Colegio de Postgraduados

Soy (*Glycine max* L.) production and importation determinants in Mexico and actions aimed to increase its domestic coverage

García-Fernández, Francisco[1]; Legarreta-González, Martín Alfredo[2]; Galván Vera, Antonio[1].

[1] Universidad Autónoma de Tamaulipas. Facultad de Comercio y Administración Victoria/Laboratorio de Estudios Regionales.
[2] Universidad Tecnológica de Tarahumara/University of Makeny, Sierra Leone. Laboratorio de Estudios Regionales.
* Correspondence: ffernandez@docentes.uat.edu.mx

ABSTRACT
Objective: To analyze soy (*Glycine max* L.) production and importation determinants in Mexico, during the 1990-2000 period.
Design/Methodology/Approach: Using lineal models, two econometric models were developed, in order to evaluate the relation between the soy production, harvested area, and soy production vs. importation variables.
Results: We confirmed that soy production in Mexico is related to the increase of the harvested area, which promotes an increase in the domestic market and a reorganization of the soy harvested areas. The second model verified that the importations are the result of the limited domestic production. We propose a set of actions to increase domestic soy production.
Study Limitations/Implications: The models must consider new variables to broaden the determinants and to improve the public policy actions proposed.
Findings/Conclusions: The low domestic coverage rate and the high dependency on imports requires the implementation of policy actions to improve the domestic production capacity. A specific set of actions is proposed.

Keywords: soy production, soy importation, harvested area, econometric models, public policy actions.

Citation: García-Fernández, F., Legarreta-González, M. A., & Galván Vera, A. (2023). Soy (*Glycine max* L.) production and importation determinants in Mexico and actions aimed. *Agro Productividad*. https://doi.org/10.32854/agrop.v16i3.2423

Academic Editors: Jorge Cadena Iñiguez and Libia Iris Trejo Téllez

Received: November 07, 2022.
Accepted: January 26, 2023.
Published on-line: May 19, 2023.

Agro Productividad, 16(3). March. 2023. pp: 119-127.

INTRODUCTION

Soy (*Glycine max* L.) is one of the most dynamic food markets in the world, as a result of the growth of the production, the consumption, the cultivation areas, and the exportation. Between 1990 and 2020, the soy cultivation area worldwide increased 121% (about 70 million hectares) and the production volume multiplied by 3.1%, reaching 336 million tons. In 1990, a ton of soy costed US$357. The prices increased since the beginning of the new century, reaching US$670 in 2012 (World Bank, 2018). Recently, prices have escalated again. This price escalation has increased during the last

Image by pnmralex at Pixabay

months, as part of the inflationary process that has impacted all food prices around the world. Specifically, the price of soy increased 105% between May 2020 and June 2022 (FAOSTAT, 2022).

Soy is a high value input for the vegetable oil industry and the biodiesel production industry. This oilseed has a wide range of uses, as a consequence of its high protein and oil content. Dried soy seeds are made up of 20% oil and 40% protein. Researches carried out by the food industry have led to the incorporation of soy into a wide variety of foods, both for human and animal nutrition. The American Soybean Association (ASA) has been a very effective pressure tool used by farmers to develop a consumption market for American soy. In Mexico, it has supported or developed all sort of actions to promote soy demand (García-Fernández *et al.*, 2018).

In terms of volume, soy production in Mexico has been stagnant since the late 1980s. Those levels have not been surpassed yet. The highest production volume (700 thousand tons) was reached from 1985 to 1989 (García Fernández *et al.*, 2018). Between 1990 and 1994, soy production remained at high levels, reaching its maximum point in 1991. In 1995 —the year that Mexico entered the North American Free Trade Agreement (NAFTA)—, a contraction process began, both in production and in area. Compared with the previous year, soy production and harvested areas diminished 63% and 53%, respectively (Claridades Agropecuarias, 1997). The domestic market continued to expand: between 1980 and 2020, the apparent consumption increased by 225%. The maximum coverage (40%) of the domestic market was reached in 1990. Mexico experienced a fall in domestic production, harvested areas, and domestic coverage. Consequently, a 592% increase in importations was recorded during that same period (SIAP, 2022). Between 2010 and 2020, the domestic soy market increased by 30% (apparent consumption). However, the capacity of Mexican soy to supply the market is very limited, accounting for only 4% (Table 1).

Specifically, this study seeks to identify the soy production and importation determinants in Mexico, using two econometric models in order to establish the soy production and importation behavior in the country. The two models showed that the changes in soy production were mainly the consequence of the increase of the harvested area and the

Table 1. Production, imports, exports, harvested area, and self-consumption of soy in Mexico (selected years: 1990-2022).

Year	Production (Q) ton.	Yield (Ton/Ha)	Harvested Area (AC) (ha)	Exports (X) ton	Imports (M) ton	Apparent Consumption (C)(ton). C=Q+M−X	Self-consumption (Q/C)
1990	575,366	2.01	285,615	74	897,021	1,472,313	0.39
1991	724,969	2.12	341,679	0	1,489,310	2,214,279	0.33
2000	102,314	1.46	69,969	1,728	3,984,886	4,085,472	0.03
2006	81,113	1.50	54,211	191	3,765,610	3,846,532	0.02
2017	432,927	1.65	262,602	100	4,343,000	4,775,827	0.09
2018	324,210	1.70	190,628	0	4,343,000	4,667,210	0.07
2019	232,679	1.59	145,923	0	4,853,000	5,085,679	0.05
2020	246,019	1.57	156,979	0	5,727,000	5,973,019	0.04

Source: SIAP, 2022.

importation. This increase is the result of the soy production contraction, although other variables also influenced the results. Based on these results, a set of public policy actions are proposed to increase domestic soy production.

MATERIALS AND METHODS

This research sought to establish the relationship between the *Producción* (*Production*) dependent variable and the *Superficie cosechada* (*Harvested Area*) and *Importaciones* (*Imports*) independent variables, using the stepwise method. First, a search for a relationship between each independent variable and *Producción* was carried out, including only the significant variables. Subsequently, a multiple regression model was tested —returning to a simple lineal regression model, if the determination coefficient did not significatively improve. R (R Core Team, 2022) was used to perform all the statistical analysis and the lmtest package software was used to diagnose the models (Achim and Hothorn, 2002).

Two econometric models were tested based on the objectives of this study, in order to identify the variables that impacted the behavior of soy production and importation in Mexico, during the 1990-2020 period. The two models evaluated the relationship between soy production, soy importation, and the harvested area in the country. In the mid-1990s (1994), soy production in Mexico grew, reaching its maximum point in 1991. This maximum point has not been surpassed yet. Soy production diminished and soy importation increased in order to cover the growing domestic market, after the NAFTA and the agricultural liberalization measures entered into force.

The two econometric models attempted to explain the domestic soy production, based on the area variable (as dependent variable), during the 1990-2020 period. A lineal regression was developed to understand the harvested area effect in soy production. The second model attempted to explain the relationship between soy importation and soy production, as a dependent variable.

RESULTS AND DISCUSSION

The results of the two developed and tested econometric models are included below. Subsequently, the results are discussed. On the one hand, the fall and the scarce soy production capacity in Mexico is explained. On the other hand, a set of actions is proposed to increase domestic soy production.

The following equation was used for the first model:

$$y_{ij} = \beta_0 + \beta_1 x_j + \varepsilon_{ij} \tag{1}$$

Where: y_{ij} is Producción$_i$ (Production$_i$) in soy tons in Superficie$_j$ (Area$_j$). x_j is Superficie$_j$ harvested in hectares. ε_{ij} is the random error of Producción$_i$ in Superficie$_j$.

Assumption of the model:

$$y_{ij} \sim \mathrm{NI}\left(\mu_y, \sigma_y^2\right) \tag{2}$$

$$x_j \sim \mathrm{NI}\left(\mu_x, \sigma_x^2\right) \quad (3)$$

$$\varepsilon_{ij} \sim \mathrm{NI}\left(0, \sigma^2\right) \quad (4)$$

$$V\left(\varepsilon_{ij}\right) = \sigma^2 \quad (5)$$

Hypothesis:

$$H_0 : \beta_1 = 0$$

$$H_1 : \beta_1 \neq 0$$

A lineal regression was carried out in order to understand the harvested area effect on soy production. To evaluate linearity between variables, a scatter plot was developed, along with the line of the estimated lineal regression model (Figure 1). The visual examination indicated a lineal relationship between harvested area and production. The visual examination of histograms and graphs of the standardized residuals suggests normality; however, there was no homoscedasticity. Consequently, several models were evaluated, using the logarithmic transformation of the production and the harvested area, one at the time, and both at the same time.

The model that best corrected the homoscedasticity problems was obtained using a logarithmic transformation of *Producción*. The visual examination of the graphs and

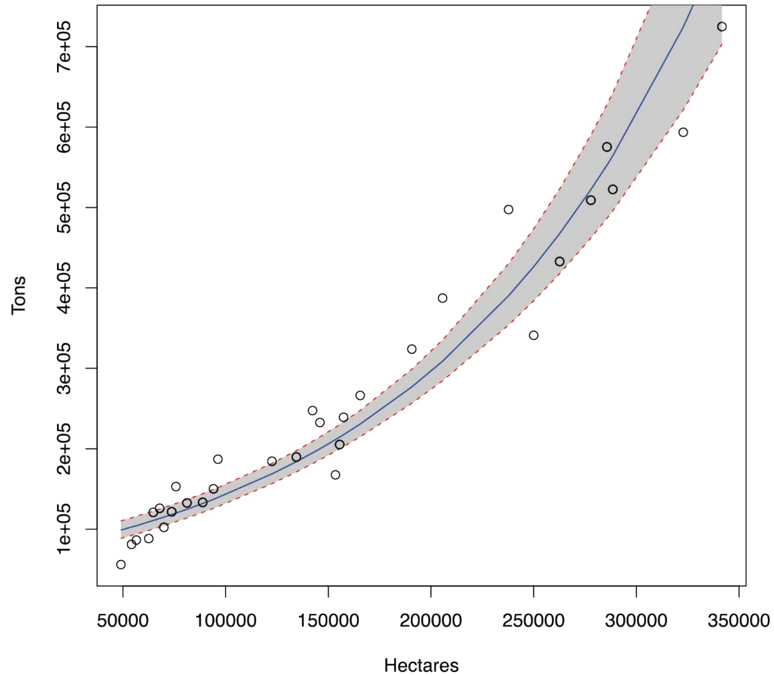

Figure 1. Relationship between soy production and harvested area during the 1990-2020 period. The figure was developed by the authors.

the application of both the Shapiro-Wilks (0.941, p=0.08819) and the Kolmogorov-Smirnov (0.1077, p=0.8872) tests showed that the standardized residuals had a normal distribution. Meanwhile, the Breusch-Pagan $\left(\chi^2(1)=1.624,\ p=0.2025\right)$ test confirmed the homoscedasticity of the errors of the variance.

The following prediction equation was used:

$$Producción_i = \exp^{11.144771+7.275\times10^{-6}}\left(Superficie_j\right)$$

The soy production was predicted in a statistically significant way, based on the harvested area $F(1, 29)=339.1$, $p<.001$, counting 92% of the production variation with a R^2 adjusted=91.85%.

The second model tried to explain the relationship between the soy importation and production. When NAFTA came into force in 1994, the soy production and soy importation trends in the country changed. Soy importation grew at very high rates, while soy production has remained stagnant.

Another evaluated econometric model links *Importaciones* (*Importation*) as a dependent variable of the *Producción* (*Production*), *Superficie* (*Area*), and *Precio* (*Price*) as independent variables. Producción was the only independent significative variable that can determine the behavior of importation during the analyzed period.

The equation of the second model was as follows:

$$y_{ij} = \beta_0 + \beta_1 x_j + \varepsilon_{ij} \tag{6}$$

Where: y_{ij} are the Importaciones_i (Importation_i) in US dollars, along with the domestic Producción_j (Production_j). x_j is domestic soy Producción_j (Production_j) in tons. ε_{ij} is the random error of Importaciones_i, with Production_j.

Assumption of the model:

$$y_{ij} \sim \text{NI}\left(\mu_y, \sigma_y^2\right) \tag{7}$$

$$x_j \sim \text{NI}\left(\mu_x, \sigma_x^2\right) \tag{8}$$

$$\varepsilon_{ij} \sim \text{NI}\left(0, \sigma^2\right) \tag{9}$$

Hypothesis:

$$H_0 : \beta_1 = 0$$

$$H_1 : \beta_1 \neq 0$$

In order to evaluate the linearity between variables, a scatter plot was developed, along with the line of the estimated lineal regression model. The visual examination indicated a lineal relationship between importation and production (Figure 2). The visual examination of the histograms and graphs, as well as application of the Shapiro-Wilks (0.9636, p=0.3819) and Kolmogorov-Smirnov (0.136, p=0.5887) tests, showed that the standardized residuals had a normal distribution. Meanwhile, the Breusch-Pagan $\left(\chi^2(1)=3.321, p=0.06842\right)$ test confirmed the homoscedasticity.

The prediction equation was the following:

$$Importaciones_i = 4243144 - 2.89\ Producción_j$$

which means that a reduction of 2.89 tons of imports is expected per ton of soy production. Soy importation was predicted in a statistically significant way by production, $F(1, 29)=12.44$, p=0.001, with 30% variation in importation.

Relationship between production, importation, and harvested area

The two models confirmed the effects of the production, harvested area, and importation variables on soy production and importation in Mexico. During the 1990-2020 period, the increase of the domestic soy production resulted from changes in the harvested areas and not from technological efficiencies. Consequently, the modest increases of the period were mainly the result (R^2=92%) of an expansion of the sowing area. This situation proves that this factor is the main source of growth. Derived from the possible increase in productivity, yield and other factors were not the cause of this increase. However, this factor alone is not enough to guarantee a soy production increase in the country. The increase of the area is

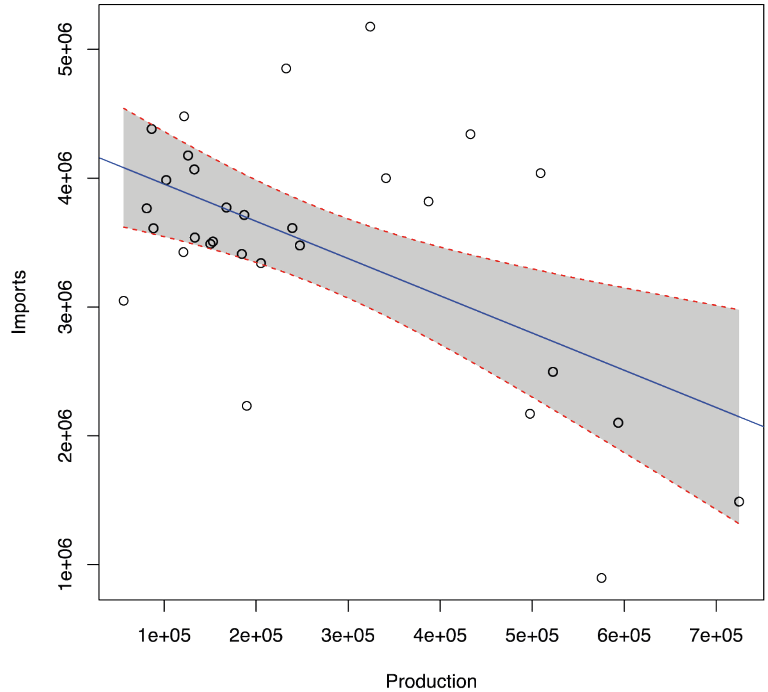

Figure 2. Relationship between importation and production during the 1990-2020 period. Figure developed by the authors.

a limited factor, because soy competes with other products that can also attract productive investment.

The second model proved that imports are directly determined by the production variable. This result shows that the increase in the domestic market was mostly met using imports, given the low sensitivity of the domestic offer to respond to the stimulus of the demand. This phenomenon can be explained by a R^2 of 30%, which means that other factors are involved in the importation level, but were not taken into consideration in the model. These factors led to an exponential growth of imports during the said period.

An approach to the limited domestic production

Between 2000 and 2020, the commercialized value, the volume, and the harvested area grew at an average annual rate of 15%, 6.44%, and 4.73%, respectively (SIAP, 2022). Yields have not grown; quite the opposite, they remained stagnant, although there were important differences among states. The domestic average was 1.35 t ha^{-1} —lower than the average value in the northwestern Mexico and far below the yields of the leading countries.

Several factors are responsible for the low yields of the domestic production. One factor is the cost of technology, machinery, fertilizers, and technological packages in the domestic market, which are higher than the relative prices that producers pay in leading countries. Another factor that impacts soy production is the productive model. After the Mexican Revolution, the land was divided into plots. These small properties (*ejidos*) are still the dominant type of private property in the country. Meanwhile, in the main world producers (the United States, Brazil, and Argentina) ranchers own large properties. The situation in Mexico is very different, since the smallholding structure still prevails (Escobar, 2016; Urioste, 2012). This difference mainly impacts the productivity of certain crops, such as grains, which require machinery and technology to appropriate economies of scale, which are a source of high productivity for this type of crop. Other crops require a lower scale to achieve high productivity and, therefore, their technification level is lower. From the mid-1980s, the implementation of liberalization policies in the Mexican economy started to rupture the ejido structure. In 2013, 77% of the land structure was still made up of <5.0-ha *ejidos* (SAGARPA, 2013). Consequently, the size of the agricultural exploitation areas has been a key limitation for the spread of the technological packages of the multinational companies (García Fernández *et al.*, 2014).

Actions proposed to increase the domestic soy production

As a consequence of the permanent soy deficit of the country, importation reaches an annual expenditure of approximately US$3,000,000. After corn, soy is the most important grain included among the Mexican agricultural imports. Several actions related to the soy value chain are required to strengthen strategies that should be carried out by the private sector and the different government institutions, in order to promote an increase in the domestic production.

One of the main actions is the urgency to provide affordable interest rates for rural producers and companies that require fundings. Currently, the inequality regarding foreign competitors is huge. Several private and public banks offer this kind of fundings, but their offers are not attractive enough to make the risk worthwhile. In addition, the bureaucratic costs (mainly the waste of time) discourage this type of procedure. The fundings must not only take into consideration the production elements, but also include the purchase market risk management tools, which can help producers to mitigate in advance their uncertainty.

Currently, producers cannot afford purchasing new machinery, as a consequence of the low profitability levels. Therefore, productive arrangements for collective groups (productive and commercialization associations) are a feasible alternative when managed as a company. At this point, the public sector can play an important role, providing the tools required to encourage the purchase of technology and materials. The federal government can also encourage the creation of producer associations, awarding various prizes, tax reductions, or another type of incentives.

At regional level, Mexico has experts on soy cultivation. Consequently, the Mexican government must actively promote knowledge transference. The experts can help the producers depending on the specific needs of their production units, adapting technological packages and optimizing the resources to reduce production costs.

CONCLUSIONS

Increasing the consumption of soy in Mexico is a major pending issue. Despite the progressive increase of the demand, soy production has remained stagnant and has not surpassed the levels reached before the 1990s. The prevailing productive model in Mexico accounts for the setback of the domestic production, which impacts soy and all grains. The situation became more pronounced once the NAFTA came into force. The agreement promoted and deepened the specialization of the country's economy in certain goods and increased the dependency on other imports (*e.g.*, almost all grains). This overview of the economy of the country —regarding the specialization of the agricultural sector— forces the sector, as part of a development strategy, to implement a set of actions, aimed to the improvement of food safety in the domestic grain production.

The econometric models verified the role of the increase of the harvested area in the evolution of the domestic soy production. The predominant productive model is based on the extensive growth of the land productive factor. Although some actions have been implemented to promote the use of science and technology as a growth factor, the efforts have not managed to promote a change in the productive model and to respond to the growth of the demand through an intensive growth of the offer. There is still a long way to grow at the pace that the domestic demand requires. Therefore, the second econometric model proved that soy importation has been determined by the scarce capacity of the domestic production to meet the demands of the growing domestic market.

The proposed actions seek to provide affordable fundings for producers, to encourage them to create associations, to award productivity prizes, and to increase resources for the research about oilseeds and the transference activities with producers. All these actions should modify the grain productive model in the country and could contribute to the transformation of the Mexican agricultural sector, and the life conditions of producers, particularly medium and small producers.

REFERENCES

Achim, Z., & Hothorn, T. (2002). Diagnostic Checking in Regression Relationships. *R News, 2*(3), 7–10.

Claridades Agropecuarias. (1997). Los últimos años de la producción de soya en México. 50.

Escobar, G. (2016). Estructura y tenencia de la tierra agrícola en América Latina y el Caribe. *Nueva Sociedad*, 3–8.

FAOSTAT, F. and A. O. of U. N. (2022). *Datos sobre alimentación y agricultura*. Cultivos y Productos de Ganadería. https://www.fao.org/faostat/es/#data/QCL

García-Fernández, F.;, Legarreta-González, M. A. ., & Serna Hinojosa, J. A. (2018). La producción de soya en México y en el mundo. Datos sectoriales. In Francisco; García-Fernández, A. L. Domínguez-Jardines, & A. Galván Vera (Eds.), *Sistema de innovación y cadena de valor de la soya en el noreste de México* (1st ed., p. 185).

García Fernández, F., Sánchez Muñoz, N. E., & Sánchez Tovar, Y. (2014). Análisis y estrategias para potenciar la cadena de valor de la soya en la región El Mante (Tamaulipas), México. *Agroalimentaria, 20*(39), 119–135. http://www.saber.ula.ve/handle/123456789/39125

R Core Team. (2022). *A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria*.

SAGARPA. (2013). *Comparecencia de Enrique Martínez y Martínez, titular de la Sagarpa en la Cámara de Diputados*. http://www.sagarpa.mx/saladeprensa/discursos2012-2018/Paginas/2013D010.aspx

SIAP. (2022). *Anuario Estadístico de la Producción Agrícola*. http://infosiap.siap.gob.mx/aagricola_siap_gb/ientidad/index.jsp

Urioste, M. (2012). Concentration and "foreignisation" of land in Bolivia. *Canadian Journal of Development Studies / Revue Canadienne d'études Du Développement, 33*(4), 439–457. https://doi.org/10.1080/02255189.2012.743878

World Bank. (2018). *World Bank Commodities Price Data* (*The Pink Sheet*).