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The steel production in Mexico, an econometric analysis

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La producción de acero en México, un análisis econométrico
A produção de aço no México, uma análise econômica

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To determine the own price elasticity of Mexican steel production, as well as to quantify the level of impact of the international price on the wholesale price in Mexico; In this work we estimate a simultaneous equations model with annual information from 1980 to 2017, integrated by 3 regression equations. In the short as in the long term, the steel production in Mexico responds inelastically (0.0425 and 0.2419%) before changes of 1% in the own price. The international price of steel is the wholesale price in Mexico at a level of 0.05, for each unit percentage change in the first.

Determinar la elasticidad del precio propio de la producción mexicana de acero, así como cuantificar el nivel de impacto del precio internacional sobre el precio mayorista en México. En este trabajo estimamos un modelo de ecuaciones simultáneas con información anual de 1980 a 2017, integrada por 3 ecuaciones de regresión. A corto y largo plazo, la producción de acero en México responde de manera inelástica (0.0425 y 0.2419%) ante cambios del 1% en el precio propio. El precio internacional del acero es el precio mayorista en México a un nivel de 0.05, por cada cambio porcentual unitario en la primera.

Determinar a elasticidade-preço própria da produção mexicana de aço, bem como quantificar o nível de impacto do preço internacional sobre o preço de atacado no México; Neste trabalho estimamos um modelo de equações simultâneas com informações anuais de 1980 a 2017, integradas por 3 equações de regressão. No curto como no longo prazo, a produção de aço no México responde inelasticamente (0,0425 e 0,2419%) antes de mudanças de 1% no preço próprio. O preço internacional do aço é o preço de atacado no México em um nível de 0,05, para cada variação percentual unitária no primeiro.

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1. Introduction

In 2016, world steel production registered a volume of 1,628 million tons (Mt), reflecting an increase of 0.49% compared to 2015 and a decrease of 3% compared to 2014 according to the data of Association World Steel (WSA, 2018).

By continent, Asia produced 1,124.7 Mt of steel, an increase of 1.3% compared to 2015. Highlighting the production of China, which was 808.4 Mt, 0.57% more than in 2015. Japan produced 104.8 Mt of steel, decreased one 0.29% compared to the previous year. South Korea produced 68.6 Mt, 1.6% less than in 2015. The European Union (EU) produced 162 Mt of steel, which represented a decrease of 2.5% compared to 2015. Germany produced 42.1 Mt, which represented a reduction of 1.4% compared to the previous year; while Italy's production was 23.4 Mt, which is equivalent to 6.4% increase. Spain produced 13.6 Mt of steel, a decrease of 8.7% compared to 2015. Outside of the European Union, it stands out Turkey's steel production which in 2016 was 33.2 Mt, which registered an increase of 5.4% in comparison with 2015 (**Table 1**).

In Africa, steel production in South Africa and Egypt stands out, which in 2016 was 6.1 and 5 Mt, which represented a decrease of 4.7 and 9.1% compared to 2015. Steel production in North and Central America (Canada, Cuba, El Salvador, Guatemala, Trinidad and Tobago, Mexico and the United States) was 110.6 Mt, 0.27% lower than in 2015. The United States produced 78.5 Mt, Canada 12.6 Mt and Mexico 18.8 Mt; which represented an increase of 3.3% compared to 2015. South America produced 40.2 Mt during 2016, 8.4% less compared to the previous year; highlighting the productions of Brazil and Argentina with 31.3 and 4.1 Mt. Other countries that stood out in the production of steel during 2016 were: Russia (70.8 Mt), Ukraine (24.2 Mt), Taiwan (21.8), Iran (17.8 Mt), Saudi Arabia (5.5 Mt), Indonesia (4.8 Mt), Thailand (3.8 Mt), Pakistan (3.6) and United Arab Emirates (3.1 Mt).

Table 1 - World steel production, 2015 and 2016 (thousands of tons)

	2015	*2016*	*2016 (%)*
China	803.83	808.37	49.65
Japan	105.13	104.78	6.44
South Korea	69.67	68.58	4.21
India	89.03	95.48	5.86
Taiwan	21.39	21.75	1.34
Thailand	3.72	3.83	0.23
Vietnam	5.65	7.81	0.48
Asia	1,112.87	1,124.70	69.08
Germany	42.68	42.08	2.58
Italy	22.02	23.37	1.44
Spain	14.85	13.62	0.84
France	14.98	14.41	0.89

Key words
Production; steel: simultaneous equations; elasticities.

Palabras clave
Producción; acero; ecuaciones simultáneas; elasticidades.

Palavras chave
Produção; aço; equações simultâneas; elasticidades.

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	2015	*2016*	*2016 (%)*
European Union	166.12	162.02	9.95
Turkey	31.52	33.16	2.04
Russia	70.90	70.81	4.35
Ukraine	22.97	24.22	1.49
North America	110.94	110.62	6.79
Canada	12.47	12.65	0.78
Mexico	18.22	18.81	1.16
United States	78.85	78.48	4.82
South America	43.90	40.22	2.47
Argentina	5.03	4.13	0.25
Brazil	33.26	31.28	1.92
Colombia	1.21	1.27	0.08
Africa	13.70	13.10	0.80
Egypt	5.51	5.04	0.31
South Africa	6.42	6.14	0.38
Middle East	29.43	31.48	1.93
Iran	16.15	17.90	1.10
Qatar	2.59	2.52	0.15
Saudi Arabia	5.23	5.46	0.34
United Arab Emirates	3.01	3.15	0.19
Oceania	5.72	5.84	0.36
Australia	4.93	5.26	0.32
World	1,620.00	1,628.05	100.00

Source: WSA, 2018.

In 2016, steel exports were 473.7 million tons (Mt); Asia exported a total of 211.9 Mt, which represented 44.7% of exports worldwide. The three most representative exporting countries in the Asian continent were: China with 108.1 Mt (51%), Japan 40.8 Mt (19.1%), and South Korea with 30.6 Mt (14.4%). The European Union exported a total of 140.6 Mt, which represented 29.7% of exports worldwide. The three countries with the largest share of exports from the European Union were: Germany (25.1 Mt), Italy (17.9 Mt), Belgium (16.7 Mt), France (13.7 Mt) and The Netherlands (10.2 Mt). In the Americas, steel exports, during 2016, behaved as follows: In North America, exports amounted to 29.4 Mt, representing 4.1% of world exports, with the three most representative exporters in this region: United States with a participation of 9.2 Mt, Canada with 5.8 Mt, and Mexico with 4.1 Mt. With respect to South America, the export was of 14.3 Mt representing 3% of world exports; Brazil was the largest exporter with 13.4 Mt. In Africa, the export of steel from South Africa stood at 2.2 Mt. Other important exporters were Russia (31.2 Mt), Ukraine (18.2 Mt), Turkey (15.3 Mt), Iran (5.7 Mt) and United Arab Emirates (3.3 Mt) (**Table 2**).

Table 2 - Steel exports, 2015 and 2016 (thousands of tons)

	2015	*2016*	*2016 (%)*
Austria	7.44	7.31	1.54
Belgium	15.20	16.72	3.53
Czech Republic	4.83	5.19	1.10
Germany	25.15	25.09	5.30
France	14.00	13.69	2.89
Italy	16.48	17.90	3.78
Holland	10.63	10.21	2.16
Poland	5.08	5.40	1.14
Slovenia	9.59	9.32	1.97
United Kingdom	7.28	4.59	0.97
Turkey	14.89	15.35	3.24
Russia	29.70	31.16	6.58
Ukraine	17.72	18.23	3.85
Canada	6.04	5.85	1.23
Mexico	3.90	4.08	0.86
United States	10.00	9.25	1.95
Brazil	13.71	13.40	2.83
Iran	3.80	5.65	1.19
China	111.56	108.07	22.81
India	7.56	10.33	2.18
Japan	40.80	40.51	8.55
South Korea	31.17	30.59	6.46
Taiwan	11.18	12.23	2.58
Mundo	467.44	473.68	100.00

Source: WSA, 2018.

With regard to steel imports, in 2016, a total of 461.3 Mt. Asia imported a total of 149.3 Mt, which represented 32.4% of the world total, the three most representative importing countries were: Korea South (23.3 Mt), Vietnam (19.5 Mt), Thailand (17.6 Mt), China (13.6 Mt), Indonesia (12.6 Mt) and India (9.9 Mt). The European Union imported a total of 148.2 Mt, which represented 32.1% of world imports; The three countries with the highest participation were: Germany (25.5 Mt), Italy (19.6 Mt), France (14.6 Mt) and Belgium (13 Mt). Africa imported 29.7 Mt, which represented 6.4% of the total imports in the world; the imports from Egypt (9.2 Mt), Algeria (5.5 Mt), and Morocco (2.2 Mt) stand.

In the American continent, imports of steel behaved as follows: North America imported 53.2 Mt, which represented 11.5% of the world totals, being the three most representative importers: the United States (30.9 Mt), Mexico (9.7 Mt) and Canada (7.7 Mt). In South America, the import of steel was 11.8 Mt, representing 2.6% of the world import; In this region, imports from Colombia (2.7 Mt), Peru (2.2 Mt), Chile (1.8 Mt), Brazil (1.7 Mt), Ecuador (0.9 Mt) and Argentina (0.8 Mt) stood out (**Table 3**).

Table 3 - Steel imports, 2015 and 2016 (thousands of tons)

	2015	*2016*	*2016 (%)*
Austria	4.19	4.33	0.94
Belgium	12.07	13.01	2.82
Czech Republic	6.15	6.48	1.40
Germany	24.82	25.52	5.53
France	13.66	14.57	3.16
Italy	19.94	19.62	4.25
Holland	6.80	8.36	1.81
Poland	9.21	10.11	2.19
Spain	8.89	9.38	2.03
United Kingdom	7.18	7.65	1.66
Turkey	18.61	17.01	3.69
Russia	4.36	4.45	0.96
Canada	8.02	7.73	1.68
Mexico	10.03	9.68	2.10
United States	36.49	30.91	6.70
Argelia	6.30	5.47	1.18
Egypt	7.88	9.15	1.98
Iran	4.47	4.68	1.02
Saudi Arabia	6.49	7.36	1.59
United Arab Emirates	6.61	7.37	1.60
China	13.18	13.58	2.94
India	13.28	9.90	2.15
Indonesia	11.41	12.57	2.73
Japan	5.92	6.01	1.30
South Korea	21.67	23.29	5.05
Malaysia	7.82	9.07	1.97
Philippines	7.28	7.25	1.57
Taiwan	7.51	7.86	1.70
Thailand	14.63	17.61	3.82
Vietnam	16.34	19.49	4.23
Mundo	452.93	461.25	100.00

Source: WSA, 2018.

In 2016, Mexico ranked 13th as an international steel producer, accounting for 1.2% of world production of 1,628 Mt. As regards Latin America, steel production was 59.7 Mt, and Mexico ranked second. place after Brazil (31.3 Mt), which in sum represented 84% of the total production in the region (WSA, 2018). In December 2016, with seasonally adjusted figures, the mining-metallurgical production in Mexico decreased by 4.7% with respect to the previous month. In an annual comparison, this production saw a real decrease of 6.3% in the same month of 2016 with respect to the previous year; this decrease was the result of the heterogeneous behavior among the different minerals that make up the mining-metallurgical production, the gypsum, carbon, lead, sulfur, zinc, silver, gold and fluorite, mainly, decreased. In contrast, iron, copper and dolomite pellets rose only marginally (INEGI, 2017).

In 2011, Mexico had an installed capacity for steel production of 22,227 Mt per year and only used 75.18% of it. Its total steel production was 16.71 Mt and the main producing states were: Coahuila (28.8%), Michoacán (23.6%), Nuevo León (15.5%), Guanajuato (10.8%), Veracruz (7.6%), and the the rest of the entities concentrated 17.6%. The participation of the steel industry in the national Gross Domestic Product (GDP) represented 0.7% of the total GDP, 7.9% of the GDP of the industrial sector and 3.9% of the manufacturing sector. Exports of Mexican steel in 2011 amounted to 5.9 Mt; which in value translated into 5,079 million dollars (MDD) and the amount of imported steel was 7.1 Mt, which equaled 7,986 MDD. This meant a trade deficit, in terms of steel, of 1.2 Mt (2,907 MDD) (SE, 2012).

Notwithstanding the foregoing, in 2016 Mexico imported 18.2% of those made by North America (WSA, 2017); derived from the consumption of steel by the automotive industry, the oil industry and the construction industry. This was to the detriment of the strategic action plan for the steel sector in Mexico, which in 2008 the National Chamber of the Iron and Steel Industry (CANACERO-Cámara Nacional de la Industria del Hierro y del Acero) and the Ministry of Economy (SE-Secretaría de Economía) presented, with the purpose of duplicating the steel sector GDP for 2020 from 6 thousand MDD to 12 thousand MDD, this represented an increase in national production from 17.8 to 32 Mt/year. In addition to the necessary support for integrated production chains with steel, the goal involved direct investments in installed capacity of US $ 19 billion, 30 thousand additional direct jobs and incremental tax collection for the government, over 400 MDD per year (CANACERO, 2008).

To achieve the proposed growth, CANACERO and SE specified that the steel sector should: capture the total inertial growth of the sector by 2020 (8.2 Mt), replace part of Mexico's imports (0.5 Mt), increase exports to the United States United (3.3 Mt). In addition to the inertial growth, it was expected to have important increases in several industries: Automotive industry (0.8 Mt/year), Oil industry (0.4 Mt/year), Construction industry related to the National Infrastructure Program (1 Mt/year). These growths will be achieved by focusing the sector's efforts on those products with the greatest attraction (high growth) and with the best competitive position in Mexico, for the domestic market: rod and rod, plate, hot rolled sheet and coated sheet, for the market Export: semi-finished, tubes and hot rolled sheet. To capture these opportunities, the steel sector has developed a strategic plan in the short and medium term. In the short term, the steel sector should promote actions through four main channels (CANACERO, 2008): 1) Competitiveness of costs, 2) Technological innovation, 3) Market development and 4) Attraction of investment: Development of an incentive program and a program to promote the investment of promotion of the investment of the participants in the steel sector.

For this reason, the objective in this work was the identification of the factors that determine the supply of Mexican steel, which in turn have an impact on the producer price and steel wholesale, highlighting the problems faced by Mexico: 1) In recent years there has been an excess of demand, resulting in steel imports, given that domestic production does not satisfy domestic demand (in 2016 the figure for imported steel represented 51.6% of national production) and, 2) development planning in the national steel sector without having indicators and estimates that contribute with information for better decision making in the short and long term.

The research hypotheses were that: 1) The supply of steel is determined directly by the price to the steel producer and inversely by the price of the inputs (scrap, electric power and oxygen) and, 2) The price of steel producer in Mexico is directly impacted by the wholesale price and the international price.

2. Theoretical framework

Comtois and Slack (2016) point out that the big drop in the steel industry has led to significant changes in iron ore supply chains. As a result of the slowdown in the growth of steel production in China, the demand for iron ore has decreased and has led to important changes in iron ore production worldwide. Therefore, they made a descriptive synthesis of the various determinants of the global iron ore supply chain and present aspects of the market, such as the production volumes of steel and iron ore, their evolution, geographical distribution, the main actors, the import and export flows. The analysis revealed the interrelation between several determinants of the iron ore supply chain: corporate structure, quality iron ores, contract design, inventory management, shipping costs, maritime freight rates and transport infrastructure. This allowed them to assess the vulnerability of the supply chain in terms of production risks, transport capacity, commercial conditions and environmental risks.

In 2016, Xuan and Yue found that although economic development has contributed to the rapid expansion of China's steel industry over the past two decades, it has also led to numerous problems, including increased energy consumption and excessive environmental pollution. Steel scrap as an important resource in the steel industry is attracting more attention due to its energy efficiency, low carbon emissions and cyclical regeneration. Therefore, to examine the changes in the production of crude steel, the consumption of steel scrap per ton of steel and the consumption of scrap steel from 1980 to 2012; They used an IPAT model (also known as the identical Kaya equation) modified, which directly assesses the level of influence of the environment, economy, population, technology and national policy on future steel production, is adopted for forecast Chinese steel production from 2010 to 2030. By 2020, the value of steel production and steel stocks per capita is expected to reach 901 million tons and 8.01 tons, respectively. Improved use of steel scrap will decrease the demand for natural resources and the overall environmental impact. According to the steel production forecasts, the calculated scrap efficiency rate will continue to increase from 2020 to 2030 in China, whose value is expected to reach 0.366 by 2030.

Fu et al., (2017) indicate that the supply of recycled material depends on historical consumption, that is, what constitutes scrap available today originates from previously made products. Analytical tools, such as material flow analysis, were used to estimate metal scrap flows. The supply of recycled metal also depends on changing economic conditions, as metal consumption rates correlate with changes in gross domestic product (GDP). An autoregressive approach of distributed lags was used to model the recycled copper supply as a complement to the material flow analysis approach. Finding that both industrial activity and world GDP correlate with the total supply of scrap, with a limited dependence on the price of copper. A 1% increase in industrial production leads to a 2.1% increase in the use of higher quality scrap, while a similar increase in global GDP increases the use of lower quality scrap by 1.4%.

Nielsen (2017) notes that state ownership has often been discussed as one of the main causes of poor industrial energy efficiency. Using long-term historical data on the use of energy and raw material in the production of iron and steel in countries with both systems: centralized planning and market-based planning, with a particular focus on the former Czechoslovakia in parallel with the developments in China. Czechoslovak productive efficiency in the steel sector fluctuated below the energy efficiency frontier. Until the early 1970s, the country's steel sector was one of the least efficient. However, during the 1970s and 1980s, efficiency measures were adopted and the energy efficiency of the Czechoslovak iron and steel sector increased significantly; until reaching the frontier of energy efficiency. The empirical results helped to identify a pattern of efficiency convergence: in China, despite its movement towards a more market-oriented economy, productive efficiency lagged behind as in 2000 (20-35% below the energy efficiency frontier). In the socialist economies of Eastern Europe, however, state planning was able to achieve satisfactory productivity increases, mainly driven by efficiency and savings policies and, adjustments in existing technology.

Yang et al. (2017), analyzed the regional technical efficiency of the Chinese iron and steel industry from 1996 to 2010 using a data envelopment analysis (DEA) network procedure, and provided the DEA network strategy for the sensitivity analysis of the measure of estimated border efficiency. In addition, the evolution and convergence characteristics of regional technical efficiency are examined via a dynamic regression model based on different regional divisions in China. The empirical results show that there are significant geographical differences in the technical efficiency of the Chinese iron and steel industry. On the one hand, the technical efficiency of the eastern area, the central area and the western area are unbalanced, with lower efficiency in the west and greater efficiency in the east. On the other hand, the technical efficiency of the economic zones of Central Bohai, the Yangtze River Delta and the Pearl River Delta is greater than that of the other economic zones. In addition, technical efficiency has a significant improvement during the period of the Eleventh Five-Year Plan. Finally, they establish that some determinants of the technical efficiency of the Chinese iron and steel industry are: economies of scale, the structure of production and regional location.

Gajdzik et al. (2018), evaluated the feasibility of the environmental scenarios for the Polish metallurgical sector until the year 2020. The study used: (I) Quantitative elaboration of the forecasts of the volume of steel production for Poland up to the year 2020; (II) Qualitative evaluation of factors that influence the production processes in the environment of metallurgical companies; (III) Process of Analytical Hierarchy for the evaluation of the probability of occurrence of a particular environmental scenario for the Polish steel industry: (i) optimistic (volume of steel production) exceeding the projected average of 8,895 million tons); (ii) pessimistic (volume of steel production) lower than the projected average of 8,895 million tons); (iii) base (volume of steel production adjusted to the projected average of 8,895 million tons, with a possible deviation of 10%). The results have helped in the establishment of managerial conclusions from the perspective of production engineering in Poland.

3. Methodology

3.1. The model

The simultaneous equation model used was composed of distributed lag models, in which to explain the response of the dependent variables (Y) to a unit change of the explanatory variables (X) not only were their current values considered, but also the laggards or previous

(1) $Y_t = \alpha + \beta_0 X_t + \beta_1 X_{t-1} + \beta_2 X_{t-2} + U_t$

and, autoregressive models and distributed lags; since lagged values of the dependent variable were included as explanatory

(2) $Y_t = \lambda + \lambda_1 X_t + \lambda_2 X_{t-1} + \lambda_3 Y_{t-1} + \varepsilon_t$

A system of simultaneous equations can be expressed in condensed matrix form as (Gujarati and Porter, 2010):

(3) $\Gamma Y_t + BX_t = E_t$

where: Y_t = Vector of endogenous variables of the model; X^t = Vector of predetermined variables, plus the ordered to the origin; Γ = Matrix of structural parameters associated with endogenous variables; B = Matrix of structural parameters associated with the predetermined variables; E = Vector of random error terms. The vectors Y_t y E_t are of order ***m x 1***, where ***m*** is the number of endogenous variables of the model. For its part, Γ is a square matrix of order ***m x m***. At the same time, B it is a matrix of order ***k+1 x m***, where ***k*** is the number of exogenous and endogenous delayed variables of the model plus the ordered one at the origin; in general, k it may or may not be equal to ***m***. When there is the inverse of Γ, it is possible to derive the reduced model of the system:

(4) $Y_t = \Pi X_t + V_t$

where: $\Pi = -\Gamma^{-1}B$ is the matrix of the parameters of the reduced form; $V_t = -\Gamma^{-1}E_t$ is the matrix of the perturbations of the reduced form.

Based on the above, the relationship between the factors that explain the supply of steel in Mexico was determined by calculating the elasticities, via the results obtained from a model of simultaneous equations composed of a production equation and two transmission equations of the prices. The econometric model of the supply of steel in the country in its structural form was formulated by adding functional ratios, structural coefficients or α's, which represent the estimators of the parameters of each variable and the ***ε***'s or the stochastic term:

(5) $PAM_t = \alpha_{51} + \alpha_{52} PAPMR2L_{t-2} + \alpha_{53} PCHPARL_{t-1} + \alpha_{54} PEEPARL_{t-1} + \alpha_{55} PO2PARL_{t-1} + \alpha_{56} PAML_{t-1} + \varepsilon_{5t}$

(6) $PAPMR_t = \alpha_{41} + \alpha_{42} PAMMR_t + \alpha_{43} D_t + \varepsilon_{4t}$

(7) $PAMMR_t = \alpha_{31} + \alpha_{32} CTAMR_t + \alpha_{33} PINTARL_{t-1} + \alpha_{34} D_t + \varepsilon_{3t}$

Equation 5 models the supply of steel in the country, equation 6 models the effect of transmission that the real price of wholesale steel in Mexico has on the real price of steel to the producer. Equation 7 models the effect that the transport cost and the steel producer price in China have on the wholesale price in Mexico, since it is the main producing country.

Table 4 - Variables of the model and its information sources

Acronym	*Meaning and units*	*Source of information*
PAM_t y $PAML_{t-1}$	Steel production in Mexico in year t and one year of lag ($/t)	WSA, 2018 and CANACERO, 1980-2017
$PAPMR2L_{t-2}$	Real steel producer price in Mexico in year t with two years of lag ($/t)	CANACERO, 1980-2017
$PCHPARL_{t-1}$	Price of scrap in Mexico with one year of lag ($/t)	CANACERO, 1980-2017
$PEEPARL_{t-1}$	Price of electric power to the steel producer in Mexico with one year of lag [tariff HT high voltage 230 kV] ($/kWh)	CFE, 1980-2017
$PO2PARL_{t-1}$	Price of oxygen to the steel producer in Mexico with one year of lag ($/m^3)	CANACERO, 1980-2017
$PAMMR_t$	Real steel wholesale price in Mexico ($/t)	CANACERO, 1980-2017
D_t	Classification variable with zero from 1980 to 1986 representing the closed economy period, and one from 1987 to 2015 representing the open economy	
$CTAMR_t$	Cost of transportation in Mexico ($/t)	SCT-DGTFM (2018) and CANACAR (2018)
$PINTARL_{t-1}$	International price of steel with one year of delay-variable proxy the price of steel in China ($/t)	CANACERO, 1980-2017
The monetary series were deflated with: the National Producer Price Index; the National Consumer Price Index and the National Consumer Price Index for the Transportation Sector.		INEGI-BIE (2018).

Source: Self made

The assumptions used to estimate the model were: a) The relationship between the endogenous and exogenous variables is linear; b) The endogenous variables are stochastic as well as the errors; c) The $E(\varepsilon_i \varepsilon_j) = 0, i \neq j$; d) The $E(\varepsilon_i \varepsilon_j) = \sigma_2$, has constant variance and e) The errors do not present serial correlation, that is, $E(\varepsilon_t \varepsilon_{t-1}) = 0$.

For the aforementioned variables, time series with annual information for the period 1980-2017 were created and given that, in the market, the response of supply or demand to the changes of its determining factors is rarely instantaneous, but rather with they often respond after a certain period of time, a period that is called lag or delay (Gujarati and Porter, 2010). In the cited model, it was assumed that some of the exogenous variables are influenced by one and up to two lag periods; what was statistically justified in terms of its individual significance.

The model was based on evidence of applied research in studies that have econometrically analyzed the steel market (stainless steel or iron ore) or forecast their prices as: Giuliodori et al. (2015); Labson et al. (1995); Malanichev and Vorobyev (2011); Priovolos (1987). Although, with the exception of Labson et al. (1995), it is noteworthy that they used other estimation methods; They calculated economic elasticities, which allowed comparing and discussing their results with those calculated in this work.

3.2. Estimation method

The coefficients of the model were estimated with the two-stage least squares method (MC2E) (Wooldridge, 2009; Gujarati and Porter, 2010) using the statistical package SAS (Statistical Analysis System) version 9.0 (SAS, 2002). Statistical congruence was determined by means of the overall significance of each equation through the F test, its level of self-correlation via the Durbin Watson statistic (DW), the individual significance of each coefficient through the Student's t and the normality of the variables with the Shapiro-Wilk test (SW). The microeconomic theory of demand (Samuelson and Nordhaus, 2010) was used to validate the sign of the coefficients of each exogenous variable. To determine the identification of the model, the order and rank conditions based on Gujarati and Porter (2010) were used, obtaining that each of the equations of the model is overidentified.

The estimated coefficients y, the mean values of the time series were used to calculate the economic elasticities of each factor that affects steel consumption at the national level. The short-term price elasticities (Ep, cp) at any point on the curve, it is given by (Gujarati and Porter, 2010):

(8) $$Ep, cp = (\partial Q_t / \partial P_t)\ (P_t / Q_t) = b_1\ (P_t / Q_t)$$

where: $(\partial Q_t / \partial P_t)$, is the slope of the demand curve (b_1) and P_t and Q_t, they are the price received by the consumer in year t and the amount consumed in year t.

To calculate the cross-elasticities with respect to the other determinants of consumption, the respective coefficients, price and quantity were used. To obtain the long-term elasticities, the respective coefficients of the long-term model were used, which were obtained by dividing the short-term coefficients by the coefficient of the adjustment rate (γ) and eliminating the lagged amount Q_{t-1}:

(9) $$Q_t = (b_0 / \gamma) + (b_1 / \gamma)\ P_{t-1} + \upsilon_t$$

then the own price elasticity of the long-term demand was obtained as,

(10) $$Ep, lp = (\partial Q_t / \partial P_t)\ (P_t / Q_t) = (b_1/\gamma)\ (P_t / Q_t)$$

The long-term cross-elasticities for the other factors were calculated using the respective coefficients of the long-term model.

4. Results and discussion

The three regression equations of the model in its structural form presented a high goodness of fit with coefficients of adjusted determination (R2 Ajust) of 0.93 to 0.99, the value of the test of F of each equation was significant at a level of 0.01, the Statistical DW indicates the existence of a low level of autocorrelation between the time series (1.97 - 2.64) and the SW value per variable ranged between 0.93 and 0.98; which implies that its distribution is close to normal (**Table 5**). The t-values indicate that all the coefficients of the explanatory variables of the model are statistically significant and also their signs presented congruence with the microeconomic theory of production.

Table 5 - Results of the model

PAM=	*2305591 +*	*4.902453PAPMR2L +*	*318.0911PCHPARL -*	*314135PEEPARL*
t	(2.34***)	(1.86**)	(1.85**)	(-1.68**)
Error sd.	1081013	2.693402	163.1231	244147.2
SW		0.96	0.93	0.97
	-26920.7PO2PARL +	*0.831063PAML*		
t	(-1.35**)	(8.55***)		
Error sd.	19938.30	0.097271		
SW	0.97	0.95		
R^2=0.94; R^2Ajust=0.93; Pr > F=0.0001; DW=2.24; BP=1.86				
PAPMR =	*10565.91 +*	*0.69397PAMMR -*	*8740.59D*	
t	(12.9***)	(401.38***)	(-10.59***)	
Error sd.	818.8143	0.001731	828.2206	
SW		0.98	0.97	
R^2=0.99; R^2Ajust=0.99; Pr > F=0.0001; DW=2.64; BP=1.89				
PAMMR =	*19976.73 +*	*6.219147CTAMR +*	*0.631465PINTARL -*	*24303.74D*
t	(2.26**)	(70.36***)	(2.22**)	(-3.35***)
Error sd.	8849.869	0.088138	0.284527	7257.942
SW		0.95	0.96	0.98
R^2=0.99; R^2Ajust=0.99; Pr > F=0.0001; DW=1.97; BP=1.86				

1 Statistic Breush-Pagan (BP) as a test of heteroscedasticity between the time series.
Note: Statistical significance of the t values at 0.1 (*); 0.05 (**); 0.01 (***).
Source: Self made.

4.1. Short and long term elasticities

In the short term, the estimated own price elasticities indicate that steel production in Mexico responds inelastically with 0.0425. This differs from that calculated by Giuliodori and Rodríguez (2015) for Germany, which was 1,318 and those of Priovolos (1987) for the production of iron ore in the period 1960-1984 for Canada (2.19) and Spain (1.94), for Mexico calculated it at 0.84 and although it was also inelastic, it is superior to that of this work. On the other hand, Labson et al. (1995) calculated for the

1972-1992 period, price offer elasticities for iron ore significantly lower than those of the previous works for Australia (0.30), Brazil (0.26), China (0.13), India (0.10), Europe East (0.04) and North America (0.04); highlighting that these last two results are similar to those found in this research.

With respect to the effect of price transmission, the unit changes in the steel wholesale price cause adjustments to the producer price, at a rate of 0.9733. On the other hand, a unitary percentage change in the cost of real transportation in Mexico causes an adjustment of the wholesale price at 1.05% and 0.05% if the international price of steel increases in the same magnitude.

In the long term, the estimated elasticities indicate that steel production in Mexico will continue to respond inelastically (0.2419), before changes in their respective real price (**Table 6**).

Table 6 - Own price elasticities and transmission of short and long-term prices

Exogenous variables	*Endogenous variables*		
Short term	*PAM*	*PAPMR*	*PAMMR*
PAPMR2L	0.0425		
PAMMR		0.9733	
CTAMR			1.0482
PINTARL			0.0532
Long term			
PAPMRL	0.2419		

Source: Self made with data from Table 5

If the Annual Average Growth Rate (TMAC's) recorded from 2010 to 2017 is maintained, in the producer price (6.2%), it will result in an increase in the amount produced of Mexican steel of the order 0.26%; The TMAC recorded in the wholesale price was 5.8% and if this is maintained it will affect the steel producer by 5.6%. The cost of transport and the international price registered rates of 6 and 3%, which generates adjustments in the steel wholesale price of the order of 6.3 and 0.15%, respectively; if these levels of change are maintained.

In relation to the other factors that most affect steel production (PAM), they are, directly, the price of scrap to the steel producer in Mexico with a cross price elasticity of 0.4358. The price of electric power and the price of oxygen to the steel producer in the country cause a negative reaction with cross-price elasticities of 1.5144 and 1.0425. From 2010 to 2017, the TMACs of the price of oxygen to the steel producer, the price of scrap to the steel producer and the price of electric power to the steel producer in Mexico, were -4.2, 9.7 and -1.8. %, which affects PAM in 4.4, 4.2 and 2.7%.

For the long term, the production of steel, the unit percentage increases in the price of electricity and the price of oxygen to the steel producer in Mexico will negatively impact the order of 8.95 and 6.16%. The price of scrap to the steel producer in Mexico will directly impact PAM, a unit percentage increase in this factor will increase the production quoted by 2.6% (**Table 7**).

Table 7 - Short and long term elasticities related to other factors that affect Mexican steel production.

Exogenous variables	*Endogenous variables*			
Short term	*PCHPARL*	*PEEPARL*	*PO2PARL*	*PAML*
PAM	0.4407	-1.5129	-1.0401	0.8204
Long term	*PCHPARL*	*PEEPARL*	*PO2PARL*	
PAM	2.6083	-8.9541	-6.1560	

Source: Self made with data from Table 5

5. Conclusions

Steel production in Mexico responds inelastically to changes in the producer price. This suggests that a pricing policy will have a less than proportional impact on the amount of steel produced.

With regard to the transmission of prices, the effect of the wholesale price of steel on the producer price is significant. This must be taken into account by the steel wholesaler in Mexico, since its decisions as an intermediary have a strong impact on the Mexican producer.

The marginal effect of the international steel price on the wholesale price in Mexico, compared to the more than proportional change that the national transportation cost brings about; it reflects in part the integral problems existing in the local communication channels.

The hypotheses of investigation are not rejected, since the results show that the supply of steel presented a direct determination by the price to the producer and inversely by the price of the inputs, such as: scrap, electric power and the oxigen. The statistical method applied here has been widely used to econometrically analyze other economic sectors in Mexico and how much theoretical statistical support is necessary to be applied in other countries.

The price to the steel producer in Mexico is directly affected by the wholesale price and the international price. The positive but marginal effect of the international price on the wholesale price suggests a greater marketing margin for the Mexican steel wholesaler; what should be taken into account in public policy aimed at encouraging the national metallurgical sector.

Finally, it is important to highlight the needs for improvement in the supply chain of inputs from the Mexican steel sector, such as: in the supply of natural gas, the reduction in the peak electricity supply period and the development of the market of scrap, among others.

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