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LABOR PRODUCTIVITY AND OTHER CHARACTERISTICS OF CEMENT PLANTS: AN INTERNATIONAL COMPARISON

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An International Comparison

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This paper compares labor productivity and other characteristics of cement plants in Latin America with those in Australia, Canada and the United States, and tries to explain and quantify the sources of productivity differences in this industry. The major data were obtained from answers given to mailed questionnaires sent to all plants listed in the World Cement Directory[1] (1963) for the region and countries indicated.

Cement is a relatively homogeneous output, produced by a straightforward, vertically-integrated production process, with most plants having next to them their own quarries. The questionnaire, therefore, referred mainly to physical amounts of inputs and gross output (e.g. metric tons of cement produced, number of employees, etc.). International comparison is facilitated by this approach.

The questionnaires asked for 1963, 1964 and 1965 data for each plant; in most of the subsequent discussion these years were averaged. In some cases, as when a plant was starting operations, the early years were dropped; in a few cases, 1966 was included in the averages.

Questionnaire data for 1963 which overlapped with that given in the Directory was checked for consistency; no significant disparities were found for the common data. Table 1 compares some characteristics of the sample with those of the universe for 1963. The sample for non-Latin America (NLA) is a bit thin,[2] but on the whole the response was satisfactory, and much better than expected. Not all questions were answered by those responding; in what follows the size of the sample will fluctuate depending on what variables are discussed (and minor discrepancies will appear in averages).

The major characteristics of the sampled plants are presented in Table 2. The average Latin American (LA) plant has more than twice the number of employees than the NLA plants, but only produces less than sixty percent of the output of those plants (nearly all output is of portland cement in both regions). Average labor productivity in Latin America, therefore, is only one-fourth the average for the sample of industrialized countries.[3] LA hourly wage and salary costs, however, are more than one-third those of industrialized countries. LA plants have on average a higher share of employees in quarries, and a smaller share of their labor force with diplomas and university degrees.

If all plants for which output and total employment are given in the 1963 World Cement Directory are also taken into account, the resulting average labor productivities for 1963 are as follows:

	Number of Plants	Metric Tons Per Employed Persons
Latin America	92	503.4
Australia, Canada and the U.S.	94	1,724.0

Richard R. Nelson has suggested that it is likely that the range of average labor productivity will be greater in less developed than in developed countries.[4] A similar hypothesis would postulate that the ratio of standard deviation to the mean average labor productivity for a given industry will be greater for a less developed than in developed countries. If our sample is divided just into NLA and LA, this hypothesis is rejected. The data are as follows for average labor productivity (expressed in metric tons of cement per employed person):

	Number of Plants (a)	Mean (b)	Standard Deviation (c)	(c) as a Percentage of (b)
Latin America	42	565.5	300.9	53.2
Non-Latin America	27	2,277.7	1,291.0	56.7

Results more favorable to the hypothesis are obtained taking additional 1963 data from the World Cement Directory, introducing more geographical subdivisions, and excluding the two Puerto Rican plants from Latin America:

	Number of Plants (a)	Mean (b)	Standard Deviation (c)	(c) as a Percentage of (b)
United States	69	1,727.2	653.8	37.9
Canada	13	2,135.0	1,100.0	51.5
Australia	11	1,111.0	239.5	21.6
Mexico	18	677.0	330.0	48.7
Argentina	14	333.9	152.8	45.8
Brazil	25	417.2	218.8	52.4
Other Latin America	33	458.7	202.2	44.1

Surprisingly (in view of much recent literature), capacity utilization in the sample is higher, on the average, in Latin America. "Capacity" in the cement industry is traditionally estimated on the basis of the size and number of kilns, which are assumed to work continuously (three shifts), except during an annual shutdown for repairs.[5] But adding all plants for which output and capacity data are given in the World Cement Directory for 1963, the results are as follows:

	Number of Plants	Percentage Capacity Utilization
Latin America	100	85.1
Australia, Canada and the U.S.	102	86.9

Furthermore, the standard deviations of the means given in Table 2 for percentage capacity utilization are high (13.6 percent for Latin America and 16.6 percent for Non-Latin America) relative to the sample gap in average capacity utilization. We cannot say that a significant difference emerges between the capacity utilization rates of LA and NLA plants.

An indirect measure of capacity utilization is given by the relationship between kilowatt-hours of electricity consumed and horsepower of electrical motors installed. Table 2 data show that ratio to be roughly the same in LA and NLA, the average for the latter being only 3.2 percent higher than for the former.[6]

It was thought unwise to ask in the questionnaire for the "capital" of each plant. Rather, physical proxies were sought. These include installed horsepower (for electricity and other motors), kilowatt-hours used (from sources both inside and outside the plant), and number, size and age of kilns. Kilns are generally regarded as the main component of capital costs in cement plants, especially when the wet process is in use.[7] There is, furthermore, evidence linking the price of this kind of equipment to the area of its surface.[8] These proxies, unfortunately, fail to capture such things as differences in installation costs and inventories. More importantly, they will not reflect the degree of use of new types of control equipment, like computers, which are increasingly being installed in new cement plants in industrialized countries.

Horsepower of electrical motors, kilowatt-hours consumed and total kiln surface in the average LA plant hover around 60 to 64 percent of the mean for NLA plants, not far from the 58 percent corresponding to output comparisons. LA kilns, on the other hand, are on the average slightly older than those in NLA plants. Our proxies fail to show substantial differences in capital-output ratios between LA and NLA plants, even though the difference is marked for capital-labor ratios.

Table 2 shows that the average plants being compared produce in fact different bundles of goods and services, even though both apparently specialize in portland cement. The LA factory is really a combination of electric plant (only 39 percent of its electricity consumption is purchased outside, compared with 95 percent for NLA), bagging operation (82 percent of output shipped in bags vs. 19 percent for NLA), and cement production. A more systematic comparison of labor productivities will have to take this fact into account. Non-electrical motors, for example, appear closely linked to the plant generation of electricity.[9]

Average cement prices, obtained dividing sales values by sales in metric tons, are similar in LA and NLA, even though unit labor costs appear higher in LA. Here is a Latin American industry whose prices do not appear grossly out of line with those of "world" markets, even at going exchange rates.[10]

Average Labor Productivity as Dependent Variable

Multiple regression analysis has been used for untangling various influences on average labor productivity. No attempt has been made to fit particular production functions to the data. Empirical opportunism was also followed in deciding which variables, and in what form, were used in the regressions. The best results are presented in Tables 3, 4 and 5. In all cases the dependent variable is the logarithm of average labor productivity, defined as output per person employed in the plant.[11]

The independent variables listed on those which survived, or came close to surviving, significance tests based on t-statistics, which are given in parentheses under the coefficients. The variables are defined as follows:

LKLI: logarithm of the capital-labor ratio, where the surface area of all kilns is used as a proxy for capital. Labor refers to total employment in the plant.

LKL2B: as LKLI, except that the horsepower of electrical motors in the plant is as a proxy for capital.

LKL3: as LKLI, except that total kilowatt-hours comsumed are used as a proxy for capital.

LCAP: logarithm of maximum output capacity of the plant, expressed in tons of cement.

CAPU: actual output expressed as a percentage of capacity.

LKILNS: logarithm of the number of kilns installed in the plant.

SKILL: number of employees with university and technical diplomas expressed as a percentage of total employment.

WET: dummy variable, with a value of one when the wet process is in use, and zero when the dry process is used.

AGE: average age of kilns used in the plant, in years. Age is measured from installation date. The average is unweighted.

BAGS: output shipped in bags as a percentage of all output.

Other variables were used with poor results, in most cases. Interesting failures will be reported below.

Table 3 presents regressions using both LA and NLA data, while Tables 4 and 5 show the same regressions but using just LA or NLA data. The R^2's are quite high (bearing in mind we use cross-section data). The coefficients for "capital"-labor ratios all have a high degree of significance, but show a disturbingly high range of estimates for the elasticity of output with respect to "capital". Furthermore, such elasticity is uniformly higher for NLA than for LA. The result closest to a priori expectations is obtained with LKL2B, which yields the lowest coefficients.

The coefficients for the capacity variable indicate substantial economies of scale, especially for Latin American ranges, although once more the estimates show great variability depending on the proxy used for capital. For the Latin American observations, a 1.0 percent increase in capacity would yield, ceteris paribus, an increase in average labor productivity of between 0.35 and 0.61 percent. These figures, combined with those discussed in the previous paragraph, again show the difficulty of empirically separating the results of capital-deepening and scale expansion.

The capacity utilization variable has the expected sign and is in most cases significant. A more surprising result was the significance of (log of) the number of kilns in the plant, implying that the larger the number of kilns, the lower the average labor productivity, for any given level of capacity. It should be noted that a fairly high correletion exists between the number of kilns in each plant and a simple measure of dispersion of the age of those kilns.[12]

The skill variable yields significant results for the Latin American and pooled data, but not for NLA. For the latter, better results (not shown) were obtained using a variable expressing just the number of employees with university degrees as a percentage of total employment; but this variable did worse than SKILL for LA and pooled data.

The dummy variable for the process used in production gave mixed results, often insignificant, but generally showing lower labor productivity in plants using the wet process.

Considerable experimenting was carried out with variations on the AGE variable, but with disappointing results. Often when the variable yielded significant coefficients (as that shown in Table 3), the sign was unexpected, implying that the older the kilns, the higher the plant's labor productivity. It is noteworthy that the simple correlation for the pooled data between number of kilns in the plant and the average kiln age is +0.43 (see also footnote 12). Variables limiting the maximum age of kilns to 25 years, and weighting the average age of kilns in each plant by their size were tried with mediocre results. This may be due to AGE reflecting offsetting influences: equipment vintage, on the one hand, and accumulated experience, on the other. The variable, as defined, also fails to take into account frequency of repairs.

The variable measuring the share of output shipped in bags gave mixed results; even the apparently sensible outcome in Table 3 is suspect, as significance disappears when the pooled data is broken down into its LA and NLA components.

When kilowatt-hours consumed by the plant (from all sources) were used as proxies for capital, the significance of other variables decreased. Most obviously, it appears to "steal" explanatory power from capacity utilization, which is also reflected in the plant's use of electricity.

The consumption of kilowatt-hours is the variable with the highest simple correlation with cement output, and that correlation remains very high whether LA, NLA or pooled data are used:

Pooled	+0.95
LA	+0.90
NLA	+0.98

Results very similar to those obtained using kilowatt-hours as independent variable were reached when the calories provided by electricity were added to the calories provided by fuel consumption, to create a new independent variable.

Table 6 presents the results of one way of judging the quantitative importance of each independent variable in explaining differences in labor productivity between LA and NLA plants. The pooled data regressions of Table 3 predict the following average labor productivities when their coefficients are used together with the average values for the independent variables in the LA and NLA samples (in Metric Tons of Cement):

	(1)	(2)	(3)
LA	512.7	516.2	500.7
NLA	1,897.0	2,030.6	1,858.7
LA/NLA	0.270	0.254	0.269

The question may be asked as to what would happen to the productivity gap, using the same regressions, if all independent variables but one had the NLA values. For example, in Table 6 the entry under column (1), Row LKLI, says that if in regression (1) of Table 3 we use NLA average values for all variables except LKLI, for which we use the LA average value, the predicted LA average labor productivity would be 813.8 Tons, or 43 precent of the NLA productivity.

Table 6 indicates that variables for the capital-labor ratio and scale dominate the explanation of the gap. Among other variables, only that for the share of output shipped in bags emerges as quantitatively important. Taken at face value, the results of Table 6 attach great importance to low capital-labor ratios in Latin America as a drag on average labor productivity; even if scale, number and age of kilns, etc., were the same in LA and NLA, low capital-labor ratios in LA would keep its average labor productivity at between 32 and 54 percent of that of NLA. Smaller LA plant scale would, ceteris paribus keep LA productivity at between 58 and 84 percent of that of NLA.

An alternative procedure is presented in Table 7, using LA values as bases in the regressions, and observing by how much the predicted average labor productivity is increased (or decreased) by introducing NLA values for variables, one at a time. The columns marked (a) show the net change in productivity, measured in metric tons, obtained by introducing the NLA value for the variable in the corresponding row. The (b) columns show the share that such a net change represents of the observed total productivity differences between LA and NLA. As before, differences in capital-labor ratios and in scale appear as key explanatory variables. Note, however, that even in regression (3) these two variables leave a substantial part of the productivity gap unexplained; that residual is also left unexplained (except in regression (2), where BAGS has a large quantitative importance) by the other variables.

A final exercise with the regression results consists of taking, say, LA mean values for the variables and introducing them into the regressions of Table 5, i.e., those for NLA data. The average labor productivity predicted by combining LA mean values with coefficients obtained using NLA data can then be contrasted with those obtained with NLA coefficients and mean values ("row" ratios in Table 8), and with those obtained with LA mean values and LA coefficients ("column" ratios in Table 8). It may be seen in Table 8 that relatively little difference is made to the predicted LA average labor productivity whether LA or NLA coefficients are used, and the results are similar to, although usually lower than, those obtained using coefficients derived from the pooled data. The same cannot be said for NLA productivity; here LA coefficients applied to NLA mean values for variables yield productivities between only 49 and 71 percent of those obtained by NLA mean values with its own coefficients. It may also be noted that the predicted LA/NLA productivity gap is smaller when LA coefficients are used; but the larger gaps predicted by NLA coefficients correspond better to the true gap, as reflected in the sample. In both cases, the trouble lies with the abnormally low predicted NLA productivity when NLA variable values are used together with LA coefficients. One may speculate that the coefficients estimated for NLA are attributing to the most important independent variable, i.e., the capital labor ratio, responsibility for higher productivity which may arise elsewhere. But this may not be the only difficulty involved in the use of capital-labor ratios as explanatory variables for average labor productivity. To those additional difficulties we now turn.

Output and Average Capital Productivity as Dependent Variable

The results obtained in the previous section are, on the whole, rather "neoclassical", in the sense that they attribute a significant share of the explanation for productivity gaps to differences in capital-labor ratios.

In other words, by yielding high elasticities of output per employee with respect to capital per employee, they imply considerable substitution possibilities between capital and labor in cement production.

Although the technique of making average labor productivity a function of, among other things, the capital-labor ratio, is used widely in the literature, it is easy to see that it could often yield misleading results. Consider an activity with L-shaped isoquants, or no substitution possibilities at all between capital and labor. Now suppose that plants differ in the efficiency with which they use labor, or simply differ in hiring practices, so that some plants have more than the minimum labor which is technically necessary to produce a given output. Under these circumstances, one could get a good fit between average labor productivity and the capital-labor ratio, yielding or spuriously positive elasticity of output per employee with respect to capital per employee. In other words, by dividing both output and capital by the same variable, which is subject to influences not foreseen in pure neoclassical theory, we may get an apparently good relation between productivity and capital intensity.[13]

The direct approach, relating output to each of the inputs and other independent variables, is plagued by multicollinearity. The best streamlined results of that approach are given in Table 9, where new variables are defined as follows:

LKI: logarithm of capital, where the surface area of all kilns is used as a proxy for capital.

LK2B: as LKL2B, except that the horsepower of electrical motors in the plant is used as a proxy for capital.

LK3: as LKI, except that total kilowatt-hours consumed are used as a proxy for capital.

LEMPTO: logarithm of total employment in the plant.

As before, the more sensible results are given by the groups (1) and (2). Output elasticity with respect to "capital" is significant and quantitatively important in all regressions; the corresponding elasticity with respect to labor, however, is [for groups (1) and (2)] only clearly significant for the Latin American regressions. The output-capital elasticity is higher for NLA than for LA; if the average output-capital ratios implied in Table 2 are added to this information, one concludes that the marginal productivity of capital is higher in NLA (presumably capital-abundant) than in LA (presumably capital poor). For regressions in group (2), in fact, the implied NLA marginal capital productivity is 63 percent higher than that of LA.[14] For these same [group (2)] regressions, the implied NLA marginal productivity of labor is also higher, but only by about 25 percent, than in LA. This is so even though the LA output-labor elasticity is about 3.2 times that of NLA, because the NLA average labor productivity is roughly four times that in LA. Table 2 also showed NLA hourly wages about 2.8 times those in LA. NLA capital costs would have to be more than three times those in LA to make all of these pieces fit into the standard neo-classical cost-minimizing conditions!

Before leaving the results of Table 9, it may be noted that LA regressions (1) and (2) suggest the presence of economies of scale, with the coefficients for capital and labor adding up to 1.13 and 1.08, respectively. But this is not the case for the regressions using pooled data. The coefficients for the capacity utilization variables do well in regressions (2), which on the whole give the more "sensible" results. The AGE coefficients shown are again of low significance, while those for SKILL do better with LA than NLA data, as in earlier results.

If the good results obtained correlating average labor productivity and the capital-labor ratio are due partly or totally to the spurious reasons discussed above, one should obtain poorer results when making average capital productivity (or its inverse, the capital-output ratio) the dependent variable. These will be reflected on the size of the correlation coefficient and of the t-statistics, although the coefficients obtained in the new regressions are linked to the old by the identity:

$$\frac{K}{Y} = \frac{K/L}{Y/L}$$

Suppose one has estimated coefficients for the following regression:

$$\log (Y/L) = B_o + B_1 \log (K/L) + B_2 \log CAP$$

And then estimates:

$$\log (K/Y) = \alpha_o + \alpha_1 \log (K/L) + B_2 \log CAP$$

Because of the identity shown, it will be true that :

$$B_1 = 1 - \alpha_1$$

And,

$$B_2 = - \alpha_2$$

Table 10 presents the major differences between these two types of regressions; the results for variables LCAP, CAPU, LKILNS, SKILL, WET, AGE and BAGS were identical with those shown in Tables 3, 4 and 5 for the corresponding regressions (i.e., same numerical value for the coefficient and for its t-statistic), but with a different sign. They are not shown in Table 10.

With one exception, the R^2's and the F's in Table 10 are lower than the corresponding ones in Tables 3, 4 and 5. Only two t-values are higher in Table 10 than for the corresponding coefficients of Tables 3, 4 and 5. The collapse of the R^2's, F's and t's is sharpest in regressions using kilowatt-hours as a proxy for capital; on the other hand, regressions using electrical motors as that proxy hold up well, or even show improvements in explanatory power, in Table 10.

Plants on the "Efficiency Frontier"

Another way of approaching differences between LA and NLA plants, as well as characteristics of the whole sample, is to deal just with "efficient" observations. Efficiency is here defined in a technological sense, i.e., the attempt tries to isolate points on an isoquant.[15] For a given capacity range, a plant with a higher capital and labor requirements per unit of output than another one is eliminated, until only undominated or "efficient" plants remain, for which, say, a higher per unit capital requirement is offset by a lower unit labor use.

Table 11 presents the outcome of such an exercise, which is, of course, very sensitive to extreme observations (sometimes of doubtful reliability). Ranges were selected somewhat arbitrarily, but experiments with different ones did not change the results significantly. It may be seen that "efficient" LA plants have, on the whole, lower unit capital requirements, and higher labor use than NLA plants, whether kiln surface or electric horsepower is used as the capital proxy. Unit capital use in NLA plants is on the average 58 or 49 percent higher than in LA plants, while labor inputs are 68 or 84 percent less.

While positive evidence on capital-labor substitution is stronger here than when all plants were taken into account, the opposite is the case on scale economies. Indeed, looking at efficient LA and NLA plants separately, when electric horsepower is used as the capital proxy, capital unit requirements first tend to decline, but then increase for plants in ranges higher than 550 TMT. No clear pattern emerges for labor requirements, nor for capital use when kiln area is the proxy. While in this case the biggest plant dominates all others, five (4 NLA, 1 LA) "efficient" plants remain in the case of electric horsepower as proxy, even when all ranges are pooled together.

Taking these five "efficient" plants (and working with a single capacity range), Table 12 estimates how LA and NLA plants exceed, on the average the minimum unit labor and capital requirements. In other words, Table 12 presents a rough calculation of the "X-inefficiency" for the group of plants in the sample. The excess of unit capital use in LA plants relative to each "efficient" plant is only about 12 percent above the corresponding excess of NLA plants, but the excess of unit labor requirements in LA plants is about four times the corresponding "X-inefficiency" of NLA plants. These results, of course, are compatible with the greater variation (noted earlier) in labor productivity than in the capital-output ratio.

"Efficient" plants #2, #3, and #4 clearly dominate the averages for "inefficient" LA and NLA plants. But comparing LA "inefficient" plants with the most capital-intensive "efficient" plant (#5), one observes a (rather expensive) trade-off between capital and labor use. Trade-offs can also be detected comparing NLA "inefficient" plants with "efficient" plant #1, and (in the opposite direction) with "efficient" plant #5.

Final Remarks

The data presented in this paper contain much ambiguity, but, especially if (electrical) horsepower is admitted as the best available capital proxy, they yield evidence favorable to the hypothesis that some capital-labor substitution exists in cement production, even though differences in capital intensity fail to explain all of the productivity gap between LA and NLA plants. This conclusion is somewhat strengthened by regressions relating, for all plants, the capital-labor ratio to wage rates and capacity. Those results are as follows (where LRATE refers to the logarithm of the dollar wage rate, and the rest of the notation is as before):

$$\underset{(0.20)}{\text{LKL1} = 0.115} + \underset{(3.78)}{0.331\ \text{LRATE}} + \underset{(3.31)}{0.337\ \text{LCAP}}$$

$R^2 = 0.45$

Observations = 51

F-test = 19.51

$$\underset{(2.49)}{\text{LKL2} = 1.708} + \underset{(5.10)}{0.501\ \text{LRATE}} + \underset{(2.95)}{0.359\ \text{LCAP}}$$

$R^2 = 0.53$

Observations = 48

F-test = 25.18

$$\underset{(3.41)}{\text{LKL3} = 1.963} + \underset{(5.49)}{0.475\ \text{LRATE}} + \underset{(4.39)}{0.453\ \text{LCAP}}$$

$R^2 = 0.57$

Observations = 57

F-test = 36.15

It should however be noted that when the same regressions are estimated for LA and NLA separately, the t-statistics for the wage rate variable all fall below two.[16] With the exception of the equation using LKL3 as dependent variable with LA data, the link between capital intensity and scale also loses significance.

The data leave unclear what kinds of capital labor can substitute for. A closer look at labor allocation within cement plants, as well as a more detailed inventory of capital goods is the next step in clarifying this point. Such an investigation may also shed light on what other factors, besides scale and capital per worker account for the much higher average labor productivity of NLA plants.

Notes

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1 World Cement Directory is published by the European Cement Association (CEMBUREAU). The plants listed include clinker grinding plants (excluded from this study), as well as cement plants under construction, and some which have gone out of operation since 1963. Two rounds of questionnaires were sent, roughly six months apart.

2 Leading a cynical wag to remark that Latin American productivity was lower because its entrepreneurs spent their time answering questionnaires sent by silly academics. While on the topic of wags, I should warn the wit that scores of colleagues and friends have already told me that they expected concrete results from this study.

3 The average labor productivity data of Table 2 may also be compared with those given by the Organisation for Economic Co-Operation and Development (OECD) for the cement universe of some countries (all data is metric tons of cement per employee for the average of 1963, 1964 and 1965, excepting Australia):

		Index
Netherlands	2,175	100
Canada	2,063	95
United States	1,784	82
Switzerland	1,777	82
Sweden	1,657	76
United Kingdom	1,470	68
France	1,464	67
Federal Republic of Germany	1,370	63
Italy	1,183	54
Australia (1963 Only)	1,094	50
Greece	986	45
Ireland	888	41
Spain	692	32
Latin America (sample)	566	26
Turkey	428	20

For basic data see OECD, The Cement Industry, several annual issues. Australian data from the World Cement Directory for 1963.

4 See his pathbreaking," A Diffusion Model of International Productivity Differences in Manufacturing Industry", The American Economic Review, Volume LVIII, No. 5, Part 1, December 1968, p. 1231.

5 The correlation coefficients (R's) between capacity and total kiln volume for the sampled plants are as follows:

	Number of Plants	R
Latin America	40	0.85
Non-Latin America	21	0.88
Pooled	61	0.89

6 Kilowatt-hours of electricity consumed per horsepower of electrical motor installed are as follows:

LA	2,502
NLA	2,584
All U.S. Manufacturing (1954)	2,349

The last line was obtained from Murray F. Foss, "The Utilization of Capital Equipment: Postwar Compared with Prewar", Survey of Current Business, Vol. 43, No. 6, June 1963, p. 11. This article used U.S. data for electric power consumption and the horsepower of electric motors, together with assumptions, to estimate the average number of hours per year that electric-power-driven equipment was utilized. It makes the point that most production equipment in manufacturing is powered by electric motors and suggests that "...there is probably a fairly good positive correlation between the horsepower of a machine and its dollar cost". (p. 11)

7 See, for example, Leonard A. Doyle, Inter-Economy Comparisons: A Case Study (Berkeley and Los Angeles: University of California Press, 1965), p. 21.

8 See John Haldi and David Whitcomb, "Economies of Scale in Industrial Plants," The Journal of Political Economy, Volume 75, No. 4, August 1967, Part I, pp. 373-86. "The amount of material required for containers (tanks, furnaces, kettles, pipes and so on) depends principally on the surface area, whereas capacity depends on the volume inclosed" (p. 375). A check (which I have not carried out for lack of data) would be to see how close a correlation exists between the indicated capital proxies and book value of plant and equipment in cement in countries where all those data are avoidable.

9 For 49 plants (LA and NLA), the correlation between horsepower installed in non-electrical motors and kilowatt-hours produced in the plant is +0.68. For the NLA plants by themselves the correlation is +0.80, and it becomes +0.68 again for just the LA plants.

10 Sales values in local currencies were translated into U.S. dollars by using average merchandise exchange rates. The latter were found by dividing the sum of exports and imports valued in local currencies by the same variables expressed in U.S. dollars, for the relevant years. Basic data obtained from International Monetary Fund, International Financial Statistics.

The secular progress of Latin American import substitution in cement may be seen in the following table, showing for the major countries cement imports as percentages of total apparent domestic cement consumption:

	1920-24	1935-38	1951-54	1960-64
Argentina	67	6	16	nil
Brazil	100	13	27	nil
Chile	51	2	nil	1
Colombia	82	28	1	nil
Cuba	54	6	28	8
Mexico	20	4	2	nil
Peru	86	34	10	2
Uruguay	13	7	16	nil
Venezuela	68	70	10	nil
Central America (six)	90	88	40	22

Basic data obtained from CEMBUREAU, World Cement Market in Figures, (Paris, 1967). Between 1920-24 and 1962-66 Latin American cement output has grown at an average annual rate of 10 percent, while apparent cement consumption (production plus imports minus exports) grew at about 7 percent per annum.

11 Most, but not all, plants also provided data on hours worked per year per employed person. The averages were as follows:

	Number of Plants	Hours
LA	35	2,127
NLA	26	2,021

12 The measure of dispersion for each plant is:

$$\frac{\Sigma \mid xi - \bar{x} \mid}{n}$$

Where:

xi = age of kiln i

$\bar{x}$ = average age of kilns in plant

n = number of kilns

The R^2 between this measure of dispersion and number of kilns is 0.50; the relationship is positive. When the measure of dispersion is correlated with the average age of kilns in plant, the R^2 drops to 0.20 (the relationship is also positive).

13 Consider the following simple numerical example, where capital and output are the same in all plants (say they are both equal to 10), but where the labor employed differs as follows:

	Labor Employed	Average Labor Productivity	Capital Labor Ratio
Plant 1	1	10	10
Plant 2	2	5	5
Plant 3	3	3.3	3.3
Plant 4	4	2.5	2.5
Plant 5	5	2.0	2.0

The fit between the last two columns is obviously good, and the (apparent) output-capital elasticity is one.

14 The ratio of NLA to LA output-capital elasticities may be written as follows:

$$\frac{[\partial O/\partial K]NLA}{[\partial O/\partial K]LA} \cdot \frac{[O/K]LA}{[O/K]NLA} = \frac{0.757}{0.498}$$

From Table 2, using horsepower of electrical motors as capital proxies, we have that:

$$\frac{[O/K]\ LA}{[O/K]\ NLA} = 0.93$$

Therefore, we get:

$$\frac{[\partial O/\partial K]NLA}{[\partial O/\partial K]LA} = \frac{1.52}{0.93} = 1.63$$

15 This approach was pioneered by M. J. Farrell, "The Measurement of Productive Efficiency", Journal of the Royal Statistical Society, Series A (General), Vol. 120, Part 3 (1957), pp. 253-81. See also D. J. Argner and S. F. Chu, "On Estimating the Industry Production Function", American Economic Review, September 1968, pp. 826-39. I am grateful to Peter T. Knight for calling my attention to this approach.

16 Similar results are obtained when the logarith of average labor productivity (LOE) is regressed against (log of) wage rates and (log of) capacity, as follows:

$$LOE = \underset{(70.77)}{6.572} + \underset{(6.56)}{0.609}\ LRATE$$

$R^2 = 0.43$
Observations = 59
F-test = 43.08

$$LOE = \underset{(6.90)}{3.850} + \underset{(5.52)}{0.462}\ LRATE + \underset{(4.93)}{0.492}\ LCAP$$

$R^2 = 0.60$
Observations = 59
F-test = 42.46

When the sample is divided into its LA and NLA components the results are much worse, and the t-ratios for LRATE drop way below two.

The data were also used to estimate price equations, where (the log of) price was made a function of selected cost and productivity variables, as follows:

$$\begin{aligned} \text{LPRICE} = {} & \underset{(2.86)}{3.551} + \underset{(3.26)}{0.196}\ \text{LRATE} - \underset{(2.77)}{0.209}\ \text{LOE} \\ & + \underset{(0.81)}{0.167}\ \text{LCALTN} + \underset{(0.43)}{0.077}\ \text{LK03} \end{aligned}$$

R^2 = 0.29
Observations = 46
F-test = 4.28

The variable LCALTN stands for (the log of) calories of fuel consumed per ton of cement; other variables are defined as before. When the sample is divided into its LA and NLA components, the LOE coefficient is the only one to remain significant for NLA observations (its t-statistic, in fact, increases to -3.24), while for LA observations only LRATE maintains a t-statistic above two.

For LA plants, the variable LCALTN shows a significantly negative correlation with plant capacity, while with NLA data it shows significantly negative correlation with CAPU.

Table 1

Comparison of Sample with Universe Characteristics for 1963

	(1) Sample	(2) Universe	(1) as a Percentage of (2)
Cement Output (Million Metric Tons)			
Latin America	8.86	20.39	43.5
United States, Canada and Australia	9.48	68.46	13.8
Number of Plants			
Latin America	41	117	35.0
United States, Canada and Australia	26	218	11.9
Average Plant Output (Thousand Metric Tons)			
Latin America	216.2	174.3	124.0
United States, Canada and Australia	364.5	314.0	116.1

Sources and Method: "Universe" obtained from CEMBUREAU, World Cement Directory, for 1963. It was assumed that all plants for which capacity data were given in that Directory were in operation during 1963, as not all plants listed in that publication reported their output. Total output obtained from the Directory, pp. IX-X. "Latin America" is defined to include, besides the twenty Latin American Republics, the Bahamas, Jamaica, Puerto Rico and Trinidad. Therfore, Puerto Rico is excluded from U.S. totals. The sample includes plants which did not report 1963 data; they are excluded from this Table, but will be used below. This Table underestimates the size of the non-Latin American sample; eleven U.S. plants, owned by the same company, answered in two questionnaires, giving averages, each of which was treated as a single plant, even when obtaining total output.

Table 2

Major Characteristics of the Sample (mostly 1963-65)

(Average per plant per year)

	(1) Latin America	(2) Non-Latin America	(1) as a Percentage of (2)
Total Employment (persons)	432.4	189.4	228.3
--In quarries	60.5	24.3	249.0
--Elsewhere in plant	385.6	165.1	233.6
--With University and technical diplomas	19.4	9.7	200.0
--With University degrees	7.4	5.3	139.6
Output (thousand metric tons)	227.9	390.8	58.3
--Percentage of Portland in output	96.1	97.2	------
Output per employed person (metric tons)	565.5	2,277.7	24.8
Capacity (thousand metric tons)	276.5	505.0	54.8
--Percentage capacity utilization	84.6	78.8	------
Horse Power installed (thousand)	13.4	19.3	69.4
--Horse Power of electrical motors (thousands)	11.3	18.1	62.4
Kilowatt-hours consumed (million)	28.4	46.7	60.8
--Percentage of electricity purchased	39.0	94.7	------
Percentage of output shipped in bags	82.3	19.0	------
Number of kilns	2.8	2.5	112.0
Average age of kilns (years)	14.1	13.3	106.0
Average surface of kilns (square meters)	827.4	1,557.4	53.1
Percentage of plants using wet process	65.1	77.8	------
Percentage of plants with own quarries	86.8	92.6	------
Hourly cost per employed person (U.S. dollars)	1.20	3.41	35.2
Sales value per cement ton (U.S. dollars)	23.24	23.16	100.3

Sources and Method: "Averages" for magnitudes such as output per employed person have been generally obtained by averaging the corresponding data for each plant.

Table 3

Regressions "explaining" (Log. of) Average Labor Productivity

Data for LA and NLA Pooled.

	(1)	(2)	(3)
Constant	1.099 (2.87)	2.883 (5.27)	1.496 (4.97)
LKL1	0.709 (12.54)	-----	-----
LKL2B	-----	0.425 (6.23)	-----
LKL3	-----	------	0.806 (17.37)
LCAP	0.655 (10.15)	0.370 (4.31)	0.255 (4.11)
CAPU	0.936 (4.25)	0.971 (3.83)	0.239 (1.31)
LKILNS	-0.553 (7.20)	-0.250 (2.48)	-0.218 (3.36)
SKILL	2.460 (3.05)	2.109 (2.47)	1.024 (1.72)
WET	-0.222 (2.88)	-----	-----
AGE	0.010 (2.65)	-----	-----
BAGS	-----	-0.07 (3.96)	-----
R^2	0.93	0.92	0.94
Observations	55	51	64
F-test	91.2	79.0	189.8

Table 4

Regressions "explaining" (log. of) Average Labor Productivity; Data for LA only

	(1)	(2)	(3)
Constant	1.368 (2.90)	1.596 (2.35)	1.690 (4.23)
LKL1	0.537 (6.00)	------	------
LKL2B	------	0.314 (4.17)	-------
LKL3	----	----	0.563 (5.81)
LCAP	0.607 (8.51)	0.467 (4.66)	0.357 (4.40)
CAPU	1.156 (4.12)	1.252 (3.54)	0.392 (1.34)
LKILNS	-0.466 (4.28)	-0.183 (1.18)	-0.212 (2.29)
SKILL	3.384 (3.67)	4.114 (3.44)	2.694 (2.92)
WET	-0.207 (2.51)	-----	-----
AGE	0.004 (0.92)	-----	-----
BAGS	-------	0.000 (0.07)	-----
R^2	0.88	0.82	0.86
Observations	36	27	38
F-test	28.6	15.3	40.7

Table 5

Regressions "explaining" (log. of) Average Labor Productivity
Data for HIA only

	(1)	(2)	(3)
Constant	1.120 (0.87)	3.638 (4.51)	1.553 (2.65)
LKLI	0.911 (4.62)	-----	-----
LKL2B	-----	0.662 (5.87)	-----
LKL3	-----	-----	0.924 (9.40)
LCAP	0.545 (2.44)	0.076 (0.61)	0.111 (1.28)
CAPU	0.668 (1.70)	0.835 (3.19)	0.460 (2.23)
LKILNS	-0.340 (1.56)	-0.035 (0.31)	-0.140 (1.82)
SKILL	4.258 (1.64)	0.948 (0.90)	0.371 (0.47)
WET	-0.180 (0.82)	-----	-----
AGE	0.014 (1.82)	-----	-----
BAGS	-----	-0.006 (1.48)	-----
R^2	0.83	0.87	0.89
Observations	19	24	26
F-test	7.83	19.01	31.67

Table 6

Ratio of LA to NLA average labor productivity if indicated variable takes the average value for LA data, while all other variables take the average values for NLA data, using regressions of Table 3

	(1)	(2)	(3)
LKLI	0.429	------	------
LKL2B	------	0.538	------
LKL3	------	------	0.323
LCAP	0.576	0.771	0.843
CAPU	1.059	1.065	1.016
LKILNS	0.949	0.933	0.969
SKILL	1.038	1.005	1.006
WET	1.053	------	------
AGE	0.996	------	------
BAGS	------	0.614	------

Table 7

Gains in productivity obtained by introducing NLA average values, one at a time, into Table 3 regressions, using LA average values for all other variables (Columns (a) expressed in Metric Tons of Cement; Columns (b) as percentages)

	(1) (a)	(1) (b)	(2) (a)	(2) (b)	(3) (a)	(3) (b)
LKLI	682.5	49.3	-----	-----	-----	-----
LKL2B	-----	-----	442.5	29.2	-----	-----
LKL3	-----	-----	-----	-----	1,048.9	77.2
LCAP	377.2	27.2	153.8	10.2	93.5	6.9
CAPU	-28.4	-2.1	-31.3	-2.1	-7.6	-0.6
LKILNS	27.8	2.0	37.3	2.5	16.2	1.2
SKILL	-18.8	-1.4	-2.6	-0.2	-2.9	-0.2
VET	-25.6	-1.8	-----	-----	-----	-----
AGE	1.9	0.1	-----	-----	-----	-----
BAGS	-----	-----	324.4	21.4	-----	-----
	1,016.6	73.3	924.1	61.0	1,148.1	84.5
LA Productivity	512.7	-----	516.2	-----	500.7	-----
Residual	367.7	26.6	590.3	39.0	209.9	15.5
NLA Productivity	1,897.0	-----	2,030.6	-----	1,858.7	-----
Gap	1,384.3	100.0	1,514.4	100.0	1,358.0	100.0

Table 8

Average Labor Productivities predicted by Interchanging LA and NLA mean values of independent variables, and LA and NLA coefficients of Tables 4 and 5

(Predicted productivities in Metric Tons of Cement per employed person)

	Regression (1)		Regression (2)		Regression (3)	
	LA Coefficients	NLA Coeff.	LA Coeff.	NLA Coeff.	LA Coeff.	NLA Coeff.
LA Mean Values	500.2	472.1	497.2	527.8	489.3	494.2
NLA Mean Values	1,398.2	1,984.5	1,034.9	2,111.8	1,355.4	1,922.7
"Row" Ratios	35.8	23.8	48.0	25.0	36.1	25.7
"Column" Ratios						
LA mean values	106.0		94.2		99.0	
NLA mean values	70.5		49.0		70.5	

Table 9

Regressions "explaining" (log. of) Output

	(1)			(2)			(3)		
	(P)	(LA)	(NLA)	(P)	(LA)	(NLA)	(P)	(LA)	(NLA)
Constant	-2.585 (3.50)	-3.065 (3.22)	-2.814 (2.38)	2.343 (4.85)	-0.060 (0.07)	2.332 (5.61)	2.261 (9.93)	1.897 (4.33)	2.410 (7.51)
LKI	0.985 (11.81)	0.612 (4.72)	0.958 (4.19)	-----	-----	-----	-----	-----	-----
LK2B	-----	-----	-----	0.782 (11.56)	0.498 (4.76)	0.757 (8.58)	-----	-----	-----
LK3	-----	-----	-----	-----	-----	-----	0.925 (23.49)	0.868 (11.40)	0.938 (10.45)
LEMPTO	-0.004 (0.04)	0.519 (2.83)	0.073 (0.35)	0.146 (1.94)	0.581 (4.29)	0.180 (1.86)	0.015 (0.35)	0.104 (1.07)	-0.021 (0.22)
CAPU	0.424 (1.19)	0.439 (0.90)	0.515 (1.31)	0.742 (2.12)	1.047 (2.03)	0.785 (3.05)	-----	-----	-----
SKILL	1.691 (1.25)	3.939 (2.30)	4.065 (1.83)	-----	-----	-----	-----	-----	-----
AGE	-----	-----	-----	-0.007 (1.15)	-0.005 (0.63)	-0.005 (1.20)	-----	-----	-----
R^2	0.76	0.77	0.80	0.77	0.80	0.91	0.91	0.89	0.91
Observations	58	37	21	53	29	24	67	41	26
F-test	42.1	27.1	16.2	40.5	24.5	46.5	320.1	157.7	122.6

Table 10

Regressions "Explaining" (log of) the Capital-Output Ratio

	LKL1	LKL2B	LKL3	R^2	F-test
Pooled data					
(1)	0.291 (5.15)	-----	-----	0.71	16.6
(2)	-----	0.575 (8.43)	-----	0.67	15.2
(3)	-----	-----	0.194 (4.18)	0.27	4.4
LA data					
(1)	0.463 (5.18)	-----	-----	0.81	17.1
(2)	-----	0.686 (9.13)	-----	0.84	17.7
(3)	-----	-----	0.437 (4.51)	0.46	5.4
NLA data					
(1)	0.089 (0.45)	-----	-----	0.64	2.8
(2)	-----	0.338 (2.99)	-----	0.56	3.5
(3)	-----	-----	0.076 (0.77)	0.31	1.8

Table 11

Capital and Labor Inputs per Unit of Output of Plants on the "Efficiency Frontier"

(Starred plants belong to LA; Per Unit Inputs of Labor and Capital expressed as indices, with averages for all efficient plants equal 100; TMT stands for Thousand Metric Tons).

	Using Kiln Surface Area as Capital Proxy		Using Horsepower of Electric Motors as Capital Proxy	
	K/O	L/O	K/O	L/O
Range 0 to 110 TMT	[*] 95	288	[*] 107	179
Range 110-175 TMT	[*] 92	87	[*] 69	200
	190	81	[*] 93	54
			118	50
Range 175-250 TMT	[*] 55	145	[*] 54	130
	104	80	101	20
Range 250-350 TMT	[*] 56	147	[*] 78	244
	93	69	[*] 82	239
	106	41	98	26
Range 350-550 TMT	127	75	[*] 52	130
	133	64	79	24
	148	39		
Range 550-700 TMT	[*] 61	244	[*] 83	70
	96	84	110	17
	97	37		
More than 700 TMT	47	18	[*] 105	192
			[*] 111	84
			112	29
			247	11
Average LA	72	182	83	152
Average NLA	114	59	124	25
(Average NLA/Average LA)	(158.3)	(32.4)	(149.4)	(16.4)

Table 12

Average Excess of Unit Capital and Labor Requirements compared with "Efficient" Plants, when Horsepower in Electric Machinery is used as Capital Proxy; Single Range

(Unit Requirements is "Efficient" Plants equal 100)

Relative to "efficient" Plant:	K/O		L/O	
	NLA Plants	LA Plants	NLA Plants	LA Plants
#1 (LA)	274	308	35	141
#2 (NLA)	178	200	187	747
#3 (NLA)	140	157	224	891
#4 (NLA)	128	144	267	1066
#5 (NLA)	57	64	411	1640

Note: There are 22 plants in the NLA average and 28 in the LA average. "Efficient" plant #1 is the most labor-intensive; #5 is the most capital-intensive.