Factors that Impact the Market of Agricultural Tractors in Mexico

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ABSTRACT
Objective: To determine the main factors that impact the market of agricultural tractors in Mexico.
Design/Methodology/Approach: Time series data from 2000 to 2020 were used to estimate two national-scale models for agricultural tractors: one for supply and the other for demand.
Results: The results suggest that, in the long run, the supply and demand for agricultural tractors have an inelastic responsiveness to price changes, with a 0.079 and −0.083 elasticity, respectively.
Study Limitations/Implications: The main limitation is the lack of official data on the historical prices, sales, and production of tractor units in recent years. Consequently, estimates must be employed.
Findings/Conclusions: In addition to the price factor, producer income and interest rate affect demand, with elasticities of 0.178 and −0.002, respectively. Consequently, the government should implement the necessary measures, such as improving income and maintaining low interest rates, to encourage the demand for tractors in Mexico.

Keywords: tractor, supply, demand, elasticity.

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INTRODUCTION

The significance of agriculture as a source of food for the population and a provider of raw materials for the industry, along with the country's rich biodiversity, means that this sector is an indispensable market for the agricultural machinery industry, which encompasses the production and commercialization of agricultural machinery, vehicles, and implements (ICEX, 2019).

The agricultural tractor is the main element of agricultural mechanization and is the main source of power within production units (Ayala-Garay *et al.*, 2013). The 2022 Census of Agriculture recorded 473,000 tractors in operation in the country, serving 1.8 million agricultural production units (INEGI, 2023).

According to the information provided by the Agrifood and Fisheries Information Service (SIAP, 2022), Mexico covers an area of 197 million hectares, out of which 32.4 million are dedicated to agricultural activities. Over 300 products are grown in this surface to nourish a population of 126 million individuals, predominantly through the use of agricultural machinery (INEGI, 2020).

The primary objective of agricultural machinery manufacturers and sellers is to provide equipment for open field and protected agriculture. The responsibility for selecting the necessary machinery lies with the producer. Together, they create a machinery market where supply and demand interact.

The current supply of agricultural tractors in Mexico is comprised of products from multiple manufacturers who also produce and sell related agricultural machinery. In Mexico, the most important manufacturers are John Deere, CNH Industrial, AGCO Corporation, KUHN Group, and Kubota.

According to INEGI (2009), the annual domestic production of agricultural tractors amounted to 12,000 and 11,300 units in 2002 and 2003, respectively. According to John Deere's annual report for 2021, the average annual sales of agricultural tractors in Mexico from 2011 to 2015 amounted to 10,400 units, while from 2016 to 2020 this figure rose to 12,300 units.

The demand for tractors has fluctuated over time. In 2009, 2010, and 2011, this indicator reached 19,000, 14,000, and 10,000 units, respectively (Suárez-López, 2011). Conversely, in 2017 and 2018, it decreased to 14,000 and 12,000 units, respectively (Perea, 2018). Agricultural machinery represents a major input in the context of agricultural production activities. In 2019 alone, the value of primary sector activities reached $589 billion Mexican pesos, accounting for 3.7% of the GDP (CEDRSSA, 2019).

Several studies about agricultural machinery in Mexico share similarities with this research. Aburto-Irigoyen (1984) studied the market and prospects for agricultural tractors. Mora-Flores (1986) conducted a study on the supply and demand of agricultural tractors. Morales-Carrillo and Martínez-Damián (1998) developed an almost ideal demand system for agricultural tractors. Ayala-Garay *et al.* (2012) conducted an analysis of the mechanization situation in the State of Mexico, specifically in the regions of Teotihuacán, Tepotzotlán, and Zumpango. Finally, Terrones-Cordero *et al.* (2020) analyzed the behavior of the primary sector in Mexico from 1980 to 2020.

There is an overall lack of in-depth studies about the situation of agricultural machinery in Mexico. Some studies focus on specific states or regions. Therefore, the aim of this study was to analyze the variables that influence the supply and demand of agricultural tractors in Mexico. Given the crucial role of agricultural machinery (particularly tractors), as a fundamental component of agricultural production, the objective was to identify and analyze the factors affecting this market. The hypothesis was that both supply and demand would have an inelastic response to price changes in the long run.

MATERIALS AND METHODS

In order to achieve the results, an econometric model was developed for the supply and demand for agricultural tractors in Mexico. The model was estimated using the ordinary

least squares regression method (Gujarati and Porter, 2010), in the Statistical Analysis Software (SAS, 2013). The geographical scope of the research included the national territory and the 2000-2020 time series were used to estimate the models.

The following econometric models were proposed:

$$QDT_t = \alpha_0 + \alpha_1 PCT_t + \alpha_2 YA_t + \alpha_3 TIR_t + \alpha_4 QDTL_{t-1} + e_t \quad (1)$$

$$QPT_t = \beta_0 + \beta_1 PUE_t + \beta_2 CREA_t + \beta_3 SMIN_t + \beta_4 QPTL_{t-1} + e_t \quad (2)$$

Where for the year *t*: QDT_t is the quantity of tractors demanded (tractor units); PCT_t is the consumer price of the tractors (pesos per unit); YA_t is the producer income (pesos per hectare); TIR_t is the annual interest rate (%); $QDTL_{t-1}$ is the one-year delay of the QDT_t variable; QPT_t is the tractor quantity offered (tractor units); PUE_t is the unit export price (pesos per unit); $CREA_t$ is the agricultural credit (pesos); $SMIN_t$ is the minimum wage (pesos); and $QPTL_{t-1}$ is the one-year delay of the QPT_t variable.

The long- run econometric models were obtained with the following formulas:

$$QDT_t = \frac{\alpha_0}{\&} + \frac{\alpha_1 PCT_t}{\&} + \frac{\alpha_2 YA_t}{\&} + \frac{\alpha_3 TIR_t}{\&} \quad (3)$$

$$QPT_t = \frac{\beta_0}{\&} + \frac{\beta_1 PUE_t}{\&} + \frac{\beta_2 CREA_t}{\&} + \frac{\beta_3 SMIN_t}{\&} \quad (4)$$

Where α are the coefficients of the demand function; β are the coefficients of the supply function; and & is the autoregressive parameter.

The model formulation was justified by economic theory. According to García-Mata *et al.* (2003), the price of the product and the price of inputs are the factors that determine the quantity supplied. The factors that determine the quantity demanded are the price of the good, the price of substitute or complementary goods, and available income.

According to economic theory, the supply of a product (*e.g.*, agricultural tractors) is determined by several factors, including the price of the product itself. Since obtaining the prices of new tractors at the output level from assembly plants proved to be a difficult task, the export unit price was taken as the producer price. Other key factors that influence the domestic supply include the minimum wage for labor and agricultural credit. The latter allows producers to purchase production inputs and encourages the production of tractors.

The quantity consumed of a good is based on its price and the consumer income. Higher income leads to higher demand, and *vice versa*. The producer income variable is the gross income per hectare. Another variable that affects the tractor demand is the interest rate. This variable is important because it drives investment in the agricultural sector.

The data used to develop the model was obtained from several sources. The quantity of tractors produced per year was obtained from INEGI (2009) and John Deere (2021). The export unit price for the 2010-2020 period was sourced from SIAVI (2021), based on the duty rate 87019001, while the price for the 2000-2009 period was obtained from FAOSTAT (2022). Agricultural credit was obtained from FIRA (2021). The minimum wage was obtained from CONASAMI (2021).

To quantify the extent of the demand, the apparent domestic consumption of agricultural tractors was calculated based on the sum of the domestic production and the trade balance. According to the 2007 Agricultural, Livestock and Forestry Census (INEGI, 2007), tractors are classified into four groups: group 1 (up to 60 Hp), group 2 (from 60 to 85 Hp), group 3 (from 85 to 145 Hp), and group 4 (over 145 Hp). The consumer price of tractors was selected according to the power range of group 2 (from 60 to 85 Hp), considering that most of the existing tractors in the country fall into this classification. Once the power range was selected, average prices were taken based on the selected power. Since obtaining nominal prices for all years in the study period proved to be difficult and given the lack of public data regarding the prices of new agricultural tractors sold in Mexico, the prices were estimated in US dollars, based on information from agricultural machinery websites and documents published by marketing companies (COMEXI, 2015; COMEXI, 2020; CNH, 2017; CNH, 2018), as well as information about agricultural tractors provided by government agencies (SEDRAE, 2019). Income per hectare and interest rate were obtained from SIAP (2022) and BANXICO (2022), respectively. Monetary variables were deflated based on 2018 figures from the National Producer Price Index and the National Consumer Price Index (INEGI, 2021a; INEGI, 2021b).

The statistical validity of the models was established using the F-test or global test for a multiple regression, the t-test, and the coefficient of determination (R2) (Gujarati and Porter, 2010).

RESULTS AND DISCUSSION

Table 1 shows the estimated coefficients. The F-test values demonstrate that, at the aggregate level, the explanatory variables have a significant influence in determining the variation in tractor supply ($P \leq 0.0001$) and demand ($P \leq 0.0001$). The coefficient of determination is acceptable for both equations: 0.73 for supply and 0.73 for demand.

The t-asymptotic pointed out that most parameters were individually significant. In other words, the coefficient of the parameters is greater than their respective standard value and the t-statistic is greater than one in absolute terms. In the case of the supply model, the variables have a $t<1$ in absolute terms, except for the lag of the quantity produced. However, in accordance with economic theory, they were allowed in the model as a result of their importance. In the case of the demand model, the variables have a $t<1$ in absolute terms, except for the price and interest rate variable. Nevertheless, according to economic theory, this variable was deemed important enough to be included in the model (Table 1).

The estimated coefficients match the sign outlined in economic theory (García-Mata *et al.*, 2003). On the one hand, the consumer price of tractors is inversely related to the quantity demanded and income has a positive effect. On the other hand, the interest

Table 1. Statistical results of the supply and demand model for tractors in Mexico.

Dependent variable	Intercept	Independent variables				R^2	Prob>F
QPT		*PUE*	*CREA*	*SMIN*	*QPTL*		
Coefficient	4413.05	0.000725	0.000008	−29.341280	0.787830		0.0001
Standard error	2683.83	0.003660	0.000021	30.615180	0.200120	0.73	
t value	1.640000	0.200000	0.400000	−0.960000	3.940000		
Pr>t	0.120900	0.845500	0.694100	0.353100	0.001300		
QDT		*PCT*	*YA*	*TIR*	*QDTL*		
Coefficient	4804.33	−0.001010	0.061410	−1.719000	0.6532		<0.0001
Standard error	2854.31	0.001300	0.047240	144.534730	0.2117	0.73	
t value	1.680000	0.780000	1.300000	−0.010000	3.0860		
Pr>t	0.113000	0.449300	0.213200	0.990800	0.0075		

Source: Developed by the authors with data from the estimated model.

rate is inversely related to the quantity demanded, indicating that a higher interest rate corresponds to a lower demand, because acquiring a new tractor at a higher interest rate is more expensive.

The supply of agricultural tractors is influenced by the producer price, with a positive correlation between the two variables. The agricultural credit variable has a positive impact on the tractor supply, with higher credit leading to a higher supply. Espinoza-Zamorano and Martínez-Damián (2017) have proved that agricultural credit plays a significant role in stimulating the growth of the agricultural sector. Between 1970 and 2013, the ratio of credit to agricultural GDP increased (GDP increase: 5.0% to 28.5%). The minimum wage has an inverse effect on the quantity supplied —*i.e.*, as the wage rises, the supply of the product falls.

The short-run elasticities were calculated using the partial derivatives of each equation, the structural form of the estimated model, and the average values of the variables in question over the 2000-2020 period. Three short- and long-run elasticities were calculated. García-Mata *et al.* (2003) indicate that the long-run model was derived, to ascertain the dynamic trend, using the short-run linear supply and demand models. The speed of adjustment (&) for the long-run model was also calculated with the estimated parameters of the lagged endogenous variables. The estimated parameter was 0.7878 for supply and 0.6532 for demand. The formula (1−&) was used to determine the speed of adjustment, resulting in 0.21217 and 0.3468 for supply and demand, respectively.

Table 2 shows that all the absolute values of the short-run and long-run elasticities are less than one, suggesting that both supply and demand have an inelastic response to changes in determining factors. Additionally, the short-run elasticities are lower than the long-run elasticities in all cases. In conclusion, the reaction of agricultural producers (who act as consumers of agricultural tractors) to price variations is relatively limited.

The long-run price elasticity of the demand coefficient was calculated to be −0.083, indicating that a 10% increase in price would result in a 0.83% decrease in the tractor demand. This value is similar to that reported by Terrones-Cordero and Martínez-

Table 2. Elasticities of supply and demand for agricultural tractors.

Supply	Short run	Long run	Demand	Short run	Long run
E_{PUE}^{QPT}	0.017	0.079	E_{PCT}^{QDT}	−0.029	−0.083
E_{CREA}^{QPT}	0.035	0.164	E_{YA}^{QDT}	0.062	0.178
E_{SMIN}^{QPT}	−0.200	−0.942	E_{Tir}^{QDT}	−0.0006	−0.002

Source: Developed by the authors with data from the estimated model.

Damián (2012) and Terrones-Cordero *et al.* (2020), who report elasticities lower than one, implying that the response of agricultural producers to price changes in the purchase of machinery is low. Morales-Carrillo and Martínez-Damián (1998) calculated the elasticities of tractor demand and reported that 80-100 hp vehicles have an inelastic demand with respect to the price.

The long-run income and interest rate elasticities were 0.178 and −0.002, respectively, indicating that a 10% increase in income will result in a 1.78% increase in demand, if all other factors remain constant. Conversely, a 10% increase in interest rates will lead to a 0.02% reduction in tractor demand (Table 2). Producer income is a key factor that determines their capacity to make investments, including the acquisition of agricultural machinery.

The coefficient of the long-run price elasticity of supply was 0.079, indicating that a 10% increase in price will result in a 0.79% increase in supply, if all other factors affecting the quantity produced remain constant. The long-run elasticities of credit and the minimum wage were 0.164 and −0.942, respectively. These values indicate that a 10% increase in credit will result in a 1.64% increase in output, whereas a 10% increase in the minimum wage will lead to a 9.4% decrease in output. These results assume that all other factors remain constant. The analysis revealed an increase in credit for the agricultural sector (FIRA, 2021). However, this increase has not been substantial enough to drive a significant rise in the tractor supply, resulting in a continued stagnation in supply.

The interest rate is a monetary policy instrument implemented by the Bank of Mexico. It has an inverse relationship with investment —*i.e.*, when this variable is high, producers are unable to mechanize their fields through the acquisition of machinery. A constant interest rate increase in the future would continue to prevent producers from investing in machinery.

The results of the long-run elasticities show that supply and demand have an inelastic response to changes in its determining factors. Therefore, major changes would be necessary to modify the quantity produced and demanded. It is essential to continue supporting agricultural mechanization (*i.e.*, the acquisition of tractors), by means of credits and subsidies. Terrones-Cordero *et al.* (2020) point out that the decision of producers not to acquire more tractors and other agricultural inputs through credit amounts is a consequence of the high interest rates set by the institutions.

To promote demand for agricultural tractors in Mexico, institutions must provide loans at competitive interest rates, consequently boosting tractor sales and expanding the tractor fleet in Mexico.

Given the high price point of current agricultural tractors (in some cases exceeding $400,000 Mexican pesos), producing smaller, less powerful tractors would be advisable. Such tractors are well-suited to the country's plots and affordable for small producers. Institutions, universities, and mechanical design experts should propose equipment capable of performing maneuvers in the varying conditions of each region. Furthermore, the Federal Government must support the establishment of a national technology-based industry that promotes the development of tractors for small producers.

Implementing public policies focused on the agricultural sector is essential. Likewise, the appropriate institutions should ensure the efficient and socially responsible use of allocated resources. These measures will encourage tractor demand through subsidies and low interest rates.

CONCLUSIONS

The estimation of a model of the supply of agricultural tractors in Mexico indicates that this variable has a long-run inelasticity in response to changes in price, minimum wage, and agricultural credit. Tractor supply is expected to continue following a stable trend, with an average of 12,000 units offered and sold each year. Tractor demand is determined by three key factors: consumer price, farm income, and interest rate. The response of the quantity demanded also has an inelastic response to changes in these three factors. Among these factors, income is the variable that most affects the demand for tractors, thereby highlighting the importance of recording the prices of products sold by the producer. One limitation of this research was the lack of public data. Therefore, the competent authorities should collect and provide the necessary data on this market. Further research should be conducted to analyze the adoption of agricultural machinery and additional projects should contemplate the production of smaller tractors that can be easily purchased by producers. The support for agricultural mechanization should continue through the implementation of policies that, on the one hand, maintain low tractor prices and high prices for agricultural products, improving producer income, and, on the other hand, offer low interest rates that encourage greater demand for tractors.

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