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

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Labor Productivity and Other Characteristics of Cement Plants: 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. It also attempts to measure the degree of capital-labor substitution that exists in this activity. 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 were 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, and will be briefly reviewed in this introductory section. 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 annual wages and salaries per employed person, however, are 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. The share of wages and salaries in total sales is higher in LA plants, but the difference is small and the standard deviations (not shown) very high.

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, a result which may be typical for continuous process industries.

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, inventories and buildings and structures. 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. More on this below.

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 38 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. Comparison of labor productivities has to take this fact into account. Non-electrical motors, for example, appear closely linked to the plant generation of electricity.[9]

The variety of services and processes carried out under the label of a "portland cement plant" suggests that for some types of analysis plant data may be too aggregated, while for others it may be too micro and incomplete. If, as Yoav Kislev notes, the construction industry of a country lacks facilities to handle cement in bulk, cement plants will have to install bagging operations, regardless of other economic parameters. Under these circumstances, one may attribute low productivity to plants which simply reflect extra-plant conditions. A more accurate picture could be obtained by comparing the combined production and distribution systems for cement across countries. Similar considerations would apply to the combination of infrastructure services (of which electricity is only one example) and cement production. On the other hand, for the purpose of isolating exactly where within the plant the possibilities of capital-labor substitution are greatest, more disaggregated data on the input uses of different intra-plant processes would be desirable.

To complete the review of Table 2, one may note that average cement prices, obtained by dividing sales values (excluding bags) 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 (often overvalued) exchange rates.[10]

The rest of the paper will use plant data, in spite of their limitations, to investigate productivity differences between LA and NLA, and the degree of capital-labor substitution which exists in cement production. It will be seen that differences in capital-labor ratios and scale explain significant shares of the productivity gap. But a large part of that gap remains unexplained either by those two variables, or by any other variable which could be unambiguously labelled.

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 annual average labor productivity, defined as tons of cement per person employed in the plant.[11]

The independent variables listed are 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:

LKL1: 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 LKL1, except that the horsepower of electrical motors in the plant is used as a proxy for capital.

LKL3: as LKL1, except that total kilowatt-hours consumed 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.

AGESQ: the variable AGE squared.

LA: dummy variable, with a value of one for Latin American plants, and zero for the rest.

Several other variables were used, including a dummy for whether or not the plant has its own quarry, the share of portland cement in output, etc., with mixed or poor results. As expected, multicollinearity presented problems. For example, a variable expressing for each plant output shipped in bags as a percentage of all output performed well in equations using pooled data (as those shown in Table 3), but was "killed" when the dummy variable LA was introduced. The simple correlation coefficient between the LA dummy and the variable for the share of cement shipped in bags is +0.84 (with 69 observations). The corresponding figure for the correlation between the same dummy and the percentage of electricity each plant purchased from outside sources is -0.62 (with 67 observations). It may be noted, however, that even when the LA dummy was not introduced, the variable for share of electricity purchased did poorly in most equations. (Other interesting failures will be reported below.)

A fuller idea of the multicollinearity problems present in the regressions of Table 3, and in other regressions to be shown below, is given by the following correlation matrix for some of the independent variables:

	KL1	KL2B	CAP	CAPU	AGE	LA	AWR	BAGS	PKWHP
KL1	---	0.54	0.43	-0.16	-0.13	-0.80	0.71	-0.69	0.59
KL2B	---	----	0.41	-0.06	-0.20	-0.50	0.61	-0.52	0.56
CAP	---	----	----	-0.23	0.05	-0.39	0.49	-0.41	0.24
CAPU	---	----	----	-----	-0.08	0.19	-0.06	0.27	-0.11
AGE	---	----	----	-----	-----	0.05	-0.22	-0.04	-0.03
LA	---	----	----	-----	-----	-----	-0.82	0.84	-0.62
AWR	---	----	----	-----	-----	-----	-----	-0.78	0.41
BAGS	---	----	----	-----	-----	-----	-----	-----	-0.48
PKWHP	---	----	----	-----	-----	-----	-----	-----	-----

AWR stands for average wages per employee, BAGS for the share of output shipped in bags and PKWHP for the percentage of total electricity consumed purchased outside the plant.

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. (Note that the regressions for each group use slightly different samples.) 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 high range of estimates for the elasticity of output with respect to "capital". (When Table 3 regressions were run without the LA dummy, the range was even higher.) Furthermore, such elasticity is uniformly <u>higher</u> for NLA than for LA.

The result closest to a priori expectations is obtained with LKL2B, using the horsepower of electrical motors as a proxy for capital, and which yields the lowest coefficient. This variable also performs best in other regressions to be discussed below. On the other hand, LKL3, using kilowatt-hours consumed (from all sources) as a capital proxy, performs in a sense "too well". Electricity consumption is so closely related to output that other variables tend to lose significance (especially capacity utilization), while the a priori case for relating electricity consumption to capital is weaker than with the other two proxies.

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

A similar statistical problem would arise if the proxy chosen refers to a plant activity which, though relatively unimportant, is registered accurately and is closely bound to output (e.g., number of paper bags consumed). Horsepower and kiln surface area proxies, in that order, can be considered, therefore, as more reliable than electricity. It may be noted that 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 to act as capital proxy.

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 0.34 and 0.61 percent. These figures, combined with those discussed above, again show the difficulty of separating the results of capital-deepening and scale expansion.

Attempts were made, in a Cobb-Douglas spirit, to measure scale by the number of employees. The results were uniformly poor.

The capacity utilization variable has the expected sign and is in most cases significant. The coefficients for other variables were little affected whether or not this variable was introduced into the regressions; that experiment (not shown) was motivated by the fear that the introduction of CAPU biased the results obtained for other coefficients.

An interesting result is the significance of (log of) the number of kilns in the plant in all regressions of Table 3, and in two of those in Table 4. The results indicate that the larger the number of kilns, the lower the average labor productivity, for any given level of capital density and scale. As LKL1 uses total kiln surface as a capital proxy, the results in the first columns of Tables 3 and 4 are better than the rest. More fundamentally, this variable could be picking up productivity differences between plants which achieved a given capacity by a gradual process of adding new kilns, and those which from the start adapted their (smaller) number of kilns to the desired (and observed) plant capacity. Presumably, the latter have a higher productivity than the former, among other things because the larger number of kilns for a given output will require a greater amount of raw material and final product handling. It may be noted that a fairly high positive correlation exists between the number of kilns in each plant and a simple measure of dispersion of the age of those kilns. A (lower) positive correlation also exists between that measure of dispersion and the average age of kilns.[12] Finally, plants faced with greater fluctuations in demand may have adapted by having a larger number of kilns.

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 or near-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. Note also that the variable, as defined, fails to take into account frequency of repairs.

It is possible that the variable AGE picks up two offsetting influences: equipment vintage, on the one hand, and the accumulated experience and learning of the plant's workers and management, on the other. To test this possibility, both AGE and AGE squared were introduced in several regressions, with the supposition that the former would pick up the vintage effect, and the latter the learning effect. The signs came out as supposed, but the coefficients were insignificant. Some of these experiments will be reported below.

The significance of the LA dummy can be interpreted as meaning that LA and NLA plants operate on different production functions; in other words, there appears to be a (neutral) efficiency difference, with the LA plants producing less output than the rest for given capital-labor ratio, scale, skill, etc. Such an interpretation is reinforced by the results of Table 8 (to be discussed). But this straightforward interpretation is clouded by the multicollinearity among the LA dummy, the percentage of output shipped in bags, the percentage of electricity purchased from outside the plant, and similar variables. It is difficult, then, to separate apparent productivity gaps arising from the fact that cement plants in LA and NLA include different processes and activities, from those which result from "true" efficiency differences in the handling of the basic factors of production. The LA dummy, however, performs so much better than the other variables (of less ambiguous interpretation), that one is left with the general efficiency difference as the major interpretation.

A Quantification of the Sources of the Productivity Gap

The previous section has provided us with equations which, in spite of several weaknesses, appear to explain a very high share of the variability in average labor productivity across plants, and isolate several independent variables which are significant in that explanation. One may ask about the quantitative importance of each of those variables.

The pooled data regressions of Table 3 predict the following average labor productivities (in metric tons of cement), when their coefficients are used, first with the average LA values for the different independent variables, and then with those for the NLA sample:

	Regression (1) (Using LKL1)	Regression (2) (Using LKL2B)	Regression (3) (Using LKL3)
Predicted LA Productivity	500.4	493.5	497.1
Predicted NLA Productivity	1986.1	2080.5	1921.1
Predicted LA Productivity as a percentage of predicted NLA Productivity	25.2	23.7	25.9

The question may be asked as to what would happen to the predicted productivities and to the productivity gap if using the same Table 3 regression coefficients, we combine them with all but one of the average NLA values for the independent variables. For example, in Table 6 the entry under Column (1), Row LKL1, says that if in regression (1) of Table 3 we use NLA average values for all variables except LKL1, for which we use the LA average value, the predicted average labor productivity would be 984.5 tons, or 49.6 percent of the NLA productivity.

The results shown in Table 6 indicate that the capital-labor ratio, scale and the LA dummy variable (or general efficiency differences) dominate the explanation of the gap. Other variables, although significant for inter-firm labor productivity differences, contribute little to explaining the LA/NLA productivity gap, and in several cases (e.g., CAPU, SKILL and WET in the first column) indicate that LA plants have average values which yield higher productivity, ceteris paribus, than NLA plants. (It should be remembered that the sample used changes from column to column.)

Taken at face value, the results of Table 6 attach great importance to the LA dummy as a drag on average labor productivity; even if LA plants had the same capital-labor ratio, scale, etc., as NLA plants, their labor productivity would remain at between 55 and 82 percent of that of NLA plants. Even greater importance is attached by this method to low LA capital-labor ratios as drags on average labor productivity.

An alternative, and more natural procedure is presented in Table 7, using LA average values for the independent variables as bases in the regressions of Table 3, 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, while all other variables keep their LA values. 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, scale and the LA dummy, appear as key explanatory variables. Note, however, that even in regression (3) these three variables leave a substantial part of the productivity gap unexplained; that residual, which did not appear in the exercise of Table 6, is also left unexplained by the other variables. It is now seen that raising the LA capital-labor ratio to NLA levels, leaving other variables unchanged, would only eliminate between 26 and 58 percent (more reliably: between 26 and 34 percent) of the productivity gap. If both the capital-labor ratio and the scale of LA plants were brought up to NLA levels, the two more reliable equations of Table 3 would still predict a LA average labor productivity between half and two-thirds that of NLA.

A final exercise (not shown) with the regression results consisted of taking, say, LA mean values for the independent variables and introducing them into the regressions of Table 5, i.e, those with coefficients estimated using 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 <u>and</u> mean NLA values, and with those obtained with LA mean values <u>and</u> LA coefficients. A similar exercise was carried out with the NLA mean values combined with LA coefficients. Relatively little difference was made to the predicted LA average labor productivity whether LA or NLA coefficients were used, and the results were 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 independent variables yielded productivities between only 49 and 71 percent of those obtained by NLA mean values combined with their own coefficients (those of Table 5). 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 independent variable average values are used together with LA coefficients (those of Table 4). One may speculate that the coefficients estimated using only NLA data are attributing to the most important independent variable, i.e., the capital-labor ratio, responsibility for higher productivity which arises 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 Variables

The results obtained in the previous section are, on the whole, somewhat "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. (However, the importance they give to scale economies and general efficiency differences make them less "neoclassical".)

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 yield misleading results. Consider the following extreme hypothesis (adapted from arguments often given by knowledgeable "practical" men). Take 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 the "right" amount of capital but more than the minimum labor which is technically necessary to produce a given output. In other words, their "X-inefficiency" is not neutral with respect to labor and capital, but is concentrated in the use of labor. This may be due to custom, which requires that each skilled worker be aided by a bevy of unskilled ones, socio-political pressures inducing padding of payrolls, or by a desire of entrepreneurs to have within the factory a reserve of trained employees, even if they are not fully occupied. (It is sometimes argued that more workers are used in LA plants for repairs; this is likely to be the case, but it would be just one way to substitute labor for capital, unless the argument refers to in-plant vs. outside repairs.) Under the hypothesized circumstances, one could get a good fit between average labor productivity and the capital-labor ratio, yielding a spuriously positive elasticity of output per employee with respect to capital per employee. 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.

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. But changes in the capital-labor ratio occur while the capital-output ratio remains unchanged.

A direct way to check on the previous hypothesis, relating output to each of the inputs and to other independent variables, is plagued by multicollinearity in a worse fashion than for previous results. The best streamlined results of this approach are given in Table 8, where the new variables are defined as follows:

LK1: 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 LK1, 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 is significant for both the pooled and the LA samples in groups (1) and (2). The fact that LA regressions yield significant coefficients for both labor and capital, while those for NLA show significant coefficients only for capital, casts doubt on the general validity of the hypothesis sketched in the previous paragraph.

As in Tables 4 and 5, 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 72 percent higher than that of LA.[13]

The results of Table 8 also confirm the presence of economies of scale, particularly in LA plants; the coefficients for capital and labor in LA regressions (1) and (2) add up to 1.21 and 1.26, respectively, while those for the pooled sample add up to 1.12 and 1.07. Note that the coefficients for capital in Table 8 are always higher than those for the corresponding capital-labor ratios in Tables 3, 4 and 5; this is due (at least in part) to their picking up scale effects directly in Table 8.

The coefficients for the capacity utilization variables maintain their significance only in the group (2) regressions, while those for SKILL hold up better. The AGE and AGESQ coefficients came close enough to significant levels in group (1) regressions to be of some interest. For groups (1) and (2) the LA dummy is not only highly significant, but its introduction into the regressions improved markedly the significance of other coefficients. This result confirms the view that there are (neutral?) efficiency differences between the LA and NLA production functions.

There is another way to check on the validity of the extreme hypothesis sketched above. If the good fit between average labor productivity and the capital-labor ratio is due partly or totally to the indicated spurious reasons, one should obtain much poorer results when making average capital productivity, or its inverse, the capital-output ratio, the dependent variable. The poorer results will be reflected on the size of the correlation coefficient, of the F-test, and of the t-statistics for the capital-labor ratio. If the extreme hypothesis is correct, variations in the capital-labor ratio would have no significant effect on the capital-output ratio. Note, however, that the coefficients to be 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:

$$\log (K/Y) = \alpha_o + \alpha_1 \log (K/L) + \alpha_2 \log CAP$$

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

$$B_1 = 1 - \alpha_1$$

And,

$$B_2 = - \alpha_2$$

Table 9 presents the major differences between these two types of regressions; the results for variables LCAP, CAPU, LKILNS, SKILL, WET, AGE and LA 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 9.

With one exception, the R^2's and the F's in Table 9 are lower than the corresponding ones in Tables 3, 4 and 5. The t-values for the constant terms in Table 9 are higher than the corresponding ones in the earlier tables; but only two t-values for independent variable coefficients share that characteristic. For regressions using kilowatt-hours consumed as a capital proxy, the collapse of the R^2's, F's and t's is quite sharp; on the other hand, regressions using horsepower of electrical motors as the proxy hold up well, and in some cases show improvements in explanatory power in Table 9. On the whole, the results shown in Table 9 indicate that the link between labor productivity and capital-intensity is not simply due to the spurious reasons sketched in the extreme hypothesis.

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.[14] For a given capacity range, a plant with a higher capital and labor requirement 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. This procedure in effect traces out isoquants made up of the most efficient plants in the sample.

Table 10 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.

As could be expected from the methodology used, positive evidence on capital-labor substitution is stronger here than when all plants were taken into account, but 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. When all ranges are pooled together in just one group, the biggest plant dominates all others when kiln area is used as the capital proxy, but five "efficient" plants (4 NLA, 1 LA) remain when horsepower in electrical motors is used for that proxy.

Taking these five "efficient" plants (and working with a single capacity range), Table 11 estimates how LA and NLA plants exceed, on the average the minimum unit labor and capital requirements. In other words, Table 11 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. This evidence is compatible with previous results showing that LA plants operated with different, and less efficient, production functions than NLA plants. But it now suggests that such efficiency difference is not neutral, but biased toward the relatively less efficient use of labor than of capital. In other words, it hints that there is a kernel of truth in the extreme hypothesis of the previous section, and highlights the greater variation in labor productivity than in the capital-output ratio. Given available data, it appears difficult to settle the issue as to whether the LA "X-inefficiency" is neutral or labor-using; indeed, it may be as difficult to settle this issue, as it is to determine whether technological change is neutral or biased toward the greater use of one or another factor of production.

Returning to Table 11, it may be noted that "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.

When the characteristics of the ten LA "efficient" plants shown in Table 10, using horsepower of electrical motors as the capital proxy, are compared with those for the whole LA sample, it is seen that the "efficient" plants have averages very similar to those of the complete LA group in age and number of kilns, use of the wet process, percentage of cement shipped in bags, share of electricity purchased from outside the plant, and wages per employee. Indeed, when the LA sample is divided into frontier and non-frontier plants, and differences in the means of both groups for each variable are tested for significance, the variables whose means are significantly different include only capacity utilization and variables related to the size of plant (output, employment, etc.), for both of which the efficient plants have higher values, and capital-output ratios, prices per ton of cement, and share of portland cement in total output, for which the efficient plants have lower values.[15] For the NLA sample, significant differences between the means of frontier and non-frontier plants emerge in a different group of variables; here the frontier plants have higher capital-labor ratios, newer kilns, higher average labor productivities, higher shares of employees with technical and university degrees, and pay higher average wages (but have lower shares of wages in sales) than other NLA plants.[16]

Capital-intensity and Productivity as a Function of Wages

The analysis so far has proceeded using non-monetary variables. An alternative approach would be to ask how do plants in different countries react to differences in factor prices. The questionnaire data provide information only regarding wages per employee in the different plants. This will be used in what follows, on the assumption that variations in wages provide a lower limit estimation to variations in factor prices. That is, variations in factor prices between NLA and LA will be no lower than observed variations in wage rates, as it can be supposed that LA capital costs will typically be no lower than those in NLA, and are likely to be higher.

With these considerations in mind, one can ask whether the observed variations in capital-labor ratios (which we have seen influence average labor productivity) are in turn related to underlying economic conditions, as reflected in wage rates. Besides wage rates, it may be hypothesized that other variables influence the capital-labor ratio used in each plant, including scale or plant capacity, as well as the age of the equipment.

If LA and NLA plants are on different production functions, this could also affect the capital-labor ratios of plants. Table 12 presents regressions which explore these relationships, using several definitions for the dependent variable, the capital-labor ratio. The independent variables are labelled as in previous tables, except a new one, LAWR, which refers to the logarithm of annual wages and salaries paid per person employed in the plant (the basic wage data was all converted into U.S. dollars).

For the pooled and the LA data, all wage rate coefficients are significant; for NLA regressions (not shown), they were all insignificant. On balance, these results provide further evidence of some capital-labor substitution in the cement industry. The value of the wage rate coefficients may be taken as rough approximations to the (upper limit of the) elasticity of substitution between labor and capital, and are very similar in both pooled and LA regressions, ranging from 0.30 to 0.70. It may be noted that when in the pooled regression the LA dummy is not included, the corresponding estimates were higher, ranging from 0.55 to 0.84, and their t-statistics were also higher.

With one exception, the t-statistics for the coefficients of the capacity variable are all substantially below two. (Note that the simple correlation between capacity and wage rates, for the pooled data, is +0.49). The age variable again does poorly, but its sign indicates that the older the kilns, the lower the capital intensity of the plant. The LA dummy variable performs worst in the regression with the highest estimated elasticity of substitution; the simple correlation coefficient between the LA dummy and the wage rate is -0.82. Again the separation of the true elasticity of substitution from efficiency differences (which may be neutral or biased) proves to be difficult.

The literature on production functions has also attempted to estimate elasticities of substitution by examining the relation between average labor productivity and wage rates. Table 13 presents the results of similar experiments using the questionnaire data. The first group of results, using pooled data, shows how the coefficient for wage rates drops as other relevant variables, scale and the LA dummy, are introduced in the regressions where average labor productivity (still measured in tons of cement per employee) is the dependent variable. In the pooled and LA regressions all coefficients have t-statistics far above two; the complete regressions for both groups yield very similar coefficients for the wage rate (0.43 and 0.41), consistent with previous estimates of the elasticity of substitution.[17]

Finally, a bothersome negative result should be reported. Regressions making the capital-output ratio a function of wage rates and other variables (as in Table 12) yielded poor results. In no case the t-statistic for the wage rate coefficient reached two; it climbed to 1.42 when horsepower of electrical motors was used as the capital proxy, and pooled data were used in the regression. However, if only the frontier plants identified in the previous section (using horsepower of electrical motors as capital proxy) are entered into a regression pooling LA and NLA efficient plants, one emerges with a significant and positive coefficient for the wage rate, as explanatory variable for the capital-output ratio.[18]

Conclusions

Major conclusions can be summarized as follows: gaps in average labor productivity between LA and NLA plants can be explained only in part by differences in capital-labor ratios and scale. The two groups of plants appear to operate in what for the sake of brevity can be called different production functions. The elasticity of substitution, although not very high, seems to be significantly different from zero for the cement industry. This result is obtained even though the capital proxies used may fail to pick up equipment used in quarries and for materials handling, as well as computers, which are more widely used in NLA than in LA.

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. It should also help to establish whether efficiency differences are neutral regarding labor and capital, or whether systematic biases exist. A last point which could be cleared up with those detailed data concerns the degree to which the LA plants incorporate within themselves (or around themselves) a larger amount of processes and social overhead facilities, including not only bagging and electricity but also housing and repairs, which are excluded from NLA cement plants.

Another line of research would be to complement this cross-section study with one contrasting the performance of LA and NLA plants through time. Our snapshot has captured plants at different points in their learning curves, and sheds no light on that process nor on other dynamic changes. Yet a glance at available time series for both LA and NLA shows rapid changes in plant sizes, labor productivity, etc.

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 of 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

The duration of the annual shutdown is likely to depend on market conditions and other variables, but this point was not researched.

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 available.

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 Measure of dispersion for each plant is:

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

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

$$\frac{[\partial O/\partial K]NLA}{[\partial O/\partial K]LA} \cdot \frac{[O/K]LA}{[O/K]NLA} = \frac{0.753}{0.472}$$

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

$$\frac{[\partial O/\partial K]NLA}{[\partial O/\partial K]LA} = \frac{1.60}{0.93} = 1.72$$

14 This approach was pioneered by N. 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.

15 For the LA efficient plants, the share of portland cement in total output was 84 percent, capacity utilization was 92 percent and average sales price was $19.5 per ton of cement. The corresponding figures for non-frontier LA plants were 99 percent, 82 percent and $24.3 per ton, respectively. The standard significance tests for difference of two means using t-statistics were carried out at the 95 percent confidence levels. Steve Kadish, who urged me to perform these tests, also pointed out that they involve the assumption of equality in the variances for the two groups. When this assumption is dropped, approximate tests can be devised, such as that outlined in Paul G. Hoel, Introduction to Mathematical Statistics (New York: John Wiley and Sons, Inc, 1962, Third Edition), pp. 278-79. With that approximation to t-statistics, for example, the difference in the mean share of portland cement in total output for frontier and non-frontier LA plants becomes insignificant.

16 While non-frontier LA plants have a very similar share of wages in total sales as non-frontier NLA plants (18.7 percent vs. 18.3 percent), the corresponding figure is relatively higher for LA frontier plants (16.7 percent) than for NLA frontier plants (12.3 percent). This conflicts with the empirical generalization that the labor share is higher in high wage countries than in low wage ones.

17 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:

$$\begin{aligned} \text{LPRICE} = & -0.584 + 0.314\ \text{LAWR} - 0.369\ \text{LOE} \\ & \ \ (0.37) \quad (3.41) \qquad\qquad (3.63) \\ & +0.018\ \text{LCALTN} + 0.057\ \text{LKO3} \\ & \ \ (0.10) \qquad\qquad\quad (0.32) \end{aligned}$$

R^2 = 0.30
Observations = 48
F-test = 4.63

The variable LCALTN stands for (the log of) calories of fuel consumed per ton of cement; LOE refers to (the log of) average labor productivity; other variables are defined as before. Similar results are obtained when the sample is divided into its LA and NLA components.

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.

18 The sample made up by pooling LA and NLA frontier plants was also used to estimate regressions similar to those shown in Tables 12 and 13. The results, as measured by t-statistics and F-tests, were not generally as good as those in the tables. The coefficients for LAWR were lower (about half) and those for the LA dummy higher than those in Tables 12 and 13 for pooled data. For the ten LA frontier plants a relatively high simple correlation (+0.76) was registered between the capital-output ratio (horsepower of electrical motors as proxy) and average age of kilns. Within this group (LA frontier plants), very high simple correlations were also obtained between average wage rates and capital-labor ratios (+0.86, +0.97 and +0.96 for the three different proxies), between wage rates and average labor productivity (+0.93) and also between labor productivity and all proxies for the capital-labor ratio (+0.95, +0.94 and +0.99, respectively). The corresponding correlations were much lower for the LA non-frontier group.

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. Therefore, 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	19.1	9.7	196.9
--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	-----
Horsepower installed (thousand)	13.4	19.3	69.4
--Horsepower of electrical motors (thousands)	11.3	18.1	62.4
Kilowatt-hours consumed (million)	28.4	46.7	60.8
--Percentage of electricity purchased	37.6	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	-----
Sales value per cement ton (U.S. dollars)	23.24	23.16	100.3
Total wages and salaries as a percentage of sales value	18.4	16.9	-----
Annual wage and salary bill per employee (U.S. dollars)	2,238.6	6,762.3	33.1

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	1.817 (3.69)	2.737 (6.10)	1.928 (5.36)
LKL1	0.588 (7.59)	-----	-----
LKL2B	-----	0.404 (6.63)	-----
LKL3	-----	-----	0.706 (10.33)
LCAP	0.590 (8.57)	0.381 (5.09)	0.262 (4.35)
CAPU	0.915 (4.32)	0.988 (4.32)	0.324 (1.78)
LKILNS	-0.447 (5.06)	-0.202 (2.26)	-0.191 (2.97)
SKILL	3.192 (3.78)	2.480 (3.19)	1.483 (2.37)
WET	-0.200 (2.67)	-----	-----
AGE	0.007 (1.90)	-----	-----
LA	-0.286 (2.19)	-0.594 (5.05)	-0.200 (1.98)
R^2	0.94	0.93	0.95
Observations	55	54	65
F-test	86.9	99.6	168.9

Table 4

Regressions "explaining" (log. of) Average Labor Productivity;

Data for LA only

	(1)	(2)	(3)
Constant	1.368 (2.90)	1.620 (3.12)	1.721 (4.27)
LKL1	0.537 (6.00)	-----	-----
LKL2B	-----	0.307 (4.44)	-----
LKL3	-----	-----	0.607 (6.58)
LCAP	0.607 (8.51)	0.473 (5.10)	0.338 (4.19)
CAPU	1.156 (4.12)	1.265 (3.75)	0.290 (1.02)
LKILNS	-0.466 (4.28)	-0.207 (1.53)	-0.209 (2.23)
SKILL	3.384 (3.67)	3.999 (3.62)	2.357 (2.62)
WET	-0.207 (2.51)	-----	-----
AGE	0.004 (0.92)	-----	-----
R^2	0.88	0.82	0.86
Observations	36	28	39
F-test	28.6	20.2	41.1

Table 5

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

Data for NLA only

	(1)	(2)	(3)
Constant	1.120 (0.87)	2.966 (4.59)	1.553 (2.65)
LKL1	0.911 (4.62)	-----	-----
LKL2B	-----	0.733 (7.28)	-----
LKL3	-----	-----	0.924 (9.40)
LCAP	0.545 (2.44)	0.120 (1.04)	0.111 (1.28)
CAPU	0.668 (1.70)	0.844 (3.35)	0.460 (2.23)
LKILNS	-0.340 (1.56)	-0.079 (0.78)	-0.140 (1.82)
SKILL	4.258 (1.64)	0.648 (0.67)	0.371 (0.47)
WET	-0.180 (0.82)	-----	-----
AGE	0.014 (1.82)	-----	-----
R^2	0.83	0.86	0.89
Observations	19	26	26
F-test	7.8	23.6	31.7

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)
LKL1	0.496	-----	-----
LKL2B	-----	0.549	-----
LKL3	-----	-----	0.377
LCAP	0.609	0.758	0.841
CAPU	1.057	1.080	1.020
LKILNS	0.958	0.959	0.972
SKILL	1.050	0.997	1.007
WET	1.047	-----	-----
AGE	0.997	-----	-----
LA	0.752	0.552	0.819

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)		(2)		(3)	
	(a)	(b)	(a)	(b)	(a)	(b)
NLA Productivity	1986.1	-----	2080.5	-----	1921.1	-----
LA Productivity	500.4	-----	493.5	-----	497.1	-----
Productivity Gap	1485.7	100.0	1587.1	100.0	1424.0	100.0
LKL1	509.1	34.3	------	-----	------	-----
LKL2B	------	-----	405.1	25.5	------	-----
LKL3	------	-----	------	-----	823.3	57.8
LCAP	321.7	21.6	157.8	9.9	94.1	6.6
CAPU	-27.2	-1.8	-36.5	-2.3	-9.8	-0.7
LKILNS	21.8	1.5	21.1	1.3	14.5	1.0
SKILL	-23.7	-1.6	1.7	0.1	-3.5	-0.2
WET	-22.6	-1.5	------	-----	------	-----
AGE	1.3	0.1	------	-----	------	-----
LA	165.4	11.1	400.0	25.2	109.9	7.7
Residual	539.9	36.3	637.9	40.2	395.5	27.8

Table 8

Regressions "explaining" (log. of) Output

	(1)			(2)			(3)		
	(P)	(LA)	(NLA)	(P)	(LA)	(NLA)	(P)	(LA)	(NLA)
Constant	-2.306 (3.42)	-3.543 (3.65)	-3.807 (2.83)	0.828 (1.66)	-1.693 (1.63)	2.185 (5.06)	2.135 (8.15)	1.837 (3.98)	2.410 (7.51)
LK1	0.668 (6.11)	0.581 (4.44)	1.156 (4.51)	------	------	------	------	------	------
LK2B	------	------	------	0.536 (7.50)	0.472 (4.94)	0.753 (8.04)	------	------	------
LK3	------	------	------	------	------	------	0.894 (14.98)	0.875 (11.04)	0.938 (10.45)
LEMPTO	0.448 (3.29)	0.628 (3.31)	-0.031 (0.14)	0.531 (5.40)	0.739 (5.13)	0.179 (1.76)	0.065 (0.90)	0.112 (1.09)	-0.021 (0.22)
CAPU	0.558 (1.73)	0.696 (1.39)	0.399 (1.00)	0.907 (3.23)	1.196 (2.50)	0.838 (3.43)	------	------	------
SKILL	4.106 (3.04)	4.815 (2.74)	6.064 (2.22)	2.370 (2.33)	4.430 (2.43)	0.713 (0.76)	------	------	------
AGE	-0.024 (1.43)	-0.027 (1.16)	-0.026 (0.98)	------	------	------	------	------	------
AGESQ	0.0006 (1.50)	0.0006 (1.13)	0.0010 (1.41)	------	------	------	------	------	------
LA	-0.731 (4.09)	------	------	-0.765 (5.30)	------	------	-0.082 (0.78)	------	------
R^2	0.83	0.80	0.86	0.85	0.83	0.90	0.91	0.89	0.91
Observations	55	36	19	54	28	26	65	39	26
F-test	33.4	19.1	12.2	54.6	28.6	48.7	204.6	145.2	122.6

Table 9

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

	Constant	LKL1	LKL2B	LKL3	R^2	F-test
Pooled Data						
(1)	5.091 (10.34)	0.412 (5.32)	-----	----	0.74	16.3
(2)	4.171 (9.30)	-----	0.596 (9.79)	----	0.72	20.4
(3)	4.980 (13.84)	-----	-----	0.294 (4.31)	0.32	4.49
LA Data						
(1)	5.540 (11.75)	0.463 (5.18)	-----	-----	0.81	17.1
(2)	5.287 (10.18)	-----	0.693 (10.00)	-----	0.85	24.4
(3)	5.187 (12.87)	-----	-----	0.393 (4.26)	0.43	5.0
NLA Data						
(1)	5.788 (4.47)	0.089 (0.45)	-----	-----	0.64	2.8
(2)	3.942 (6.10)	-----	0.267 (2.65)	-----	0.51	4.1
(3)	5.355 (9.15)	-----	-----	0.076 (0.77)	0.31	1.8

Table 10

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 11

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 in "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.

Table 12

Regressions "explaining" (log. of) Capital-Labor Ratio

	Pooled Data			LA Data		
	LKL1	LKL2B	LKL3	LKL1	LKL2B	LKL3
Constant	3.008 (4.65)	5.433 (6.07)	5.034 (6.12)	2.438 (2.94)	5.439 (4.30)	4.371 (3.58)
LAWR	0.298 (2.71)	0.677 (3.99)	0.417 (2.80)	0.339 (2.73)	0.704 (3.56)	0.436 (2.36)
LCAP	0.120 (1.47)	0.158 (1.41)	0.267 (2.51)	0.147 (1.40)	0.105 (0.70)	0.245 (1.60)
AGE	-0.008 (1.35)	-0.003 (0.29)	-0.001 (0.14)	-0.011 (1.22)	0.000 (0.00)	0.005 (0.42)
LA	-0.626 (3.36)	-0.353 (1.20)	-0.739 (3.10)	-----	-----	-----
R^2	0.68	0.71	0.67	0.32	0.41	0.26
Observations	50	48	60	32	25	34
F-test	23.5	25.9	27.7	4.3	4.9	3.5

Table 13

Average Labor Productivity as a Function of Wages and Capacity

	Pooled Data			LA Data		NLA Data	
	(1)	(2)	(3)	(1)	(2)	(1)	(2)
Constant	9.725 (34.93)	7.366 (11.79)	6.942 (12.00)	8.193 (17.28)	6.241 (9.26)	9.813 (8.85)	7.593 (4.83)
LAWR	0.841 (10.71)	0.702 (9.07)	0.427 (4.14)	0.488 (4.18)	0.410 (4.03)	0.816 (2.01)	0.622 (1.56)
LCAP	-----	0.331 (4.11)	0.300 (4.07)	-----	0.304 (3.62)	-----	0.280 (1.90)
LA	-----	-----	-0.610 (3.64)	-----	-----	-----	-----
R^2	0.66	0.74	0.79	0.35	0.55	0.14	0.26
Observations	60	60	60	34	34	26	26
F-test	114.7	81.5	70.4	17.5	18.6	4.0	4.1