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Boston University

Center for Latin American Development Studies

PRODUCTION EFFICIENCY AND THE TRANSFERABILITY OF INPUT-OUTPUT COEFFICIENTS

by

David Wheeler

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David Wheeler
Department of Economics
Boston University
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I. Introduction

A recurrent problem in the specification of planning models is the need to represent input-output relations for new industries. Inevitably, national planners have resorted to borrowing estimated input-output vectors from other economies, on the assumption that the observed relations of production would survive transplantation. Despite a reasonable preference for data from economies which are "nearby" both geographically and developmentally, they have frequently been forced to use the advanced industrial economies as sources of information.

Although this borrowing procedure is necessary, it seems very risky. Several sources of potential distortion can be identified when entire vectors are transferred, all of them stemming from variations in relations which are assumed to be fixed. Much attention has been focused on the plausibility of constant factor proportions across markets with different relative factor prices, and the assumption of non-substitutability of materials inputs has not escaped critical analysis. Little attention, however, has been paid to the assumption that production at different locations will exhibit the same level of efficiency in materials use.

This paper will contend that such constancy should not be maintained when input-output vectors are transferred to LDC planning models from the matrices of industrialized countries. Several arguments for the existence of variable efficiency in materials use will be employed to support the assertion that borrowed vectors persistently underestimate input-output relations when they are applied to poorer countries. The potential significance of this distortion will be discussed in the context of some standard planning models. Finally, plant-level data will be used to test the basic hypothesis, and the econometric results will serve as a basis for estimating the magnitude of the problem.

II. Use Efficiency in Production

Because economic growth theory has been primarily concerned with changes in value added during the process of development, the standard models have not taken explicit account of materials processing in production. Of course, it is not difficult to make the appropriate modifications, at least in an approximate, aggregative way. Suppose that the standard profit function of the firm is re-written as:

(1) $\Pi_j = r_j Q_j(R_j, T_j) - s'_j N_j - v'_j R_j$

where Π_j = The profit level of the jth firm

r_j = The market price of its product

$Q_j(R_j, T_j)$ = Some specification of the production function, allowing for an adjustment for the state of technology (T_j)

s_j, v_j = Vectors of prices of intermediate and primary inputs, respectively

N_j, R_j = The associated input vectors.

Under the assumption that N_j is the optimum intermediate input vector (and that materials use exhibits constant returns to scale), we have

(2) $N_j = \alpha_j Q_j$

where α_j is the vector of appropriate input-output coefficients

Thus, the profit function becomes

$$(3)\quad \Pi_j = r_jQ_j\,(R_j,\,T_j) - s'_j\,\alpha_jQ_j\,(R_j,\,T_j) - v'_jR_j$$

$$= \left[r_j - s'_j\alpha_j\right]\,Q_j\,(R_j,\,T_j) - v'_jR_j$$

or, if we calculate a "net price,"

$$P_j = r_j - s'_j\alpha_j$$

we have the usual profit function:

$$(4)\quad \Pi_j = P_jQ_j\,(R_j,\,T_j) - v'_jR_j$$

The incorporation of material inputs in this way makes it clear why they are not usually given explicit attention. If α_j is a disembodied parameter which does not vary, then it has no effect on any of the standard results in production theory. The assumption of constancy in α_j is worrisome, however, since its immediate corollary is that efficiency of materials use (or "use efficiency", as it will subsequently be called) does not vary across economies at different levels of development.[1] A modest extension of the notion of X-efficiency leads us to the suspicion that this corollary is not defensible. At least three plausible reasons can be cited for assuming relative inefficiency of materials handling in LDC's: Two pertain to the internal state of the firm, while the third involves its linkage with the economy.

Within the firm, relative inefficiency of materials handling by operatives seems a natural correlate of lower levels of industrial discipline and

1. Although the focus here is on relative national efficiency levels, the same argument obviously applies to intertemporal differences for one economy and to differences between regional sub-economies.

skill.[1] Workers in an LDC firm may be less likely, on average, to find ways of "cutting corners" which economize on materials use. At the same time, relatively low levels of management skill may combine with the relative lack of labor discipline to produce higher rates of degradation of input inventories (e.g., rusting of stockpiled metal, spoilage of agricultural inputs).[2]

This inventory problem seems likely to be compounded by a general state of transactional inefficiency in the economy. With communications and transport infrastructure poorly developed, the timing of materials deliveries can become very uncertain. The steady drawing down of inventories by production requirements and a stochastic delivery response pattern suggest enlarged input stockpiling as a reasonable precaution.[3] At a constant rate of inventory

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1. For substantial anecdotal evidence on this score, see A.O. Hirschman, Development Projects Observed (Washington, 1967), particularly Chapter 3. Hirschman's recommendation of investment in processes which minimize "latitude" (i.e., discretion in maintenance, etc.) is based on his assertion that LDC's suffer from a relative lack of labor discipline. More systematic evidence can be found in C.F. Diaz Alejandro, "Industrialization and Labor Productivity Differentials," Review of Economics and Statistics (May, 1965), pp. 207-14, as well as C. Clague, Economic Efficiency in Peru and the United States (unpublished Ph.D. Thesis, Harvard, 1966).

2. A general discussion of the management problem from the perspective of X-efficiency can be found in H. Leibenstein, Beyond Economic Man - A New Foundation for Microeconomics (Cambridge, 1976), Chapter 3. L.J. White has recently extended Leibenstein's argument by proposing a supply curve of entrepreneurial effort, with the choice of effort level (and therefore profitability) reflecting the opportunity cost of leisure time. White's argument can apply only to non-competitive sectors, of course. See L.J. White, "Appropriate Technology, X-Inefficiency, and a Competitive Environment: Some Evidence from Pakistan", Quarterly Journal of Economics (November, 1976), pp. 575-589. Additional evidence can be found in F.H. Harbison, "Entrepreneurial Organization as a Factor in Economic Development", QJE (May, 1962) pp. 303-316. See also "ILO Productivity Missions to Underdeveloped Countries", Parts I and II, International Labor Review, (July, and August, 1957), pp. 1-29, and 139-166, respectively.

3. For a systematic discussion of the phenomenon of inventory buffering under conditions of uncertainty, see J. Emery, Organizational Planning and Control -- Theory and Technology, (unpublished Ph.D. Thesis, MIT, 1967).

degradation (and, as previously noted, it may well be higher in LDC's) material inputs should naturally be "used up" at a higher rate in the process of production.

Hopefully, this general line of argument has a certain plausibility. It can be enhanced by recognizing the possibility of substitutability among all inputs, including materials.[1] Since the relative price of advanced vintages is high, reflecting the higher quasi-rents which they capture in the industrialized economies, the competitive result for LDC's should be the choice of equipment which is less materials-efficient.[2]

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1. Recent work with estimation of translog production functions in "gross output" form (most notably KLEM (capital, labor, energy, materials) models) has reinforced this notion, at least for the industrial economies. Results from the estimation of an aggregate manufacturing production function for the postwar American economy suggest that materials have a small but positive cross-price elasticity of demand with respect to capital. While capital and materials should thus be thought of as weakly substitutable in production, the same results suggest that labor and materials should best be thought of as weakly complementary. See E.R. Berndt and D.O. Wood, "Technology, Prices, and the Aggregate Production Function," Review of Economics and Statistics (August, 1975), pp. 259-268.

2. It may well be that the choice of less-efficient vintages by competitive LDC firms is also an indirect reflection of X-inefficiency. Suppose for example, that the elasticity of substitution between capital and materials varies directly with the industrial discipline and experience of the labor force, reflecting the ability of the latter to insure adequate maintenance and handling of advanced equipment. In such a case, the tendency to opt for use-inefficient processes would be compounded in LDC's. This "generalized learning" by workers seems to be attracting increasing attention as a major source of technical progress, with apparent augmenting effects on both labor and capital. For particularly impressive recent evidence, see G.R. Saxonhouse, "Productivity Change and Labor Absorption in Japanese Cotton Spinning, 1891-1935," Quarterly Journal of Economics (May , 1977), pp. 195-219.

The relative price structure should also push the choice toward labor-intensity, with the attendant X-efficiency problems mentioned previously.[1]

For several reasons, then, a positive relation between use efficiency and level of development may exist. If the validity of the argument is provisionally accepted, then two questions immediately arise: (1) Can the existence of variable use efficiency be demonstrated empirically? (2) If its existence can be convincingly demonstrated, is it of any practical importance? In order to motivate the econometric work properly, it seems appropriate to attempt answers to these questions in reverse order.

The practical importance of variable use efficiency lies in its implication for the resource requirement estimates which underlie the determination of optimal investment strategies. If LDC production is less efficient, then borrowed coefficients will underestimate local materials requirements and all planning exercises which rely on the estimation of

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1. Where competition is weak, of course, this result will not necessarily be produced. Recent work by L.J. White suggests that capital intensity varies with degree of market power in Pakistan, reflecting the desire of entrepreneurs for the latest equipment and a simultaneous distaste for time spent on labor relations. S.A. Morley and G.W. Smith cite similar evidence from Brazil, with an emphasis on the tendency of multinationals to stay close to the capital-intensities characterizing their domestic operations. Since newer capital vintages generally have superior use efficiency, their employment in protected sectors may partially offset the X-efficiency factors mentioned previously. This question will be raised again in the discussion of results. See L.J. White, op. cit., and S.A. Morley and G.W. Smith, "Limited Search and the Technology Choice of Firms in Brazil," Quarterly Journal of Economics (May, 1977), pp. 263-287. It should be noted that neither set of results is very conclusive.

total (i.e., direct-indirect) primary resource needs will be affected in systematic ways. Two standard exercises will be employed as illustrations.

Consider first the estimation of total primary resource requirements coefficients for an LDC economy whose input-output matrix contains unadjusted production vectors borrowed from an advanced economy. Let the complete matrix be specified as

$$D = \begin{bmatrix} A \\ \hline M \\ \hline V \end{bmatrix}$$

where A = The matrix of direct input-output coefficients.

M = The matrix of direct import coefficients.

V = The matrix of primary input coefficients.

Since it is the distortion inherent in non-adjustment of transferred coefficients which is of primary interest, some additional definitions are convenient:

$$\tilde{A} = AT$$

$$\tilde{M} = MT$$

$$\tilde{R} = V'(I-\tilde{A})^{-1}$$

$$R = V'(I-A)^{-1}$$

where $\tilde{A}$ = The A matrix adjusted for use efficiency effects.

$\tilde{M}$ = The import coefficients matrix, similarly adjusted.

T = A diagonal matrix of adjustment coefficients such that

$$t_{ii} = \begin{cases} 1 & \text{If the column } i \text{ of } A \text{ has been calculated from local data.} \\ 1+\gamma & \text{If the column has been borrowed from a more developed economy.} \end{cases}$$

R = The matrix of primary resource multipliers (and $\tilde{R}$ is the adjusted matrix).

A comparison of adjusted primary resource multipliers with their unadjusted counterparts yields the conclusion that the former will generally be larger:

$$\begin{aligned}
(5)\quad \tilde{R} - R &= V' \left[(I - \tilde{A})^{-1} - (I - A)^{-1} \right] \\
&= V' \left[(I - AT)^{-1} - (I - A)^{-1} \right] \\
&= V' \left[(I + AT + (AT)^2 + \ldots) - (I + A + A^2 + \ldots) \right] \\
&= V' \left[A(T - I) + \left[(AT)^2 - A^2 \right] + \ldots \right] \\
&= V' \left[W \right]
\end{aligned}$$

Since all elements in the matrix W are non-negative, this must also be the case for the matrix $\left[\tilde{R} - R\right]$. Thus, planning exercises which use the unadjusted matrix of total multipliers to project resource requirements for pre-specified final demand targets will generally understate the ultimate use of primary resources.

Similarly, import requirements will be understated. As a result, the standard calculation of sectoral domestic resource costs will also underestimate the true cost in every case.[1] Let the following definitions hold:

$\rho = i'KR$

where ρ = The vector of primary resource values per unit of output (by sector), with all primary resources valued at appropriate shadow prices.

K = A diagonal matrix of shadow prices.

i = A unit vector of appropriate dimension.

$m = i'LM'(I-A)^{-1}$

where m = The vector of total value of imports (in domestic currency) by sector.

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1. For a detailed discussion of domestic resource cost analysis, see M. Bruno, "Domestic Resource Costs and Effective Protection: Clarification and Synthesis", JPE (Jan./Feb. 1972), pp. 16-33. A detailed application of the method can be found in M. Bruno, Interdependence, Resource Use and Structural Change in Israel (Jerusalem, 1962).

L = A diagonal matrix of import prices (in domestic currency).

From (5) above, it can be established that $\tilde{\rho} \geqq \rho$

(6) $\tilde{\rho} - \rho = i' K(\tilde{R} - R)$, where all elements of the matrix $\left[K(\tilde{R} - R) \right]$ are non-negative.

Similarly, $\tilde{m} \geqq m$ since

(7) $\tilde{m} - m = i'LM'W$

and LM'W contains only non-negative elements.

For any sector i, the standard DRC calculation is:

(8) $d_i = E\left(\dfrac{\rho_i}{q_i - m_i}\right)$

where E = The official exchange rate (in units of domestic currency per unit of foreign exchange)

q_i = The ratio of f.o.b. price to domestic market price (both expressed in local currency)

ρ_i and m_i are as previously defined.

Since $\tilde{\rho} \geqq \rho$ and $\tilde{m} \geqq m$, it is clear that $\tilde{d}_i \geqq d_i$ (adjustment simultaneously increases the numerator and decreases the denominator of the expression). Sectoral DRC calculations using unadjusted input-output vectors are likely to be over-optimistic, with an added risk of error if some arbitrary level is employed as the cut-off criterion for project choice. In addition, of course, the possibility of large variation in the use efficiency effect across sectors casts the entire validity of unadjusted DRC calculations into doubt.

III. The Measurement of Use Efficiency Effects

Specification

In theory, the specification of a model for testing the presence of use efficiency effects should present no great difficulty. Since the transferability of input-output coefficients is in question, the appropriate model could be drawn from Diewert's generalization of the Leontief production function.[1] An adequate specification would relate unit materials input demand (i.e., the materials use ratio) to the relative product price, the relative prices of other inputs, and some index of development level. Unfortunately, data limitations in the present case have forced the adoption of a very degenerate form of the function which relates the materials use ratio only to the level of development. Obviously, the omission of all other variables from the equation raises the risk of serious specification bias. Because the potential magnitude of this bias is central to the interpretation of the regression results, it seems appropriate to show precisely how the simple equation to be employed here relates to the full specification of the materials input demand function.

Let the profit function which is dual to the generalized Leontief production technology be specified as:

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1. See W.E. Diewert, "An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function," Journal of Political Economy (May/June, 1971), pp. 481-507, and "Functional Forms for Profit and Transformation Functions", Journal of Economic Theory, (June, 1973), pp. 284-316.

$$(9)\quad \pi(\rho,\omega) = \delta_{oo}\rho + 2\sum_{i=1}^{n} \delta_{oi}\rho^{1/2}\omega_i^{1/2} + \sum_{i=1}^{n}\sum_{j=1}^{n} \delta_{ij}\omega_i^{1/2}\omega_j^{1/2} + \beta_m\omega_m y$$

where ρ = the product price

ω_j = the price of the jth input

β_m = a linear measure of the "materials-augmenting" (i.e., use efficiency) effect of development level.

y = some index of development level.

This specification allows for cross-country differences in choice of technique by individual firms at the same point in time, with the choice determined by relative prices and use efficiency.[1] If inputs are defined in general terms as capital (K), labor (L), and materials (M), the appropriate form of the materials demand function follows from Hotelling's Lemma:[2]

$$(10)\quad D_m(\rho,w) = \frac{-\partial\pi(\rho,w)}{\partial w_m} = \alpha_{mm} + \alpha_{om}(\rho/w_m)^{1/2} + \alpha_{km}(w_k/w_m)^{1/2} + \alpha_{\ell m}(w_\ell/w_m)^{1/2} + \beta_m y$$

This can be regarded as a generalization of the unit demand function which allows for an adjustment of α_{mm} (the aggregate materials use ratio). As previously noted, it is not possible to estimate most of the parameters of (10) with the available data. For econometric work, it has been necessary to adopt the following grossly simplified function:

$$(11)\quad D_m = \frac{M}{Q} = \alpha_{mm} + \beta_m y$$

where M = total material inputs

Q = total output

1. (9) is an adaptation of the conventional Diewert profit function, which would allow for linear augmentation due to technical progress for all inputs. In standard econometric work, derived input demand functions are estimated from time series and it is sensible to allow for augmentation in all factors. Here the approach is cross-sectional; all current production techniques are assumed to be everywhere available, but countries differ by a scaling factor (β_m) whose value reflects the X-efficiency factors discussed on pp. 4-5.

2. See W.E. Diewert, op. cit. In the function which follows, α is substituted for $(-\delta)$ in each case as a notational convenience.

Some discussion of specification bias is obviously appropriate here. Among the exclusion restrictions, the dropping of (ρ/ω_m) from the equation seems the least damaging for estimation of β_m. The ratio (ρ/ω_m) will vary across countries as differences in transport costs and rates of protection affect both its numerator and denominator. The net effect of these differences has no apparent correlation with y, however. The same cannot be said, of course, for the input price ratios which are also excluded from the equation.[1] They are likely to be highly correlated with y, so that some bias in the estimate of β_m must result from their exclusion. Fortunately, this effect may not be very great. Recent evidence from translog production functions estimated for manufacturing in the U.S. suggests that the cross-price elasticities of demand for materials with respect to capital and labor are quite small and opposite in sign.[2] If these results are acceptable as evidence in the current context, the immediate implication is that (11) may come quite close to providing an unbiased estimate of β_m.

Even if significant bias in the estimate of β_m is possible under specification (11), the problem is of more theoretical than practical importance.

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1. A detailed description of the data can be found in the next section. The basic problem is the measurement of wages and profits in national prices which incorporate sector-specific protection rates. Appropriate adjustments for these rates are not available for most of the countries and sectors included in the study.

2. See E.R. Berndt and D.O. Wood, op. cit. For American manufacturing, their results suggest that labor and materials are best regarded as complements in production while capital and materials are substitutes. If the previously-discussed results obtained by G. Saxonhouse can be generalized, the elasticity of substitution between capital and materials would be even smaller in LDC's under competitive conditions. (See G. Saxonhouse, op. cit.)

Bias is present because of the significant co-variation of factor price movements and development level. But since it is the total effect of development level on input-output vectors which matters for planning exercises, even an estimate of β_m which "absorbs" the net effect of factor price differences is of interest.

The Data

The best data currently available for a cross-sectional analysis of use-efficiency come from a survey of several hundred manufacturing establishments in eleven countries taken by UNIDO during the mid-1960's. From the published data, 497 observations spanning 25 three-digit SIC categories were selected as appropriate for econometric work. All sectors with fewer than 4 observations were excluded, as were sample entries which were identified with more than one three-digit SIC category simultaneously (Tables 1 and 2 tabulate the selected observations by country and manufacturing sector). For the purposes of this study, only measures of material inputs, total output, and some index of development level [M, Q and y, respectively, in (11)] were necessary. The usual measurement and aggregation problems necessitated the use of total material input value and value of output as reported by the UNIDO survey. The level of development was indexed by the level of national GDP per capita (in 1970 U.S. dollars) prevailing during the year of each plant observation.[1]

Obviously, these numbers are all very rough and aggregative. Although the UNIDO data are as good as could realistically be hoped for, several potential sources of measurement bias must be taken into account before any conclusions about measurable use efficiency effects can be drawn. First,

1. A simple exchange rate conversion was used for the translation of all GDP's to U.S. dollar values.

Table 1

Observations by Sector and Country

		202	203	205	207	231	232	243	251	271	291	300	311	312	313	319	331	332	334	339	341	342	350	360	370	383	385
	TOTALS	(17)	(6)	(19)	(14)	(46)	(12)	(17)	(16)	(14)	(4)	(14)	(34)	(11)	(14)	(32)	(13)	(8)	(18)	(19)	(15)	(17)	(53)	(47)	(35)	(10)	(13)
E. Africa	(14)	-	-	2	-	4	1	1	1	-	-	-	-	1	-	1	-	-	1	-	-	-	2	-	-	-	-
El Salvador	(6)	-	-	-	-	2	1	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Mid. Europe	(58)	2	2	3	-	2	1	4	2	2	-	2	2	1	2	3	2	1	4	2	-	1	5	7	6	1	1
Mexico	(45)	1	1	1	2	4	-	-	2	2	1	1	8	1	1	3	1	2	-	-	1	1	4	4	2	1	1
France	(54)	4	-	-	2	5	-	2	2	1	1	1	2	-	2	-	-	1	2	3	2	6	8	7	2	1	-
India	(104)	3	1	2	2	9	2	-	2	3	-	5	7	2	4	11	4	-	5	3	4	3	9	8	9	1	5
Israel	(60)	3	2	4	1	8	1	-	3	-	1	1	6	-	2	2	2	-	2	5	-	1	6	4	3	3	-
Yugoslavia	(108)	4	-	4	5	9	5	6	2	3	1	3	7	3	1	6	4	3	3	4	1	4	9	9	8	1	3
Japan	(52)	-	-	3	2	2	1	-	2	2	-	-	2	3	2	3	-	-	-	2	7	1	9	6	1	1	3
So. Europe	(6)	-	-	-	-	1	-	3	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-
Iran	(11)	-	-	-	-	-	-	-	-	-	-	1	-	-	-	2	-	1	1	-	-	-	-	2	3	1	-

Source: Profiles of Manufacturing Establishments, UNIDO, Vols. I, II, III.

Table 2

Sector Key

202	-	Dairy Products
203	-	Food Canning
205	-	Grain Mill Products
207	-	Sugar Refineries
231	-	Spinning, Weaving, and Finishing Textiles
232	-	Knitting Mills
243	-	Wearing Apparel
251	-	Wood Mills
271	-	Pulp, Paper, and Paperboard
291	-	Leather Products
300	-	Rubber Products
311	-	Chemical Fertilizers and Basic Industrial Chemicals
312	-	Vegetable and Animal Oils and Fats
313	-	Paints, Varnishes, and Lacquers
319	-	Matches, Medical Preparations, Soap and Detergents, Etc.
331	-	Bricks, Tiles
332	-	Glassware
334	-	Cement
339	-	Concrete, Asbestos, and Gypsum Products
341	-	Rolling, Drawing, and Casting of Ferrous Metals
342	-	Rolling, Drawing, and Casting of Non-Ferrous Metals
350	-	Manufacture of Metal Products (Other than Machinery and Transport Equipment)
360	-	Manufacture of Machinery, Non-Electrical
370	-	Manufacture of Electrical Machinery and Appliances
383	-	Manufacture and Assembly of Buses, Trucks, Truck-Trailers
385	-	Manufacture of Motorcycles and Bicycles

any comparison of measured input-output relations across countries seems immediately suspect, since there is a clear compositional shift within aggregate manufacturing sectors as level of development rises. If the ratios $(m_j = \frac{M_j}{Q_j})$ employed in the regression equations were calculated from aggregate input-output measures at the two-digit SIC level, this would indeed be a problem. Fortunately, the UNIDO survey was specifically designed to preserve intrasectoral comparability across countries. Similar production processes identified at the plant level have been observed and recorded. Compositional shift is not, therefore, an important source of measurement bias.[1]

Unfortunately, there is another regular shift in the pattern of manufacturing activity which careful sample selection cannot possibly remove. It is clear that the degree of vertical integration of production will be generally correlated with level of economic development. Firms in more sophisticated economies will sub-contract more of their operations, ceteris paribus. The result must be a rise in the value of intermediate inputs in relation to primary inputs with advances in the level of development.[2]

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1. It should be noted that important differences may persist, even when production processes are similar. If the latest technology has been employed in non-competitive LDC firms (see the discussion on p. 5) one result may be a more highly-refined product, even when the same raw materials are used as inputs. To the extent that this phenomenon exists in a particular sector and country, it will be a source of downward bias, since the market value of output per unit of input will be greater. It seems likely that the problem would be most acute for LDC economies with heavy multinational representation. Fortunately, a large number of observations for this study are provided by India, which does not have such heavy representation.

2. J.R. Harris has pointed out that no such monotonic relationship may be detected when actual plants are observed, because plants in LDC's may well be owned by multinational firms which have vertically-integrated international operations. This source of upward bias will thus co-exist with the source of downward bias mentioned in footnote (1), with uncertain consequences. Again, the presence of a large number of Indian firms in the present sample is reassuring.

While vertical integration effects interfere with the use of the ratio m_j as a basis for measuring use efficiency effects, they are probably not as serious as the other major source of error - the use of national prices in calculating input and output values. Measured values of m_j for a specific country will incorporate the effects of market distortions which are unique to that country. Two results are of consequence for this study. First, the omnipresence and magnitude of distortion effects, especially for poor countries, might be sufficient to "wash out" all meaningful sources of variation in the data by introducing an overwhelmingly dominant error component. If this were the case, no meaningful econometric results could be obtained.[1]

Even if market-distortion effects are not large enough to be fatal for statistical work, they are readily identifiable as another source of measurement bias. The measured proportion of value added (and therefore of intermediate inputs) in value of output must incorporate those distortions which, taken together, constitute the effective rate of protection. The available evidence suggests that the general level of effective protection is inversely related to level of economic development. But as the effective rate of protection declines, so does the proportion of output value accounted for by value added. As a consequence, the presence of the effective rate of protection in the valuation of all inputs and outputs in national prices must introduce another component of positive correlation between the measured m_j

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1. In principle, distortion effects could be eliminated by re-valuing all inputs and outputs with a consistent set of international prices. Unfortunately, the cataloguing of specific inputs in the UNIDO survey has been done very inconsistently. Sometimes very detailed information is provided; sometimes whole groups of inputs are lumped together and given an aggregate value. Re-valuation under such conditions did not seem worth the immense time and effort which would have been required. In any case, distortion effects did not turn out to be a serious problem for estimation.

and measured level of economic development.

It is clear, then, that the use of m_j with numerator and denominator both valued in national prices cannot yield parameter estimates which are unambiguous measures of use efficiency adjustments. However, the measurement biases which have been identified impart a positive bias to the relationship.[1] This is extremely fortunate, since it suggests that a measured negative association between development level and m_j would reflect differences in use efficiency.

Some Estimates

The regression results which follow are presented sequentially, with a test for the existence of a general use-efficiency effect followed by an attempt to identify efficiency effects by sector. In the concluding section, a more detailed analysis of covariance is employed in an attempt to distinguish between the general effect of development level on use efficiency and the effect of purely national differences.[2]

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1. An exception is the product-refining effect of advanced technology, mentioned on the previous page. Since this effect is matched by an opposite vertical-integration effect and must be absent from most of the Indian plants in any case, it may not be important. It does remain a source of ambiguity, however.

2. It seems appropriate to discuss the problem of outliers at this point. As a basis for identifying outliers among the calculated m_j's, means and standard errors for individual sector input ratios were estimated in a first pass through the data. Fortunately, the presence of price-distortion effects did not turn out to be very damaging. The pattern was in all cases a very ordered one, with tight sampling distributions and readily-observable differences in mean ratios across sectors. The general rule adopted for the exclusion of outliers was simply the elimination of all estimated sector ratios whose distance from the sample mean was greater than .30. Since the standard error estimates were almost all clustered around .05, the exclusion procedure resulted in the elimination of ratios located more than 6 standard errors away from their sector means. Clear exceptions to the general pattern were presented by sectors 331, 332, and 334. For these cases the general exclusion rule was not appropriate, but an examination of the data for the three sectors confirmed that no reasonable rule for exclusion would have eliminated any measured ratios from the sample.

a. Generalized Effect of Development Level on Materials-Use Ratio

It is useful here to recall the simplified specification of the material demand function which serves as the basis for measuring use-efficiency effects:

$$(11) \quad m_j = \alpha_{mm} + \beta_m y$$

At the most general level, this specification translates to the following regression equation:

$$(12) \quad m_{ijk} = \alpha_o + \sum_{j=1}^{25} m_j I_j + \beta y_k + \varepsilon_{ijk}$$

where m_{ijk} = direct materials input ratio for plant i in industry j, located in country k

$$I_j = \begin{cases} 1 \text{ if industry } j \\ 0 \text{ otherwise} \end{cases}$$

y_k = real per capita GDP in country k

In (12), the coefficients of the dummy variables are simply shift parameters which correct the observed ratio for industry effects. Of more particular interest in the current context is β, the general development parameter which should measure net efficiency effects. For equation (12) estimated on the full sample, the estimate of β is -.0372, with a standard error of .0085 (y_k is measured in thousands of 1970 U.S. dollars). It seems clear that the hypothesis that level of GDP has no effect on the average materials input ratio can be rejected with 99% confidence. The coefficient has the expected sign.

According to this result the most likely effect of GDP on the input ratio is a decline of approximately .037 per $1,000 rise in real GDP per capita. Since the sampled countries span a broad income spectrum (from a 1966 GDP value of $90.00 for India to $2,376.00 for France), this result suggests that a very substantial average mark-up for efficiency loss is appropriate when poor countries borrow rich-country coefficients. The average mark-up in the case of Indian borrowing of French input-output vectors would be .08, or approximately 19% of the predicted French average. The fact that this strong efficiency effect is observable in spite of integration and price distortion effects pushing in the other direction suggests that the real effect must be very strong indeed.

b. Industry-Specific Effect of Development Level on Materials-Use Ratio

Although the general impact of development level on use efficiency seems clearly present, the pattern of impacts across sectors is of substantial interest. It may well be the case that these impacts are much more strongly apparent in some sectors than in others. The possibility of differential industry effects can be examined by estimating the following simple equation, industry-by-industry:

$$(13)\ m_{ik} = \beta_{oi} + \beta_{1i} y_k + \varepsilon_{ik}$$

This has been done for all industries in the original sample, and the results are presented in Table 3. They suggest that level of development has a very different impact on materials use in different sectors. In 18 of the 25 sectors examined, the most likely adjustment for GDP increase is downward,

Table 3

Input Ratio Correction Estimates

Industry	Degrees of Freedom	β_o (Limiting Ratio Value) [a]	β_1 (Adjustment per $1,000 GNP/capita)
202 Dairy Products	15	.66 (.08) [b]	.019 (.049)
203 Food Canning	4	.49 (.11)	-.063 (.086)
205 Grain Mills	17	.82 (.07)	-.009 (.057)
207 Sugar Refineries	21	.55 (.07)	.006 (.059)
231 Spinning, Weaving Mills	44	.51 (.05)	.005 (.030)
232 Knitting Mills	10	.46 (.07)	-.057 (.073)
243 Wearing Apparel	15	.62 (.07)	-.075 (.050)
251 Wood Mills	14	.46 (.07)	.048 (.053)
271 Pulp, Paper, Paperboard	12	.39 (.06)	.051 (.052)
300 Rubber Products	11	.40 (.05)	-.071 (.049)
311 Fertilizers, Industrial Chemicals	32	.40 (.05)	.015 (.042)
312 Vegetable, Animal Oils	9	.72 (.08)	-.016 (.088)
313 Paints, Varnishes, Lacquers	12	.58 (.07)	-.025 (.053)
319 Light Consumer Chemicals	31	.42 (.05)	-.053 (.042)

Table 3 (cont.)

Industry	Degrees of Freedom	β_o (Limiting Ratio Value) [a]	β_1 (Adjustment per $1,000 GNP/capita)
331 Bricks, Tiles	11	.30 (.09)	-.120 (.090)
332 Glassware	6	.28 (.08)	-.121 (.111)
334 Cement	16	.10 (.06)	-.019 (.038)
339 Concrete, Asbestos, Gypsum Products	17	.55 (.06)	-.143* (.040)
341 Ferrous Metal-Working	13	.47 (.06)	-.002 (.050)
342 Non-Ferrous Metal-Working	15	.49 (.07)	.040 (.041)
350 Metal Products	51	.56 (.04)	-.067* (.024)
360 Machinery (Non-Electrical)	45	.50 (.05)	-.076* (.026)
370 Machinery (Electrical)	33	.58 (.05)	-.074* (.036)
383 Buses, Trucks, Trailers	8	.60 (.10)	-.068 (.073)
385 Motorcycles and Bicycles	11	.64 (.07)	-.087 (.077)

* Indicates rejection of the standard null hypothesis with 95% confidence.

[a] Literally, the predicted materials-use ratio at a per capita GDP of zero. The lowest per capita GDP figure actually in the sample is $90.00 for India.

[b] Estimated standard errors are in parentheses

while the opposite is true for the remaining 7. In most cases, degrees of freedom are simply too limited to draw any strong inferences from the results.

In only one major industrial area are ample degrees of freedom available -- the production of metal products (350) and machinery, both non-electrical and electrical (360 and 370, respectively). Here the sample estimates are a good deal tighter, and the effect of GDP level on use efficiency seems unambiguously present. The same is true for concrete, asbestos, and gypsum products (339). In the case of several other industrial categories (203, 232, 243, 300, 319, 331, 332, 383, 385) the most likely estimates of the appropriate downward correction factors are quite large, although the probability distributions are too diffuse for much confidence to be placed in them.

Generally, then, we can be very confident about these sectoral results only in the case of metal products and machinery. The results also suggest that a sizable correction should be applied for the production of clothing, construction materials and transport equipment. Among those for which correction in the opposite direction is suggested by the results, the correction is of noticeable size only for sectors 251, 271, and 342.

The general impression which emerges from these results is that efficiency impact is a highly variable phenomenon. In some sectors, it seems quite substantial. In others, it is either very weak or obscured by the presence of the natural upward measurement biases which were previously discussed. While it is possible that such biases are instrumental in producing the seven "perverse" results reported above, there is no way to be sure about this. Thus, it is somewhat comforting to note that all seven estimates are smaller than their own standard errors.

c. Distinguishing Between Industry-Specific and Country-Specific Effects

The disproportionate representation of some countries in the sample drawn for this survey (see Table 1) must be considered in evaluating the results which have been presented thus far. The weight of India is particularly large, and it is relevant to ask whether or not the estimated efficiency drop at low income levels may not in fact be a reflection of some particular pattern of Indian inefficiency. This is a potentially crucial weakness in the argument that efficiency effects are distinguishable from other effects in the sample of factories, and an attempt has been made to examine the question empirically. Since substantial degrees of freedom are necessary for this exercise, only the data for sectors 231, 311, 350, 360, and 370 have been employed. For these sectors, an attempt has been made to see whether a GDP effect remains discernible after correction for specific national effects in the case of the six countries (France, Israel, India, Yugoslavia, Japan, and "Middle Europe") which dominate the sample. Table 4 presents the results for a simple equation which tests for GDP effects by industry while allowing for all-industry national correction effects through the use of appropriate dummy variables. Among the countries, only Yugoslavia seems to warrant a significant adjustment. Surprisingly, the most likely adjustment for Indian industry is downward, although the sampling distribution is too diffuse for any inferences to be drawn (since India is about equally represented in the five sectors, the observed downward correction cannot be a disguised industry effect).

Table 4

Distinguishing Industry and Country Effects: Simple Model

Sector	Industry Constant	GDP Adjustment	Country Adjustments: India	Israel	Yugoslavia	Mexico	France	Japan
231	.545* (.04)	-.025 (.037)						
311	.439* (.05)	-.021 (.050)						
350	.600* (.04)	-.095* (.035)	-.013 (.036)	.023 (.032)	-.068* (.033)	-.037 (.043)	.021 (.043)	.016 (.036)
360	.539* (.05)	-.106* (.034)						
370	.599* (.05)	-.088* (.038)						

*Denotes rejection of the standard null hypothesis with 95% confidence.

Table 5

Distinguishing Industry and Country-Specific Effects

Sector	231	311	350	360	370
Constant	.414*	.383*	.674*	.475*	.695*
	(.06)	(.07)	(.07)	(.08)	(.07)
GDP Adjustment	.050	.064	-.153*	-.031	-.156*
(per $1,000/GDP/cap.)	(.041)	(.069)	(.059)	(.053)	(.049)
India	.138*	.105	-.066	.057	-.119
	(.069)	(.090)	(.075)	(.087)	(.067)
Japan	-	-	-.022	-.046	-
	-	-	(.055)	(.063)	-
France	-	-	.099	-.077	-
	-	-	(.087)	(.092)	-
Yugoslavia	.067	-.090	-.161*	-.018	-.154*
	(.060)	(.070)	(.063)	(.073)	(.068)
Middle Europe	-	-	-	-.118	.065
	-	-	-	(.069)	(.072)

Simple Correlation Matrix

	231	311	350	360	370
India	-.04	-.01	-.053	-.04	.12
Japan	-	-	.31	.29	-
France	-	-	.70	.45	-
Yugoslavia	.10	.15	.07	.09	.15
Middle Europe	-	-	-	.49	.67

* Denotes rejection of the standard null hypothesis with 95% confidence.

While country effects do not appear particularly important, industry specific GDP adjustments are again obviously present. A potentially more powerful test of the distinguishability between industry and country effects can be provided by estimating industry-specific effects for GDP and countries, taken together. The results are presented in Table 5. Country dummy variables are included in the regressions only where warranted by the available number of observations.

These results suggest strongly that country effects do not explain the results which have been obtained. Industry-specific country effects appear to enter somewhat randomly. India and France, which appear at opposite ends of the per-capita GDP distribution, exhibit no particular tendency once GDP effects are taken into account. The estimate of efficiency adjustment for sectors 231 and 311 becomes positive (but not significantly so) in the results. A strong effect is still observable for sectors 350 and 370, while it is clear that the heightened uncertainty in the estimate for sector 360 is due to a high degree of collinearity with the dummy variables for France and Middle Europe.

IV. Conclusions

None of the results which have been examined have cast much doubt on the original proposition -- that economic development can foster substantial use efficiency effects. The fact that industry-specific effects show up in 18 of 25 sectors sampled despite countervailing measurement bias suggests that they are quite strong, and particularly so in metals production and the manufacture of machinery. The possibility remains that the observed negative association is due solely to the exclusion of the price of capital services from the model, although it seems doubtful that misspecification can be the only explanation. Even if this is the case, the causal link between GDP level and use efficiency remains unbroken, since substitution toward materials-intensive production processes in LDC's will simply reflect the opportunity cost of the newest vintages. Whatever its cause, the size of the indicated adjustment for several sectors should be of interest to practicing planners. When planning exercises are forced to employ many input-output vectors borrowed from advanced economies, the credibility of the results may depend on some attempt to compensate for this phenomenon.

Appendix A: A Simple Adjustment Methodology

In the regression equations estimated for this study, the following linear relation is specified:

(1a) $m_j(y) = \overline{m}_j - \beta_j\,(y)$

where y = some index of development level

β_j = the appropriate adjustment factor

$\overline{m}_j$ = the "minimum efficiency" level of $m_j(y)$ (i.e., the use-efficiency which characterizes the poorest existing economy).

Suppose that a country at development level y_1 borrows the jth vector of intermediate input coefficients from a country at level y_2. Generally we have:

$$m_j(y_1) = \overline{m}_j - \beta_j(y_1)$$

$$m_j(y_2) = \overline{m}_j - \beta_j(y_2)$$

If an estimate of β_j is available, then the appropriate correction factor is

(2a)
$$\hat{\gamma}_j = \frac{\hat{m}_j(y_1)}{\hat{m}_j(y_2)} = \frac{\overline{m}_j - \hat{\beta}_j(y_1)}{\overline{m}_j - \hat{\beta}_j(y_2)}$$

In effect, $\hat{\gamma}_j$ is a common multiplier which can be used to correct all the elements (a_{ij2}) of the borrowed vector simultaneously:[1]

---

1. The following adjustment for individual coefficients clearly depends on the assumption that physical input ratios stay constant. Note that

$$a_{ij1} = \hat{\Pi}_j a_{ij2} \rightarrow \sum_i a_{ij1} = \hat{\Pi}_j \sum_i a_{ij2}$$

but the converse (which we are employing) is not necessarily true.

(3a) $a_{ij1} = \hat{\Pi}_j a_{ij2}$

Table A (1) presents the more pronounced input-ratio adjustments which would be appropriate if Bolivia were to borrow coefficients from an economy at a GDP level of $2,000 per capita. A striking pattern emerges in the case of most of these corrections. With the exception of the cases of sectors 334 and 339, the mark-ups cluster rather tightly around 30%.

Table A (1)

Materials Input Adjustments in the Bolivian Case

SIC Sector [c]			Western European Ratio[a]	Adjusted Bolivian Ratio[b]	% Upward Adjustment
(6)	203	Food Canning	.36	.48	33.3
(12)	232	Knitting Mills	.35	.45	28.6
(17)	243	Weaving Apparel	.47	.60	27.7
(13)	300	Rubber Products	.41	.53	29.3
(32)	319	Consumer-Oriented Light Chemicals	.31	.41	32.3
(18)	334	Cement	.06	.10	66.7
(19)	339*	Concrete, Asbestos, and Gypsum Products	.26	.52	100.0
(53)	350*	Manufacture of Metal Products	.43	.55	27.9
(117)	360*	Manufacture of Machinery (non-electrical)	.35	.48	37.1
(35)	370*	Manufacture of Electrical Machinery and Appliances	.43	.56	30.2
(10)	383	Manufacture and Assembly of Buses, Trucks, Truck-Trailers	.47	.59	25.5
(13)	385	Manufacture of Motorcycles and Bicycles	.46	.62	34.8

[a]Ratios adjusted for an economy characterized by a per-capita income of $2,000 in 1970 U.S. dollars.

[b]Ratios adjusted for estimated 1974 Bolivian per-capita income of 230 in 1970 U.S. dollars.

[c]Number of observations in parenthesis.

*Denotes rejection of the standard null hypothesis on the adjustment parameter with 95% confidence.

Source: United Nations Statistical Yearbook

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