and all the independent variables used in the regressions. Although a great deal of effort went into the construction of the factor shares, it turns out that the results of the regressions explaining relative efficiency are quite insensitive to the details of the procedure followed in calculating these shares. In fact, the relative efficiency regressions look very similar even when the observed prices are not corrected for differences in factor intensities.

The relative factor price data are described here in some detail, partly because they are of interest in their own right. Once again, however, the relative efficiency regressions are not terribly sensitive to the precise assumptions made about the quality of labor in LDCs compared to MDCs. In fact, one of the interesting points to emerge from the calculations is that no reasonable manipulation of the factor

price data permits one to escape the conclusion that the differences in relative efficiency between LDCs and MDCs are far from uniform across products.

The ICP itself contains the prices (relative to the United States) of construction, producer durables, and various categories of labor costs. The data for construction and producer durables are shown in the upper part of table 1. The construction costs are a weighted average of 14 detailed categories, and they do not of course include the cost of land. Producer durables are a weighted average of 22 categories. The table shows both the averages for each group relative to the United States and the averages for each group relative to group IV.

Since a study by A. C. Harberger indicates that annual rates of return to capital do not differ in a systematic way across countries (in particular the rates of return are not notably higher in poor countries than in rich countries), the rates of return will be assumed the same across countries.[12]

The ICP also contains the relative costs of various types of labor. Some of these are presented in the lower part of table 1, along with per capita income converted at exchange rates (Y_{ER}) and at PPP (Y_{PPP}). The table shows the wages of domestic servants, first- and second-level teachers, college teachers, and the costs of clothing repair and footwear repair (the latter two are largely labor costs). These data are presented for the sake of interest and completeness. The next four columns show the data that were actually used in constructing relative labor cost, namely, the earnings of government employees in four categories.[13]

These categories are defined as follows. Blue-collar employees are divided into unskilled and skilled according to whether they have the first level (primary) or the second level (secondary) of education. White-collar employees have the second level of education, and professionals have the third level of education.[14]

The data indicate that the wages in poor countries relative to those in rich countries are higher for the more skilled categories of labor; that is, they are higher for professional than for white collar and higher for skilled blue collar than for unskilled blue collar workers. The data for domestic servants and teachers are generally consistent with this pattern.

It seems reasonable to suppose that even within the categories listed the average labor quality is lower in poorer than in richer countries and that the quality differences are greater for the more skilled categories. One way of making a quality adjustment is to compare the earnings of recent immigrants to the United States with those of native American workers. G. Borjas has estimated earnings functions from 1970 and 1980 U.S. census data in which (log) earnings are a function of the usual variables (age, schooling, marital status, health) and of

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immigrant status and years since immigration.[15] In Borjas's regressions the coefficient on the dummy for immigration status is interpreted as the proportional reduction in earnings of newly arrived immigrants—before any assimilation has taken place. These coefficients are available for individual countries of origin for 2 years (1970 and 1980). Averaging coefficients over relevant countries and for the 2 years gives the following results.

Group I	(India, Philippines, Korea, Taiwan,* Egypt*)	−.443
Group II	(Iran, Brazil, Colombia, Jamaica, Mexico, Argentina*)	−.297
Group III	(All six ICP countries)	−.043

(*Taiwan and Egypt are not ICP countries; their inclusion changes the group average only slightly. Argentina is not an ICP country but is probably similar to Uruguay in the earnings of its nationals in the United States.)

If these coefficients are taken at face value, then a group I immigrant is 44.3% less productive than a native American with the same schooling, marital status, age, and health. This coefficient would seem to be an overestimate of the appropriate quality adjustment since the immigrant is likely to be handicapped by a language barrier and lack of familiarity with U.S. culture (handicaps that would not be relevant in his country of origin), and these handicaps would seem to be likely to outweigh the possible biases arising from the selection of immigrants.[16]

It is interesting to compare these coefficients with labor quality adjustments estimated some time ago in a survey study by M. Kreinin.[17] Kreinin sent questionnaires to U.S. firms with plants both in the United States and abroad, asking them to compare the labor time per unit of output in the two countries, under conditions in which similar equipment and organization were used. Some of his results are reproduced in table 2, which shows relative labor requirements per unit of output for various regions and countries. The figures apply to a composite of all employees. (For comparison with the Borjas results, note that Borjas's coefficient of −.443 would correspond to a relative labor requirement of 1/.557 = 1.795.) The point of the Kreinin study was that U.S. comparative labor effectiveness was nowhere near the 300% figure suggested by Leontief to resolve his famous paradox. While precise correspondence between the Borjas and Kreinin results is not to be expected, the two sets of findings, derived by completely different methods, do suggest labor-quality adjustments of the same order of magnitude. Kreinin himself urged that the figure for Africa, the Far East, and the Middle East be treated cautiously, as it was based on few observations, which were widely scattered in their estimates.

The relative labor costs adjusted by the Borjas coefficients are shown in the table 3. In the calculation of predicted relative prices,

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TABLE 1

RELATIVE COSTS OF FACTORS

Number of Countries	Relative to United States: Construction	Relative to United States: Producer Durables	Relative to Group IV: Construction	Relative to Group IV: Producer Durables
Group I (6)	.394	1.086	.328	.849
Group II (8)	.554	1.209	.461	.945
Group III (6)	1.031	1.128	.857	.882
Group IV (7)	1.202	1.279	1.000	1.000

	Y_{ER}	Y_{ppp}	Domestic Service	Teachers: First and Second Levels	Teachers: College
Relative to the United States:					
Group I	.043	.118	.057	.045	.130
Group II	.156	.288	.189	.120	.327
Group III	.526	.590	.648	.454	.509
Group IV	.930	.832	1.186	.971	1.078

	Repairs		Blue Collar		White Collar	Professional
	Clothing	Footwear	Unskilled	Skilled		
Group I	.166	.305	.093	.098	.128	.215
Group II	.223	.468	.266	.305	.479	.594
Group III	.709	.631	.667	.610	.867	1.053
Group IV	1.220	1.147	1.242	1.099	1.418	1.606

				Teachers	
	Y_{ER}	Yppp	Domestic Service	First and Second Levels	Colleges
Relative to group IV:					
Group I	.046	.142	.048	.046	.121
Group II	.168	.346	.181	.124	.303
Group III	.566	.709	.545	.468	.472
Group IV	1.000	1.000	1.000	1.000	1.000

	Repairs		Blue Collar		White Collar	Professional
	Clothing	Footwear	Unskilled	Skilled		
Group I	.136	.266	.075	.089	.090	.134
Group II	.209	.408	.214	.278	.338	.370
Group III	.581	.550	.537	.555	.611	.656
Group IV	1.000	1.000	1.000	1.000	1.000	1.000

Source.—Irving B. Kravis, Alan W. Heston, and Robert Summers, *World Product and Income* (Baltimore: Johns Hopkins University Press for the World Bank, 1982), pp. 176–79, 208–15.

TABLE 2

FOREIGN/U.S. LABOR REQUIREMENTS PER UNIT OF OUTPUT BY REGION AND COUNTRY

Country or Region	Mean (%)	Median (%)	Observations
Canada	102	100	71
Europe	123	120	171
Germany	115	115	28
Benelux	118	120	32
Italy and France	128	120	33
United Kingdom	126	120	51
Other Europe	126	119	27
Japan, Australia, New Zealand, South Africa	132	110	35
Latin America	149	130	76
Mexico	130	125	24
Other Latin America	156	135	52
Africa, Far East, Middle East	242	175	14

SOURCE.—Mordechai Kreinin, "Comparative Labor Effectiveness and the Leontief Scarce Factor Paradox," *American Economic Review* 55 (March 1965): 131–40.

the relative cost of raw labor was taken from column 1 (blue collar unskilled) and the relative cost of production labor skill and of nonproduction labor were taken from column 4 (professional). This procedure was followed to allow for the possibility that labor-quality differences between LDCs and group IV countries are greater among more skilled workers. Several alternative procedures were tried, and the results are quite insensitive to choice of procedure; these results are contained in the working paper cited in note 11 above.

V. Adjustment for Economies of Scale

The adjustment for economies of scale was carried out by following a procedure used by H. Pack.[18] The adjustment is based on the relative size of factories in LDCs and MDCs and on the degree of economies

TABLE 3

ADJUSTED RELATIVE LABOR COSTS

	Blue Collar		White Collar	Professional	Nonproduction*	Borjas Coefficient
	Unskilled (1)	Skilled (2)	(3)	(4)	(5)	(6)
Group I	.134	.160	.160	.240	.200	.557
Group II	.304	.395	.481	.526	.503	.703
Group III	.561	.580	.638	.685	.662	.957

* Nonproduction worker relative labor cost is the unweighted average of that for white collar and professional.

of scale. The paucity of data makes the adjustment somewhat crude, but the results for the relative efficiency variable turn out to be rather insensitive to the details of the procedure.

We assume that the relation of total cost (C) to output (X) is $C = BX^{1-\alpha}$, where $0 < \alpha < 1$. Hence average cost (c) is $c = C/Q = BX^{-\alpha}$.

The ratio of average cost in the LDC to that in the MDC is

$$c^{LDC}/c^{MDC} = (X^{LDC}/X^{MDC})^{-\alpha} = (X^{MDC}/X^{LDC})^{\alpha}. \quad (2)$$

Relative factory size is approximated by relative employment size. Employment size in an industry is calculated as a weighted average of the employment size in the different size classes. This type of index, called a Niehans index, is a much better way of comparing employment size in different industries and in different countries than is industry employment divided by the number of factors.[19] Specifically, employment size in an industry is $\lambda = \Sigma_i \lambda_i(L_i/\Sigma_i L_i)$, where λ_i is the average employment size in size class i and $L_i/\Sigma_i L_i$ is the relative share of employment in plants of this size in the particular industry.

The industrial organization literature contains some estimates of the minimum efficient scale (MES) of factories and of the percentage increase in average cost resulting from producing at half the size of the MES instead of at the MES. Let us denote this cost elasticity by Ecx. I took estimates of the cost elasticity from F. M. Scherer and C. F. Pratten.[20] The coverage of these estimates of Ecx is far from complete, and judgments had to be made in order to assign values to each of the ICP categories. Details are provided in the working paper appendix (n. 11 above). The adjustment was made only for the manufacturing categories, not for construction and services.

From the definition of Ecx and the exponential cost function used in equation (2), we have

$$1 + Ecx = 2^{\alpha} \text{ or } \alpha = \ln(1 + Ecx)/\ln 2. \quad (3)$$

Equation (3) was used to infer a value of α from the value of Ecx, and it was assumed in accordance with (2) that this value of α applies throughout the range of factory sizes between the average size in the LDC and that in the MDC.

The Niehans index of factory size could be calculated only for countries for which the size distribution of factories was available. This includes the United States and, from the resources of the IMF–World Bank library, only Korea and Colombia among the LDCs in the ICP sample.[21] The relative size of factories in Colombia (compared to those in the United States) was used to calculate the economies-of-scale adjustment for groups I and II. As an alternative the Korean relative size (compared to that of the United States) was also used.

The data for Colombia are preferred because relative factory size is somewhat smaller on the average than in Korea (.29 for Colombia and .60 for Korea) and Colombia is probably more typical of LDCs in factory size. The use of Colombian data probably overstates the difference in relative factory size for groups I and II because factory size is probably larger in most of the other countries. Pryor found the Niehans index of factory size in all manufacturing to be positively related to aggregate market size, and only five of the 14 countries in groups I and II have smaller domestic markets than Colombia.[22]

While the use of Colombian data probably overstates the economies-of-scale adjustment, the use of employment as a measure of factory size biases the adjustment in the other direction. If factory size were measured by an aggregate of inputs instead of labor alone, the Colombian factories would appear even smaller relative to the U.S. factories. Moreover, since LDC factories tend to produce a wider range of products than MDC factories,[23] the appropriate adjustment would be still larger. On the other hand, the use of the U.S. factories as representative of MDC factories undoubtedly exaggerates the appropriate measure of the difference in relative size. On balance, it is thought that the correction is probably overstated, but in any case the relative efficiency variables come through loud and clear both in the presence and the absence of the economies-of-scale adjustment.

VI. Relative Efficiency Variables

The proportional price deviations (RDEV) were regressed on several variables reflecting product characteristics that were thought to affect relative efficiency. These variables are as follows:

PROF = share of professional and technical workers among all employees;[24]
COLL = share of college graduates among all employees;[25] and
R&D = research and development expenditures as a percentage of sales.[26]

The rate of growth of total factor productivity (1960–79) in Japan and the United States is available in D. Jorgenson, M. Kuroda, and M. Nishimizu; rates of growth of total factor productivity for U.S. manufacturing sectors only for 1950–57 are available in B. F. Massell.[27] The variables used were

TFP = average of U.S. and Japanese rates of growth of total factor productivity, 1960–79; and
TFP2 = U.S. growth rate of total factor productivity 1950–57 (manufacturing sectors only).

The employment size distribution of establishments in services and construction is available in U.S. data sources,[28] and the size distri-

bution of manufacturing establishments is available for the United States, Colombia, and Korea. For manufacturing the measure actually used was the average of the Niehans index for the United States and Colombia. For construction and services the U.S. data were used.[29] Experiments incorporating the Korean data revealed that this modification made very little difference. The log of the Niehans index was used to reduce the importance of extremes of size, but again the results were not sensitive to this choice. The variable is

SIZE = log of Niehans index of establishment employment.

In searching for a measure of the degree to which an industry relies on a well functioning transportation and communications system in the economy, I examined the input coefficients of the U.S. 480-sector input-output table. I first considered the ratio of inputs to sales, but a little reflection indicated that this variable does not capture the industry characteristics we seek. (Consider as a counterexample a processing industry such as a food canning or flour milling; the input-to-sales ratio is high, but the industry does not have complex interactions with the rest of the economy.) Two measures of the dispersion of inputs purchased by the industry were calculated: (*a*) one minus the Herfindahl index of concentration of input shares and (*b*) the number of industries from which the industry makes purchases. The Herfindahl index, which is the sum of the squared shares, lies between zero and one. For practical purposes, in our data it is determined by the top four shares; thus it measures the degree of concentration among the important inputs. The second measure, the number of input sectors, captures the variety of inputs required.

In summary, then, the two additional variables are denoted as follows:

DISP = dispersion of input shares, or one minus the Herfindahl index; and
VRTY = variety of inputs, or number of input sectors.

Since the 480-sector table provides very little detail on construction and final demand services, these two variables are available only for the manufacturing categories.

VII. Results

The regressions were run according to equation (1). There is good reason to believe that the error variance differs across product categories; the categories contain somewhat heterogeneous goods, and products are priced in some countries and not in others. To correct for different degrees of product heterogeneity across categories, I first calculated the variance of prices (VAR_i) across all 34 countries in the

TABLE 4

CORRELATION MATRIX, 63 CATEGORIES

	PROF	SIZE	R&D	TFP	COLL
PROF	1.000				
SIZE	.604	1.000			
R&D	.770	.438	1.000		
TFP	.554	.585	.338	1.000	
COLL	.867	.540	.647	.570	1.000
CNST	−.227	−.223	−.225	−.711	−.240
SRVC	−.341	−.782	−.247	−.272	−.384

NOTE.—PROF = share of professional workers in industry employment; SIZE = log of Niehans index of establishment employment; R&D = research and development expenditures as a percentage of sales; TFP = average growth rate of total factor productivity in the United States and Japan, 1960–79; COLL = share of college graduates in industry employment; and CNST and SRVC = dummies for construction and services.

ICP sample. The price observations were then weighted by $1/v_i$, where $v_i = VAR_i/PRP^2$, as required by equation (1).

Because the input-output variables were available only for the 45 manufacturing products, this sample was run separately. I start with the full sample of 63 categories. Table 4 gives the correlation matrix for the full sample.

According to (1), the proportional deviations RDEV should be regressed on the relative efficiency variables.[10] The RDEVs are of course the deviations of observed prices from the predictions based on the factor proportions theory and the corrections for economies of scale. As a check on the robustness of the results, the regressions were run on the observed relative prices (denoted PRICE), on the prices corrected for factor proportions (denoted RDEV1), and on the prices corrected for both factor proportions and relative size (denoted RDEV). On the whole the results are quite robust: the pattern of coefficients on the relative efficiency variables is similar for the unadjusted prices and for the two sets of price deviations.

In table 5 I show for groups I and II the regressions on each of the relative efficiency variables, taken separately. All of the variables have the expected positive signs, and most are highly significant. The results for group III (not shown) are completely different; in that group of industrial countries below the top group in income per capita, none of the relative efficiency variables is significant.

Table 5 shows the standard deviation of PRICE and of the prices corrected for factor proportions (PDEV1) and for both factor proportions and relative size (PDEV). It can be seen that the various adjustments reduce the standard deviation, as expected, indicating that factor proportions and relative size explain part of the variation in observed relative prices, but they leave a substantial amount to be

TABLE 5

REGRESSIONS WITH A SINGLE INDEPENDENT VARIABLE, 63 CATEGORIES

Dependent Variable and SD*	PROF	SIZE	R&D	TFP	COLL
Group I:					
PRICE, .4317					
(no adjustments)	.3773	.2462	.1118	.1531	.3262
	(6.18)	(5.98)	(5.47)	(3.43)	(3.17)
PDEV1, .3852					
(no scale adjustment)	.4987	.2626	.1304	.2042	.4314
	(6.46)	(5.07)	(5.11)	(3.83)	(3.26)
PDEV, .3533					
(standard case)	.3640	.2184	.1003	.1582	.3060
	(5.11)	(4.43)	(4.17)	(3.20)	(2.66)
PDEV2, .3630					
(Korean relative size)	.4143	.2385	.1127	.1811	.3577
	(5.52)	(4.66)	(4.42)	(3.50)	(2.89)
Group II:					
PRICE, .4002	.3659	.2291	.1132	.1538	.3299
	(6.15)	(6.70)	(5.50)	(3.52)	(3.28)
PDEV1, .3546	.3193	.2060	.0938	.1537	.3173
	(5.04)	(5.64)	(4.23)	(3.81)	(3.16)
PDEV, .3167	.1927	.1590	.0572	.1048	.1894
	(3.38)	(4.58)	(2.96)	(2.84)	(2.20)
PDEV2, .3274	.2339	.1782	.0679	.1265	.2366
	(3.88)	(4.97)	(3.30)	(3.27)	(2.55)

NOTE.—PDEV1 = prices corrected for factor proportions only; PDEV = prices corrected for factor proportions and relative size; PDEV2 = prices corrected with Korean relative size data. The dependent variable in the regressions was not PDEV, but RDEV, which is PDEV/PRP. Numbers in parentheses are t-ratios.

*SD of PRICE or of price deviation (PDEV1, PDEV, PDEV2).

explained by the relative efficiency variables. The last row in table 5 for each group shows PDEV2, the deviations based on Korean relative size instead of Colombian relative size as in the base case. The results for the relative efficiency variables are not much affected by this change.

Some multiple regressions are shown in table 6. The high degree of multicollinearity among the independent variables (see table 4) causes the coefficients to change a good deal as variables are added. The SIZE variable is quite strong in most regressions, and the PROF variable is especially strong in group I. The college share variable (COLL) is rather highly correlated with PROF and does not perform as well as PROF; consequently, COLL is not shown in the multiple regressions.

The R&D and TFP variables become insignificant when either PROF or SIZE is in the regression, but R&D and TFP are not highly correlated (r = .338), and both enter the regression significantly.

Regressions were also run on dummies for the construction sector

TABLE 6

MULTIPLE REGRESSIONS OF RDEV, 63 CATEGORIES

PROF	SIZE	R&D	TFP	Intercept	$\bar{R}^2$/S.E.E.
Group I:					
.2611	.1128	. . .	. . .	−.9410	.3186
(3.66)	(1.93)			(−2.91)	(.3406)
.2999	. . .	.0269	. . .	−.3256	.2832
(2.71)		(.76)		(−4.72)	(.3487)
.3249	. . .		.0435	−.3351	.3840
(3.76)			(.80)	(−4.86)	(.3485)
. . .	.1576	.0674	. . .	−1.1287	.2297
	(3.02)	(2.68)		(−3.69)	(.3442)
. . .	.1835	. . .	.0551	−1.2217	.3017
	(2.98)		(.95)	(−3.47)	(.3615)
. . .	. . .	.0830	.1064	−.2775	.2561
		(3.37)	(2.21)	(−4.36)	(.3552)
Group II:					
.0674	.1322	. . .	. . .	−.8828	.2438
(.99)	(3.01)			(−3.67)	(.2676)
.1488	. . .	.0189	. . .	−.1731	.1356
(1.65)		(.63)		(−3.15)	(.2861)
.1455	. . .	. . .	.0521	−.1817	.1500
(2.10)			(1.19)	(−3.36)	(.2837)
. . .	.1365	.0258	. . .	−.9000	.2524
	(3.54)	(1.30)		(−4.03)	(.2661)
. . .	.1481	. . .	.0177	−.9439	.2335
	(3.38)		(.41)	(−3.80)	(.2694)
. . .	. . .	.0437	−.0772	.1631	.1548
		(2.19)	(2.04)	(−3.29)	(.2829)

(CNST) and the service sector (SRVC) (see table 7). The negative signs on these variables are consistent with the conjecture that LDC relative efficiency is comparatively high in these two sectors. The introduction of the relative efficiency variables weakens both of these sectoral dummies, and both become quite insignificant when PROF and SIZE are in the equation (see table 7) or when R&D and TFP are in the equation (not shown). These results suggest that the comparatively high relative efficiency of LDCs in construction and services is explainable by the fact that these two sectors do not require large organizations and are not very technically progressive.

For group III the construction dummy entered with a positive sign (t = 2.22) and the service dummy with a negative sign (t = 1.94); the coefficients themselves were rather small (+.117 and −.141, respectively). These results indicate once again that the group III countries' pattern of relative prices is quite different from that of the LDCs.

Next is the sample of 45 manufacturing products. The correlation matrix of the independent variables is shown in table 8, and the regres-

TABLE 7

REGRESSIONS WITH CONSTRUCTION AND SERVICE DUMMIES, 63 CATEGORIES

CNST	SRVC	PROF	SIZE	Intercept	$\bar{R}^2$/S.E.E.
Group I:					
−.3492	−.3737	. . .	. . .	−.0001	.0772
(−2.35)	(−1.48)			(−.002)	(.3956)
−.1726	−.1311	.3290	. . .	−.2762	.2851
(−1.26)	(−.57)	(4.29)		(−3.44)	(.3482)
.0233	.5655	. . .	.2990	−1.9083	.2482
(.14)	(1.69)		(3.83)	(−3.81)	(.3571)
−.0196	.3137	.2329	.1642	−1.2433	.3106
(−.12)	(.93)	(2.52)	(1.78)	(−2.27)	(.3420)
Group II:					
−.2674	−.3303	. . .	. . .	.0153	.1025
(−2.51)	(−1.88)			(.38)	(.2915)
−.1867	−.2217	.1478	. . .	−.1074	.1718
(−1.74)	(−1.27)	(2.45)		(−1.69)	(.2800)
−.1347	.3314		.2047	−1.2849	.2519
(−.11)	(1.36)	. . .	(3.60)	(−3.54)	(.2662)
−.0207	.2866	.0378	.1822	−1.1737	.2426
(−.17)	(1.10)	(.52)	(2.55)	(−2.78)	(.2678)

sions are in table 9. Panel A of table 9 contains the single-variable regressions and panel B, the multiple regressions.

The two input-output variables, variety of inputs (VRTY) and dispersion of input shares (DISP), are each quite strong, even in the presence of other explanatory variables. The variables PROF, SIZE, and R&D are significant individually but not when VRTY and DISP are in the equation.[31]

Curiously, the technical change variables for 1960–79 (TFP) is not as strong as the technical change variable for 1950–57 (TFP2). No particular explanation for this finding is apparent; it should be kept in

TABLE 8

CORRELATION MATRIX, 45 MANUFACTURING PRODUCTS

	VRTY	DISP	PROF	SIZE	R&D	TFP	TFP2
VRTY	1.000						
DISP	.410	1.000					
PROF	.368	.521	1.000				
SIZE	.631	.669	.576	1.000			
R&D	.348	.463	.753	.387	1.000		
TFP	−.103	.310	.478	.429	.120	1.000	
TFP2	.291	.533	.502	.676	.199	.768	1.000

NOTE.—VRTY = variety or number of input sectors; DISP = dispersion of input shares; TFP2 = rate of growth of total factor productivity in the United States, 1950–57. See also table 4 above.

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TABLE 9

REGRESSIONS FOR 45 MANUFACTURING PRODUCTS

	VRTY	DISP	PROF	SIZE	R&D	TFP	TFP2
A. Regressions with a single independent variable:							
Group I	.9833	3.535	.3234	.3524	.0877	.1409	.1830
	(3.46)	(5.10)	(3.92)	(3.82)	(3.34)	(1.63)	(2.96)
Group II	.7979	1.929	.1370	.2295	.0442	.0570	.1291
	(4.21)	(3.68)	(2.21)	(3.57)	(2.24)	(.91)	(3.01)

	VRTY	DISP	PROF	SIZE	Intercept	$\bar{R}^2$/S.E.E.
B. Multiple regressions:						
Group I	.5474	2.926	. . .	. . .	−2.896	.4057
	(2.04)	(3.99)			(−4.70)	(.3044)
	.4405	2.467	.1147	. . .	−2.528	.4137
	(1.57)	(3.03)	(1.25)		(−3.72)	(.3024)
	.5461	2.922	. . .	.0009	−2.898	.3912
	(1.65)	(3.27)		(.01)	(−4.18)	(.3081)
Group II	.6022	1.264	. . .	. . .	−1.411	.3479
	(3.05)	(2.40)			(−3.20)	(.2244)
	.6418	1.411	−.0378	. . .	−1.531	.3371
	(3.04)	(2.38)	(−.56)		(−3.10)	(.2263)
	.6202	1.311	. . .	−.0012	−1.384	.3323
	(2.52)	(2.01)		(−.12)	(−2.80)	(.2271)

mind that the ranking of industries by TFP growth did not remain constant over the periods considered.

VIII. Concluding Observations

The relative prices examined in this article indicate rather clearly that there are large differences across products in the relative efficiency of LDCs compared to that of MDCs. This conclusion emerges whether one looks at the relative prices themselves or at the deviations of relative prices from predictions based on the factor proportions theory and economies of scale.

The LDC relative prices (and the deviations of prices from the predictions) are positively related to R&D intensity and the growth of total factor productivity in the MDCs. These two variables, which are indicators of technological progress, are suggested by technological gap theories and have been used frequently in studies of trade patterns.[32]

The LDC prices and price deviations are also positively related to the two input-output variables, the number (variety) of input sectors, and the dispersion of input shares. These two variables, which

do not seem to have been used before, are suggested rather directly by the self-containment hypothesis described in Section II above.

In addition, LDC relative prices and price deviations are positively related to the share of professionals and the share of college graduates among all employees. These variables have been used frequently in studies of trade patterns and have often been interpreted as reflecting the influence of factor intensity within the context of the factor proportions theory.[33] Both here and in the prior literature, the professional share works better than the college share. In the present study, however, the professional share variable in the price deviation regressions is not to be interpreted as a factor intensity variable in the ordinary sense, for the influence of skill intensity has supposedly already been taken into account through the predictions based on the factor proportions theory. Several interpretations of the professional share are possible. One could argue that the importance of this highly trained labor has been understated in the factor-proportion-based calculations because this type of labor generates large external benefits (a theme pursued in Lucas).[34] Alternatively, the professional share may be regarded as an indicator of technological progress of the industry or as an indicator of the degree to which the industry requires information processing (either within organizations or across sectors).

The establishment size variable is suggested by the hypothesis that LDCs are particularly deficient at managing large organizations. This variable is strongly positively related to LDC relative prices and thus provides strong support for the hypothesis.

Consistently with the self-containment hypothesis, the LDC relative price deviations of construction and services were negative, but the negative coefficients on these sectoral dummies became quite insignificant when either the professional share and establishment size or the two technological progress variables were added to the regression. This result indicates that the characteristics of construction and service that make them especially cheap in LDCs are well captured by these relative efficiency variables.

The finding in this study, that LDCs seem to be relatively efficient in self-contained activities and relatively inefficient in interdependent ones, has implications for comparative advantage in international trade. The results suggest that successful trade performance in LDCs will not usually be found in activities with a high degree of what Hirschman called "forward and backward linkage."[35] This implication has received some support in a companion study of LDC trade.[36] The results also suggest that those LDCs that are successful in exporting products with a high degree of linkage (such as Korea in its automotive exports) are countries that are developing institutions that favor economic efficiency. Since the effects of such efficiency-enhancing institutions extend well beyond international trade, we might expect that

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countries successfully exporting such products would exhibit higher than normal rates of economic growth. This plausible hypothesis would seem to merit further investigation.

It is obvious that one's interpretation of relative prices and trade patterns is strongly affected by whether one adopts a framework emphasizing factor proportions and economies of scale or a framework stressing relative efficiency. The choice of framework also influences one's view of the development process. The results of this study tend to support a view of the development process in which organizational and institutional change is as important as factor accumulation and economies of scale.

Notes

* I have benefited from constructive criticism by Joe Francois, John Haltiwanger, Paul Isenman, Peter Murrell, Nat Leff, Mancur Olson, Arvind Panagariya, James Rauch, Ken Reinert, and two referees, who do not, however, share responsibility for remaining deficiencies. Many thanks also to Margaret McCarthy of INFORUM for help with the input-output data. Computer time was provided by the University of Maryland Computer Science Center.

1. Irving B. Kravis, Alan W. Heston, and Robert Summers, *World Product and Income* (Baltimore: Johns Hopkins University Press for the World Bank, 1982).

2. The reasons LDCs are relatively inefficient in activities requiring large-scale organizations are spelled out persuasively in Mancur Olson, "Diseconomies of Scale and Economic Development," *Cato Journal* 7 (Spring/Summer 1987): 77–97.

3. Robert E. Lucas, "On the Mechanics of Economic Development," *Journal of Monetary Economics* 22 (July 1988): 3–42.

4. Jane Jacobs, *The Economy of Cities* (New York: Random House, 1970), and *Cities and the Wealth of Nations* (New York: Random House, 1984).

5. Larry E. Westphal, "Fostering Technological Mastery by Means of Selective Infant-Industry Protection," in *Trade, Stability, Technology and Equity in Latin America*, ed. M. Syrquin and S. Teitel (New York: Academic, 1982).

6. For example, Raymond Vernon, *Exploring the Global Economy* (Lanham, Md.: University Press of America, 1985).

7. Irving B. Kravis, Alan W. Heston, and Robert Summers, "The Share of Services in Economic Growth," in *Global Econometrics: Essays in Honor of Lawrence Klein*, ed. F. Gerard Adams and Bert Hickman (Cambridge, Mass.: MIT Press, 1983).

8. See, e.g., James M. Henderson and Richard E. Quandt, *Microeconomic Theory*, 3d ed. (New York: McGraw-Hill, 1980), p. 118.

9. The expression A^* is calculated in such a way as to equalize the mean predicted price and the mean observed price. That is, $A^* = \overline{PRICE}/\overline{PRP}$.

10. As stated above, for each product category i the relative prices (PPP_i/ER) were averaged across the countries in each group. An alternative procedure is to take the ratio of PPP_i to the country's average PPP as the measure of relative price. This variation in procedure makes no substantive difference to the results. The correlation of (PPP_i/ER) and PPP_i/PPP), when averages are taken of groups I and II relative to group IV, exceed .99.

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11. Christopher Clague, "Comparative Costs and Economic Development," Working Paper no. 88-46 (University of Maryland, Department of Economics, 1988); available on request.

12. Arnold C. Harberger, "Perspectives on Capital and Technology in Less Developed Countries," in *Contemporary Economic Analysis*, ed. M. J. Artis and A. R. Nobay (London: Croom Helm, 1978).

13. Of course, the earnings of government workers do not necessarily represent the cost of labor to the private sector, but inspection of the table indicates that the disparities across groups of countries are sufficiently great that precise measurements are unnecessary.

14. In the ICP, the three levels of education are approximated as follows: first level, 7–9 years of completed education or less; third level, more than 12 years of completed education; second level, years completed above the first level and below the third level (Kravis, Heston, and Summers, *World Product and Income*, p. 68).

15. George Borjas, "Self-Selection and the Earnings of Immigrants," *American Economic Review* 77 (September 1987): 531–54.

16. For an interesting study of wages and labor quality in different countries, see Gregory Clark, "Why Isn't the Whole World Developed? Lessons from the Cotton Mills," *Journal of Economic History* 47 (March 1987): 141–73, who attributes most of the differences in factor efficiency to the quality of operative labor. See also Mira Wilkins, "Efficiency and Management: A Comment on Gregory Clark's 'Why Isn't the Whole World Developed?' " ibid., 47 (December 1987): 981–84, and Clark's reply, "Can Management Develop the World? Reply to Wilkins," ibid., 47 (March 1988): 143–48.

17. Mordechai Kreinin, "Comparative Labor Effectiveness and the Leontief Scarce Factor Paradox," *American Economic Review* 55 (March 1965): 131–40.

18. Howard Pack, "Total Factor Productivity and Its Determinants: Some International Comparisons," in *Comparative Development Perspectives*, ed. Gustav Ranis, Robert L. West, Mark W. Leiserson, and Cynthia Taft Morris (Boulder, Colo.: Westview, 1984).

19. See Frederic Pryor, *Property and Industrial Organization in Communist and Capitalist Nations* (Bloomington: Indiana University Press, 1973), for a discussion of different indexes used to make international comparisons of factory size.

20. F. M. Scherer, *Industrial Market Structure and Economic Performance* (Chicago: Rand McNally, 1980); C. F. Pratten, *Economies of Scale in Manufacturing Industry* (Cambridge: Cambridge University Press, 1971).

21. The data sources are U.S. Bureau of the Census, *Census of Manufactures 1977* (Washington, D.C., 1979); Colombia, Departmento Administrativo Nacional de Estadistica, *Anuario de Industria Manufacturea* (Bogota, 1982); and Republic of Korea, Economic Planning Board, *Report on Mining and Manufacturing* (Seoul, 1975).

22. Pryor.

23. See, e.g., Howard Pack, *Productivity, Technology and Industrial Development* (New York: Oxford University Press, 1987).

24. U.S. Bureau of Labor Statistics, "The National Industry-Occupation Employment Matrix, 1970, 1978 and Projected 1990," *BLS Bulletin* 2086 (April 1981).

25. U.S. Bureau of the Census, *Census of Population 1970*, vol. 6, *Industrial Characteristics* (Washington, D.C., 1975).

26. U.S. Federal Trade Commission, *Annual Line of Business Report, 1976* (Washington, D.C., 1982).

27. Dale Jorgenson, Masahiro Kuroda, and Mieko Nishimizu, "Japan-U.S. Industry-Level Productivity Comparison, 1960–79" (paper delivered at NBER U.S.-Japan Productivity Conference, Cambridge, Mass., 1985); Benton F. Massell, "A Disaggregated View of Technical Change," *Journal of Political Economy* 69 (December 1961): 547–57.

28. U.S. Bureau of the Census, *Census of Construction 1977, Census of Retail Trade 1977, Census of Service Industries 1977* (Washington, D.C., various dates).

29. No data were available on the size distribution of service and construction establishments in Columbia. One would imagine that they were smaller than in the United States, but the relative difference is probably less than in manufacturing. Even with the procedure described in the text, construction and service establishments are calculated to be much smaller than manufacturing establishments.

30. RDEV is defined as PDEV/PRP.

31. The multicollinearity of VRTY, DISP, and PROF and of VRTY, DISP, and SIZE is high. The multiple correlation (R) coefficient of PROF on VRTY and DISP is .548, and the coefficient of SIZE on VRTY and DISP is .775.

32. For a sample of trade studies, see Alan V. Deardoff, "Testing Trade Theories and Predicting Trade Flows," *Handbook of International Economics*, vol. 1, ed. Ronald W. Jones and Peter G. Kenen (Amsterdam: North-Holland, 1984), esp. pp. 493–99. However, Pack, "Total Factor Productivity" (n. 18 above), found no correlation across industries between TFP growth in the United States and the relative efficiency of either Philippine or Israeli industries.

33. See Deardorff.

34. See Lucas (n. 3 above).

35. Albert O. Hirschman, *The Strategy of Economic Development* (New Haven, Conn.: Yale University Press, 1958), pp. 98 ff.

36. Christopher K. Clague, "Factor Proportions, Relative Efficiency and Developing Countries' Trade," *Journal of Development Economics* (in press).

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