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REGIONAL TECHNOLOGICAL LEARNING IN TURKISH CEMENT INDUSTRY

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Abstract

The learning curve reflects the reduction in average costs as the company's cumulative production increases. These curves are utilized when measuring company performance, managing production processes, and planning. In terms of cost reduction and profitability, the impact of learning is particularly important. The learning curves have been traditionally used in industries. In this study, the learning curves concerning the cement industry are examined. The cement sector inherits a high export potential in Turkey. Additionally, it is the industry branch that supplies the raw materials needed by countries' construction industries. On the other hand, the construction sector is a leading sector that mobilizes other markets. This sector is a major contributor to production, investment, and employment and plays a vital role in the development of the country. This paper aims to make a detailed analysis of the learning curves regarding the Turkish cement industry at the regional level covering the 2000-2018 period. In order to realize this aim, the linear and cubic learning models have been applied and the technological learning values for regions from 2000 to 2018 have been calculated. For the analysis, data of 68 factories operating in the Turkish cement industry obtained from Turkey Cement Manufacturers' Association have been used. The estimated results suggest that cubic models explain technological learning better than the linear models. The results indicated that learning levels differed across regions and times. While the highest learning level was observed in 2004, the highest level of forgetting was recorded in 2018. Finally, we can state that the learning curve of the Turkish cement industry between 2000 and 2018 is convex.

Keywords: Learning Curve, Technological Learning, Cement Industry, Turkey

JEL Classifications: D83, L60, O33

1. Introduction

The Turkish cement industry has an important sector position in the economy with its significant contributions to the Gross Domestic Product, as well as the value-added, employment and export figures. In 2018, the industry employs a total of 15.766 personnel, including managers, civil servants, engineers, workers, technicians, and, contractors.

Governments are investing in infrastructure projects, particularly in reducing regional disparities. Therefore, it is important to investigate the effects of public capital on the performance of the private sector at national and regional level (Karadağ *et al.* 2004). Cement industry is always open to growth and development as it provides the raw materials required for the urban transformation, infrastructure projects and construction activities of the industry.

Competition among firms within this industry is increasing day by day. Companies wishing to provide competitive advantage must take into account both their own advantages and disadvantages and the existing structures of other firms. That is, the firm should compare its cost, efficiency and technology level with those of other firms. In this way, the firm will gain a significant advantage within the industry while discouraging other firms from entering the industry.

Workers can often improve their performance by constantly performing certain tasks. Engineers can perfect their product design by accumulating information about their production processes. Firms can become more proficient in handling and processing materials as their production experience deepens. These situations lead to arise economies of experience. The economies of experience express cost advantages resulting from accumulated experience over a long period of time (Basenko and Braeutigam, 2013). Considering that learning or experiencing can manufacture ways to raise the performance, productivity and efficiency necessary to gain competitive advantage, many firms try to transform into learning organizations (Smits and Bowden, 2015). The economies of experience are described by the experience or learning curve. This curve shows the decrease in average cost while the cumulative total output of the firm gradually increases (Petrakis *et al*. 1997; Church and Ware, 2000; Salvatore, 2008).

The learning curve was initially used by authorities during World War II, to estimate the construction costs of aircraft and ships to be employed in the war. Analysts discovered that with the cumulative increase in the number of aircraft produced, labor input per aircraft is drastically reduced (Krajewski *et al*. 2019).

Learning curves or experience curves have been applied in manufacturing and service industries including manufacturing of airplanes, appliances, ships, etc. Besides, in order to detect the need for labor, materials and raw materials and to plan the production process, to identify the price at which the goods or services will be sold, and even to assess the suppliers' price quotations, learning curves have been utilized (Salvatore, 2008).

The learning curves explain to firm managers how the production cost per unit varies for the cumulative amount of production. The firm managers compete with other firms in price and non-price competition. Managers that prefer low price as a competitive strategy rely on high production levels to maintain their profit margins (Krajewski *et al.* 2019). To determine the shape of the learning or experience curve, it is necessary to find the answer to the question of why learning should occur in firms. Learning is presumed to occur when repeating similar but not necessarily identical processes in any production process. Learning is desired because it represents a reduction in unit costs (Damnjanovic and Reinschmidt, 2020). Therefore, to analyze learning curves in the cement industry is important to determine the competitive advantages of factories operating in the industry. The contribution of this paper to literature is that it is the first time that learning curves will be examined at regional level in Turkish cement industries.

The aim of this paper is to examine the technological learning level of the Turkish cement industry at regional level for the 2000-2018 period. In this context, linear and cubic learning models were used to determine the annual technological learning level in 7 regions in the Turkish cement industry from 2000 to 2018.

This paper is composed of five main sections. The second section demonstrates economic situation of Turkish cement industry. The third section explains the methodology of the paper. The fourth section covers estimation results for the linear and cubic learning models. The fifth and the final section draws conclusions from the estimation results.

2. Turkish cement industry

The first cement factory in the Turkey was established in 1911 in Istanbul. This factory, established in Darica, had a capacity of 20,000 tons/year. In addition, Eskihisar Production Plant, were put into operation in 1912. These factories were to meet the Turkey's cement needs. Finally, those two factories could not withstand the competition and merged under the name Arslan and Eskihisar Müttehit Cement Co. in 1920 (Calmasur and Dastan, 2015).

Until 1950, four new factories were founded in Ankara, Istanbul (Zeytinburnu, Kartal) and Sivas. Later, ÇISAN (Turkish acronym for Turkish Cement Industry Co.) was founded in 1953 to build 15 factories in various regions. Between 1963 and 1980, 17 new factories were established in Turkey. Thanks to the foundation of these cement factories, Turkey occurred the third major manufacturer in Europe in the early 1990s (Saygili and Taymaz, 2001). With the growth in the construction sector, cement production has started to increase gradually. Before 1980, Turkey was among the countries that imported cement. However, cement production was about 22 million tons in 1987 and it became a self-sufficient industry with 29 million tons in 1992 (Alvan, 2008).

Today, approximately 7 million tons of cement and 6 million tons of clinker are exported by 68 factories operating in seven regions to many countries, mainly USA, Israel and Ghana. Table 1 shows Turkish cement industry's domestic sales at regional level.

Table 1. Turkish cement industry's domestic sales at regional level (2014-2018)

Region	2014	2015	2016	2017	2018
Aegean	4,848,188	4,991,533	5,317,293	5,419,847	5,591,074
Black Sea	9,279,124	8,429,524	8,672,754	9,032,760	7,829,074
Central Anatolia	10,531,092	11,302,326	12,096,096	13,936,852	12,937,908
Eastern Anatolia	4,991,903	4,838,826	5,402,992	6,398,922	6,065,412
Marmara	16,061,927	16,529,531	17,798,865	19,575,602	16,496,531
Mediterranean	11,408,933	11,961,601	12,583,743	12,172,100	10,402,520
S. East Anatolia	6,054,763	5,643,322	4,932,860	5,691,177	5,041,492
Total	63,175,930	63,696,663	66,804,603	72,227,260	64,364,011

Source: Turkish Cement Manufacturers' Association (2020)

According to Table 1, Turkish cement industry's domestic sales constantly increased for 2014-2018 period. In 2018, the biggest domestic sale is in the Marmara region (16,496,531 tons) and the lowest sale is in the Southeastern Anatolia region (5,041,492tons). Table 2 shows that the Turkish cement industry employed at regional level. In the 2014-2018 period, the Mediterranean region is at the top of employment and the last one is Southeastern Anatolia.

Table 2. Turkish cement industry's employment at regional level (2014-2018)

Region	2014	2015	2016	2017	2018
Aegean	1,124	1,140	1,184	1,194	1,454
Black Sea	1,698	1,497	1,502	1,368	1,322
Central Anatolia	1,472	1,617	1,685	1,694	1,617
Eastern Anatolia	1,004	1,007	1,253	1,232	1,432
Marmara	1,255	1,216	1,178	1,144	2,503
Mediterranean	2,526	2,486	2,519	2,539	2,608
S. East Anatolia	2,256	2,604	2,658	2,718	1,103
Total	11,335	11,567	11,979	11,889	12,039

Source: Turkish Cement Manufacturers' Association (2020)

Table 3 demonstrates the Turkish cement industry's production capacity in 2018 and rate of capacity utilization by region. As can be seen from Table 3, Mediterranean region has the highest clinker capacity while the Marmara region has the highest cement capacity. Rate of capacity utilization in cement and clinker are top in Marmara.

Table 3. Turkish cement industry's production capacity and rate of capacity utilization by regions (2018)

Region	Clinker Capacity	Cement Capacity	Clinker Rate of Capacity Utilization	Cement Rate of Capacity Utilization
Aegean	9,444,600	13,777,960	65.92	42.79
Black Sea	8,672,550	18,359,839	92.15	49.19
Central Anatolia	15,025,890	22,315,866	82.26	58.04
Eastern Anatolia	7,447,440	13,176,595	68.25	47.23
Marmara	20,068,820	29,117,921	93.95	67.28
Mediterranean	22,929,230	33,964,430	85.75	49.85
S. East Anatolia	6,273,830	11,164,145	75.12	47.01
Total	89,862,360	141,876,755	82.91	53,39

Source: Turkish Cement Manufacturers' Association (2020)

3. Methodology

Whilst the cement sector has a crucial role in terms of affecting Gross Domestic Product (GDP), additionally, it is critical for the economy owing to its contribution to employment, value-added production, production value, and its share in foreign trade (Directorate-General for Industry and Productivity, 2019). The cement sector is characterized to be inheriting a low elasticity of supply since it requires high investment values and takes a while to activate these investments. Entering and exiting the market is not easy, since it is a sector that requires considerable capital investment (Kalkan *et al*. 2016). It is therefore very important for this sector to gain cost and competitive advantage. For this purpose, the cement industry has been chosen and learning curves have been analyzed.

The data for 68 factories operating in the Turkish cement industry were obtained from the Turkish Cement Manufacturers' Association. The data set covers the annual data set for the 2000-2018 period. In this paper, export and domestic sales is used to represent the output level (Q) and number of employees is the labor level (L).

The first publication analyzing the learning curve model was published in 1936. Wright (1936) studied the cost of production in the aircraft industry. There are different learning curve models including univariate and multivariate. The traditional univariate learning curve symbolizes a dependent variable such as production cost in terms of independent variables (cumulative output, etc.). The most famous univariate models are the log-linear model, the S-curve, the Stanford-B model, DeJong's (1957) learning formula, Levy's (1965) adaptation function, Glover's learning formula, Pegel's exponential function, Knecht's (1974) upturn model, Yelle's product model, and multiplicative power model (Yelle, 1979; Badiru, 1992; Asgari and Gonzalez-Cortez, 2012).

Until to the today, learning curve models have been widely used in different industries. Hartley (1965), Argote and Epple (1990), Benkard (2000), Bongers (2017) in the aircraft industry; Levitt *et al.* (2013) in the automobile industry; Boston Consulting Group (1973), Dick (1991), and Chung (2001) in the semiconductor industry; Argote *et al.* (1990), Kim *et al.* (2019) in the ship industry; Lieberman (1984), Sinclair *et al*. (2000) in the chemical industry; Karali *et al*. (2015) in the iron and steel industry; Chen and Lu (2012), Xu *et al*. (2017), Hayashi *et al.* (2018) in the wind power and other power technologies; Tan and Elias (2000) in the construction industry; Pramongkit *et al.* (2002), Franceschini and Galetto (2003), Karaoz and Albeni (2005), Asgari and Yen (2009), Asgari and Gonzalez-Cortez (2012), Aduba and Izawa (2018), Aduba and Asgari (2019), Feizpour *et al.* (2020) analyzed the learning curve in the manufacturing industry.

Both the learning and experience curves indicate that more experience will be gained and production costs will decrease with the production of a good or service (Louwen and Lacerda, 2020).The learning or experience curve illustrates the decrease in average cost as the cumulative total output of the firm increases (Church and Ware, 2000; Salvatore, 2008).Wright's model is referred to as the log-linear model has been widely used to estimate the linear learning curve.

The model can be expressed as (Pramongkit *et al.* 2000; Pramongkit *et al*. 2002; Karaoz and Albeni, 2005; Louwen and Lacerda, 2020):

$$C_t = C_1 X_t^{-a} \quad (1)$$

or equivalent in logarithmic form:

$$lnC_t = lnC_1 - alnX_t \quad (2)$$

where C_t is the labor input per unit of output at time period t; C_1 is the labor input needed to produce the first unit of output; X_t is the cumulative number of units of output produce until time t; and -a represents the learning elasticity.

Equation 2 expresses that the unit production cost at time t (C_t) is a function of cumulative production level X_t, and the cost of producing the first unit C_1 in the production process. Additionally, the learning effect is determined by the value of a.

The bigger the value of a, the more important are the learning effects. The progress ratio (d) is reproduced from the representing learning elasticity a. The progress ratio is a portion of the beginning unit cost when the cumulative production level or experience doubles. This is expressed as; $d = 2 - a$ (Pramongkit *et al*. 2000; Pramongkit *et al*. 2002; Karaoz and Albeni, 2005; Aduba and Izawa, 2018).

If there is learning in any firm or industry, the values of the progress ratio are hoped to be between zero and one. When the value of the progress ratio approaches 0, the learning becomes better and better. However, the value of the progress ratio close to 1 suggest low learning rate. In addition to, when the value of the progress ratio is 1, there is neither learning nor forgetting (Argote and Epple, 1990; Karaoz and Albeni, 2005).

To measure the learning curve effect, the traditional Cobb-Douglas production function commonly used. The function expressed as:

$$Q_t = A_t L_t^{a} K_t^{\beta} \quad (3)$$

or equivalent in logarithmic form:

$$lnQ_t = lnA_t + alnL_t + /3lnK_t \quad (4)$$

where Q_t is the output level at time t; L_t is the labor level at time t; K_t is the capital level at time t. A_t refers the level of technology at time t. α and β are respectively the output elasticity of labor and output elasticity of capital. The sum of the α and β parameters is a measure of the returns to scale for the production function (Pramongkit *et al*. 2002; Salvatore, 2008; Karaoz and Albeni, 2005).

Equation 3 assumes that there exists a functional relationship between the level of technology at time t, At and the cumulative level of production at time t, X_tEquation 5 is expressed as:

$$A_t = H X_t^{a} \quad (5)$$

or equivalent in logarithmic form:

$$lnA_t = lnH + alnX_t \quad (6)$$

where H refers a constant and X_t^{a} is the inverse of X_t^{-a} earlier expressed in equation 1 ($X_t^{a} = {C_1}/{C_t}$). Hence, using $X_t^{a} = {C_1}/{C_t}$ relationship, we could rewrite equation 5 as:

$$A_t = H\frac{C_1}{C_t} \quad (7)$$

using the natural logarithm, equation 7 can be written in a linear form as:

$$lnA_t = lnH + ln\left(\frac{C_1}{C_t}\right) \quad (8)$$

If we combine equation 4 and equation 6 and substitute for A_t, we have

$$lnQ_t = lnH + alnX_t + /3lnL_t + ylnK_t \quad (9)$$

By adding lnL_t from both sides of equation 9 and multiplying the results $by\ -1$, we have:

$$ln\left(L/_Q\right)_t = -lnH - alnX_t i + (1-\beta)lnL_t - ylnK_t \quad (10)$$

Additionally, in Equation 10, the relationship between capital and labor is assumed to be:

$$K_t = \mu L_t^{\lambda} \quad (11)$$

or using the natural logarithm, equation 11 can be written follows as:

$$lnK_t = ln\mu + \lambda \ln L_t \quad (12)$$

where $\mu\ and\ \lambda$ are constants. The value of λ indicates the technical biases associated with production expansion. $\lambda = 1$ implies neutrality in technological progress whereas $\lambda > 1$ suggests that capital-labor ratio proportionally raises as production level enlarges (see Pramongkit *et al*. 2002; Karaoz and Albeni, 2005; Aduba and Izawa, 2018).

Combining equation 10 and equation 12, and substituting for lnK_t we have equation 13:

$$ln\left(L/_Q\right)_t = -lnH - yln\mu - alnX_t + (1-\beta-y\lambda)lnL_t \quad (13)$$

Equation 13 is the linear learning model. It is used empirical estimation of the learning curve. To express in a shorter way, presume $\sigma_0 = -lnH - \gamma ln\mu$, $\sigma_1 = -\alpha$, $\sigma_2 = 1-\beta-\gamma\lambda$, and $lnC_t = ln\left(L/_Q\right)_t$. Then,

$$lnC_t = \sigma_0 + \sigma_1 lnX_t + \sigma_2 lnL_t + \varepsilon_t \quad (14)$$

The cubic learning model assumes that the level of learning varies over time. Carlson (1973) justifies the use of the S-curve function to estimate cubic learning rates. The S-curve function implies that per the unit cost of production level at time t is a function of cumulative production up to third order polynomial. In this article, we used the cubic learning model. The cubic learning model can be expressed as (Badiru, 1992; Karaoz and Albeni, 2005, Asgari and Yen, 2011; Aduba and Izawa, 2018):

$$lnC_t = lnC_1 + BlnX_t + C(lnX_t)^2 + D(lnX_t)^3 \quad (15)$$

Equation 15 states per unit cost of output at time t is a function of the cumulative production level. The learning index is determined by the first derivative of the Equation 15.

$$-a = \frac{dlnC_t}{dlnX_t} = B + 2ClnX_t + 3D(lnX_t)^2 \quad (16)$$

In addition to, Equation 17 derived from Equation 15 as:

$$ln\left(\frac{C_1}{C_t}\right) = -[BlnX_t + C(lnX_t)^2 + D(lnX_t)^3] \quad (17)$$

We replace the $ln\left(\frac{C_1}{C_t}\right)$in Equation 8 with Equation 17. We have a new relation as:

$$lnA_t = lnH - BlnX_t - C(lnX_t)^2 - D(lnX_t)^3 \quad (18)$$

Equation 18 is added in Equation 4 and the following form is obtained:

$$lnQ_t = lnH - BlnX_t - C(lnX_t)^2 - D(lnX_t)^3 + \alpha lnL_t + \beta lnK_t \quad (19)$$

Additionally, in Equation 19, the relationship between capital and labor is assumed to be:

$$K_t = \mu L_t^{\lambda} \quad (20)$$

where μ and λ are constants. The logarithmic form of this equation can be added in Equation 19:

$$lnQ_t = lnH - BlnX_t - C(lnX_t)^2 - D(lnX_t)^3 + \alpha lnL_t + \beta(ln\mu + \lambda lnL_t) \quad (21)$$

after adding lnL_t to both sides of the equation, the following final equation is attained:

$$ln\left(\frac{L}{Q}\right)_t = -lnH - \beta ln\mu + BlnX_t + C(lnX_t)^2 + D(lnX_t)^3 + (1 - \beta\lambda - \alpha)lnL_t \quad (22)$$

to express in a shorter way, assume $\theta_1 = -(lnH + \beta ln\mu)$, $\theta_2 = (1 - \beta\lambda - \alpha)lnL_t$ and $lnC_t = ln\left(L/Q\right)_t$. Then,

$$lnC_t = \theta_1 + BlnX_t + C(lnX_t)^2 + D(lnX_t)^3 + \theta_2 lnL_t \quad (23)$$

The derivative of Equation 17 gives us the learning elasticity, stated as follows:

$$-a = \frac{\partial C_t}{\partial X_t}\frac{X_t}{C_t} = B + 2ClnX_t + 3D(lnX_t)^2 \quad (24)$$

Through regression analysis, to estimate B, C and D parameters Equation 23 is employed and so to calculate the value of α, and progress ratio $d = 2^{-a}$ is computed.

4. Estimation results

In order to determine the technological learning level for the Turkish cement industry in the 2000-2018 period, Equation 14 was estimated. Table 4 shows coefficients (σ_0, σ_1 and, σ_2), and progress ratio indices (d) estimated using the linear models for each region in the Turkish cement industry. All the models estimated in Table 4 are statistically significant as a whole at a 1% significance level respectively (F values). That is, the independent variables significantly explain the dependent variable as a whole. R^2 values of the models vary between 70.0%-91.8%. The t values for σ_0, σ_1 and, σ_2 parameters demonstrate that the estimates are significant for most of the regions.

Table 4. Linear regression model results

Region	C_0	C_1	C_2	*d*	*F values*	*R2*
Aegean	-11.772 (-7.76)*	-0.109 (-6.75)*	0.741 (3.71)*	1.078	38.73*	0.829
Black Sea	-6.702 (-9.40)*	-0.148 (-3.87)*	0.101 (0.62)	1.108	18.54*	0.700
Central Anatolia	-2.877 (-1.55)	-0.172 (-5.01)*	-0.377 (-1.18)	1.127	60.60*	0.883
Eastern Anatolia	-4.863 (-6.48)*	-0.243 (-3.87)*	0.107 (0.50)	1.184	23.75*	0.748
Marmara	-7.919 (-7.85)*	-0.249 (-13.31)*	0.486 (3.71)*	1.189	89.65*	0.918
Mediterranean	-7.278 (-16.68)*	-0.211 (-5.46)*	0.314 (2.98)*	1.157	18.79*	0.701
S. East Anatolia	-6.407 (-6.16)*	-0.201 (-6.08)*	0.214 (1.16)	1.150	24.50*	0.754
Total	-5.883 (-5.61)*	-0.192 (-7.92)*	0.116 (0.76)*	1.143	77.66*	0.907

Note: *denotes statistical significance at 1%.

The third column of Table 4 shows the estimated progress ratio for each region. All cells of the third column emphasize technological learning level over unity. In other words, these numbers imply the per unit cost efficiency missed for the 2000-2018 period. For instance, the unit production costs for the Marmara region in the Turkish cement industry increased 18.9% for each doubling of the production level.

Table 5 demonstrates coefficients estimated using the cubic model (Equation 24) for each region from 2000 to 2018.All the models estimated in table 5 are statistically significant as a whole at a 1% significance level respectively. R^2 values of the models vary between 83.5%-97.0%. The t values for 0_1, 0_2, *B*, *C*, and *D* parameters show that the estimates are significant for most of the regions.

Table 5. Cubic model regression results

Region	0_1	0_2	*B*	*C*	*D*	*F values*	*R2*
Aegean	-326.626 (-4.49)*	0.759 (5.41)*	55.677 (4.32)*	-3.289 (-4.33)*	0.065 (4.34)*	44.43*	0.927
Black Sea	-456.149 (-2.41)**	0.718 (2.78)**	77.421 (2.34)**	-4.489 (-2.32)**	0.086 (2.30)**	17.68*	0.835
Central Anatolia	-156.892 (-1.76)	0.355 (1.24)	24.506 (1.61)	-1.356 (-1.55)	0.025 (1.47)	68.41*	0.951
Eastern Anatolia	-259.868 (-2.81)**	1.017 (4.49)*	44.119 (2.60)**	-2.609 (-2.51)**	0.051 (2.39)**	35.70*	0.911
Marmara	-307.906 (-2.63)**	0.709 (4.35)*	49.419 (2.53)**	-2.751 (-2.52)**	0.051 (2.50)**	61.36*	0.946
Mediterranean	-160.650 (-1.14)	0.413 (1.40)	26.106 (1.10)	-1.507 (-1.12)	0.029 (1.14)	9.42*	0.729
South East Anatolia	-812.343 (-7.33)*	1.262 (6.97)*	144.894 (7.25)*	-8.755 (-7.25)*	0.175 (7.24)*	65.06*	0.949
Total	-536.659 (-5.22)*	1.101 (5.13)*	80.440 (5.11)*	-4.139 (-5.09)*	0.071 (5.06)*	111.50*	0.970

Note: *and **denotes statistical significance at 1%, and 5% level respectively.

Table 5 demonstrates coefficients estimated using the cubic model (Equation24) for each region from 2000 to 2018.All the models estimated in table 5 are statistically significant as a whole at a 1% significance level respectively. R^2 values of the models vary between 83.5%-97.0%. The t values for 0_1, 0_2, *B*, *C*, and *D* parameters show that the estimates are significant for most of the regions.

Then, the technological learning levels about any region and for the 2000-2018 were computed and presented in Table 6. The annual learning elasticities for each region were computed by using the estimates from Equation 24. After, these elasticities were transformed to the annual technological progress ratios (learning levels) via $d = 2\text{-}a$. Shaded cells emphasize technological learning level over unity. Shaded cells show loss in efficiency and increase or f forgetting in per unit production cost. Unshaded cells refer to per unit cost reductions or technological learning in the production process by the corresponding region.

Each year's annual technological learning level in Table 6 shows the decreases or increases in unit production costs in the face of doubling production for corresponding industry. The fact that annual learning levels vary from one year to the next indicates that the level of technological learning is different for each year. For instance, in 2000, 2001, and, 2002, the annual technological learning levels for the Aegean region are 1.210, 0.972, and 0.898 respectively. These numbers imply the per unit cost efficiency acquired or missed for a given year. For example, in 2000, the unit production costs for the Aegean region increased 21.0% for each doubling of the production level but in 2001 and 2002, unit production costs declined to and 2.8% and 10.2%.

The average technological learning level was 0.829 in the Turkish cement industry for the 2000-2018 period. This number refers to unit production costs declined to 17.1%. In the 2000-2018 period, there is good learning potential in all regions except for the South East Anatolia Region. The biggest technological learning level belongs to the Eastern Anatolia region.

Table 6. The annual technological learning level for regions (2000-2018)

Region Year	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South East Anatolia	Total
2000	1.210	1.499	1.145	1.456	1.161	1.038	1.821	1.417
2001	0.972	1.068	0.986	1.037	0.950	0.904	0.955	1.018
2002	0.898	0.897	0.914	0.872	0.863	0.851	0.720	0.869
2003	0.867	0.818	0.872	0.783	0.819	0.828	0.632	0.795
2004	0.859	0.773	0.844	0.728	0.797	0.816	0.604	0.755
2005	0.863	0.749	0.824	0.691	0.786	0.810	0.608	0.732
2006	0.876	0.739	0.810	0.665	0.784	0.809	0.635	0.721
2007	0.893	0.739	0.801	0.648	0.787	0.810	0.684	0.718
2008	0.912	0.745	0.796	0.635	0.794	0.814	0.748	0.721
2009	0.932	0.756	0.793	0.625	0.804	0.820	0.831	0.728
2010	0.954	0.774	0.790	0.618	0.816	0.830	0.929	0.739
2011	0.977	0.797	0.790	0.615	0.829	0.841	1.034	0.752
2012	1.001	0.822	0.790	0.615	0.842	0.853	1.150	0.767
2013	1.026	0.851	0.791	0.619	0.856	0.868	1.282	0.786
2014	1.050	0.884	0.793	0.624	0.872	0.882	1.416	0.805
2015	1.074	0.914	0796	0.630	0.889	0.897	1.546	0.825
2016	1.099	0.946	0.799	0.638	0.907	0.913	1.663	0.847

Note: Shaded cells emphasize technological learning level over unity.

The Aegean region showed declined in unit cost production between the 2001- 2011 period. However, its unit cost increased in 2000 and, between 2012 and 2018. The Black Sea region demonstrated learning potential (unit cost reduction) from 2002 to 2017. However, there was an increase in unit production cost for every doubling of cumulative production for 2000, 2001 and 2018 for this region. Besides the Central Anatolia, Marmara, and Mediterranean regions show continuous good learning potential and real cost saving from 2001 to 2018. The Eastern Anatolia region demonstrated an increase in unit production cost in 2000 and 2001, and thereafter lost is efficiency in cost saving/reduction at each doubling of cumulative production for the rest of the years (2002 to 2018). This is called early forgetting and later learning. Finally, the South East Anatolia region showed continuous good learning potential from 2001 to 2010. However, its unit labor cost increased in at each doubling of cumulative production in 2000, and between 2011 and 2018. The progress ratio for this region shows that the forgetting was continuous in the last eight years.

Figure 1 illustrates the learning curves derived from the numbers indicating the technological learning levels of each region in Table 6, for the period 2000-2018. The learning curves for the regions and industry have convex learning path with a minimum. The Aegean, the Black Sea, and the South East Anatolia regions show forgetting at some beginning and end period. These regions demonstrate learning potentials from the beginning period and after a while lost this ability to save cost from technological learning. Also, other regions and industry show forgetting at some beginning period only. In other words, the Central Anatolia, the Eastern Anatolia, the Marmara, the Mediterranean regions and cement industry illustrate learned-by-doing and this led them to huge cost saving after the beginning period. Once started, learning for these regions and industry is continuous.

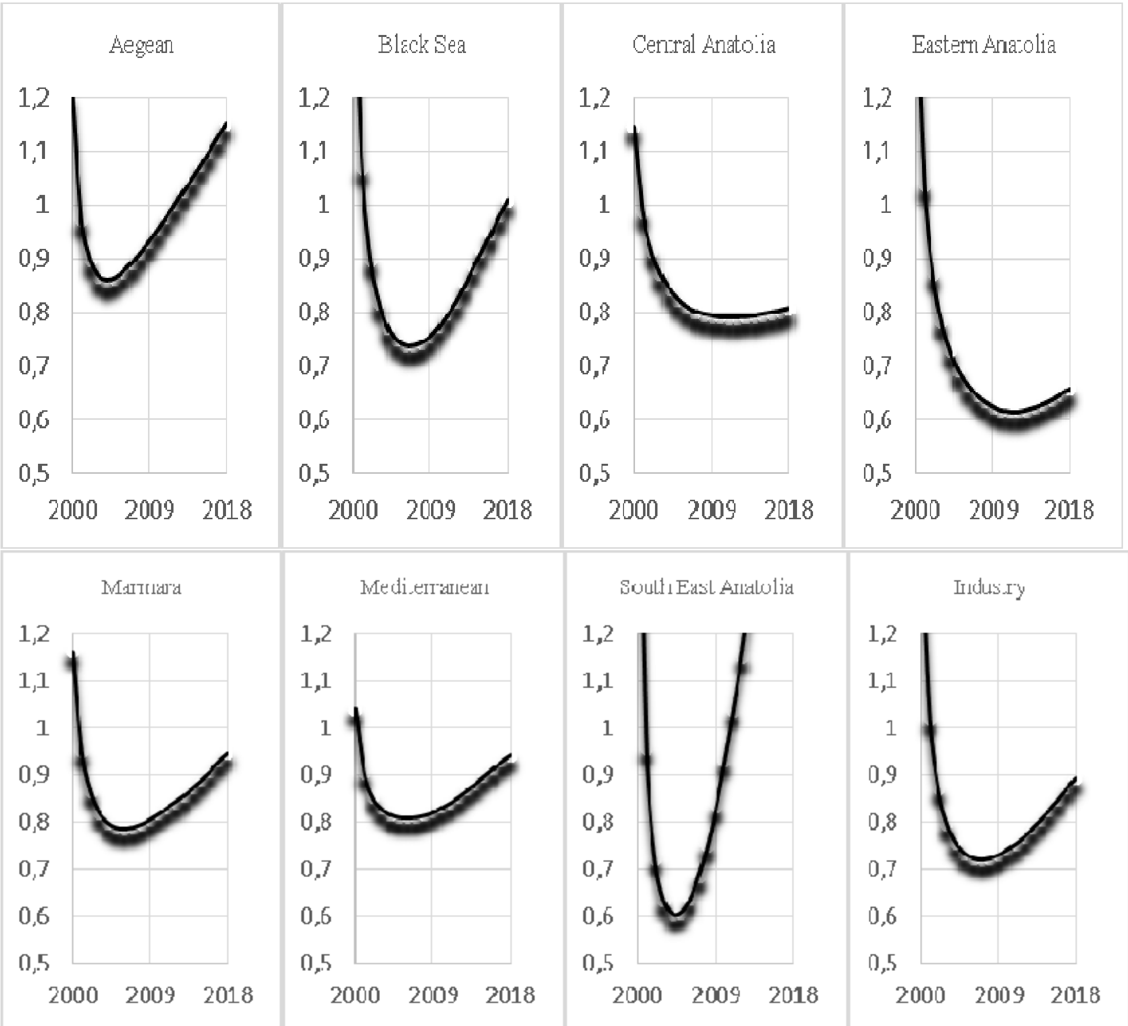

Figure 1. The learning curves for regions and industry (2000-2018)

5. Conclusion

Cement industry is a leading industry that makes a significant contribution to the development and growth of the construction sector considering the provided employment, added value and export rates in Turkey. Today, the development of this industry and the strengthening of its competitive structure depend on the speed of technological change and transformation. This is closely related to the technological learning level. The learning curve, which has been used for more than seven decades, is used to determine the technological learning level of any industry.

In this paper, learning curves are analyzed for the Turkish cement industry in terms of regions for the 2000-2018 period through the linear and cubic learning models. Findings obtained from this paper show that cubic models provide better information about the technological learning levels in the regions compared to the linear model. The estimation results obtained from linear and cubic learning models have indicated that the learning levels in the Turkish cement industry and regions vary over time period. It was found that overall the Turkish cement industry had a convex learning path that reached its minimum in 2007.

Some regions had better learning after the beginning period, while others demonstrated forgetting at some end periods. The Black Sea, the Central Anatolia, the Eastern Anatolia, the Marmara, and the Mediterranean regions show good learning potentials after the beginning period. However, the Aegean and the South East Anatolia regions displayed forgetting at the beginning and some end periods. The biggest learning level was in 2004 in the South East Anatolia region, while the highest level of forgetting was in 2018 in the same region.

The Turkish cement industry performed well overall in the analysis period. The technological learning levels were analyzed by considering the micro-economic variables in this paper. Also, macro-economic variables that may affect the technological learning levels can be the subject of analysis.

In light of the economic effects of the COVID-19 pandemic, rising competition, and changing cost structures, it is proposed that further analyses should be carried out to enhance the sector's performance and reduce its costs.

This research is intended to be a reference for the subjects covering learning curve modeling for different industries. These models can be built and compared with similar countries, and policies can be formulated on the basis of results. What has been inferred is that the study results would be useful in assessing new targets and potential opportunities in the market.

Consequently, the technological learning levels factors that may vary from period to period, country to country and region to region. Also, the results obtained in the paper are limited to the data gathered during the examination period, the variables used, and the analysis methodology. Using different periods, variables and methods may lead to different analysis results.

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