Investigation note

Dual analysis of the behavior of the primary sector in Mexico 1980-2020

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Abstract

The present investigation analyzed the productive activity of the primary sector in Mexico during the period 1980-2016, with prediction towards 2020. A translog cost function was used to estimate the demands of the inputs: labor, machinery, nitrogen fertilizers and credit of development banking. Prices and quantities of each of the inputs and of the primary gross domestic product were considered in 2013 real base values. The Allen-Uzawa elasticities were calculated, the four inputs were inelastic, with labor being the most important in the cost structure, representing 52.7%. Tractors and fertilizers were complementary to labor, the credit from the development bank showed a substitution relationship with the other inputs, indicating that the interest rates charged are high and cause the producer to decrease the demand for credit. Primary activity requires increases in tractors, fertilizers and labor of at least 2.8, 2.3 and 2.2%, respectively, by 2020.

Keywords: Allen-Uzawa elasticities, dual function, input demand.

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In 1986 Mexico joined the General Agreement on Tariffs and Trade (GATT), today the World Trade Organization (WTO) in order to eliminate barriers to foreign trade, in 1992 modifications were made to constitutional article 27 with the aim of opening the field to the market (Sánchez *et al*., 2015), the national banking system was privatized in 1993 and in 1994 the Free Trade Agreement (FTA) between the United States comes into force from America, Canada and Mexico in order to increase trade flows between the participating countries (Calva, 1997; Perales, 2011).

The participation of the primary sector (made up of agricultural, livestock, forestry and fishing activities), with respect to Mexico's gross domestic product (GDP), has shown a decreasing trend, going from 8.4% in 1980 to 3.3% in 2016, registering an average annual growth rate of only 0.69% during the period 1980-2016 (Inegi, 2018a). The foregoing reflects that said sector is in crisis characterized by the lack of financing, low productivity of labor, processes carried out in a traditional and low-tech way, and abandonment of primary activities, which has caused marginalization, poverty and emigration of the rural population (Calva, 1997; Damián *et al*., 2007; Sánchez *et al*., 2015).

Faced with this primary sector problem, the new federal administration 2018-2024 had as strategies to promote primary activities through actions such as granting financing, technical advice, technological innovation and guarantee pricing in order to reactivate the field, create jobs and achieve food self-sufficiency. To make agricultural production profitable, government, educational and research institutions must direct their development strategies to the countryside, which will allow the generation of food and raw materials, transfer of capital to the economy, provision of labor to industry and services and will contribute to economic growth (Terrones and Sánchez, 2010; Almeraya *et al*., 2011; Sánchez *et al*., 2015).

The translog cost function to estimate and derive factor demands for agricultural production has been widely used, Yotopoulos *et al*. (1976) for Taiwan, considering labor inputs, fertilizers, land and animal and mechanical traction, and agricultural gross domestic product as output variable, Sidhu and Baanante (1981) in wheat production in Punjab India, López and Tung (1982), for Canada capital inputs, land, labor, energy, fertilizers and pesticides and agricultural GDP as a product variable, Weaver (1983), estimated the demand for inputs for wheat production in the United States of America, for this he used the inputs fuels, fertilizers, materials, capital services and labor, and the products wheat, rye, oats, sunflower, hay, corn and livestock products, Omaña (1999) estimated demand for factors in corn production in Mexico.

It's considered fertilizer inputs, labor, mechanical and animal traction, pesticides, seed, soil, gravity irrigation and others, and corn production as a variable product. Terrones and Sanchez (2010), in Mexico estimated demands for labor inputs, tractors, threshers, development bank credit, commercial bank credit, nitrogen fertilizers, phosphate fertilizers, potassium fertilizers and as a product variable the agricultural GDP. A Bayesian estimate is in (Terrell, 1996; Griffiths *et al*., 2000), with a system of quadratic cost equations for agricultural activities in Australia and Markov Chain Monte Carlo (MCMC) simulation using land, capital, and other inputs (Griffiths *et al*., 2000).

The objective of this research was to estimate the demand for labor inputs, tractors, nitrogenous fertilizers and credit from the development bank of the primary sector in Mexico during the period 1980-2016, predicting the years 2017-2020, using the translog cost function.

Annual input and output data from the primary sector of Mexico were considered during the period 1980-2016 (37 years). The inputs used were labor, tractors, nitrogen fertilizers and credit from the development bank, obtaining prices and quantities and as a product the GDP of the primary sector. Input costs represented 34%, average during the study period, of the value of primary GDP. For labor, the number of wages used (Inegi, 2018b) and the average annual remuneration per day (Inegi, 2017) were considered. The quantity (units) and price of the tractors were obtained, from the Food and Agriculture Organization of the United Nations (FAO, 2018a).

For nitrogenous fertilizers, these were obtained from FAO both the total amount used in tons and the price per ton (FAO, 2018b). The amount of the credit assigned by the development bank was obtained from the Inegi (2019a), as the price was considered the nominal interest rate set by said banking institution (Inegi, 2019b). The GDP of the primary sector was obtained from the Inegi (2019c). The costs of the four inputs considered were obtained by multiplying the quantity of each of them by their price. In the particular case of tractors, a depreciation of 10% was taken into account, considering a useful life of 10 years. Values are in constant terms using the 2013 base year GDP deflator (IMF, 2019).

The flexible translog functional form was developed by Christensen *et al*. (1973) define it as follows.

$$\ln C = \ln \alpha_o + \alpha_y \ln y + \sum_{i=1}^{n} \alpha_i \ln w_i + \tfrac{1}{2} \beta_{yy} (\ln y)^2 + \tfrac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_{ij} \ln w_i \ln w_j + \sum_{i=1}^{n} \beta_{iy} \ln y \ln w_i$$

For all i ≠ j and i, j = 1, 2, n (1) where: *C*= the total cost of production; *y*= the total product; w_i= the price of factor i; *ln*= the natural logarithm and $\alpha_o, \alpha_y, \alpha_i, \beta_{ij}, \beta_{iy}$ *and* β_{yy} are the parameters to estimate.

Deriving (1) with respect to factor prices results in their contribution to total cost (Shephard's Lemma), factor participation is expressed as (Baanante and Sidhu, 1980).

$\frac{\partial \ln C}{\partial \ln w_i} = S_i = \alpha_i + \sum_{i=1}^{n} \beta_{ij} \ln w_j + \beta_{iy} \ln y$ for i, j = 1, 2, n (2). Where: S_i they add up to unity, it is say: $\sum_{i=1}^{n} S_i = 1$ (3) equation (3) establishes the existence of n-1 linearly independent participations, which allows avoiding singularity problems.

The proposed model considers the following assumptions: i) linear homogeneity in factor prices; that is to say: $\sum_{i=1}^{n} \boldsymbol{\alpha_i} = \mathbf{1}$, $\sum_{i=1}^{n} \beta_{ij} = 0$, and $\sum_{j=1}^{n} \beta_{ij} = 0$ (4); ii) perfect competitive market structure, producers are price takers; and iii) symmetry. Where:, $\beta_{ij} = \beta_{ji}$, for i ≠ j. (5) iv) the S_i in 2 show additive errors, with zero hope and finite variance.

The assumptions of homogeneity and symmetry help to increase the efficiency of the estimation and allow reducing the number of parameters to be estimated without loss of information Pindyck and Rubinfeld (1998). Applying expression (2), the demand for factors such as: $S_i = \alpha_{im} + \beta_{im} \ln w_m + \beta_{it} \ln w_t + \beta_{in} \ln w_n + \beta_{id} \ln w_d + \beta_{iy} \ln y + e_i$ (6) S_i the contribution of factor *i* (dependent variables) within the total cost was obtained; w_j is the price of factor *j* (independent variables); *ln* is natural logarithm; *y* is the GDP of the primary sector (independent variable); $\boldsymbol{\alpha_i}, \boldsymbol{\beta_{ij}}$ were the parameters to estimate; and *i* are the estimation errors. Where: *i*, *j*= m (labor); t (tractors); n (nitrogen fertilizers); and d (development bank credit), for *i* ≠ *j*.

The variation in the price of the j-th factor, with prices of the other factors and constant product was obtained from the Allen-Uzawa partial substitution elasticity (σ_{ij}), which was determined as (Weaver, 1983).

$\sigma_{ii} = \frac{\beta_{ii}}{(si)^2} + 1 - \frac{1}{si}$; $\sigma_{ij} = 1 + \frac{\beta_{ij}}{s_i s_j}$. Where: *i* ≠ *j*, for $\sigma_{ij} = \sigma_{ji}$. (7). Inputs *i* and *j* are substitutes if $\sigma_{ij} > 0$; and if $\sigma_{ij} < 0$, then inputs *i* and *j* are complementary. The result of the demand of the *i*-th factor before changes in its price is the elasticity of the demand for factors (n_{ii}), it measures the response of the demand of the i-th factor to price changes of the j-th factor, maintaining the prices of the other factors and constant product (Chung, 1994; Pope and Just, 1998): $n_{ii} = \sigma_{ii} s_i$; $n_{ij} = \sigma_{ij} s_j$; for *i* ≠ *j*. (8) If $n_{ii} > 0$, input i is elastic; and if $n_{ii} < 0$, input i is inelastic. If $n_{ij} < 0$, inputs *i* and *j* are complementary and if $n_{ij} > 0$, inputs i and j are substitutes. The factor participation system 6 was estimated with the apparently unrelated equation method (Greenberg, 2012), with the use of System Analysis Statistics (SAS) Version 9.0.

In order to assess the behavior of factor demand for the period 2017-2020, a trend of price variation of all factors (w_i) and of primary GDP until 2020 was assumed. To do this, the projection of logarithms was obtained. natural prices of the four factors and primary GDP for four more years (2017-2020), based on the period 1980-2016. With the predictions of prices and primary GDP, the demand of the four factors was determined using the following expression: $S_i = \hat{\alpha}_i + \sum_{j=1}^{4} \hat{\beta}_{ij} \ln w_j + \hat{\beta}_{iy} \ln y$ with *i*, *j* = m, t, n, d, (8). Where: $\hat{\alpha}_i$, $\hat{\beta}_{ij}$, $\hat{\beta}_{iy}$ are the parameters estimated by the model for the period 1980-2016; ln w_j is the natural logarithm of the input price prediction j; ln y is the natural logarithm of primary GDP based on the projection; S_i it is the contribution of the cost of factor i to the total cost.

For the t-test, the significance level of 5% with 33 degrees of freedom was considered, the critical value being $t_{0.025}$= 2.021 (Anderson *et al*., 2008). Table 1 shows the ratios t (figures in brackets) of the regression model. Of the eleven estimated coefficients (β_{ij}), nine were statistically reliable at 95%. The determination coefficients (R^2) of the three factor demand equations were greater than 80%. Taking these statistical indicators into account, the estimated model was pertinent to characterize the agricultural sector of Mexico during the period 1980-2016.

Table 1. Estimation of the restricted parameters of the translog cost function for the primary sector of Mexico, 1980-2016.

$S_i^{\dagger}$	Independent variables$^{\perp}$				Y_i^{Γ}	R^2 Adjusted
	W_m	W_t	W_n	W_d		
S_m	0.1648 (23.3)	-0.0227 (-7.52)	-0.0344 (-10.86)	-0.1077 (-19.47)	0.4099 (4.28)	0.84
S_t	-0.0227 (1.46)	0.032 (12.51)	0.0026 (1.39)	-0.0119 (-12.53)	0.0228 (1.46)	0.93
S_n		0.0026	0.0425 (15.97)	-0.0107 (-8.21)	0.0586 (2.64)	0.81
S_d			-0.0107	0.1303	-0.4913	0.86
				(20.95)	(-4.52)	

The subscripts m, t, n and d refer to the factors labor, tractors, nitrogenous fertilizers and credit of the development bank. †= are the functions of the factor demands considered; $^{\perp}$= are the prices of the factors; $^{\Gamma}$= is the coefficient of the product.

The relationship between production factors and primary activity was analyzed using the coefficient of the primary sector in the estimated model. Regarding work, an increase of 10% in the production of the primary sector requires an increase of 4.09% in the labor used in said sector, with given levels of factor prices, which indicates low productivity of this productive factor, characterized by developing in traditional and subsistence agriculture, a situation also found by Sánchez *et al*. (2015).

The use of machinery in agricultural activities causes an increase in productivity (López, 1980; Terrones and Sánchez, 2010; Palacios and Ocampo, 2012; Negrete *et al*., 2013), in the case of Mexico, an increase of 0.2% in the used tractors registered an increase of 10% in the level of primary sector product during the period 1980-2016, indicating that the Mexican countryside is developed with traditional production techniques and demands higher levels of technification through greater use of agricultural tractors, justified increase also by Gutiérrez *et al*. (2018); however, the number of tractors used in agricultural activities has shown a decreasing trend in the period 2000-2016, going from 185 000 units in 2000 to 228 000 in 2016 (FAO, 2018a); that is, 43 000 units less, which represented a decrease of 23%.

The use of fertilizers in the primary sector contributes to the increase in agricultural production an increase of 10% of the agricultural product in Mexico demands an increase of 0.58% in the use of nitrogen fertilizers, being similar to the product coefficient of 0.0681 found by Terrones and Sánchez (2010) for the period 1975-2006.

The four eigen elasticities calculated are less than unity, so all the factors are inelastic (Table 2). These obtained values are similar to those calculated for the Canadian agricultural sector by López and Tung (1982), in the range -0.28 to -0.464, to those of Griffiths *et al*. (2000) for the Australian agricultural sector, from -0.053 to -0.647 and those of Terrones and Sánchez (2010) for the agricultural activity of Mexico, from -0.026 to -0.3057. Labor force presented an elasticity of -0.1601, being less sensitive to that calculated for agriculture in the United States of America by Binswanger (1974), which was -0.911, to that obtained by López (1980) for Canadian agricultural activity (-0. 517), but more sensitive to that calculated by Terrones and Sánchez (2010) for the agricultural sector of Mexico during the period 1975-2006, which was -0.0632.

Table 2. Own and cross-elasticities of production factors in the primary sector of Mexico, 1980-2016.

$Supplies^{\perp}$	Independent variables†			
	W_m	W_t	W_n	W_d
S_m	-0.16008699	-0.0053292	-0.00538073	0.17079691
S_t	-0.0053292	-0.11279056	0.12818985	0.05921205
S_n	-0.00538073	0.12818985	-0.22918205	0.19589061
S_d	0.17079691	0.05921205	0.19589061	-0.27752156

The subscripts m, t, n and d refer to the factors labor, tractors, nitrogenous fertilizers and credit of the development bank. †= they are the functions of the demands of the factors; $^{\perp}$= they are the prices of the factors.

The low sensitivity of labor to changes in its price indicates the stagnation of primary activity (average annual growth of 0.69% in the period 1980-2016) due to abandonment, low productivity and low wage levels. For 2016, a worker in the agricultural sector received $14 758 pesos constant in 2013 annual average; that is, $40.43 pesos per day, representing a loss of the average annual salary of 1.22% in the period 1980-2016 (Inegi, 2017). The elasticity of demand for tractors was inelastic -0.11279), the reaction of producers in the acquisition of agricultural machinery to variations in their prices is low.

Nitrogen fertilizers behave as an inelastic input, -0.22918, where their use in primary activities registered an average annual increase of just 1.3% during the 2012-2016 period, going from 1 291 108 tons in 2012 to 1 361 598 tons in 2016 (FAO, 2018b), which explains the low annual average growth of 0.69% of the primary sector. Financing in the productive activity is important since it allows the producer to acquire inputs (Jaramillo *et al*., 2012). The development bank has been characterized by providing financing to low-income producers, the low response that the Mexican farmer presents in the acquisition of the credit that the development bank granted in the period 1980-2016 (elasticity of -0.2775) is due to the high interest rates charged and the low profitability of primary activity, being similar to that obtained by Omaña (1999), -0.4058, in corn production in Mexico and to that calculated by Terrones and Sánchez (2010), -0.3057.

In order to identify the complementary or substitution relationships between factor pairs, the Allen-Uzawa partial substitution elasticities were obtained (Table 3). The workforce presented complementarity with mechanization (tractors), -0.1414, coinciding with that obtained by Omaña

(1999), -2.7985 and Terrones and Sánchez (2010) in the period 1975-2006, -0.6365, indicating that the primary activities in Mexico are carried out in small production units with traditional and subsistence production systems that do not allow the use of machinery in agricultural work.

Contrary to the substitution relationship found by López (1980) for Canadian agriculture, 1.779, characterized by the decrease in workers and an increase in the size of production units and the incorporation of more tractors in primary activities, concluding that it is an agriculture technified and intensive in the use of capital.

In order to achieve higher levels of growth in agricultural activity in Mexico, development banks are required to design and implement a credit system with lower interest rates so that the agricultural producer can acquire resources at lower costs and is in a position to acquiring inputs such as labor, mechanization for production and harvesting (tractors and threshing machines) and fertilizers and above all paying for such financing, this will allow capitalizing the field and will contribute to achieving competitiveness in the primary sector.

Conclusions

By applying the cost function translog, parameter estimates of the factor demand are generated and determines useful elasticities in the characterization of the behavior and prediction of the productive structure, which contributes to empirical analysis in the area of the sectoral economy. The complementarity of labor with tractors and nitrogenous fertilizers implies that primary activities in Mexico are carried out through traditional production systems with incipient mechanization. Despite this, there is also a type of agriculture with tendencies to mechanization due to the substitution relationship between labor and development bank credit, where the farmer uses credit resources to acquire other inputs instead of hire labor.

The decision of the producers in the primary sector not to acquire larger amounts of credit, via development banks, for the purchase of more tractors and nitrogen fertilizers, is due to the high interest rates set by said institution. Considering the simulation of the model, the promotion of the Mexican primary sector requires increases in the use of inputs for the coming years, for 2019 and 2020, tractors must increase 2.8%, nitrogen fertilizers 2.3% and labor 2.2%. The use of more inputs in the Mexican countryside demands lower interest rates from development banks.

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