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Scale and Learning Effects in The Cost Structure of The Cement Industry of The Kingdom of Saudi Arabia

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Abstract. In this paper we conduct an econometric study of the cost-scale relationships in 5 of the 8 cement companies in the Kingdom of Saudi Arabia using plant level data. Simple cost analysis is firstly conducted on a plant by plant basis and simplified cost functions are estimated on individual basis allowing for time and cross-sectional effects. Analysis and estimates allow us to compute valuable cost parameter estimates in the shapes of returns to scale and economies of scale. Panel estimation was also undertaken within fixed and random effects norms in order to induce more efficiency in the estimates. Results conform largely to those obtained in the case of individual regressions. They suggest that increasing returns to scale and significant economies of scale are predominant in the industry. We also allowed for the possibility of learning effects on costs through the estimation of augmented learning curve-cost functions. However, learning effects were found to be significantly operative in only one of the five cement plants in the sample.

Introduction

The cement industry is the second most important industry in the Kingdom of Saudi Arabia (KSA) closely following the oil and petrochemicals industry in importance(1). The industry has witnessed a massive overhaul in its structure since the 1970s because of the accelerating pace of development and construction in the Kingdom following the oil boom of the seventies. The Kingdom is the largest producer and consumer of the product in the region but the market for the product witnessed large structural changes after the initial acceleration. Increasing local production and imports coupled with subsequent falling local demand resulted in the buildup of massive inventories of the product and the collapse of prices plus the occurence of large unused capacities of plants(2). During periods of falling demand one would expect the

(1) On the importance of the Cement industry in KSA, see Ayoub[1], Gulf Organization for Industrial Consulting[2,3] and Tuncalp and Al Ibrahim[4] for example.

(2) Of lately, and after the end of the second Gulf war, local demand for cement has been growing rapidly and shortages started to occur again in the production and availability of cement.

cement companies in the Kingdom to operate as cost minimizers since their levels of output are then determined exogenously by demand conditions. The cement companies would hence tend to choose their input levels in such a way as to minimize total costs and a study of total costs structures thus becomes imperative.

In this paper, we investigate plant and industry level cost effects of scale economies and learning curves of the cement industry in the KSA by estimating the relevant technical and learning parameters. The results should indicate whether potential economies of scale can be exploited resulting in average or unit cost reductions as the level of output increases per time period. If such economies of scale exist, then it may be rational to accelerate capacity use, reduce prices and thereby achieve higher levels of production at lower unit cost than if scale economies were absent or unexploited. The demand constraint should then be slackened by tapping other markets in addition to the local one.

In as far as the sources of economies of scale in the cement industry of KSA are concerned, we note that they might arise because of the large fixed capital expenditures undertaken before production took place. The constrained nature of market demand in the Kingdom as witnessed in the period of the eighties, also forced the cement companies to reduce their outputs hence moving leftward along their average cost curves into the regions where increasing returns to scale and positive economies of scale predominated. Physical-technical relationships intrinsic to the cement industry *e.g.* the capacity of kilns may also have resulted in additional scale effects.

On the other hand, and in as far as the sources of learning effects are concerned, then we note that unit costs tend to fall over time as production experiences accumulate. Theoretically, the learning curves tend to relate unit real costs or real price to cumulative production. They provide a rationale for a pricing and marketing strategy in which producers initially price low-perhaps even below current marginal cost- in order to expand sales and gain market penetration rapidly thereby quickly accumulating experience and exploiting the cost-reducing effects of such learning. Because of the existence of learning curves, it may make sense for governments to provide limited temporary protection to domestic manufacturers from foreign competition[3]. In the case of the KSA the cement industry is capital intensive and the relatively small work force needed to operate this capital intensive technology is usually of foreign origin with considerable expertise, specialization and learning levels in their areas of operation. Consequently, the sources of learning curves behavior lie in experiences gained and exploited by managers and other company officials. Because of the experiences gained by management and labor, dramatic cost reductions can occur as cumulative production increases; these cost declines should then be passed

(3) See Berndt[5], for example.

on to consumers in the form of price reductions. However, the extent to which this process is undertaken depends on market structure and other strategic pricing decisions. On the other hand, it might be argued that the Saudi Cement industry is still in its infancy for substantial learning experiences to occur.

The paper analyzes simple cost functions to determine the returns to scale (RTS) and the economies of scale (ES) effects ruling in five out of the eight cement companies comprising the cement industry in KSA. Section 1 of the paper provides preliminary data analysis on the five plants including the share of each plant in the total cement production in the Kingdom; their capacity utilizations etc... . Section 2 then provides the estimation of individual cost functions in a first subsection whereas another subsection considers the estimation of the aggregate cost functions within a panel data framework allowing for fixed and random effects and for individual or/and time effects in the case of the former fixed effects model. Section 3 integrates cost functions with learning behavior and discusses results on empirical individual cost-learning curve effects whereas a final section then concludes the study.

1) Preliminary Cost Analysis

Output in thousands of tons of the final cement product and real total cost in thousands of Saudi Riyals (SR) obtained by deflating nominal total costs- which were the sum of fixed costs and variable costs of production- by the Gross Domestic Product Deflator (GDPD) were used on the following five Cement companies:

1. Yamama Saudi Cement Company (YSCC).
2. Arabian Cement Company (ACC).
3. Southern Province Cement Company (SPCC).
4. Saudi-Bahraini Cement Company (SBCC).
5. Saudi-Kuwaiti Cement Manufacturing Company (SKCMC).

The sample of five companies out of a population of eight was dictated by the availability of data. The information on output, costs and components was made available to us by the above five companies only. The cost analysis conducted related to total costs and no breakdown in terms of labor, capital, energy and materials components costs was possible because of the nature of the data which was highly aggregative.

The data set was initially restricted to the period 1985-1990 for this preliminary type of analysis to preserve sample homogeneity and to allow for comparisons to be undertaken. The sample thus consists of 5 cross-sectional units each observed through 6 time periods. For each cement company we computed its share of total cement production (SHARE), the rate of capacity utilization (CU), average costs(AC), marginal costs(MC) and the elasticity of costs with respect to output

(ε_{CQ}) on an average basis over the time interval 1985-1990. The results of the analysis for the companies are provided in Table 1.

Table 1. Simple cost analysis for the cement companies* 1985-1990.

PLANT	SHARE	CU	AC	MC	ε_{CQ}
YSCC	0.169	0.78	130.386	92.123	0.606
ACC	0.124	0.97	147.418	153.020	0.619
SPCC	0.162	1.11	124.050	–	–
SBCC	0.149	0.72	132.822	122.903	0.735
SKCMC	0.112	0.42	133.634	252.959	1.392

* Dashed figures are negative values, hence not reported.

Overall, the share of each of the five plants ranged between 11 - 17% in total KSA cement production. Capacity use ranged more widely between a minimum of 42% for the SKCMC plant to a maximum of above capacity use of 111% for the SPCC plant. Moreover, the structure of production was cost inelastic for at least three plants during the period of study.

On a plant by plant basis, some variation in performance is detectable. Over the period, the YSCC[(4)] plant contributed 17% of total cement production on average with a capacity use of 78%. The ACC[(5)] plant provided a 12% share of total cement production in the KSA with a somewhat high average capacity use of 97% reflecting itself in some high - but declining - MC overtime. The SPCC[(6)] plant's average share in total cement production was 16% attained with a higher than full capacity use average of 111%. The SBCC[(7)] plant contributed a share of almost of 15% of total cement production in the Kingdom and its capacity use hovered around a value of 72% although the plant did work over capacity in the initial year of 1985. The cost picture of the SKCMC[(8)] plant shows a relatively low contribution in share of 11% to total

(4) Situated in the capital city of Riyadh, the central region, the YSCC plant started production in 1966 but its productive structures went through different expansions since then. The factory's present productive capacity is 2700 thousand tons per annum.

(5) The ACC is the oldest cement company in the Kingdom. It started its operations in 1959. The plant was initially situated at Jeddah but subsequently moved to Rabigh. The productive capacity of the present plant is 1260 thousand tons per annum.

(6) The SPCC plant is situated about 70 km outside of Jizan in the southern region of the KSA. The company started production in 1982 with a productive capacity of 1560 thousand tons per annum.

(7) The SBCC is a joint venture between the KSA and the state of Bahrain. Its plant is located 15 km west of Abgaig at Ain Dar with a productive capacity of 2000 thousand tons per annum. The company started its operations in 1981. In 1992 SBCC was amalgamated with the Saudi Cement Company (SCC) in El Hafouf of the Eastern region of the Kingdom.

(8) The SKCMC is a joint venture between the KSA and Kuwait. Its plant is located at Khursaniyah 60 km north of Jubail, it started its operations in 1985 and its current productive capacity is 2155 thousand tons per annum.

cement production in the Kingdom with a rather low 42% use of capacity. Its cost structure appears to be elastic with a magnitude of 1.392 over time.

Overall, then the companies were largely similar in size and, to some extent, in capacity use. There was considerable excess capacity during the period due to the fact that the market for cement was operating on its short demand side because of flagging demand conditions.

2) The Cost Functions

The cost functions estimated related again to total costs with no breakdown in terms of components costs because of the nature of the data available to us as noted above.

The data set here consisted primarily of the 5 cross-sectional units observed through 6 time periods extending from 1985 to 1990 inclusive and a total number of 30 observations. In the case of individual cost regressions and in the discussion on cost-learning effects we used differing times data sets as the specific situation under study warranted. For example, we estimated cost functions over differing time periods in order to compare and to test for possible structural changes in cost parameters. In the case of cost-learning effects we used the maximal data length possible in order to allow for the process of accumulation of knowledge over time. Results obtained upon the estimation of the various cost functions are provided in the subsections below:

2. A. Individual Time Series Regressions

Individual cost functions were estimated for each of the plants of the five cement companies in the sample. The regression forms used were simple within a Cobb-Douglass structure of the following linearized shape:

$$\ln C_j = \alpha_j + \beta_j \ln Q_j + \varepsilon_j \qquad j = 1, \ldots ,5$$

where:

C_j real total cost expenditures by the jth plant.
Q_j actual output of the jth plant in millions of tons.
ε_j a random error term for the jth plant.

According to this function MC for the jth plant is given by:

$$MC_j = \beta_j \frac{C_j}{Q_j}$$

whereas its AC is given by:

$$AC_j = A_j Q_j^{\beta_j - 1}$$

where

$$A_j = \exp(\alpha_j)$$

Again, real cost expenditures in thousands of Saudi Riyals(SR), were used as the dependent variable of costs since that enabled us to effectively remove the effect of factor and output price variables- whose data were not available to us in any case- from the cost function. This is due to an implicit assumption that the effects of the inputs prices are captured by the use of an appropriate deflator from the national income accounts[(9)]. Another justification for assuming away the price effects could be obtained by noting that over the short time interval used for estimation in this section *i.e.* 1985-1990, factor and product prices tended to stay constant. The deflator we used here to convert nominal costs into real magnitudes was the GDPD as noted above. Output on the other hand was the usual thousand tonnage of the final product-cement.

Again we note that the estimation period was primarily[(10)] 1985-1990. This was due to the above mentioned requirement of sample homogeneity especially when attempting pooled estimation. Although the requirement itself is not theoretically binding, we were forced to rely on it because of the inavailability of necessary software which could handle the situation of different time periods within the pooled estimation context. Moreover, focusing on the later parts of the sample enables us to bypass the long-standing issue of the inability to disentangle the effects of economies of scale from those of technological change. Changes in RTS correspond to movements along the average cost curves whereas changes in the state of technical knowledge induce shifts in these curves.

The estimation method used for the individual cost functions was Ordinary Least Squares (OLS) but in some instances, where there was evidence of autocorrelation, a Cochrane-Orcutt (CORC) procedure was also attempted and used to correct for that. Results on the estimation of the regressions are now provided in Table 2.

The YSCC equation is statistically well estimated with an R^2 value of 0.778, which is quite good in view of the small size of sample used. The cost-output elasticity is significant and showed an inelastic 0.768. From the above estimates, we can calculate the returns to scale (RTS) parameter estimate $\hat{\gamma}$ as the reciprocal of the elasticity coefficient:

$$\hat{\gamma} = \hat{\beta}^{-1} = 1.302$$

(9) See Berndt [6, p. 72] for example.

(10) We say primarily because- and as noted above- in certain instances and for comparison purposes we undertook estimation for the whole sample period and for differing subperiods as well.

Table 2. Estimated Time-Series Effects 1985-1990.

Company	$\hat{\alpha}$	$\hat{\beta}$	$\bar{R}^2$	$\hat{\sigma}$	d	$\hat{\gamma}$	ES*
YSCC	6.716 (5.075)	0.768 (4.301)	0.778	0.138	2.200	1.302	0.302
ACC	9.684 (7.763)	0.353 (2.011)	0.379	0.141	2.563	2.833	1.833
SPCC	9.104 (8.647)	0.438 (8.647)	0.628	0.057	2.972	2.283	1.283
SBCC	7.125 (3.184)	0.710 (2.307)	0.464	0.122	1.375	1.408	0.408
SKCMC	7.469 (2.480)	0.651 (1.514)	0.205	0.199	1.406	1.536	0.536

* $\bar{R}^2$ is the adjusted coefficient of determination. d is Durbin-Watson d statistics. $\hat{\sigma}$ is the standard error of the regression. ES is economies of scale.
Figures in brackets below $\hat{\alpha}$ and $\hat{\beta}$ coefficients are t-values.

showing increasing RTS for this company. Economies of scale typically calculated as RTS minus one *i.e.* $\hat{\gamma}-1$ are 0.302. Since RTS are increasing for this factory then increases in output will reduce average costs. Since RTS cannot vary with the level of output in the above used Cobb-Douglas cost function, it follows that the average cost curve is always sloping downwards for the YSCC plant.

To compare results and to test for any possible structural changes affecting the RTS parameter estimates in the case of the YSCC plant we attempted estimation for the period 1980-1990 over which data were available. OLS estimation indicated the presence of autocorrelation problems and an alternative CORC procedure yielded the following regression:

$$\ln C_1 = \underset{(5.228)}{7.166} + \underset{(3.938)}{0.712} \ln Q_1$$

$$\bar{R}^2 = 0.749$$

$$SSR = 0.220$$

$$\hat{\sigma} = 0.166$$

$$d = 2.412$$

$$F = \underset{(0.001)}{27.411}$$

$$\hat{\varrho} = \underset{(3.446)}{0.737}$$

where $\hat{\varrho}$ is the estimate of the coefficient of autocorrelation and the figure in brackets associated with it is its t-value. SSR is the sum of squares of the residuals and F is the F statistic with its associated significance level in brackets beneath.

The RTS parameter estimate for the period 1980-1990 is 1.404 and the ES estimate is 0.404. On the whole, then, there seems to be little difference between the whole and the sub time periods.

For the ACC plant the computed $\hat{\beta}$ -which proved to be significant at 11% level- was found to be 0.353 showing a lower cost-elasticity and a higher RTS of magnitude 2.833 in comparison with the YSCC. Economies of scale- being positive and substantial- are also higher and equal in magnitude to 1.833. This might be attributable to the newness of the Rabigh plant. Also, the completion of the new plant and its commencement of production occurred at the same time when local demand for the cement product suddenely fell. This led to unused capacity and the occurrence of large economies of scale.

As for the SPCC plant, the computed $\hat{\beta}$ was 0.438 showing RTS of magnitude 2.283 and an associatd positive economies of scale estimate of magnitude 1.283. This is much higher than the YSCC plant but lower than that shown in the case of the ACC plant.

As far as the cost function of the SBCC plant is concerned, the computed $\hat{\beta}$ was significant at 8% level and attained a value of 0.710 with RTS of magnitude 1.408. Economies of scale are again positive and of value 0.408 which is quite close to the YSCC plant but much less than the case in the other two plants. Whence, the average cost curve although declining with output, would tend to be flatter for this plant.

In the case of the SKCMC cost function, the estimated $\hat{\beta}$ coefficient was of magnitude 0.651, and is only significant at level 0.205. Consequently, we do not emphasize inferences about RTS and economies of scale as related to this plant.

Overall, hence, individual case results point to mostly inelastic cost-output structures, increasing returns to scales with various scopes of unexploited positive economies of scale, increasing marginal costs and decreasing average costs in a reflection of the fact that the different cement companies are producing at less than their points of optimal productions. This pattern of behavior is largely consistent with cost minimization in regulated industries(11).

2. B. Individual Cross Sectional Regressions

The form of the regression used for this effect is:

$$\ln C_i = \alpha_i + \beta_i \ln Q_i + \varepsilon_i$$
$$i = 1985, \ldots, 1990.$$

For each year from 1985 to 1990 we estimated the cross-sectional regressions on the five companies in the sample. Prior to 1985 there were only three data points available on three companies and the attempted estimation will consequently suffer from high imprecision. The results obtained are listed in Table 3.

Examining the six cross-sectional regressions, we note that the t-values on the estimated β coefficients are generally low which could be ascribable to the small sample size. Moreover, in the year 1987 the fit of the model was quite bad with a negative R^2 which - even for a cross section - is unacceptable. The slope coefficient- and the regression as a whole were insignificant at any reasonable level. An overall U-shape pattern over time in the magnitudes of the $\hat{\beta}$ slope coefficients, the RTS and ES estimates is easily detectable. This pattern could be in reflection of the decline in capacity use witnessed during the period which had its peak around 1987. Apart from results on the year 1987, the patterns on parameter estimates, RTS and ES were largely similar to those obtained for the individual time series regressions where increasing RTS and positive ES were the rule rather than the exception through time.

2. C. Aggregate Cost Functions- Panel Estimation(12)

The aggregate cost functions used in this subsection were variants of the general form:

$$\ln C_{ij} = \alpha_{ij} + \beta_{ij} \ln Q_{ij} + \varepsilon_{ij}$$
$$j = 1, \ldots, 5.$$
$$i = 1985, \ldots, 1990.$$

(11) Note, in perfect competition constant and increasing RTS are ruled out.

(12) On the econometrics of panel estimation see Judge *et al.*[6] for example.

Table 3. Estimated Cross-Sectional Effects.

Year	$\hat{\alpha}$	$\hat{\beta}$	$\bar{R}^2$	$\hat{\sigma}$	F	$\hat{\gamma}$	ES*
1985	5.721 (3.858)	0.898 (4.282)	0.812	0.166	18.339 (0.023)	1.114	0.114
1986	9.318 (6.253)	0.421 (2.002)	0.429	0.124	4.006 (0.139)	2.375	1.375
1987	12.170 (7.314)	0.005 (0.020)	–0.333	0.052	0.0003 (0.986)	–	–
1988	9.693 (7.612)	0.348 (1.990)	0.425	0.049	3.961 (0.141)	2.874	1.874
1989	6.295 (6.498)	0.810 (6.272)	0.905	0.093	39.342 (0.008)	1.235	0.235
1990	4.744 (1.421)	1.029 (2.272)	0.511	0.133	5.164 (0.108)	0.972	–0.028

* Durbin-Watson d statistics is not reported here since it has no relevance within this cross-sectional context.

where C_{ij} refers to real total costs incurred by the jth plant in time period i and Q_{ij} refers to output of plant j in period i. In some instances the parameters α_i and β_j – as in the previous subsections- are held constant between plants and through time; *i.e.*

$$\alpha_{ij} = \alpha, \text{ for all i and j.}$$

and

$$\beta_{ij} = \beta, \text{ for all i and j.}$$

and in other instances they are allowed to vary between plants or through time.

Thus by keeping the parameters constant first, the overall OLS regression for the simple total cost function was obtained after estimating the pooled sample over the years 1985-1990 as:

$$\ln C = \underset{(12.450)}{7.661} + \underset{(7.460)}{0.635} \ln Q$$

$\bar{R}^2 = 0.653$
SSR = 0.512
$\hat{\sigma} = 0.135$
d = 1.839

The equation appears to be well estimated with significant coefficients and no evidence of autocorrelation problems as judged by the statistics. Moreover a white test for heteroscedasticity(13) was also conducted leading to nonrejection of the null hypothesis.

The RTS parameter estimate in the whole five plant sample is equal to 1.595 while economies of scale are positive and equal to 0.595.

Both individual and total regressions point to the fact that increasing RTS and positive economies of scale are the rule in the Saudi cement industry. The presence of these may be explained by the occurence of large recent fixed costs which arose during the installation phases and because of falling demand conditions in a market which was largely demand determined over the period. Because of these, there tended to be an interval of increasing RTS. In particular, during these initial phases of increasing RTS the second unit produced requires fewer inputs than the first. Later, as the effect of the fixed cost component becomes less important and as demand responds more fully and the companies' span of attention and control becomes stretched, there may be ranges of decreasing RTS and negative economies of scale.

Following the previous model of common intercept and slope coefficients, we proceeded next to investigate a different class of models. These are attained by relaxing the assumption of a common intercept while retaining that of a common slope. This could be handled within a framework of either fixed effects or random effects as in the following subsections. We elected to provide both types of effects and to compare between them at a later stage according to the empirical results obtained instead of favoring one effect over the other *a priori*. The 'institutional' realities of the problem did not help us in deciding in favor of one effect against the other beforehand.

2. C.1. Fixed Effects

Fixed effects which assume that differences across the five companies are captured in differences in the constant term were firstly investigated. Initially, we used a fixed effect model where the slope coefficient is constrained to be equal for the five

(13) For details of this test see White [7].

cement companies and where the individual company intercept differences from an overall mean are held to be fixed resulting in a covariance model to be estimated by a 'Within estimator' for the model of the form:

$$\ln C = \sum_{j=1}^{5} \alpha_j D_j + \beta \ln Q + \varepsilon$$

$$j = 1, \ldots, 5.$$

OLS estimation of the resultant covariance-cost structure where individual firm effects are captured through the introduction and use of suitable dummy variables produced the following result:

$$\ln C = \underset{(10.782)}{8.205} D_1 + \underset{(11.203)}{8.169} D_2 + \underset{(10.739)}{8.149} D_3$$

$$+ \underset{(10.937)}{8.167} D_4 + \underset{(11.187)}{8.057} D_5 + \underset{(5.530)}{0.567} \ln Q$$

$$\bar{R}^2 = 0.645$$

$$SSR = 0.449$$

$$\hat{\sigma} = 0.137$$

$$d = 1.971$$

where D_j, $j=1, \ldots, 5$ are plant dummy variables assuming the usual binary values of ones and zeros.

Testing the joint significance of the individual dummies then we employed the following joint hypothesis:

$$H_o : \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0$$

where the resultant F test statistics indicated joint significance of the dummy coefficients with a calculated value of 30.966.

More importantly and since we are primarily interested in possible differences across companies, we tested the hypothesis that the constant terms are all equal by the application of the appropriate F test(14). Under the null hypothesis:

$$H_o : \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = \alpha$$

(14) For details of the used test see Greene [8] pp. 484, for example. The formula used in the test is: =

the efficient estimator is the pooled LS. The calculated F-value for the test was 0.837 with 4 and 24 degrees of freedom respectively and a probability value of 0.515 whence the hypothesis that the firm effects are the same is accepted.

Next, to investigate fixed time effects over the years 1985-1990 we constrained the slope coefficients on the output variable to be equal across all time periods and specified dummy variable intercept terms for each of the six years 1985-1990, *i.e.*

$$D_i = 1 \quad \text{for year } i;\ i=1985, \ldots, 1990.$$
$$= 0 \quad \text{otherwise.}$$

and the form of the regression used was:

$$\ln C = \sum \alpha_i D_i + \beta \ln Q + \varepsilon \qquad i=1985, \ldots, 1990$$

Upon conducting the covariance regression we obtained the OLS estimated equation:

$$\ln C = \underset{(10.749)}{6.904}\ D_{1985} + \underset{(11.065)}{7.126}\ D_{1986} + \underset{(10.941)}{7.037}\ D_{1987}$$

$$+ \underset{(10.455)}{6.914}\ D_{1988} + \underset{(10.123)}{6.894}\ D_{1989} + \underset{(10.372)}{6.947}\ D_{1990}$$

$$+ \underset{(8.060)}{0.730}\ \ln Q$$

$$\bar{R}^2 = 0.734$$
$$SSR = 0.322$$
$$\hat{\sigma} = 0.118$$
$$d = 1.677$$

Tests were also conducted on this time effect covariance relationship along lines similar to those in the previous case of the cross-sectional covariance regression. Initially, we tested the null:

$$F(n-1, nT-n-k) = \frac{(R_u^2 - R_p^2)/(n-1)}{(1-R_u^2)/(nT-n-K)}$$

where R_u^2 is the unrestricted covariance regression and R_p^2 is the restricted pooled regression with only one intercept term, n is the number of cross-sections, T is the number of time periods and K is the number of regressors excluding the constant.

$$H_o : \alpha_{1985} = \alpha_{1986} = \dots \alpha_{1990} = 0$$

i.e. the exclusion restriction where the intercepts are held to be insignificant as a group and the F statistic of the test recorded a value of 35.969 which was highly significant leading to the conclusive rejection of the null. The next hypothesis to be tested was that of:

$$H_o : \alpha_{1985} = \alpha_{1986} = \dots = \alpha_{1990} = \alpha$$

i.e. the intercepts were equal across the six time periods(15). The F statistics used in this test recorded a value of 3.539 with an associated probability level of 0.021 leading to the rejection of the null and the conclusion of some significant time effects in operation.

Overall then, the results on this subsection while rejecting the presence of differential cross-sectional fixed effects, indicate the possibility of the presence of differential time effects. To investigate these issues further and to compare we proceed in the next subsection to conduct the analysis within a random effect framework.

2.C.2. Random Effects

The fixed effects approach is a reasonable one when we can be confident that the differences between units can be viewed as parametric shifts of the regression equation. But in our setting, an alternative way of looking at things and which may be more appropriate, is to view individual specific constant terms as randomly distributed across the five cross-sectional units. Thgis is due in large part to the assertion that the five plants which are largely similar in size, structure and scale of operations- a conjecture which is largely supported by the above results on aggregate and fixed effects. Differences between plants are thus essentially random and a random effect framework may become more suitable. In turn, this leads to the adoption of an Error Components Model (ECM) as a basis for estimation. Here, and instead of assuming a set of given intercepts α_j, j = 1, ..., 5 for the five companies, a single mean intercept α is postulated and the differential- random- intercepts are merged into the equation error.

We obtained random effects by application of Feasible Generalized Least Squares (FGLS) along conventional lines where the disturbance covariance matrix was firstly estimated and a GLS estimator secondly applied to get the final estimates. The results obtained allowing for individual effects were:

(15) The form of the applicable test is similar to that discussed in footnote 14. For more details see Greene [8; p. 484] for example.

$$\ln C = \underset{(12.584)}{7.622} + \underset{(7.640)}{0.640} \ln Q$$

$$\bar{R}^2 = 0.664$$
$$SSR = 0.539$$
$$\hat{\sigma} = 0.139$$
$$d = 1.805$$

The results obtained are largely similar to those of the overall regression for the pooled sample. RTS are 1.563 and economies of scale are positive and equal to 0.563 in magnitude.

A combined ANOVA for both the individual and time effects led to the following results:

Table 4. Anova for Joint Effects.

Source	SS	df	MS	F	s.l.
Individual	0.058	4	0.014	0.997	0.432
Time	0.176	5	0.035	2.437	0.070
Joint	0.234	9	0.026	1.797	0.131
Error	0.289	20	0.014		
Total	0.522	29			

Here the theoretical F value was higher for the hypothesis of no joint individual and time effects registering a value of 2.22 at 5% level leading to the conclusion of no significant joint effects operating on the five cement companies.

3) Learning Effects(16)

It is well known from economic theory that unit labor input requirements tend to fall as cumulative output increases as a reflection of the *'learning by doing'* principle since technical and allocative inefficiency tend to decrease with increases in the level of education and experiences gained by the labor force. This cost reduction is formalized in the concept of the learning curve where the slope of the learning curve should indicate the percentage cost reductions when cumulative output is increased.

In this section we integrate possible learning curve effects into the Cobb-Douglas cost-scale framework after assuming away the effect of prices and we estimate the

(16) On learning effects and their impact on cost functions, see Alberts [9], Alchain [10], Berndt [5], Gallant [11], McDonald [12] and Womer and Patterson [13] *inter alia*.

'augmented cost-learning' model for the five plants over the maximum time periods permitted by the data. In the presence of the learning effect an increase in cumulative output shifts both the static marginal cost and average cost curves downward.

Learning curves are usually estimated in per unit terms, hence we must convert the above cost formulations to an average *i.e.* cost per unit (CPU) measure by dividing deflated real costs by output *i.e.* C/Q, and taking logs to obtain the integrated Cobb-Douglas learning cost model of the form:

$$\ln C - \ln Q \equiv \ln CPU$$
$$= \eta + \delta \ln Q + \omega \ln \Sigma Q_{-1} + \upsilon$$

where ΣQ_{-1} is accumulated production of cement used to proxy the learning effect up to period t-1.

(16) On learning effects and their impact on cost functions, see Alberts [9], Alchain [10], Berndt [5], Gallant [11], McDonald [12] and Womer and Patterson [13] *inter alia*.

If RTS were increasing then the ln Q coefficient must be negative indicating that, given the effect of experience, unit costs would fall with increases in current output. After estimation we can test the hypothesis on the coefficient of ln Q:

$$H_o : \delta = 0$$

whose acceptance indicates constant RTS and whose rejection indicates nonconstant returns. The estimated regression function for the jth cement plant thus assumes the following form:

$$\ln CPU_j = \eta + \delta \ln Q_j + \omega \ln \Sigma Q_{j,-1} + \upsilon_j \qquad j=1, \ldots, 5$$

This form of the learning curve which integrates the Cobb-Douglas cost effect is specially useful for our present context in view of the evidence on increasing RTS acquired in the previous sections.

The estimated functions for the whole data time periods are thus presented in Table 5.

The YSCC equation is statistically well estimated and the coefficients on the regressor variables are significant at 5% level respectively. RTS are included in the output parameter estimate $\hat{\delta}$ which was significant and negative as expected. The learning effect is highly significant, and positive as evidenced by the $\hat{\omega}$ coefficient.

Table 5. Learning Curve Effects.

Company	$\hat{\eta}$	$\hat{\delta}$	$\hat{\omega}$	$\bar{R}^2$	$\hat{\sigma}$	d	F
YSCC	4.964 (4.671)	−0.365 (2.530)	0.293 (5.919)	0.794	0.133	2.874	18.287 (0.002)
ACC	12.000 (12.429)	−0.977 (5.159)	0.012 (0.186)	0.954	0.061	2.883	42.700 (0.023)
SPCC	9.035 (6.642)	−0.630 (2.998)	0.065 (1.284)	0.545	0.073	2.113	4.593 (0.092)
SBCC	9.925 (7.801)	−0.537 (3.293)	−0.114 (2.584)	0.666	0.090	1.784	7.989 (0.028)
SKCMC	12.861 (4.744)	−1.193 (2.304)	0.079 (0.571)	0.805	0.082	2.464	9.246 (0.098)

The ACC equation was acceptable according to the usual statistical criteria. The output parameter estimate which reflects RTS was significant at 3.6% level and non-constant increasing. However, for this plant, the learning effect did not manifest itself in a significant way. The coefficient $\hat{\omega}$ was insignificant and we conclude that for the Rabigh plant not much time has elapsed for learning effects to work their way through on costs. Also, and on a much more stronger note, it appears that not much knowledge and experience has been passed from the older plant in Jeddah to the newer one in Rabigh. The contract system practiced in the hiring of labor for the plant, apparently does not permit the acquisition of permenant necessary skills over-time to make any positive impact on costs.

For the SPCC plant estimated augmented function the learning effect was insignificant with a probability level of 0.269; that despite the comparatively lengthy time period of operations for this particular plant.

The integrated learning-curve Cobb-Douglas function in its estimated form for the SBCC plant is well estimated and economically there are significant RTS effects but the striking feature for this plant is that its learning effects were negative and in the wrong direction.

For the SKCMC plant the estimated integrated function presented learning effects which were not significant. Also, at 5% level the estimated δ coefficient was not significantly different from zero in an indication of possible constant RTS effects.

Overall, the estimated learning elasticities showed some heterogeneity across plants.

Conclusions

In this paper, we have conducted an analysis on the costs of the cement companies in the KSA. Despite the restrictive nature of the data available to us, we were able to arrive at some results and conclusions which included the following:

1 – The Kingdom's cement industry, as examplified by the five cement companies treated in the sample, is characterized by substantial RTS and large, unexploited economies of scale. RTS were mostly greater than 1 and economies of scale were positive for all of the 5 plants considered in the sample and for the industry as a whole. Following from this, the MCs were below the ACs at all output levels below capacity. The MCs were increasing whereas the ACs were decreasing *i.e.* L-shaped. This corresponds partially to results obtained by other researchers in the field, for example, Norman [14] and Walters [15], *inter alia,* but in addition reflects certain intrinsic characteristics of the KSA cement industry. The market for the product- and consequently its production- was supply determined in the seventies but switched to being demand determined in the period of the eighties. Our sample overlaps with this latter period and in periods of slack demand substantial increasing RTS and positive economies of scale are bound to occur. To allow for optimal use and determination of output the market must be expanded by pursuing more vigourous exports promotions policies. To face international competition, ways must be found for improving the industry's X-efficiency and marketing.

2 – There are no substantial differences in individual firm effects. This is attributable to the fact that most of the plants are either of modern vintage or- for the older ones- have been refurbished and modernized completely only recently. In fact in some instances *e.g.* the ACC case, there is no relationship between the old plant at Jeddah and the new one at Rabigh.

3 – RTS did not vary much as we moved from the plant level to the industry level and overall economies of scale remained largely unexploited.

4 – There are no substantial learning effects in this industry to date. Only one plant- that of YSCC- reflected significant learning effects which might serve to optimize costs. This may be due to the capital intensity of the industry and to the modern and new nature of most of the plants. Not much time has elapsed for the companies to acquire sufficient learning effects which could manifest themselves in parallel cost reductions. However, the scope for these effects remains to be large in the future.

5 – There appears to be no spill-over effects of learning from one company to another. This may be due again to the capital intensive nature of the industry and to the fact that labor, aside from at administrative levels, is not traded between companies but rather imported anew from abroad and then sent back to countries of origin after accomplishment and expiry of contracts. Any gains in experiences are thus lost. It might thus be more cost effective to employ local labor whose skills will not be wasted in the future to foreign markets, to lengthen the duration of contracts or, failing that, to give priority in employment to those workers who had been employed by other Saudi cement companies.

6 – There emerges a picture, on the production and cost sides, of cement companies and plants being large autonomous entities with similar scales of plants, quasi-identical cost-production structures and minimal existing cooperation in the areas of production, marketing and sales. A more integrated approach might be preferable and profitable by optimizing production and sales decisions between the companies comprising the Saudi cement industry at large. Indeed, the establishment of a higher body- in the shape of a manufacturers cartel to oversee the undertaking of these decisions might be beneficial in attaining the overall objectives and thwarting wasteful competition at the local, regional and international levels. Failing that, integration and collusion efforts between companies- in the same regions may be- and in the same spirit as that of the recent collusion of SBCC and SCC should be encouraged.

7 – The shifting disequilibrium nature of the cement market in the KSA affects capacity utilization and kiln retirements in plants and hence costs of production. Even though inventory accumulation is undertaken within a year to smooth out production, inventory holding is not significant between years due to the high storage cost of cement.

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تأثيرات الحجم والتعلم في هيكل التكاليف لصناعة الأسمنت بالمملكة العربية السعودية

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(قُدم للنشر في ١٤١٣/٦/٤هـ وقُبل للنشر في ١٤١٣/١١/١٢هـ)

ملخص البحث. يقوم هذا البحث بدراسة علاقات التكاليف ـ الحجم في خمسة من المصانع الثمانية العاملة في إنتاج الأسمنت بالمملكة العربية السعودية. ويحلل البحث المسائل المتعلقة بالتكاليف على مستوى المصانع المفردة كما يجري تقديرًا لدوال التكاليف الكلية الخاصة بتلك المصانع مع السماح بالتأثيرات الزمنية والمقطعية المختلفة. وقد تم التحصل على مقدرات المعالم الخاصة بعوائد واقتصاديات الحجم ذات الأهمية في دراسات التكاليف. كذلك جرى استخدام تقدير المقاطع الطولية ضمن هياكل التأثيرات الثابتة والعشوائية وذلك بغرض توسيع قاعدة البيانات المستخدمة وإثرائها بما يكفل الحصول على مقدرات ذات كفاءة أعلى.

وتوحي النتائج بأن عوائد الحجم المتزايدة واقتصاديات الحجم الموجبة تشكل النمط السائد للتكاليف ـ الإنتاج في هذه الصناعة.

كذلك يستقصي البحث إمكانية حدوث تأثيرات للتعلم على التكاليف وذلك من خلال دعم دوال التكاليف بمنحنيات التعلم. غير أننا لم نحصل على تأثيرات تعلم ذات شأن في تخفيض التكاليف إلا في حالة واحدة فقط من الخمس التي تناولها البحث.