

## The Cement Industry in Mexico: An Analysis of its Determinants

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### Abstract:

Below, this paper analyzes and identifies some of the determinants that explain cement industry production in Mexico. The objective of this study was to identify the effect of exports and external competition on cement production, as well as internal drivers, such as investment, employment, and overall economic activity. As a function of augmented production, error correction models were estimated. The results indicate that the cement production exchange rate is positively related with exports and negatively with external competition. Overall economic activity showed a strong effect on production. Assuming that the industry operates as an oligopoly, the results imply that there are no incentives to favor the entrance of competitors.

**Key Words:** Cement industry, production, companies, market, investment, employment

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## Introduction

Measured in terms of production capacity, the Mexican cement industry is one of the largest. However, production levels have fluctuated sharply over the years. The industry gathered steam during the age of import substitution industrialization, which helped boost national production through fiscal incentives

and financial support, going from an installed capacity of 574 million to 17.02 million metric tons in the period 1940-1980 (Salomón, 2006). With six business groups comprising the industry, the annual growth rate between 1940 and 1960 amounted to 10.2%. The industry leader was Cementos Tolteca, followed by Cementos Anáhuac, Cementos Mexicanos, Cruz Azul, Guadalajara, and San Luis Mining Co. (Kumakan and Martínez, 2008).

Starting in the 1990s, Mexican cement companies began to make major moves by way of mergers and acquisitions that are extremely important to understanding how the market is distributed, how prices behave, and how Mexico currently competes in the international market. Data obtained in 2015 show that the cement industry remained highly concentrated in the hands of just six companies that continue to dominate the domestic market: Cemex, Grupo Cementos de Chihuahua, Cemento Moctezuma, Holcim-Apasco, Cruz Azul, and Cementos Fortaleza (constituted by the purchase of Lafarge by Carlos Slim and Antonio del Valle, the top shareholder in the chemical conglomerate Mexichem) (see Table 1). Cemex rules the national market with nearly 50% of production and sales, followed by Holcim-Apasco.

**Table 1.** Companies that are Part of the Mexican Cement Industry (2015)

<i>Company</i>	<i>Number of Plants</i>	<i>Headquarters</i>
Cemex	15	Monterrey, N. L.
Cemento Moctezuma	3	México, D.F.
Cementos y Concretos Nacionales (Cruz Azul)	4	México, D.F.
GCC Cemento	3	Chihuahua
Holcim-Apasco	7	México, D.F.
Cementos Fortaleza (Lafarge)	3	México, D.F.

**Source:** Created by the authors based on data from the National Cement Chamber.

Little formal work has been done to analyze the behavior of the Mexican cement industry in detail. The most germane studies have focused on analyzing the overall nature of the industry (Avalos and Schatan, 2003; Kumakan and Martínez, 2008), analyzing the efficient use of energy in production (Sterner, 1990), the market structure by which the industry operates (De la Garza and Arteaga, 2012), and the relationships of agglomeration and prices among the six multinationals (Ghemawat and Thomas, 2005). Other papers have emphasized only Cemex, in light of its role as a market and global leader (Barragán and Cerutti, 2003), or the group consisting of Cemex, Holcim-Apasco, and Lafarge (Vera, 2013).

Accordingly, this paper sets out to analyze several of the determinants of growth and production in the Mexican cement industry. The objective is to investigate to what degree the burgeoning participation of the industry in the international market, rooted in its expansion plans and the eliminating of antidumping tariffs, has increased production and to what extent external competition has had an effect through

cement imports. Another goal is to analyze the effect of more domestic determinants, such as investment, employment, and overall general economic activity, on production. Beginning with an augmented production function, various error correction models were estimated to determine the statistical significance of each of these external- and internal-order elements on cement production in Mexico, with monthly data ranging from 2005 to 2015.

This paper is separated into five sections: the first offers a theoretical analysis of the structure of the oligopolistic market. The second analyzes trends in Mexico with aggregate data on employment, investment, and foreign trade. The third describes the methodology. The fourth parses the results obtained. Finally, the fifth section provides conclusions. The hypothesis is that the rising presence of imports in the national market affects production, and the elimination of tariffs has not boosted cement exports. In the domestic market, we assume that the growth of the construction industry is the main determinant for the upswing in cement production.

## **Theoretical Discussion**

The market structure in which the cement industry operates could be considered an oligopoly, as a homogenous product is predominant and companies are interdependent in setting production or prices. High barriers to entry for new competitors mean that Mexico imports very little cement. Moreover, accusations of disloyal trade practices have afflicted the market's ability to export to its principal destination (the United States). In the past ten years, the peak growth rate was reached in 2006 with 7.7%, while the value of production grew 5.8% in real terms. However, starting in 2006, the industry took a nosedive in terms of both production and export levels. The most critical moment came between 2009 and 2010, when production declined severely at -4.21% and exports were down -52.4%. It is understandable that the financial crisis unleashed by the United States in 2008 would have such strong repercussions for the Mexican economy and, in particular, for the cement industry. However, while the economy as a whole began to recover in 2013, both the construction and cement production businesses continued to experience negative growth rates. Finally, according to the National Institute for Statistics and Geography (INEGI), in 2015, the industry produced 44.9 million tons of cement and, for the first time in ten years, managed to hit a growth rate of 7% (INEGI, 2015a).

Unlike in situations of perfect competition, where companies take the prices dictated by the market and based on that establish production levels, in an oligopoly, the decisions that each company makes affect market prices and, therefore, the profits of all of the other companies. Because they all produce the same homogenous good, they are necessarily interdependent and, consequently, they must behave strategically.

The theory of “imperfect competition” contains diverse models to explain how agents in an oligopoly behave. Departing from a simplified model where there are  $n$  companies that produce a homogenous good, companies must decide on the price they will charge or the amount they will produce. To maximize profits (revenue less costs), there are two solutions to be found: in the Cournot model, companies simultaneously choose the amount, while in the Bertrand model, they simultaneously set the price (Varian, 2011).

In an oligopoly, the income ( $IT_i$ ) and profit of company  $i$  ( $II_i$ ) are a function not only of its production level ( $q_i$ ) but also of the production of the rest of the companies:  $Q_{-i}$ . Accordingly, the equation for the profit of company  $i$  is:

$$\Pi_i = II_i(q_i, Q_{-i}) - CT_i(q_i) \quad (1)$$

Where  $CT_i$  represents total costs. In considering what its maximizing production ( $q_i$ ) should be, company  $i$  must consider the behavior of the other companies ( $Q_{-i}$ ). This function is referred to as the reaction function because it represents the company’s production in terms of the production of the other companies. As such, at equilibrium, the production amounts are the same:

$$q_i^* = F_i(q_j^*), q_j^* = F_j(q_i^*) \quad \text{where } i, j = 1, \dots, n, i \neq j \quad (2)$$

As such, when maximizing, the price of the oligopoly is:

$$P^* = (nc) / (n+1) \quad (3)$$

The price of the product depends on the marginal cost of  $c$  and  $n$ , so at the limit, the price is equal to the marginal cost, and it is a competitive price:

$$\lim_{n \rightarrow \infty} P^*(n) = c \quad (4)$$

If in a duopoly or oligopoly there are clear differences between the companies, and one of them is dominant, then there are two possible solutions. If the dominant company manages to set the price before the other, it becomes the leader in the price selection and, therefore, the other is the follower. If the dominant company fixes the amount, then it is a leader in production choice and the follower companies maximize their profits based on that production (Stackelberg model of competition).

Another strategy that companies may choose is collusion, meaning that by way of collaboration, they reduce the competition between them to maximize profits as if they were a single company:

$$\underset{q_1, q_2}{\text{Max}} \pi_1 + \pi_2 = (q_1 + q_2)P - CT_1(q_1) - CT_2(q_2) \quad (5)$$

In expression (5), the total profits are the sum of the profits of each company. The marginal costs for each company are equal to the marginal income of the industry. Because only one function is maximized, the maximum profit of the industry is similar to what would be obtained with a monopoly owning various plants. The advantage is that collusion permits, through fixing production and the price of the product, the companies already in the market to prevent new competitors from entering. However, the equilibrium in collusion is not stable, because the companies need to set the criteria for distributing the total profit. If just one of them does not respect the agreements, then it can increase its production share and profits at the cost of the rest. Collusion means that the total profits of the industry are higher, because production and prices are set, but it is detrimental to consumers and potential new competitors. For that reason, collusion is prohibited and penalized by competition law.

In practice, however, it is common for companies to agree to form cartels, which persist for many years. Levenstein and Suslow (2006) conducted an extensive review of empirical cases of cartels in different industries to identify, among other aspects, how successful they are and how long they last. They found that the duration varies widely. For example, the beer cartel (in the United States) was maintained for nine years, while the cement cartel (in South Africa) stuck around for 40 years (Levenstein and Suslow, 2006: 53). The success and duration of cartels is greater where there are fewer participants and when product demand is inelastic. In both cases, the cement industry met these conditions. Other documented cases seem to support that collusion and concentration in the cement industry are themes common around the world, including in India (Pradhan, 1992), Canada (Kleit and Palsson, 1996), and Germany (Blum, 2007), among others.

Beyond oligopolistic competitive practices, there are other theories that explain the behavior of companies that try to fend off competition. For example, the theory of vertical integration asserts that the acquisition of companies that belong to the production and distribution chain leads to vertical integration, erecting entry barriers for new competitors (Blair and Kaserman, 1983; Carlton, 1979). For example, Kleit and Palsson (1996) found that, in cement companies in central Canada, the acquisition of integrative and cement distribution companies had led to vertical integration that was blocking new competitors from entering the market because of the high costs of participating. The vertical integration of these companies therefore permitted them to set high prices as compared to companies located outside of the region.

## **The Performance of the Mexican Cement Industry**

The Mexican cement industry supplies one of the most important products for the construction industry: cement, whose productive chain in the industry is rather short (Pozas, 1999), because when construction projects are being built, very few modifications can be made that would require adding complementary materials. From another perspective, various chains converge around cement (steel, glass, aluminum, wood, etc.) until the projects are finished, and their uses will be defined depending on the types of materials and, likewise, the demand for cement.

Given the makeup of the materials and inputs required by this industry, it has become concentrated in the hands of just a few companies, to the extent that an oligopolistic market has emerged, prompting both open and concealed collusion to manipulate the market. In light of the narrowness of the productive chain and specialization in just a few products, companies do not invest in complementary industrial activities. The experience of Cemex is an example of success that defies the logic of the networks of transnational companies, which shape the globalization of the economy (Corrales, 2006; Kang and Sakai, 2000).

It is more common for cement industry companies to engage in mergers and acquisitions to control the market, which gives rise to international competition through hostile takeovers of companies and other small cement businesses that are well-positioned in growing markets with demand. Over the past two decades, this agglomeration strategy (Ghemawat and Thomas, 2005) has made evident this process of concentration in the cement industry, whose beneficiaries, in the end, have been the big transnational cement companies.

In Mexico and around the world, large infrastructure projects like bridges and buildings require significant quantities of cement and lead to competition between cement companies to supply the

cement. Surely, given the high composition of the capital to produce it and the cost to transport it to the end consumer, the cement industry is dominated by just a few companies, in other words, those with the capacity to manipulate prices (De la Garza and Arteaga, 2012).

Table 2 shows some of the performance indicators for the cement industry<sup>2</sup> from 2005 to 2015. Throughout these years, the industry has been controlled by six companies that own around 34 of the 37 plants. They currently have 30,000 points of sale in the country, creating 86,000 direct jobs. However, their share in the Gross Domestic Product (GDP) fluctuates around 1%. In the table, we can see that in 2005, national cement production amounted to 39.7 million tons, while national consumption per capita reached 384.1 kilos per inhabitant. Ten years later, production rose (44.9 million tons), but per capita consumption fell to 375.5 kilos per inhabitant.

**Table 2.** Cement Production and Consumption in Mexico

<i>Year</i>	<i>Number of plants</i>	<i>Average capital used (%)</i>	<i>Cement production (millions of tons)</i>	<i>Growth rate, production (%)</i>	<i>Consumption per capita (kilos per inhabitant)</i>	<i>Production value (millions of pesos 2008)</i>
2005	37	84.1	39.7		384.1	59828.2
2006	37	86.3	42.7	7.7	413.7	63316.9
2007	35	85.7	43.4	1.6	420.5	62352.0
2008	35	85.8	42.3	-2.6	409.5	59816.2
2009	35	85.0	40.9	-3.2	396.3	58186.5
2010	35	83.3	39.2	-4.2	349.2	56034.8
2011	35	84.2	40.6	3.6	361.6	55201.2
2012	34	83.9	41.6	2.5	370.5	56229.2
2013	35	80.6	39.8	-4.3	354.6	57189.8
2014	34	82.2	41.9	5.3	373.3	60026.8
2015	34	84.3	44.9	7.0	375.5	64047.4

a/ The number of plants in 2005 and 2007 was taken from the EAIM, Scian 2002.

**Source:** Created by the authors based on data from the EMIM, annual data, and the Population Census, INEGI.

The effects of the 2008 financial crisis reveal how consumption per capita in 2009 hit 396 kilograms, which can be explained by the pressures of recovery through new investment in infrastructure and engineering, which behave very similarly to the national economic growth rate. In view of slow economic growth in the wake of the crisis, and dependency on the American economy, the decrease in national and per capita cement consumption became marked. A more detailed examination, with statistics from the Monthly Manufacturing Industry Survey (EMIM) conducted by INEGI (2015b)

shows that production values have plummeted since 2006, when the peak prior to the financial crisis was attained, with a real growth rate of 5.8%. From 2008 to 2010, the industry only experienced negative growth rates. It is possible that the effects of the financial crisis have hit cement producers more severely, because Cemex, Holcim-Apasco, and Lafarge remain highly invested in the stock market to finance their productive activities (Vera, 2013).

The situation in 2015 was very different, because at that point in time, the industry began to show signs of a rapid recovery. That same year, production ascended to 64 billion pesos (2008 prices), representing real growth of 6.7%. The EMIM data confirm that in 2015, the productive capacity for cement was 45 million tons, with an idle capacity of 15.7%. When it comes to the characteristics of the product, most of the cement production is Portland cement, made with pulverized clinker material (accounting for more than 80% of total production). In order of importance, Portland cement is followed by white cement, which is a mixture of limestone and kaolin clay with low iron and gypsum content (around 2.5%), and then mortar, which is a mixture of cement with sand and water (around 8%). These three types of materials constitute the main products in the industry. There is also mixed cement, which is a combination of Portland cement and ground and granulated clinker from blast furnaces, volatile ash, silicate fumes, calcined clay, hydrogenated limestone, and other pozzolana (Cemex, 2016). Table 3 shows how the share of each type of cement has oscillated throughout the time period.

**Table 3.** Principal Indicators for the Cement Industry in Mexico. 2005-2015.

<i>Year</i>	<i>Total production (millions of tons)</i>	<i>Portland (%)</i>	<i>White (%)</i>	<i>Mortar (%)</i>	<i>Employed staff</i>	<i>Gross fixed investment (millions of pesos)</i>
2005	39.7	90.7	2.0	7.4	92943	1394.6
2006	42.7	84.2	2.0	7.4	93668	3026.0
2007	43.4	82.8	2.0	7.8	93960	2348.4
2008	42.3	85.1	1.9	8.2	92237	3206.7
2009	40.9	87.9	1.6	8.4	84708	1202.6
2010	39.2	91.8	1.8	6.7	84105	1816.4
2011	40.6	88.6	1.9	8.7	87471	1065.2
2012	41.6	86.5	2.1	9.1	87967	4478.6
2013	39.8	90.4	2.4	9.0	87382	1852.8
2014	41.9	85.8	2.7	9.0	86022	4365.3
2015	44.9	80.2	2.0	9.3	86802	4278.0

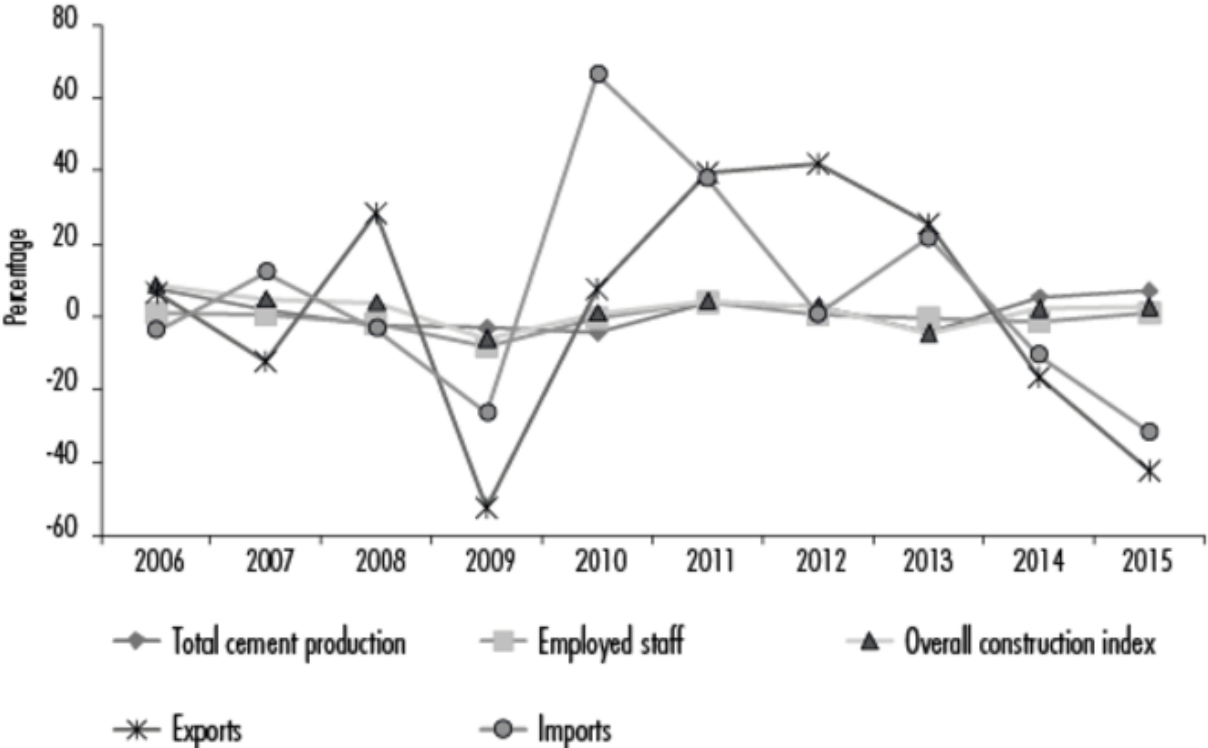
**Source:** Created by the authors based on data from the EMIM and the EIMA from INEGI and the Ministry of the Economy.



Job creation has fluctuated closely with production; merely because it is a capital-intensive industry, employment in recent years has been lower than it was in 2005. The industry has made large investments over the years, with the exception of during the 2009-2010 crisis. International trade expectations, as well as the presence of new producers (Cementos Fortaleza, from Carlos Slim and associates) gave investment a big push in recent years; in fact, of 116.2% in 2015, which could also be a result of rising consumption. The National Cement Chamber (CANACEM) placed consumption growth at 7.6%, while INEGI data reported 9.6%.

As can be observed in Figure 1, annual growth rates are represented by several of the aforementioned indicators. There is a trend derived from the recovery cycle of the industry, which came at the cost of a decrease in the number of people employed by the industry, as well as a downturn for international trade and production in 2009. It turns out that there is a close relationship between the economic activity indicator for the construction business and cement, because construction is the main source of demand for cement and pre-mixed concrete.

**Source:** Created by the authors based on data from the EMIM (INEGI, 2015b), INEGI (2015a), and the Ministry of the Economy (2016).



**Figure 1.** Annual Growth Rates (%)

In July 2014, the merger of Lafarge and Holcim-Aspasco jeopardized every other competitor, even those from Mexico, as the industry was shaken up with new and old competitors taking pieces of the market, and oligopolistic practices that affected prices. The presence of one of the wealthiest businessmen in all of Mexico and the world in this industry, the stagnation of the Mexican construction industry, and rising imports from both the United States and China are all factors that have pushed cement prices down in some regions of the country (Torres, 2014).

Mexican cement exports, in the makeup of their value, skyrocketed starting in 1985, with income higher than 150 million dollars, but tumbled again to below 70 million in 1990, in response to the antidumping laws enforced by the United States in 1989. The signing of the North American Free Trade Agreement (NAFTA) in 1994 marked a big step forward in trade negotiations; however, the Mexican cement industry did not benefit because at the same time, it was hit with the antidumping sanctions. These sanctions amounted to fees of up to 26.28 dollars per ton of cement, making it difficult to export at competitive prices.

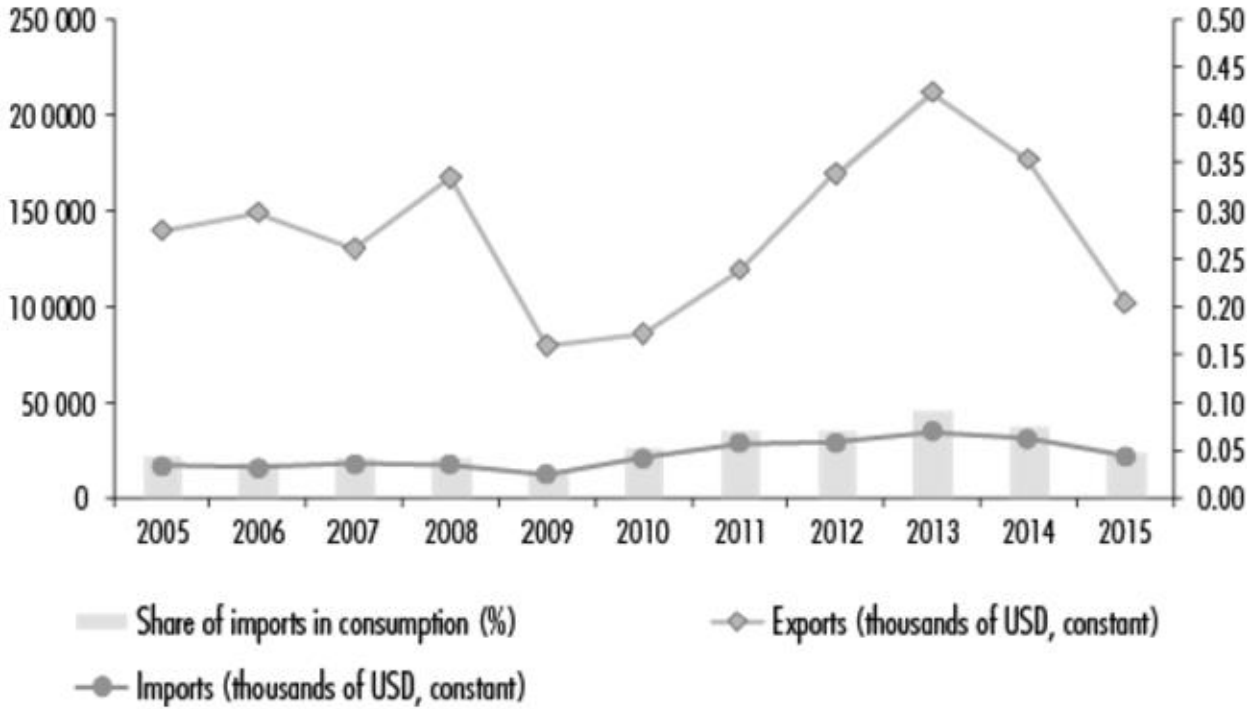
To American analysts, cement prices are largely determined by transportation costs; although Mexican cement prices were below American prices, Mexican cement needed to be transported long distances, which translated into higher prices in the end (Cook, 1994). This was reflected in compensatory taxes of between 43% and 62% in the midst of the full-on crisis of 1995. Cemex undertook a new commercial strategy: consolidate its position in the United States as an autonomous business unit, in order to not have to depend on exports (Barragán and Cerutti, 2003). In general, exports as a proportion of the total product are not high, and competitive strategies are based on mergers and acquisitions or collusion. As a result of the disloyal competition of Cemex and other companies in the world, the number of plants operating in the United States fell from 141 in 1986 to 134 in 1989, with 67 of these plants owned by foreign entities or operated in joint ventures (Cook, 1994). On the contrary, as of 2006, Cemex already had 12 plants in the United States with a capacity of 13.2 million tons (Salomón, 2006). Some studies have proven that the antidumping measures applied to the Portland cement generated differentiated effects in the United States due to market segmentation. Cohen-Meidan (2013) found that in the region of North America close to the Gulf of Mexico, the antidumping measures applied to Mexican cement inflated domestic prices 9% more than the control group; however, prices were not altered in the border region or in California. This suggests, accordingly, that Mexican imports lost market share primarily in regions where their exports were not competitive, while maintaining a stronghold in areas supplied by ocean transport (lower cost than overland).

After 16 years of disputes between Mexico and the United States, in 2006, the two countries reached an agreement to establish different time periods to permit the exportation of Mexican cement to specific regions. In these negotiations, it was agreed that grey Portland cement and clinker cement in amounts no greater than 3 million tons could be exported starting on April 3, 2006 and ending on March 31, 2007. The second period was set for April 1, 2007 to March 31, 2008, and the third from April 1, 2008 to March 31, 2009 (Secretaría de Economía, 2006). Once the agreement expired in early 2009, the quotas were eliminated, as well as the export limitations, with no need to file a suit before the United States Department of Commerce (US Department of Commerce, 2009).

According to data kept by the online Tariff Information System (SIAVI) of the Ministry of the Economy, in 2005, Portland cement exports were sent to the United States (87.86%), Guatemala (4.1%), Belize (4.3%), Panama (2.9%), and the rest of the world (0.84%). Sixty-one percent of imports, in both value and volume that same year, came from the United States, meaning that intra-industrial trade prevailed. In light of the weight to cement price ratio, the amount of exports is relatively small with respect to national production (close to 3%).

Cement imports have a much smaller weight in the trade structure; as of 2015, looking at origin, the same trend for trading partners has been maintained; 77.1% of cement imports came from the United States, 15.1% from China, and 3.6% from Croatia (Secretaría de Economía, 2016). The domestic market also receives imports from other countries, including: Spain, the Netherlands, Poland, and Germany, among the most frequent. The commercial dispute with the United States due to the antidumping measures had a significant effect on exports; even so, due to the productive capacity of the Mexican cement industry, the trade balance stayed positive (see Figure 2).

**Source:** Created by the authors based on data from INEGI (2015b) and the Ministry of the Economy (2016).



**Figure 2.** International Trade for the Cement Industry and Share held by the Competition in the Domestic Market

The above figure presents numbers on the y-axis that represent the share of foreign competition measured by the percentage of imports with respect to national cement consumption. Beginning in 2009, the share of foreign competition has been on the rise, peaking in 2013. Given that the national industry tends to be fairly closed to competition, it is important to underscore that even though the industry apparently has the capacity to supply demand, consumers are not always satisfied, which leads to the demand for imported cement.

Related to the foregoing, we might recall the case of the ship *Mary Nour*, which tried to offload 27,000 tons of Russian cement in mid-2004. The protagonists of this debacle were a group of Mexican entrepreneurs who believed in trade liberalization. For that reason, they created the company Comercio para el Desarrollo Mexicano, whose goal was to import 500 tons of cement annually through the Gulf of Mexico, and a similar amount through the Pacific Ocean (Torres, 2004; García, 2004). The argument of these new traders was that Mexican cement prices are among the most expensive in the world (De la Rosa, 2016); however, authorities in the Port of Tampico, Tamaulipas, denied the ship landing pursuant to a protective action filed by Cemex, which said that the shipment could damage the navigation channel of the port. In short, the cement was not imported.

In fact, the whole scene translated into a victory for the national cement industry, led by Cemex, which was then able to set prices above international rates, boosting profits and consolidating their position around the entire world (Salomón, 2006; Ghemawat and Thomas, 2005; García, 2004). Cemex executives justify their prices based on the characteristics of the Mexican market: 75% of cement is sold in 50- and 25-kilo sacks and not wholesale, which requires more complex logistics for distribution and transportation costs that raise the final price. Other sources of information assert that the oligopolistic privileges enjoyed by Mexican cement companies could be affording them profits as high as 300%. "The profit percentage on marketing cement to the domestic market is 271%, but between 152% and 155% for the foreign market, a figure that reveals a percentage variation of over 100% from the domestic market, favoring the foreign market" (Hernández Pérez, 2004: 3).

In an analysis of the profits earned by the agglomeration of the six large multinational companies (Lafarge, Holcim-Apasco, Cemex, Heidelberger, Italcementi, and Blue Circle Industries), Ghemawat and Thomas (2006) found that the share of multinationals out of the total capacity in a country caused an increase in the average price per ton and operational profitability. The rising profits earned by cement companies are not due to a reduction in cost or increases in efficiency, but rather to price hikes established when they enter the market. According to these authors, in Mexico, the entry of the multinationals Holcim-Apasco and Lafarge in 1989, and the expansion of Cemex from a local to a global economy, prompted real increases in Mexican cement prices since then. Added to that, Mexico's increasingly open stance towards global trade has not led to greater competition, nor has it constrained the cement industry monopoly. Shantayanan and Rodrik (1989) showed with a simulation model that the impact of trade liberalization can be positive in the presence of imperfect competition, but this tends to occur in the manufacturing industry, and not in industries with lower added value.

## Econometric Procedure

Some of the main players in the cement industry behave pursuant to the logic of oligopolistic competition. At the aggregate level, the industry can be represented by a single function of production  $Q$ . Accordingly, in order to determine the effect of external-order (exports and the competition of imports) and the effect of internal-order factors (jobs, investment, and demand) on cement production, the following augmented production function was specified:

$$Q_t = [L, K, \mu] \quad (6)$$

$$Q_t = A_t L^\alpha K^\beta \mu^{1-\alpha-\beta} \quad (7)$$

$Q$  is the total value of cement production,  $K$  is gross fixed investment,  $L$  is the number of people employed by the industry,  $A$  is productive efficiency, and  $\mu$  is the externality generated by the international cement demand (which is why we use exports as a proxy). The coefficients  $\alpha$  and  $\beta$  are the share of capital and labor, respectively, and  $(1-\alpha-\beta)$  is the share of export demand. We assume that  $\alpha$  and  $\beta$  are less than one, such that there are decreasing returns on labor and capital.

Taking the natural logarithm of Equation 7 and the derivative with respect to  $t$ , we obtain the following production function:

$$\psi_y = \psi_A + \alpha \psi_L + \beta \psi_K + (1-\alpha-\beta)\Psi_\mu \quad (8)$$

Where  $\psi$  is the growth rate of  $i=Q, L, K, \mu$ . Equation 8 implies that increases in the export demand will raise production in  $(1-\alpha-\beta)$ . The equation may take the following form:

$$q = d_0 + d_1 l + d_2 inv + d_3 ex + d_4 compes + d_5 igaet + d_6 D + \varepsilon \quad (9)$$

In Equation 9, the lower-case letters indicate natural logs,  $\Delta$  is the differences operator,  $q$  is the value of cement production,  $l$  is employment,  $inv$  is gross fixed investment,  $ex$  is the value of exports,  $compes$  is an indicator of the share of foreign competition in the domestic market and is measured as the share of imported cement in the market,  $igaet$  represents economic activity and is measured by a global economic activity indicator,  $D$  represents a dummy variable that captures the effects of antidumping (taking the value of 0 for 2005 to May 2009 and 1 starting in April 2009), and  $\varepsilon$  is the error term.

The database comes from the Monthly Manufacturing Industry Survey (EMIM) and the Monthly Expanded Industrial Survey (EIMA) published by INEGI (2015b, 2015c). The period of analysis considered was from 2005:1 to 2015:12. The data in pesos were deflated in order to eliminate the effect of prices. To do so, the National Cement Producer Price Index was used, with basis in June 2012. The amounts were subsequently converted into dollars. The original data in dollars were deflated using the Real Exchange Rate Index published by the Bank of Mexico. Finally, all of the variables were transformed into natural logs to reduce variance. This is indicated with an "l" in the notation.

## Results

The use of relatively long monthly time series requires a unit root test to prevent spurious estimates that could lead to invalid inferences. As such, unit root tests were applied to all of the variables, specifically, the Augmented Dickey Fuller (1981) and Phillips and Perron (1988) tests. The results are presented in Table 4.

**Table 4.** Results of the ADF and PP Unit Root Tests

<i>Variables</i>		<i>Augmented Dickey Fuller</i>		<i>Phillips-Perron</i>	
		<i>Level</i>	<i>Difference</i>	<i>Level</i>	<i>Difference</i>
lq	Constant and trend	0.6883	-8.094*	Constant and trend	-6.125* -34.783*
ll		-2.98	-10.8783*		-2.901 -14.302*

linv		-2.8723	-7.4134*		-5.179*	-10.038*
lex		-2.9346	-12.0427*		-5.215*	-21.72*
lcompes		-1.909	-12.9111*		-5.925*	-27.942*
ligat		-1.9802	-2.2819		-5.865*	-27.987*
ligac		-3.4093	-2.7902		-4.805*	-19.928*
lvpro	Just constant	-0.5247	-3.5660*	Just constant	-6.389*	-34.644*
IL		-2.416	-10.906*		-2.135	-14.300*
linv		-3.0008	-7.468*		-5.369*	-10.128*
lex		-3.0068	-12.063*		-5.258*	-21.705*
lcompes		-1.8973	-12.922*		-4.759*	-27.244*
ligaet		-0.2606	-2.293		-1.959	-28.154*
ligaec		-3.255**	-2.677		-3.769*	-19.746*

\*Significance level of 1%. Critical value of -4.03;

\*\*Significance level of 5%. Critical value of -3.44.

**Source:** Created by the authors.

Both tests indicate that the majority of the variables are not stationary in levels, but are in first differences. As such, we can consider that they are first-order integrated I(1). Because the variables are I(1), we need to apply the Johansen-Joselius technique (1990) to detect whether or not cointegration among them exists. If this is the case, then instead of estimating the equation as it appears in (9), we would need to add an error correction mechanism. To apply the Johansen test, a vector autoregression (VAR) was selected to which residuals tests were administered to detect problems related to serial correlation, heteroscedasticity, normality, and mathematical stability. The number of optimal lags was four, so the cointegration test was performed with three lags. Table 5 presents the results.

**Table 5.** Results of the Johansen Cointegration test. Interval: 1 to 3 Lags

<i>Null hypothesis</i>	<i>Alternative hypothesis</i>	<i>Maximum Eigen-value</i>	<i>Critical value (95%)</i>	<i>Trace</i>	<i>Critical value (95%)</i>
0	1	52.040**	46.231	129.921**	125.615
≤ 1	2	29.016	40.078	77.881	95.754
≤ 2	3	19.210	33.877	48.865	69.819
≤ 3	4	15.660	27.584	29.656	47.856

\*\*Significance level of 5%.

**Source:** Created by the authors.

The maximum Eigen-value and trace statistics signal a rejection of the null hypothesis of no cointegration, which means that the alternative hypothesis that there exists at least one vector is accepted. Once the existence of cointegration was proven, we proceeded to the Engle Granger (1987) theorem to estimate an error correction model (ECM). This model requires introducing the residuals estimated in the cointegration equation (long-term) with one lag, in the short-term equation. The ECM is only estimated with stationary variables, so all of the dependent variables were differentiated as independent, so they now represent change rates. Table 6 presents the outcomes of the estimates for the equation:  $q = d_0 + d_1 l + d_2 inv + d_3 ex + d_4 compes + ecm_{t-1} + \epsilon_{455}$ ;

**Table 6.** Estimates of the ECM. Dependent Variable: dq

	9.1		9.2		9.3		9.4	
Variables	Coefficient	T-est.	Coefficient	T-est.	Coefficient	T-est.	Coefficient	T-est.
C	0.001	0.17	-0.002	-0.26	-0.004	-0.59	-0.004	-0.61
DL	0.019	0.05	0.006	0.02	-0.244	-0.86	-0.253	-0.89
DINV	-0.013	-0.61	-0.012	-0.55	-0.031	-1.22	-0.031	-1.15
DEX	0.058*	2.98	0.058*	2.99	0.022	1.56	0.023	1.59
DCOM	-	-3.48	-	-3.47	-	-4.76	-	-4.67
PES	0.067*		0.067*		0.060*		0.060*	
DUM			0.004	0.46	0.002	0.23	0.002	0.25
MY							0.047	0.42
DIGAC							1.447*	9.13
DIGAT					1.447*	9.13	1.405*	8.25
ECM(-1)	-0.396	-4.64	-0.399	-4.69	-0.395	-3.86	-0.405	-3.79
AR(1)	-0.332	-3.04	-0.331	-3.01	0.013	0.09	0.022	0.14
R2	0.419		0.420		0.653		0.654	
S.E.								
D.W.	1.995		1.994		1.978		1.978	
LM test	0.951	0.389	0.981	0.377	0.271	0.763	0.264	0.769
BPG test	1.626	0.158	1.408	0.216	1.348	0.234	1.509	0.161

Note 1: The  $d$  prefixed to the variables indicates first difference; Note 2: Diagnostic tests were administered to the residuals to detect serial correlation problems (Lagrange Multiplier Test), heteroscedasticity (Breusch-Pagan-Godfrey test), and normality (Jarque-Bera test). The probabilities are given in brackets.



\*Indicates 1% of statistical significance. The null hypothesis of insignificance is rejected.

**Source:** Created by the authors.

The results of the estimation of Model 9.1 indicate that the change rate for cement production ( $dq$ ) is positively related with the change in exports ( $dex$ ). In other words, the stimulus to cement exports has been an essential element that has had a positive effect on the rise in production in the industry during this period. Although a lower proportion of cement production is destined for exportation, this amount still seems to be an important determinant of growth, because it perhaps entails greater investment in processes, more efficient use of resources, etc., such that it increases the value of production. We also find that the rate of change in the competition ( $dcompes$ ), measured by the share of imports, is an element that has a negative impact on the national cement production rate. This indicates that, given the market structure of the industry, the companies that comprise the oligopoly have little or no incentive to permit competitors to gain a greater share of the market. This result suggests that it is possible that the Mexican industry favors the barrier to entry for new competitors, which would match up with what other studies have identified in terms of the existence of cartels in the cement industry in other countries, aiming to maintain market power (Pradhan, 1992; Kleit and Palsson, 1996; Blum, 2007; Levenstein and Suslow, 2006). With the reference framework of the theory of the oligopoly, De la Garza and Arteaga (2011) tried to identify the nature of the behavior of the cement industry in Mexico. Drawing on data from 2005 to 2007, the authors found no evidence of collusion, but rather of Stackelberg-type competition, but these estimates were not robust. In terms of the effect of national-order variables, the growth rate in employment and fixed investment turned out to be not statistically significant.

In the estimate of Model 9.2, a fictitious variable (dummy) was added to measure the impact of the elimination of tariff barriers imposed by the United States, in particular, starting in April 2009, when the tariffs were done away with altogether. In this case, the dummy coefficient was positive but not significant, which indicates that the openness of the United States market, although with the correct sign, did not affect the growth rate of the production value. Industry performance seems to have been divorced from the sanctions imposed by the United States, perhaps due to business strategies that consider the domestic market as the principal destination for its production, but also precisely because when the tariff barriers were dismantled in 2009, the United States fell into a severe recession because of the financial crisis.

In the estimates of Models 9.3 and 9.4, two national-order variables were added to determine whether economic activity in general and that of the construction industry, specifically, are explanatory of the growth in the value of production. Accordingly, the variable *igat* was added, which is an overall indicator of total economic activity, and *igac* was also added, which is an overall indicator of economic activity, but only of the construction industry. Both variables are measured through the physical volume of production index calculated by INEGI, used to measure short-term changes in production. The estimation of Model 9.3 shows that the change rate of the variable *digat* has a positive and significant

effect on the growth rate of cement production equal to 1.447. This indicates that the growth of economic activity in general generates higher demand for cement and, as a result, there is an effect on cement production, because it includes not only commercial and industrial production but also that of self-construction, and infrastructure expansion and improvements, as well as any other activities that use cement as a raw material.

In Model 9.4, the variable *digac* was added to determine whether, specifically, it was the growth of the construction industry that had an impact on the change rate of cement production. The results indicate once again that it is total economic activity *digat*, and not just construction, which has a statistically significant effect on the value of cement production. Much of the demand for cement is to build infrastructure for government projects, which represent about 30% and 40% of demand, with around 40% for self-construction of housing and developers and around 20% for commercial and industrial construction. As such, it is evident that cement production and sales depend on economic conditions, federal government spending, credit for housing, and even the inflow of remittances, all of which are considered triggers for rising cement consumption.

## Conclusions

In general, the main results of the models illustrate that the growth rate of cement production in Mexico cannot be explained by internal-order elements of the industry, such as changes in employment or fixed investment, but rather that it responds positively to the demand for exports and negatively to the participation of foreign competitors. Given that exports still represent a low proportion of the total value of production, the quantitative effect on the cement growth rate is low. The same is true of foreign competition. However, the negative relationship with cement production is evident, which is why we believe there is little chance that the industry would view the entrance of large volumes of imports as favorable. Considering that the market structure is oligopolistic, this result suggests, indirectly, that the cement industry has greater incentives to maintain price- or amount-setting agreements in order to prevent outside competitors from making inroads and to increase profits.

When we add in a variable to measure the effect of national economic activity, we find a strong cause-effect relationship between the physical production of the economy and the change rate in cement production. If we consider that the top destination for cement is the domestic market, then the notion that the cement industry is strongly tied to the behavior of the national economy is only further reinforced.

Finally, in recognition that the estimates of the models may be sensitive to specification errors, the results show consistently that the greater the share of the market obtained by foreign competition in Mexico, the more negative the impact on the growth of the industry. This confirms the fact that national cement production looks to the domestic market as its main source of growth and justifies the oligopolistic market structure that favors coordinated decision-making.

<sup>1</sup>The data from the cement industry refer to the data classified by INEGI in branch 327310: “Manufacturing of cement and cement-based products in integrated plants.”

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