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On the Measurement of Capital-Intensity

By David Lim

The problem of the choice of technique in less developed countries has featured prominently in the literature on economic development[1]. This paper shows that despite such interest attempts to measure capital-intensity still leave much to be desired and argues that a modified capital-labour ratio, with capital adjusted for utilization and labour to refer to the number of production workers on the biggest shift, is the theoretically most suitable measure of capital-intensity.

I.

The most common measure of capital-intensity, the capital-labour ratio (K/L) where K is fixed assets valued at historical or replacement costs and L the total number of workers employed, is fraught with weaknesses. Perhaps the most important of these is the failure to define L as the number of production workers on the biggest shift. The emphasis should be on the amount of capital equipment that a production worker has to handle when at work regardless of the fact that another worker may be operating the same equipment on another shift. When more than one shift is run and the number of people working on the different shifts are different then L should be measured as the number of production workers working on the biggest shift. The biggest shift is chosen because it best reflects the underlying economic and technological relationships between the capital input and the output it helps to generate.

Table I shows that the capital-intensity of two industries, A and B, depends on the definition given to L and on the distribution of their production labour force among the three shifts. If L were defined as the total number of production workers, that is, as $E_1 + E_2 + E_3$, then the capital-intensity of the two industries would be the same. Their capital-intensity would also be identical if L is defined as the number of production workers on the biggest shift when (a) the labour force is evenly distributed among the three shifts (Case I) and (b) only one shift is operated (Case III).

Table I – *Comparison of Capital-Intensity of Two Hypothetical Industries*

	Industry A fixed assets (K) $ 12 000			Industry B fixed assets (K) $ 9 000		
	Case			Case		
	I	II	III	I	II	III
No. of production workers						
1. day-shift (E_1)	40	90	120	30	50	90
2. night-shift (E_2)	40	15	0	30	20	0
3. dawn-shift (E_3)	40	15	0	30	20	0
Index of capital-intensity						
$K/(E_1 + E_2 + E_3)$ ($)		100			100	
K/E_1 ($)	300	133	100	300	180	100

However, if there is an intermediate situation, as for example in Case II where three shifts of varying importance are run, then the use of K/E_j where j refers to the biggest shift would show industry B to be more capital-intensive than industry A. Under such circumstances, K/E_j, would appear to be a better indicator of the capital-intensity of the overall production process. K/E_j is the measure of capital-intensity suggested by Winston[2] and its definition covers all the three situations represented by Cases I, II and III, with the first and the third representing limiting cases of the second.

The usefulness of K/E_j, is, however, limited by the assumption that the stock of capital is utilized at the same rate across firms and industries as recent studies show that the level of capital utilization varies considerably between industries in less developed countries[3]. K/E_j, has therefore to be adjusted for inter-industry differences in the level of capital utilization and this has been done in two steps. The first is to multiply K by (DY/365) where DY is the number of days the plant is operated a year and 365 the total number of days available in a year. This would then give K_t/E_j where K_t is K adjusted for capital utilization in terms of time. The second step is to take the speed or operation or the plant into consideration. In other words, K_t/E_j, has to be presented as K_{ti}/E_j, where K_{ti}, is K_t, adjusted for the intensity of use during the biggest shift[4].

One major weakness of another popular measure of capital-intensity, the value added per employee (VA/L)[5], is also that it does not differentiate between shifts. The value added per employee for the night- and the dawn-shifts tend to be lower than that for the day-shift so that the overall value added per employee for a firm working three shifts may be lower than that for a firm working one shift, and the reason is not the lower volume of capital used[6].

Another important consequence of ignoring shift-work is the failure to recognize that what is required is the value added per employee during the biggest shift. The volume of human capital in VA/L is adjusted automatically in the right direction as it depends obviously on the number of workers employed on each shift. However, the same cannot be said of the physical capital component of the overall value added in view of the fixity of the capital plant and equipment. Failure to adjust VA/L for this element would produce the same weaknesses as encountered in the use of the conventional capital-labour ratio (K/L).

II.

It would thus appear that the conventional measures of capital-intensity leave much to be desired and that the modified capital-labour ratio would be theoretically more appropriate.

Table 2 shows the capital-intensity of twenty eight industry-groups in West Malaysian manufacturing as measured by the K/L, VA/L, K/E_j, K_t/E_j and K_{ti}/E_j indices where K refers to the replacement value of the fixed assets, using data which have been collected for 350 establishments for 1972[7]. Table 2 also shows the rankings of the industry-groups by their capital-intensity under the different measures. The Spearman rank correlation coefficients (r_s) of the rankings of the capital-intensity oi the industry-groups as measured by pairings of the different indices, and their *t* values, are given in Table 3.

All of the Spearman rank correlation coefficients are positive and significantly different from zero at the o.o1 level of confidence, indicating that there are strong relationships between the rankings of the capital-intensity of the 28 industry-groups as measured by the various indices. However, a closer look at the available data shows that the empirical results are not incompatible with the a *priori* contention that the new measure is the more reliable indicator of capital-intensity if shift-conditions prevailing in West Malaysian manufacturing approximate those represented by Cases I and III in Table 1. Available data shows that capital utilization and therefore shift operation in West Malaysian manufacturing is at a relatively high and even level[8] so that the shift-conditions prevailing in a significant number of industry-groups tend to approximate those represented by Case I.

Table 2 – *Capital-Intensity of West Malaysian Manufacturing by Industry-Group, 1972* (Malaysian dollars)

Industry-group	Fixed assets (K) / employees (L)		Value added (VA) / employees (L)		Fixed assets (K) / day-crew (E_j)		Adj. fixed assets (K_t) / day-crew (E_j)		Adj. fixed assets (K_{ti}) / day-crew (E_j)	
	$ 1,000	ranking	$ 1,000	ranking	$ 1,000	ranking	$ 1,000	ranking	$ 1,000	ranking
Food	28.6	12	19.3	8	187.9	4	152.9	4	141.9	4
Other food	14.8	20	22.9	6	24.6	23	20.6	24	18.3	23
Beverage	33.0	10	24.2	4	95.2	6	81.6	6	77.0	6
Tobacco	35.1	8	50.2	2	70.2	10	57.5	10	56.5	10
Textiles	15.4	19	3.6	24	38.8	19	34.9	17	33.0	15
Wearing apparel, except footwear	1.8	28	1.3	28	5.6	28	4.6	28	4.6	28
Leather & leather products	41.2	6	19.1	9	42.0	18	34.2	19	24.2	21
Footwear	9.3	24	7.5	21	9.4	27	7.6	27	6.5	27
Wood & wood products	31.4	11	20.1	7	45.8	17	35.8	16	30.9	18
Furniture & fixtures	13.8	22	7.2	22	77.3	9	63.1	9	60.6	9
Paper & paper products	22.3	15	17.6	11	46.9	15	40.8	15	34.9	14
Printing, publishing, etc.	54.7	5	14.7	15	85.8	8	76.2	8	74.9	7
Industrial chemicals	77.6	2	16.5	13	326.5	2	284.4	2	277.1	2
Other chemical products	25.7	14	29.0	3	46.0	16	34.6	18	31.4	16
Petroleum refining	1475.1	1	102.6	1	3384.0	1	3272.3	1	3148.5	1
Rubber products	27.6	13	16.1	14	88.3	7	77.6	7	72.0	8
Plastic products	14.1	21	3.6	25	31.6	22	28.5	21	26.3	20
Pottery, china, etc.	8.7	26	2.5	27	9.6	26	8.3	26	7.8	26
Glass & glass products	16.3	18	10.9	19	57.1	12	48.8	12	48.3	11
Non-metallic mineral products	64.6	3	23.4	5	192.1	3	170.6	3	164.9	3
Iron & steel products	40.9	7	6.8	23	135.8	5	114.6	5	103.2	5
Non-ferrous metal products	16.4	17	16.9	12	55.6	13	48.6	13	47.8	12
Fabricated metal products	21.5	16	18.4	10	47.9	14	41.2	14	31.4	16
Non-electrical machinery	35.1	9	11.8	16	37.0	20	30.9	20	24.2	21
Electrical machinery	12.1	23	11.0	18	32.2	21	28.1	22	27.8	19
Transport equipment	55.8	4	11.8	17	63.9	11	49.4	11	47.5	13
Professional equipment	9.2	25	7.5	20	23.4	24	20.7	23	17.8	24
Other manufacturing	6.8	27	3.1	26	14.9	25	13.1	25	10.8	25
Total manufacturing	487.7	—	46.4	—	1131.6	—	964.1	—	911.3	—

Notes: The weight used in calculating the capital-intensity at the industry-group level was the share of the replacement value of the fixed assets of the establishment in the replacement value of the fixed assets of the industry-group.

The aggregation is at the 3-digit level of the Malaysian Industrial Classification/International Standard Industrial Classification.

Table 3 – *Spearman Rank Correlation Coefficients*

Comparison	r_s	*t* value
K/E_j — K/L	0.7975	6.7388
K_t/E_j — K/L	0.7898	5.0625
K_{ti}/E_j — K/L	0.7496	4.7822
K/E_j — VA/L	0.5386	3.2585
K_t/E_j — VA/L	0.5120	2.8569
K_{ti}/E_j — VA/L	0.5019	2.8126
K/L — VA/L	0.6415	4.2595

Table 4 shows that there is a statistically significant negative relationship between D_a^2, the square of the difference in the rankings of the capital-intensity of an industry-group as measured by the K/E_j and K/L indices, and the level of capital utilization whether weighted by capital (U_k), value added (U_{va}), employment (U_e) or unweighted (U_{uw}). These results tend to suggest that the larger the number oi shifts operated and therefore the greater the approximation to the conditions represented by Case I of Table I, the smaller the difference that exists in the rankings given by the use oi the K/E_j and the K/L measures. For example, in the industrial chemical and petroleum refining industries where continuous three-shift operations are the rule the rankings given by the two measures are the same. In the food, leather, non-electrical machinery and transport equipment industries where basically only one shift is operated the differences in the rankings given by the two measures are substantial.

Table 4 – *Relationships between Differences in Rankings of Capital-Intensity as Measured by K/E_j, K/L and V A/L, and Capital Utilization*

Independent variable	Dependent variable							
	D_a^2				D_b^2			
Constant	84.3 (3.4)	92.1 (3.7)	99.6 (3.8)	98.4 (3.6)	68.5 (1.3)	83.7 (1.6)	89.5 (1.6)	123.6 (2.2)
U_k . . .	—0.9 (—2.5)				—0.14 (—0.18)			
U_{va} . . .		—1.1 (—2.8)				—0.4 (—0.5)		
U_e . . .			—1.2 (—2.9)				—0.5 (—0.6)	
U_{uw} . . .				—1.3 (—2.8)				—1.2 (—1.2)
R^2 . . .	0.19	0.23	0.24	0.23	0.001	0.009	0.012	0.052
F-ratio .	6.11	7.93	8.37	7.73	0.03	0.24	0.31	1.43

Notes: The figures in parentheses are *t* values. — 28 observations corresponding to the 28 different industry-groups were used in each of the simple regressions analyses.

Another observation that is worth making is that the Spearman rank correlation coefficients between the rankings fall when the K/E_j-type and VA/L indices are used. The presence of the considerable difference shows that the use of the VA/L measure, when compared to the use of the K/L measure, may encounter the added problem of having to assume that the value added is a good proxy for human and physical capital. This contention is further supported by the lack of any relationship between D_b^2, the square of the difference in the rankings of the capital-intensity of an industry-group as measured by K/E_j, and VA/L, and U_k, U_{va}, U_e or U_{uw}. The regression coefficients have negative signs but are not statistically significant.

III.

A strong *a priori* case can be made for preferring the modified capital-labour ratio (K_{ti}/E_j) to the conventional capital-labour ratio (K/L) and the value added per employee (VA/L) as a measure of the capital-intensity of the overall production process. when the K_{ti}/E_j, K/L and VA/L measures were used in ranking the capital-intensity of industry-groups in West Malaysian manufacturing a marked relationship was found between the rankings as a whole. But there are, nevertheless, quite a number of industry-groups for which substantial differences in the rankings were obtained.

The similarity in the overall rankings is due to the presence of conditions in West Malaysian manufacturing which approximate those in one of the limiting cases where rankings produced by the modified capital-labour ratio and the conventional measures are the same. These conditions of high capital utilization and multiple shift-work are, however, the exception rather than the rule for the utilization of capital in manufacturing in less developed countries so that the modified capital-labour ratio may still be useful for distinguishing between capital and labour-intensive techniques and industries in most other less developed countries.

Remark: The data used in this paper came from a study on capital utilization in Malaysian manufacturing carried out by the author for the World Bank as part of a multi-country project. The project will be published as R. Bautista, H. Hughes, D. Lim, D. Morawetz, F. Thoumi and G. Winston, *Captial Utilization in Developing Countries*, forthcoming.

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[1] See, for instance, the articles by Alfred E. Kahn, "Investment Criteria in Development Programs", *The Quarterly Journal of Economics*, Vol. 65, Cambridge, Mass., 1951, pp. 38 sqq.; Hollis B. Chenery, "The Application of Investment Criteria", *ibid*., Vol. 67, 1953, pp. 72 sqq.; Walter Galenson and Harvey Leibenstein, "Investment Criteria, Productivity, and Economic Development", *ibid*., Vol. 69, 1955, pp. 343 sqq.; Otto Eckstein, "Investment Criteria for Economic Development and the Theory of Intertemporal Welfare Economics", *ibid*., Vol. 71, 1957, pp. 56 sqq.; Amartya K. Sen, "Some Notes on the Choice of Capital-Intensity in Development Planning", *ibid*., Vol. 71, 1957, pp. 561 sqq.

[2] See Bautista, *et al., op. cit*., Chapter 3.

[3] See Gordon C, Winston, "Capital Utilisation in Economic Development", *The Economic Journal*, Vol. 81, London, 1971, pp. 36 sqq. — Ian Little, Tibor Scitovsky and Maurice Scott, *Industry and Trade in some Developing Countries: A Comparative Study*, London, 1970, Chapter 3.

[4] For a detailed discussion on the measurement or capital utilization see David Lim, “On the Measurement of Capital Utilization in Less Developed Countries", *Oxford Economic Papers*, N. S., Vol. 28, 1976, pp. 149sqq.

[5] see Hal B. Lary, *Imports of Manufactures from Less Developed Countries*, National Bureau of Economic Research, 4, New York, London, 1968.

[6] see for instance, the study by the Indian National Council of Applied Economic Research, *Underutilization of Industrial Capacity*, New Delhi, 1966, where it was reported that $Q_1 = 1.11Q_2 = 1.25Q_3$ here Q is labour productivity and $_1$, $_2$, and $_3$ the day-, night- and dawn- shifts respectively. – The same phenomenon was also reported for Malaysian manufacturing in David Lim, “On Estimating the Employment-Output Elasticity for Malaysian Manufacturing”, *Journal of Developing Areas*, Vol. 10, Macomb, III., 1976, pp. 305sqq.

[7] The 350 establishments accounted for about 10 percent of the number of manufacturing establishments West Malaysian and the Criterion for allocating them between the 28 industry-groups was the share of each industry-group in the total value added of the manufacturing sector. In all cases the day-shift was the biggest shift.

[8] See Bautista, *et. al., op. cit*., Chapter 7. – Lim, “On the Measurement of Capital Utilization in Less Developed Countries”, *op. cit*.