The strong factor-intensity assumption reconsidered

van Dijck, P.

1987

SERIE RESEARCH MEMORANDA

THE STRONG FACTOR-INTENSITY
ASSUMPTION RECONSIDERED

Pitou van Dijck

Researchmemorandum 1987-6 januari 87

VRIJE UNIVERSITEIT
FACULTEIT DER ECONOMISCHE WETENSCHAPPEN
A M S T E R D A M

THE STRONG FACTOR-INTENSITY ASSUMPTION RECONSIDERED

Pitou van Dijck

Economic and Social Institute
Free University of Amsterdam

THE STRONG FACTOR-INTENSITY ASSUMPTION RECONSIDERED*

INTRODUCTION

In this paper we test empirically the validity of the strong factor-intensity assumption. This assumption is of critical importance in analyses of comparative advantage in a multi-country, multi-product framework. It will be shown that the assumption does not perfectly hold in the real world and that this affects the outcomes of empirical studies of comparative advantage. Finally we show that a classification of sectors can be constructed that represents in a statistically significant way the ranking order of sectors in a large sample of countries.

THE STRONG FACTOR-INTENSITY ASSUMPTION

Trade theories have in common that they aim at establishing a link between characteristics of countries and characteristics of goods. They differ, however, in the selection of characteristics. The neo-classical theory distinguishes goods according to relative inputs of unskilled labour, physical and human capital. In Linder's theory goods are distinguished according to the level of domestic demand for them. Hufbauer distinguishes goods according to their technological sophistication with low-wage goods at one extreme and newly developed "high technology" goods at the other extreme. A similar kind of distinction is made in the product cycle theory in which goods are differentiated according to the degree of standardization of the production process.

For all theories of international trade it holds that a necessary precondition for a theoretically meaningful characterization of goods is that this characterization is independent of the location of production in the universe of countries. If products cannot be characterized in an unequivocal manner by factor inputs or some other characteristic, generalizations about what products to produce where, *i.e.* about an optimal distribution of the production of goods among countries, are impossible. For such a precondition to hold it is not necessary that production techniques are identical across countries, only that the order of ranking of goods according to factor inputs or some other characteristic is stable across countries. If ratios of factor inputs in production are dependent on factor prices, this implies that the ranking of goods according to factor input ratios is independent of factor-price ratios and underlying factor-availability ratios. This is the strong factor-intensity assumption.

By fits and starts, interest in this aspect of trade theory has revived since the study by Arrow, Chenery, Minhas and Solow on capital-labour substitution in CES production functions.[1] In a world with fixed technical coefficients, as is the case in Leontief-like analyses, or in a world with elasticities of factor substitution with value one, as is the case in the Cobb-Douglas model, the ranking of sectors of production according to factor intensities is identical in all countries, *e.g.* at all wage-interest ratios. Under such conditions interchanges in factor intensities of sectors do not occur: at all wage-interest ratios (w/i), the capital-labour ratio (K/L) of sector i is higher than of sector j. However, in a world in which sectors of production have different (constant) elasticities of substitution, interchanges in factor intensities of sectors, *i.e.* permutations in the order of ranking by factor inputs, may occur. If this is the case, the ranking of sectors according to the (K/L) ratio is not independent of the (w/i) ratio and sectors cannot be characterized as labour- or capital-intensive. Reversals of factor intensities of sectors may be a cause of the structure of trade being inconsistent with trade-theory hypotheses.

THE PHENOMENON OF CROSS-OVERS

Assume the production function takes the form

$$V = y[AK^{-\beta} + \alpha L^{-\beta}]^{-v/\beta} \quad (1)$$

in which V is value added, K and L represent the input of capital and labour respectively, A and α are distribution parameters, β is the substitution parameter, y the efficiency parameter and v the scale parameter. Assuming that factors are remunerated according to their marginal contribution to production, and furthermore assuming constant returns to scale ($v = 1$), we can estimate the constant elasticity of substitution according to

$$ln\ V/L = \alpha_0 + \alpha_1\ ln\ w \quad (2)$$

in which V/L is labour productivity and w is the wage rate. Defining $\alpha_1 = 1/\beta + 1$, we obtain the value of the elasticity of substitution. Given the wage rate w and interest rate r the optimal use of capital and labour in production is

$$\frac{w}{r} = \frac{\partial V/\partial L}{\partial V/\partial K} = \frac{\alpha(V/L)^{\beta+1}}{A(V/K)^{\beta+1}} = \frac{\alpha}{A}\ (\frac{K}{L})^{\beta+1} \quad (3)$$

and consequently

$$(\frac{K}{L}) = (\frac{w}{r}\ .\ \frac{A}{\alpha})^{1/\beta+1} \quad (4)$$

When estimating production functions for sector i and j, the cross-over point of two sectors, *i.e.* the point at which two sectors interchange their role of being labour-intensive and capital-intensive, is

$$ln\ (\frac{K}{L}) = \delta_i\ ln\ (\frac{w}{r}) + \delta_i\ ln\ (\frac{A_i}{\alpha_i}) = \delta_j\ ln\ (\frac{w}{r}) + \delta_j\ ln\ (\frac{A_j}{\alpha_j}) \quad (5)$$

$$ln\ (\frac{w}{r}) = \frac{1}{\delta_i - \delta_j}\ [-\ \delta_i\ ln\ (\frac{A_i}{\alpha_i}) + \delta_j\ ln\ (\frac{A_j}{\alpha_j})] \quad (6)$$

with $\delta = 1/\beta+1$.

Minhas demonstrates the empirical importance of potential cross-overs among sectors by estimating the values of A, α and $(1/\beta+1)$ for six manufacturing sectors. The values of the elasticity of substitution, estimated according to (2), lie in the range of 0.721 and 1.011. Comparison of the ranking of 20 industries in Japan and the USA, based on total, direct plus indirect, capital and labour inputs yields a Spearman rank correlation coefficient as low as 0.328. However, the correlation coefficient obtained from a comparison of only direct capital and labour inputs is as high as 0.730. It should be noted that Minhas' statement that the use of total coefficients is more appropriate than direct coefficients is not necessarily true and depends on the way imports are treated in the input-output table. From these findings Minhas concludes that "the nature of technology is not such as to exclude the possibility of reversals. On the contrary, the relative factor intensities do in fact change in response to different configurations of relative factor costs. Moreover, the phenomenon of goods that interchange their roles of being capital intensive seems to be general enough to be empirically important".[2]

In a review of Minhas' findings Leontief makes the following observations. First, as compared to the potential number of cross-overs the actual number is limited. Second, most actual cross-overs are among industries on curves very close to each other, *i.e.* industries that have almost identical factor inputs along the entire range of factor prices. The next observation is more fundamental from a theoretical point of view. According to Leontief, Minhas' estimates reflect substitution among different grades of labour, rather than substitution between capital and labour. The higher the level of development of a country, the more efficient the labour force. Thus, inefficiency of the labour force in countries at low wage-interest ratios cause labour inputs to be high. This point is substantiated by Leontief's calculations of capital-value added ratios that would match labour-input ratios used in Minhas' own calculations. Leontief finds that "as compared to the corresponding labor intensity, the capital intensity of any given industry varies little from country to country, and only in a few instances could one discern a visible negative relationship between the two."[3] From this he concludes that "fixed capital and labor coefficients (the latter measured in comparable efficiency units) might after all prove to be more appropriate for description of the specific productive relationships than the CES function in its general, or its particular Cobb-Douglas form."[4] We shall come back to this point when discussing the results of our empirical investigations.

The question of the stability of the order of ranking of sectors according to factor inputs has intrigued many theorists and has provoked firm statements. According to Samuelson ".... the phenomenon of goods that interchange their roles of being more labour intensive is much less important empirically than it is interesting theoretically".[5] Lary compares the ranking of manufacturing sectors according to value added per employee between India and the USA and makes complementary analyses over a number of countries and at different levels of aggregation. He finds a number of major cross-overs but concludes nevertheless that, overall, "there is really nothing that could be regarded as a clear-cut swapping of places between industries .... ".[6] In his study on the optimal international division of labour, Herman states that "(i)t is the present writer's conviction, ... that the ranking of industries is substantially the same whatever the definitions adopted for the measurement of factors or whatever the country used as a source of data."[7] In fact, Herman goes even one step further by concluding from the (assumed) pathological rarity of cross-overs that goods are produced with identical techniques in all countries.[8] Bhalla compares the ranking of manufacturing sector according to four indicators of labour intensity, the labour-output ratio, the share of wages in value added, the capital-labour ratio and the capital-output ratio, and concludes that different concepts yield different results and that rankings differ among countries.[9]

Fels' findings are particularly illustrative for the problem on hand. Fels shows that the order of ranking of sectors according to physical-, human-, and total-capital intensity is not insensitive to the concept of measurement. The ranking according to the stock concept of capital differs from that according to the flow concept which is used in our study. Next he shows that reversals in the order of ranking occur frequently. Applying the flow concept of total-capital intensity, *i.e.* value added per employee, for 18 sectors in a sample of 17 developed and developing countries, he finds that no two countries have exactly the same ranking order of sectors and that only four sectors are labour-intensive and two sectors are capital-intensive in all 17 countries.[10] The same two points follow from Teitel's study. In that study, three proxies for capital intensity are applied - value added per employee, electricity consumed per employee, and installed power per employee - to test the stability of the order of ranking of 19 sectors in samples of 26 to 30 countries. Teitel finds values of Kendall's coefficient of concordance in the range of .61 to .69 and corresponding average rank-order correlation coefficients in the range of .59 to .68.[11] Hillman and Hirsch show for 27 countries that significant differences can occur when the physical-capital intensity (non-wage value added per employee) of a country's trade structure is measured by applying US input coefficients rather than the coefficients of the country itself.[12]

The results of the empirical investigations by Minhas, Fels, Leontief, Teitel, Hillman and Hirsch, and others indicate that one should be reluctant to draw rigid conclusions for or against the correctness of the strong factor-intensity assumption.

THE ELASTICITY OF SUBSTITUTION

To start with, we take the position that there is a continuum of factor combinations so that at each factor-price ratio an appropriate technique is available. We estimate the elasticity of substitution according to equation (2). The estimates are based on data for samples of developed and developing countries. The coverage of firms is as uniform as possible for all countries included in the samples.

Alternative specifications of the production function that include a scale variable have also been applied but the scale variable did not appear to be significant.[13] The results of the estimates, presented in table 1, indicate that differences between countries in the level of labour productivity in manufacturing production are substantially smaller than differences in the wage level. The elasticities of substitution vary in the range of 0.43 to 0.90. We find substitution possibilities to be small in the sectors of beverages, industrial chemicals and iron and steel, which all are extremely capital-intensive sectors. Possibilities for factor substitution appear to be large in the sectors of wearing apparel, printing and publishing, furniture and fixtures, and footwear, most of which are labour-intensive sectors.

There are three reasons why the actual scope for factor substitution in manufacturing industry is likely to be more limited than would appear from the coefficients presented in table 1. First, full standardization of the coverage of firms included in each country's sample, and systematic exclusion of very small firms from all samples are likely to reduce the variation among countries in the labour-value added ratio.[14] Small firms play a more substantial role in the manufacturing sectors of developing countries than in developed countries whereas, at the same time, intra-sectoral productivity differences between large and small firms are likely to be more significant in developing than in developed countries. Second, narrowing down and standardization of the range of products included in each sector will probably also reduce the variation in the labour-value added ratio. The intra-sectoral product mix may differ between countries, as emphasized by Stewart and Linder.[15] The lower the level of income *per capita*, the more demand and production are concentrated in so-called low-income products produced with relatively simple, labour-intensive techniques as compared to their substitutes in high-income countries. Third, if it holds that the general (economic)

Table 1. Elasticity of substitution in manufacturing sectors.

ISIC code	Sector	Elasticity of substitution	t-statistic	n	R^2
311/2	Food products	0.74	8.29	21	0.78
313	Beverages	0.43	3.17	21	0.35
314	Tobacco	0.66	3.36	21	0.37
321	Textiles	0.64	7.78	24	0.73
322	Wearing apparel	0.90	13.31	22	0.90
323	Leather and products	0.72	10.05	21	0.84
324	Footwear	0.88	15.07	19	0.93
331	Wood products	0.77	5.69	19	0.66
332	Furniture and fixtures	0.89	16.18	19	0.94
341	Paper and products	0.72	9.13	25	0.78
342	Printing and publishing	0.89	16.72	24	0.93
351	Industrial chemicals	0.49	3.86	19	0.47
352	Other chemical products	0.62	4.88	17	0.61
355	Rubber products	0.70	9.41	23	0.81
356	Plastic products	0.75	7.42	19	0.76
361	Pottery, china	0.76	8.78	14	0.87
362	Glass and products	0.70	6.46	16	0.75
369	Non-metal products	0.72	8.10	21	0.78
371	Iron and steel	0.55	5.20	21	0.59
372	Non-ferrous metals	0.73	5.50	18	0.65
381	Metal products	0.71	9.82	19	0.85
382	Machinery n.e.c.	0.80	8.54	19	0.81
383	Electrical machinery	0.65	10.71	22	0.85
384	Transport equipment	0.65	7.25	23	0.71
385	Professional goods	0.74	6.07	17	0.71
390	Other industries	0.77	12.16	19	0.90

Note: all elasticities are significant at a 95 per cent confidence interval. Data relate to 1975.

Sources: data on number of employees, wages and value added taken from United Nations, *Yearbook of Industrial Statistics, 1978 Edition*, Volume I, New York, 1980.
Exchange rates taken from IMF, *International Financial Statistics*, Yearbook 1984, Volume XXXVII, Washington DC, 1984.

atmosphere in developing countries hampers fully efficient production, due to shortcomings inherent in the physical and administrative infrastructure, it follows that firms in developing countries operate systematically behind instead of at the production frontier.[16] Correction for *X*-inefficiency would further reduce the variation among countries in the labour-value added ratio. Nevertheless, the estimates give insight into the differences between the techniques in operation in countries at different levels of development.

CAPITAL AND LABOUR INPUTS

Recall Leontief's observation that the apparent elasticity of substitution, as estimated according to equation (2) reflects substitution among different grades of labour rather than substitution between capital and labour. The elasticity of substitution has been estimated from data pertaining to labour inputs in production and wages, not to capital inputs and interest rates. The latter kind of data are difficult to obtain. To get insight into the combination of labour and capital inputs in production in countries with different factor availabilities, we estimate labour and capital inputs per unit of value added. Capital inputs cannot be measured directly as data on capital stock or capital investment at the sectoral level are only available for a very limited number of sectors and countries. As a flow proxy for capital inputs we use electricity consumption, measured in KWH per US dollar of value added. The choice of this proxy is not unusual but may result in inaccuracies.[17] We expect techniques in operation in developing countries to be labour-intensive, with low capital inputs per unit of value added and characterized by low capital-labour ratios, compared to techniques in operation in developed countries. The relationships estimated are

$$\ln L/V = \alpha_0 + \alpha_1 \ln GDP/P$$

$$\ln K/V = \alpha_0 + \alpha_1 \ln GDP/P.$$

The results of our estimates, presented in table 2, can be summarized as follows. First, labour inputs per unit of value added are significantly and substantially higher in countries at lower levels of income *per capita*. Second, the lower the level of development of a country, the lower the capital-labour ratio in manufacturing production. Third, the relationship between capital inputs per unit of value added, as measured by electricity use in production, and the level of development of the country in which production takes place is often found to be negative, but the negative coefficients are not statistically significant in most cases. It is striking indeed that in most sectors the capital-value added ratio is not significantly lower in developing countries than in developed countries. This confirms Leontief's findings mentioned earlier.

Table 2. Factor use in manufacturing sectors.

ISIC code	Sector	*Labour inputs per unit of value added*				*Capital inputs per unit of value added*			
		Constant term	*GDP/P*	*n*	R^2	Constant term	*GDP/P*	*n*	R^2
311/2	Food products	1.67* (2.76)	-0.53* (6.43)	21	0.68	1.90* (2.48)	-0.29* (2.76)	21	0.29
313	Beverages	-0.95 (1.30)	-0.25* (2.51)	21	0.25	-2.06* (3.06)	0.16 (1.74)	21	0.14
314	Tobacco	0.51 (0.40)	-0.49* (2.83)	21	0.30	1.85 (1.68)	0.003 (0.02)	21	0.00
321	Textiles	1.43* (2.50)	-0.44* (5.73)	24	0.60	1.27 (1.75)	-0.14 (1.46)	24	0.09
322	Wearing apparel	3.67* (7.02)	-0.68* (9.69)	22	0.82	1.95* (2.65)	-0.44* (4.42)	22	0.49
323	Leather and products	2.04* (3.49)	-0.52* (6.46)	21	0.69	0.25 (0.27)	-0.12 (0.95)	21	0.05
324	Footwear	3.20* (4.37)	-0.63* (6.28)	19	0.70	0.44 (0.53)	-0.21 (1.82)	19	0.16
331	Wood products	2.97* (3.87)	-0.64* (6.03)	19	0.69	-0.74 (0.64)	0.10 (0.66)	19	0.02
332	Furniture and fixtures	3.70* (7.05)	-0.71* (9.84)	19	0.85	-1.36 (1.69)	0.08 (0.68)	19	0.03
341	Paper and products	1.34* (2.62)	-0.49* (7.19)	25	0.69	-0.48 (0.77)	0.19* (2.31)	25	0.19
342	Printing and publishing	2.85* (6.89)	-0.65* (11.91)	24	0.87	1.29* (2.73)	-0.32* (5.07)	24	0.54
351	Industrial chemicals	-0.53 (0.81)	-0.31* (3.56)	19	0.43	-3.22 (2.02)	0.56* (2.61)	19	0.29
352	Other chemical products	0.92 (1.79)	-0.45* (6.37)	17	0.73	-0.91 (1.03)	-0.0002 (0.002)	17	0.00

(Table 2 continued)

ISIC code	Sector	*Labour inputs per unit of value added*				*Capital inputs per unit of value added*			
		Constant term	*GDP/P*	*n*	R^2	Constant term	*GDP/P*	*n*	R^2
355	Rubber products	1.16 (1.94)	-0.45* (5.65)	23	0.60	0.92* (2.32)	-0.11* (2.10)	23	0.17
356	Plastic products	1.66* (2.20)	-0.50* (4.85)	19	0.58	1.36 (1.36)	-0.16 (1.19)	19	0.08
361	Pottery, china	3.08* (3.57)	-0.64* (5.59)	14	0.72	1.07 (1.35)	-0.10 (0.97)	14	0.07
362	Glass and products	1.71* (2.77)	-0.51* (6.15)	16	0.73	0.91 (0.80)	-0.06 (0.39)	16	0.01
369	Non-metal products	1.82* (4.23)	-0.55* (9.40)	21	0.82	3.91* (5.89)	-0.39* (4.30)	21	0.49
371	Iron and steel	1.25 (2.08)	-0.48* (5.98)	21	0.65	0.85 (0.83)	0.06 (0.41)	21	0.01
372	Non-ferrous metals	2.80* (2.98)	-0.66* (5.33)	18	0.64	-2.46 (1.36)	0.55* (2.32)	18	0.25
381	Metal products	2.10* (4.46)	-0.55* (8.82)	19	0.82	1.35 (1.67)	-0.24* (2.24)	19	0.23
382	Machinery n.e.c.	2.85* (5.23)	-0.65* (9.02)	19	0.83	-0.48 (0.47)	-0.19 (1.40)	19	0.10
383	Electrical machinery	1.45* (3.46)	-0.48* (8.49)	22	0.78	1.00 (1.41)	-0.23* (2.45)	22	0.23
384	Transport equipment	1.73* (3.67)	-0.52* (8.31)	23	0.77	-2.14* (2.58)	0.18 (1.62)	23	0.11
385	Professional goods	2.07* (2.44)	-0.54* (4.74)	17	0.60	-0.79 (0.86)	-0.05 (0.37)	17	0.01
390	Other industries	2.79* (4.69)	-0.62* (7.74)	19	0.78	0.12 (0.14)	-0.13 (1.06)	19	0.06

Sources: as of table 1.

Empirical studies on capital use per unit of value added in manufacturing industries in countries at different stages of development are inconclusive. Bhatt's analysis of manufacturing sectors in eight countries shows that capital inputs in developing countries are certainly not always lower than in developed countries.[18] Pack's analysis of input requirements at the firm level also shows that firms in developing countries do not always have lower capital requirements than firms in developed countries.[19] Since we are not able to measure capital in a direct way, the results of our analysis with respect to capital use in manufacturing industry in developing countries must remain tentative and inconclusive.

THE RANKING ORDER OF SECTORS

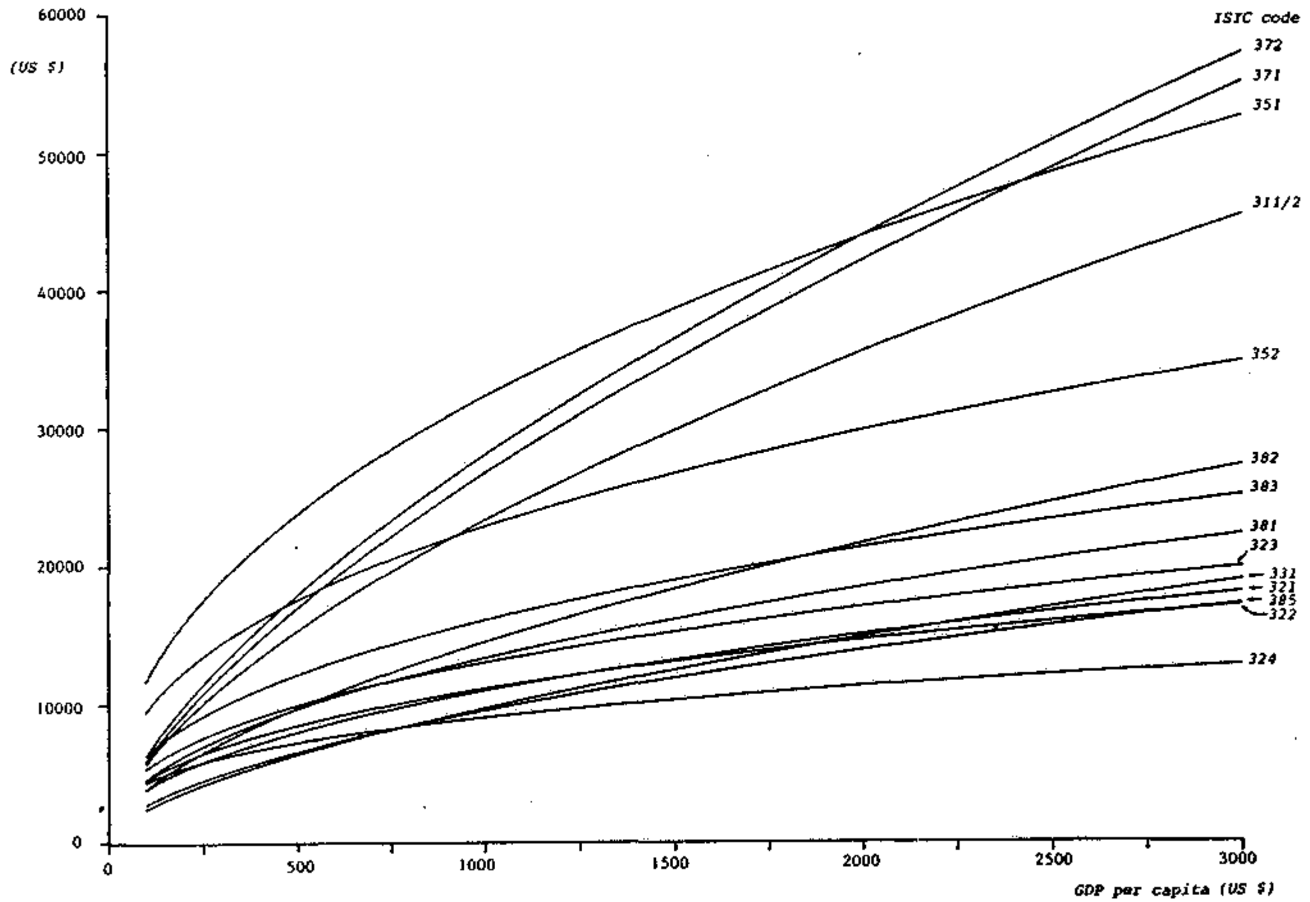
In this section we show the results of empirical investigations of the ranking order of manufacturing sectors. Figure 1 shows the estimated positions of 14 manufacturing sectors. We have estimated the relationship between output per employee in a sector and income *per capita* of the country in which the sector operates for samples of 18 to 42 developed and developing countries (see note to the figure). As shown, sectors do change their relative positions but the number of cross-overs is rather limited and most of them are not very significant.

The permutations in the ranking order of 26 manufacturing sectors according to total-capital intensity in seven developing countries are shown in the upper part of table 3. Total value added per employee has been used as a proxy for total-capital intensity. The lower part of the table shows the degree of similarity in the seven ranking orders, measured by Spearman rank correlation coefficients. As shown, sectors may take quite different positions in the order of ranking in different countries. Only a few sectors - particularly those at the extremes of the ranking order - do not interchange at all their position of being labour- or capital-intensive. It is not possible to identify the causes of the observed permutations. They may be due to substantial differences between sectors in the value of the elasticity of substitution but also to distortions in factor markets and product markets or to imponderabilities and statistical inconsistencies.

Notwithstanding permutations in the ranking orders, there is generally a significant correlation between the order of ranking of sectors in countries, as indicated by the matrix of Spearman rank correlation coefficients. Should no reversals occur, all coefficients in the matrix, of course, would have value one.

The findings presented here indicate that the choice of any country-specific order of ranking to be applied in a cross-country analysis of patterns of specialization in production and trade is arbitrary. Any selected country-specific set of factor input coefficients yields different results, as illustrated in table 4. The table shows the percentage share of labour-intensive products in manufactured exports from the seven countries to OECD

Figure 1. Output per employee in manufacturing sectors.



Note: figure based on the coefficients presented below. The relationship estimated is $ln\ O/L = \alpha_0 + \alpha_1\ ln\ GDP/P$. The *t*-statistics are in parentheses. An asterisk (*) indicates that the variable is statistically significant at a 95 per cent confidence interval. Data relate to 1975.

Output per employee (*O/L*) in manufacturing sectors.

ISIC code	Sector	Constant term	*GDP/P*	*n*	R^2
311/2	Food products	5.90* (17.0)	0.60* (11.3)	42	0.76
314	Tobacco	6.78* (10.4)	0.55* (5.6)	36	0.47
321	Textiles	6.19* (14.1)	0.45* (6.7)	42	0.53
322	Wearing apparel	6.64* (15.6)	0.39* (6.2)	35	0.54
323	Leather and products	6.83* (18.5)	0.38* (6.9)	32	0.62
331	Wood products	5.02* (12.9)	0.60* (10.1)	36	0.75
351	Industrial chemicals	7.35* (13.4)	0.44* (5.2)	27	0.52
352	Other chemical products	7.43* (17.8)	0.58* (6.0)	35	0.52
371	Iron and steel	5.69* (8.6)	0.65* (6.6)	28	0.63
372	Non-ferrous metals	5.80* (7.7)	0.64* (5.8)	18	0.68
381	Metal products	6.31* (18.2)	0.46* (8.7)	35	0.70
382	Machinery n.e.c.	5.46* (9.1)	0.57* (6.5)	32	0.58
383	Electrical machinery	6.91* (15.8)	0.40* (6.1)	37	0.51
385	Professional goods	5.47* (9.0)	0.54* (6.0)	26	0.60

Sources: as of table 1.

Table 3. Ranking of 26 manufacturing sectors according to total-capital intensity in seven developing countries.

ISIC code	Sector	Chile	Colombia	Hong Kong	India	South-Korea	Peru	Turkey
					order of ranking			
311/2	Food products	19	19	18	2	16	11	15
313	Beverages	20	26	23	18	25	23	25
314	Tobacco	25	25	26	4	26	25	24
321	Textiles	5	14	19	9	11	10	8
322	Wearing apparel	1	2	3	5	3	1	5
323	Leather and products	16	5	4	10	17	7	6
324	Footwear	6	3	9	7	4	4	2
331	Wood products	3	8	13	3	14	6	9
332	Furniture and fixtures	4	1	14	1	2	2	1
341	Paper and products	24	21	15	22	15	15	21
342	Printing and publishing	14	10	17	11	12	12	20
351	Industrial chemicals	22	24	25	26	24	24	26
352	Other chemical products	23	23	20	25	22	18	23
355	Rubber products	7	20	2	20	7	21	13
356	Plastic products	10	7	8	14	6	9	18
361	Pottery, china	17	4	1	8	1	5	10
362	Glass and products	2	13	5	6	20	3	14
369	Non-metal products	15	18	22	12	23	14	11
371	Iron and steel	21	17	24	21	21	16	22
372	Non-ferrous metals	26	15	21	24	18	22	7
381	Metal products	11	11	11	15	9	8	12

(Table 3 continued)

ISIC code	Sector	Chile	Colombia	Hong Kong	India	South-Korea	Peru	Turkey
					order of ranking			
382	Machinery n.e.c.	9	12	6	19	10	20	17
383	Electrical machinery	18	16	7	23	13	17	19
384	Transport equipment	12	22	16	16	19	19	16
385	Professional goods	8	9	10	17	8	13	4
390	Other industries	13	6	12	13	5	26	3

	Chile	Colombia	Hong Kong	India	South-Korea	Peru	Turkey
			Spearman rank correlation coefficients				
Chile	1	.63	.59	.53	.60	.63	.60
Colombia		1	.64	.52	.81	.71	.79
Hong Kong			1	.21	.72	.51	.48
India				1	.32	.64	.49
South Korea					1	.51	.67
Peru						1	.52
Turkey							1

Sources: as of table I.

countries in 1975 measured by relative factor inputs in each of the seven exporting countries. The rows of the table show that the contribution of labour-intensive products to exports in every country differs when measured by factor input coefficients of different countries. The columns show that the positions of countries in the international division of labour according to their specialization in labour-intensive products is not independent of the choice of definition of labour-intensive products.

Table 4. Specialization in labour-intensive exports in seven countries measured by factor intensities in seven countries.

Exports	Factor intensities in: Chile	Colombia	Hong Kong	India	South Korea	Peru	Turkey
Chile	*14.83*	14.75	15.70	36.48	14.06	31.48	25.37
Colombia	76.28	*49.88*	47.97	87.66	72.94	80.90	81.24
Hong Kong	86.56	79.82	*89.60*	76.41	97.91	70.09	80.94
India	73.64	54.42	55.34	*81.05*	73.65	82.63	85.40
South Korea	77.04	65.38	77.94	71.51	*82.32*	68.18	73.54
Peru	56.81	40.83	41.84	70.01	50.54	*67.11*	50.67
Turkey	64.60	33.47	34.30	88.03	62.16	88.24	*59.90*

Note : data relate to 1975 except for Hong Kong (1973) and Peru (1973).

Sources: data on manufactured exports to OECD countries taken from OECD, *Trade by Commodities, Market Summaries: Imports, Jan.-Dec. 1975*, Volumes I and II, Serie C, Paris.
Data on value added and employment as of table 1.

Notwithstanding the questionable value of the strong factor-intensity assumption, almost all cross-country studies of trade structures apply a country-specific set of data on (relative) factor inputs to all countries under investigation. For reasons of data availability these factor inputs relate to industry in a developed country in most cases. The assumption then is that this specific set of data is representative for all countries in the analysis. Here we introduce a different approach that is less arbitrary and reduces the chance of applying (relative) factor inputs that are not representative. In this approach, use is made of coefficients of (relative) factor inputs that are derived from factor input coefficients of 26 manufacturing sectors in 17 developing countries. All developing countries for which reliable data are available are included in the analysis.

In constructing the sets of coefficients that represent relative total-, physical-, and human-capital intensity of sectors, the following steps are taken.
First, we caluclate the *country-specific* relative factor intensity of sector i (i = 1...26) in country j (j = 1...17) by dividing the sectoral capital intensity by the country-specific arithmetical average value of the capital intensity in manufacturing.
Second, we calculate the sectoral relative factor intensity by taking the arithmetical average of the observations for our sample countries.
Third, we rank the 26 sectoral averages according to total-, physical-,and human-capital intensity.

As observed earlier, not all data are of the same quality and uniform definition; hence, "outlying observations" may occur. To obtain insight into the distorting effects of observations that differ significantly from the rest of the observations, rejection tests are applied to the extreme observations per sector. The acceptance region includes the values which have a high probability of being observed, and the rejection region includes the values which are highly unlikely, *i.e.* which have a probability of less than one per cent. Comparison of the order of ranking of sectors before and after rejection of such "outlying observations" shows that only some minor changes of places of sectors in the ranking order occur.[20]

Table 5 shows the positions of the 26 manufacturing sectors in the ranking order, obtained according to the procedure described earlier. Not surprisingly, the similarity in the order of ranking according to total- and physical-capital intensity is large since the larger share - about 70 per cent in most cases - of total value added is non-wage value added. Although, generally speaking, sectors that score high according to their use of physical capital also score high in their use of human capital, this similarity does not hold for all sectors.

Table 5. Total-, physical-, and human-capital intensity of 26 manufacturing sectors.

ISIC code	Sector	Total-capital intensity		Physical-capital intensity		Human-capital intensity	
		relative value	*order of ranking*	*relative value*	*order of ranking*	*relative value*	*order of ranking*
311/2	Food products	0.92	15	0.95	16	0.84	8
313	Beverages	1.67	24	1.84	24	1.15	21
314	Tobacco	2.58	26	3.05	26	1.06	15
321	Textiles	0.58^*	4	0.47^*	4	0.85	9
322	Wearing apparel	0.46^*	1	0.40^*	3	0.65^*	1
323	Leather and products	0.66^o	9	0.60^o	9	0.73^*	2
324	Footwear	0.50^*	2	0.39^*	2	0.79^o	5
331	Wood products	0.61^*	5	0.54^*	6	0.76^o	3
332	Furniture and fixtures	0.53^*	3	0.37^*	1	0.77	4
341	Paper and products	1.08	19	1.10	19	1.04	14
342	Printing and publishing	0.79	13	0.68^o	11	1.14	19
351	Industrial chemicals	1.80	25	2.00	25	1.34	26
352	Other chemical products	1.38	22	1.48	22	1.27	24
355	Rubber products	1.08	20	1.10	20	1.14	20
356	Plastic products	0.77	12	0.78	14	0.83	7
361	Pottery, china	0.73	10	0.69	12	0.87	10
362	Glass and products	0.65^*	6	0.49^*	5	1.03	13
369	Non-metal products	1.03	18	1.02	18	1.07	17
371	Iron and steel	1.33	21	1.35	21	1.31	25
372	Non-ferrous metals	1.67	23	1.71	23	1.21	22
381	Metal products	0.75	11	0.67^o	10	0.95	12

(Table 5 continued)

ISIC code	Sector	Total-capital intensity		Physical-capital intensity		Human-capital intensity	
		relative value	*order of ranking*	*relative value*	*order of ranking*	*relative value*	*order of ranking*
382	Machinery n.e.c.	0.86	14	0.77	13	1.06	16
383	Electrical machinery	0.93	16	0.99	17	1.07	18
384	Transport equipment	0.95	17	0.82	15	1.25	23
385	Professional goods	0.65*	7	0.60°	8	0.91	11
390	Other industries	0.66*	8	0.55*	7	0.82	6

Notes: * indicates that the average relative value of capital intensity of the sector in the sample countries is significantly below 1 at a 95 per cent confidence interval.
° indicates that this is the case at a 90 per cent confidence interval.

Sources: as of table 1.

The representativeness of the three sets of standardized orders of ranking of 26 manufacturing sectors is tested by comparing these standardized orders with the orders of ranking of sectors in the 17 sample countries individually (see table 6). The representativeness is indicated by the value of the Spearman rank correlation coefficients. All coefficients are statistically significant at a 95 per cent confidence interval.

Table 6. The representativeness of the standardized orders of ranking of sectors.

Country	Total-capital intensity	Physical-capital intensity	Human-capital intensity
	Spearman rank correlation coefficients		
Argentina	..	..	.55
Brazil	.74	.94	.85
Chile	.84	.84	.77
Colombia	.87	.83	.90
Cyprus	.83	.64	.78
Egypt	.42	.46	.55
Hong Kong	.60	.58	.49
India	.64	.76	.69
South Korea	.73	.67	.87
Malaysia	.92	.89	.77
Malta	.57	.52	.49
Mexico	.84	.85	.68
Peru	.80	.73	.80
Philippines	.88	.91	.68
Singapore	.84	.81	.87
Tunisia	.78	.78	.78
Turkey	.78	.71	.77

Symbols: .. = no data available.

Note : not for all countries data on all 26 sectors are available.

Sources: as of table 1.

* This article is the result of a study on Export-Oriented Industrialization and Economic Development in Developing Countries that has been undertaken at the Free University of Amsterdam. The study has been sponsored by the Dutch Minister of Development Cooperation. The full results of the author's contribution to this study have been published in *Causes and Characteristics of Export-Oriented Industrialization in Developing Countries*, Free University Press, Amsterdam, 1986.

The author is actually engaged as researcher at the Economic and Social Institute of the Free University.

NOTES

1 K.J. Arrow, H.B. Chenery, B.S. Minhas and R.M. Solow, "Capital-Labor Substitution and Economic Efficiency",in: *The Review of Economics and Statistics, Volume XLIII*, Number 3, August 1961.

2 B.S. Minhas, "The Homohypallagic Production Function, Factor-Intensity Reversals, and the Heckscher-Ohlin Theorem", in: *The Journal of Political Economy*, Volume LXX,.Number 1, February 1962, p. 147.

3 W. Leontief, "An International Comparison of Factor Costs and Factor Use", in: W. Leontief, *Essays in Economics*, Volume Two, Basil Blackwell, Oxford, 1977, p. 123.

4 W. Leontief, *op.cit.*, p. 123.

5 P. Samuelson, "A Comment on Factor Price Equalisation", in: *The Review of Economic Studies*, Volume XIX, 1951-1952, pp. 121, 122.

6 H.B. Lary, *Imports of Manufactures from Less Developed Countries*, National Bureau of Economic Research, New York, 1968, p. 72.

7 B. Herman, *The Optimal International Division of Labour*, ILO, Geneva, 1975, p. 17.

8 B. Herman, *op.cit.* p. 26.

9 A.S. Bhalla, "The Concept and Measurement of Labour Intensity", in: A.S. Bhalla (ed.), *Technology and Employment in Industry - A Case Study Approach*, ILO, Geneva, 1981, pp. 35-39.

10 G. Fels, "The Choice of Industry Mix in the Division of Labour between Developed and Developing Countries", in: *Weltwirtschaftliches Archiv*, Band 108, 1972, pp. 77-90.

11 S. Teitel, "The Strong Factor-Intensity Assumption: Some Empirical Evidence", in: *Economic Development and Cultural Change*, Volume 26, Number 2, January 1978, p. 330.

12 A.L. Hillman and S. Hirsch, "Factor Intensity Reversals: Conceptual Experiments with Traded Goods Aggregates", in: *Weltwirtschaftliches Archiv*, Band 115, 1979, p. 276.

13 To allow for scale effects we estimated the following relations:

$$ln\ V/L=\alpha_0 + \alpha_1\ ln\ w + \alpha_2\ ln\ L$$

$$ln\ V/L=\alpha_0 + \alpha_1\ ln\ w + \alpha_2\ ln\ V.$$

14 See M. Girgis, *"Aggregation and Misspecification Biases in Estimates of Factor Elasticity of Substitution: the case of Egypt"*, in: Weltwirtschaftliches Archiv, Band 110, 1974.

15 See S.B. Linder, *An Essay on Trade and Transformation*, John Wiley and Sons, New York, 1961. See also F. Stewart, *Technology and Underdevelopment*, The MacMillan Press Ltd., London and Basingstoke, 1978, chapters 1 and 7.

[16] For a study on factors causing inefficiency in manufacturing in developing countries, see H. Leibenstein, *General X-Efficiency Theory and Economic Development*, Oxford University Press, New York, 1978, pp. 18, 19, 113, 114. See also F.T. Moore, *Technological Change and Industrial Development - Issues and Opportunities*, World Bank Staff Working Papers, Number 613, Washington DC, 1983. According to Fei and Ranis, the more recent the vintage of capital goods, the greater inefficiency in manufacturing, and the more this stems from an inefficient use of capital. See J. Fei and G. Ranis, "Less Developed Country Innovation Analysis and the Technology Gap", in: G. Ranis (ed.), *The Gap between Rich and Poor Countries*, The MacMillan Press Ltd., London and Basingstoke, 1972, p. 322. According to Hirschman and Baranson, production in operator-controlled and/or labour-intensive techniques in particular suffers from inefficiency. See A.O. Hirschman, *The Strategy of Economic Development*, Yale University Press, New Haven, 1958, pp. 139-152; J. Baranson, "Bridging the Technological Gaps between Rich and Poor Countries", in: G. Ranis (ed.), *op.cit.*, pp. 301, 302.

[17] R.M. Bautista, H. Hughes, D. Lim, D. Morawetz and F.E. Thoumi, 1981, *Capital Utilization in Manufacturing - Colombia, Israel, Malaysia, and the Philippines*, Oxford University Press, New York, 1981, pp. 31-46.

[18] V.V. Bhatt, "Capital-Output Ratios of Certain Industries: A Comparative Study of Certain Countries", in: *The Review of Economics and Statistics*, Volume XXXVI, Number 3, August 1954, pp. 311-319.

[19] H. Pack, "The Employment-Output Trade-Off in LDC's - A Microeconomic Approach", in: *Oxford Economic Papers*, Volume 26, Number 3, November 1974, p. 392. See also H. Pack, *Macroeconomic Implications of Factor Substitution in Industrial Processes*, World Bank Staff Working Paper, Number 377, Washington DC, 1980.

[20] Only in one case (Peru in ISIC sector 390, other industries) does exclusion of an "outlying observation" result in a significant change of the sector's position in the ranking order. In this case - which is by far the most extreme "outlying observation" of all - the relative total-capital intensity of the sector in Peru is 5.95, nine times as high as the sector's average relative total-capital intensity in the rest of the observations. Inclusion of Peru would place the sector among the capital-intensive sectors while exclusion of the extreme observation places it among the labour-intensive sectors. With respect to the physical-capital intensity, the position of this sector in Peru is even more extreme, scoring over twelve times as high as in the rest of the observations. This most extreme observation is due to a statistical inconsistency since value added in Peru's sector of other industries includes the value added in handicraft activities while the data presented on wages and employment are exclusive of such activities. For that reason, this observation is excluded from the samples related to total- and physical intensity.

1981-1	E. Vogelvang	A quarterly econometric model for the Price Formation of Coffee on the World Market
1981-2	H.P. Smit	Demand and Supply of Natural Rubber, Part I
1981-3	R. Vos	The political Economy of the Republic of Korea; A proposal for a model framework of an open economy in the ESCAP-region, with emphasis on the Role of the State
1981-4	F.C. Palm	Structural Econometric Modeling and Time Series Analysis - Towards an Integrated Approach
1981-5	P. Nijkamp in co-op. with H. v. Handenhoven and R. Janssen	Urban Impact Analysis in a Spatial Context: Methodologie and Case Study
1981-6	R. Ruben	Primaire exporten en ekonomiese ontwikkeling
1981-7	D.A. Kodde	Het genereren en evalueren van voorspellingen van omzet en netto winst: een toegepast kwantitatieve benadering
1981-8	B. Out	Financiële vraagstukken onder onzekerheid
1981-9	P. van Dijck and H. Verbruggen	A Constant-Market-Shares Analysis of ASEAN Manufactured Exports to the European Community
1981-10	P. Nijkamp, H. de Graaff and E. Sigar	A Multidimensional Analysis of Regional Infrastructure and Economic Development
1981-11	P. Nijkamp	International Conflict Analysis
1981-12	A.J. Mathot	L'Utilisation du Crédit lors de l'Achat d'une Voiture
1981-13	S.P. van Duin en P.A. Cornelis	Onderzoek naar levensomstandigheden en opvattingen over arbeid bij mensen zonder werk, deel I
1981-14	W. van Lierop and P. Nijkamp	Disaggregate Models of Choise in a Spatial Context
1981-15	Hidde P. Smit	The World Vehicle Market
1981-16	F.C. Palm	Structural Econometric Modeling and Time Series Analysis: An Integrated Approach
1981-17	F.C. Palm and Th.E. Nijman	Linear Regression Using Both Temporally Aggregated and Temporally Disaggregated Data
1981-18	F.C. Palm and J.M. Sneek	Some econometric Applications of the exact Distribution of the ratio of Two Quadratic Forms in Normal Variates
1981-19	P. Nijkamp and P. Rietveld	Soft Econometrics as a Tool for Regional Discrepancy Analysis
1981-20	H. Blommestein and P. Nijkamp	Soft Spatial Econometric Causality Models
1981-21	P. Nijkamp and P. Rietveld	Ordinal Econometrics in Regional and Urban Modeling
1981-22	F. Brouwer and P. Nijkamp	Categorical Spatial Data Analysis
1981-23	A. Kleinknecht	Prosperity, Crises and Innovation Patterns: Some more Observations on neo-Schumpeterian Hypotheses
1981-24	Hidde P. Smit	World Tire and Rubber Demand
1982-1	Peter Nijkamp	Long waves or catastrophes in Regional Development
1982-2	J.M. Sneek	Some Approximations to the Exact Distribution of Sample Autocorrelations for Autoregressive-moving Average Models
1982-3	F.E. Schippers	Empirisme en empirische toetsing in de wetenschapsfilosofie en in de ekonomische wetenschap
1982-4	Piet van Helsdingen maart 1982	Mantelprojekt 'Management & Politiek': Produktiebeleid en overheid; een onderzoek naar de invloed van de overheid op het produktbeleid in de verpakkingsmiddelenindustrie
1982-5	Peter Nijkamp Jaap Spronk	Integrated Policy Analysis by means of Interactive Learning Models
1982-6	Ruerd Ruben (ed.)	The Transition Strategy of Nicaragua
1982-7	H.W.M. Jansen mei 1982	Een alternatieve modellering van het gedrag van een besluitvormer: 'satisficing' i.p.v. 'maximizing'
1982-8 mei	J. Klaassen and H. Schreuder	Confidential revenue and Profit Forecasts by management and financial analysts: some first results
1982-9	F. Brouwer and P. Nijkamp	Multiple Rank Correlation Analysis