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Geographic distribution of the production of certified corn (*Zea mays* L.) seed

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ABSTRACT

Objective: To analyze the effects of a greater geographic dispersion of municipalities that produce and consume certified corn seed in the State of Mexico.

Design/Methodology/Approach: A solution for the spatial equilibrium model applied to the certified seed market in the State of Mexico was reached in 2019.

Results: The results indicate that a greater geographical dispersion of producing and consuming municipalities would reduce production costs by 0.8% and increase income, distribution costs, and profits by 0.1, 3.0, and 1.3%, respectively, as compared to the data observed in the studied year.

Study Limitations/Implications: The positive effects observed in this study suggest that a greater geographical dispersion would benefit regions whose municipalities have a high potential to produce certified seed.

Conclusions: In addition to having a moderate effect on profits, the greater geographic dispersion would benefit corn producers, who would have a greater access to certified seed. As a result, both the seed use rate in the region and the yield level per hectare would increase.

Keywords: Corn, Certified seed, Geographic concentration, Earnings, Spatial equilibrium model.

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INTRODUCTION

The State of Mexico uses around 54% of its agricultural area for the cultivation of corn (INEGI, 2016), which accounts for 44% of the production value in the state's agricultural sector (SIAP, 2020).

During the 2010-2019 period, corn production experienced an average annual growth of 3%. Part of this growth resulted from a 2% yield increase, which shows a rise in productivity per surface unit (SIAP, 2020). Among other factors, this increase in productivity is the result of the intensified adoption of technological packages (Rodríguez and Donnet, 2015). Technological use data indicate that, in 2014, 29% of the state's cornfields used some type of improved seed, while in 2020 the use rate of improved corn seed was close to 40% (SIAP, 2017). These figures —which are similar to those estimated by Donnet *et al.* (2020)—

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indicate a slow (2%) but constant increase in the use of improved seeds in the state and show that most cornfields do not use this type of seeds.

The low use rate of improved seed, along with a slow adoption process, is caused by, among other things, the prevalence of small farms. Statistics from the 2017 agriculture census indicate that 60% of the land used for open sky agriculture in the State of Mexico is cultivated by small farmers in plots of 0-5 ha (INEGI, 2016); these farmers have financial difficulties. INEGI (2017) reports that 81.7% of the producers who received a loan used it to buy improved supplies.

For small- and mid-scale producers, the final price of the seed (determined by the type of hybrid), as well as its availability and accessibility, is decisive when deciding whether or not to use improved seeds (Sierra-Macías *et al.*, 2016).

Certified seed is produced in areas of the State of Mexico where grain corn is produced, 60% of which are concentrated in the Rural Development District (RDD) of Atlacomulco, 20% in Toluca, and the rest in Texcoco (SNICS, 2020).

Unlike Sinaloa, Jalisco, or Guanajuato, the companies that produce certified seed in the State of Mexico are small companies whose production is below 50 tons (MacRobert, 2014). Virgen-Vargas *et al.* (2016) identified 35 companies in the high valleys. Eight of those companies produced certified seed in 2019 (SNICS, 2020): 263 tons and an average yield of 2.79 t ha^{-1} during the 2019 spring-summer cycle. These companies produced certified seeds of 11 hybrids, three Open Pollinated Varieties (OPV), and two Synthetic Varieties (SV). Of all the seeds produced in the state, 54% comprise three varieties: H-50, CP-HS2, and H-52. Data of the cultivated area and the use of seed per hectare recommended by INIFAP (2017) indicate that the previous production represents 6.6% of the improved seed (SIAP, 2017) and 2% of all the grain corn seed used in the state.

The concentration of production in three RDDs and its low volume have restricted availability and accessibility for other municipalities that produce corn and have a high use rate of improved seed. This is the case of the District of Zumpango, with a use rate of 78% (SIAP, 2017), which makes it an important area for the production of certified seed.

A difficult access to certified seeds forces producers to acquire improved seeds that do not have an adequate certification or even informal seeds (CEDRSSA, 2015). Likewise, the higher prices resulting from the transportation costs (from the producing to the consuming areas) discourages them altogether from acquiring this kind of seeds. Distribution costs can reach 30% of the overall cost of a sack of seed and it might take as long as 30 days for the orders to be delivered (personal communication, Customer Service and Sales Office. Empresa La Semillera, August 2020).

A spatial redistribution of producing areas would improve the income of seed production companies, as well as the access of consumers to seed. They may even obtain them at better prices, as a result of a reduction in distribution costs in the producing and consuming areas.

Therefore, the aim of this study is to propose a spatial redistribution of certified seed production in the State of Mexico. This redistribution would accomplish the following objectives: a) to improve the certified seed producers' profits; and b) to favor a better access to certified seeds for small- and mid-scale producers who use improved supplies.

MATERIALS AND METHODS

In order to achieve the objectives, a spatial equilibrium model was used to develop a model of the spatial dispersion of certified seed production and consumption. The model is based on Takayama and Judge (1971); the solution seeks to replicate the current operation of the certified corn seed market in the State of Mexico. The scenarios developed consider redistributions of production and consumption that differ from the distribution observed in the base year.

The target function maximizes the net profit as an indicator to measure competitiveness, which equals the income resulting from certified seed sales, minus the costs of production, distribution, and shipment of the certified seed to nearby regions outside the state. The surplus production of the certified seed in producing areas is transported to consuming areas. The model considers the irrigation regime for certified seed production and both water regimes in the case of consumption.

Supposing that $i(i=1,2...I)$ represents the certified corn seed producing regions; $j(j=1,2..J)$ the seed consuming regions; $n(n=1,...N)$ the seed export points (shipment to regions outside the state); and $t(t=1,...T)$ the production cycles, the model could be formulated as follows:

$$Max\ Z = \sum_{t=1}^{T} \sum_{j=1}^{J} \left[p_{jt} y_{jt} \right] + \sum_{t=1}^{T} \sum_{n=1}^{N} p_{nt} y_{nt} - \sum_{t=1}^{T} \sum_{i=1}^{I} cp_{it} x_{it} - \sum_{t=1}^{T} \sum_{i=1}^{I} \sum_{j=1}^{J} cp_{ijt} x_{ijt} - \sum_{t=1}^{T} \sum_{i=1}^{I} \sum_{n=1}^{N} ct_{int} x_{int} \quad (1)$$

Where p_{jt} is the price for the seed consumer in j for period t; y_{jt} is the consumption of certified seed in j; cp_{it} is the production cost in i; x_{it} is the amount produced in i; p_{nt} is the price at the export point n; x_{nt} is the amount exported through n; ct_{ijt} are the transportation costs from i to j; x_{ijt} are the seed shipments from i to j; ct_{int} are the transportation costs from i to n; x_{int} in are the seed shipments from i to n.

The target function is subject to the following restrictions:

$$\sum_{i=1}^{I} x_{ijt} \geq y_{jt} \quad (2)$$

$$x_{it} \geq \sum_{j=1}^{J} x_{ijt} + \sum_{n=1}^{N} x_{int} \quad (3)$$

$$\sum_{n=1}^{I} x_{int} \geq x_{nt} \quad (4)$$

$$x_{it}, y_{jt}, \ldots x_{int} \geq 0 \quad (5)$$

Equation 1 maximizes the net profit, which equals the income resulting from seed sales, minus the costs of production and transportation. Restriction 2 determines how the corn seed demand is met in each consuming area. Restriction 3 indicates how the seed production is distributed. Equation 4 establishes that seed shipments from producing regions in the State of Mexico must surpass seed consumption in regions outside the state. Equation 5 establishes the non-negativity conditions.

The model's solution considers eight producing municipalities, 15 consuming municipalities, and two municipalities adjacent to the State of Mexico. Figure 1 highlights the established producing and consuming municipalities, as well as the adjoining states.

To analyze the benefits of redistributing the certified seed producing areas, first the solution for the model in a base situation was obtained. Subsequently four scenarios were developed. Scenario 1 considered the eight producing municipalities of the base scenario, but increasing the number of consuming municipalities from 17 to 22 (base+potential), and limiting the supply of the production to municipalities within the state. Scenario 2 considered the same municipalities as scenario 1, plus two consumer municipalities outside the state, for a total of 24 municipalities. Scenarios 3 and 4 considered ten producing municipalities (base+potential), while the consuming municipalities remained the same as in scenarios 1 and 2.

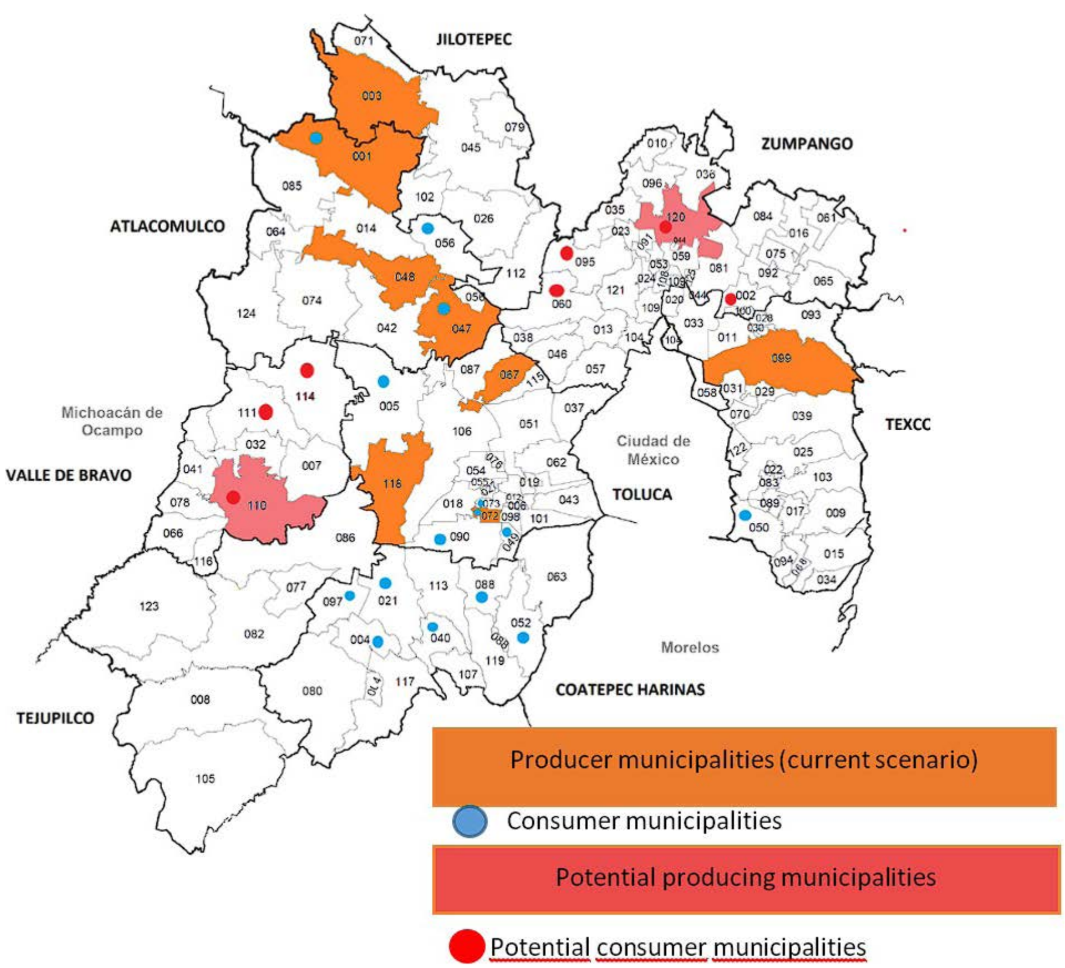

Figure 1. Spatial distribution of current and potential producing municipalities.

The consuming areas of the base and potential scenarios are those that demand certified seed according to the commercialization of corn grain, the area used to grow corn in each municipality, and the yields that suggest the use of agricultural technology (*e.g.*, improved seed, either prepared or certified). The scenario's consuming areas were established based on the following criteria: a) a cultivated area larger than 1,000 ha; b) a yield higher than 4 tons (in average); and 3) a use rate of improved seed higher than 40%.

By applying the aforementioned criteria, were identified 15 consuming municipalities and detected focalized potential consuming areas outside the zones where certified seed production and consumption are currently carried out; however, these areas were determined based on more flexible restrictions. They are located in the RDDs of Zumpango —with a surface of over 700 ha, a yield of 2.5 t ha^{-1}, and a use rate of improved seed higher than 40%— and Valle de Bravo —with a surface of over 700 ha, a yield of over 3.7 t ha^{-1}, and a use rate higher than 25%. The distribution of consumption within each municipality was estimated based on García and Ramírez (2012).

The data were taken from the several sources. Production by water regime and production cycle data were found in Córdova-Téllez *et al.* (2019), SNICS (2020), and SIAP (2020). Seed shipments from the State of Mexico to other states and certified seed production costs were taken from a personal communication from Mancera-Rico (2020), professor-researcher in postharvest seed handling at the Universidad Autónoma Agraria Antonio Narro. The price of the different hybrids was provided by SNICS (2017) and COLPOS (2020). Distribution costs from producing to consuming areas were estimated based on distances and tolls (RCO, 2020). Operation costs in Mexican pesos per vehicle-kilometer for 2019 were found in Arroyo-Osorno (2020), while loading and unloading costs were taken from Transportes SIGFRA (2019). Costs were calculated considering a general quote based on the loading and unloading cost divided by the transported volume. Potential producing areas were determined based on information from SIAP (2017) and the preference for certified seed per municipality was established using data from SIAP (2017; 2020).

RESULTS AND DISCUSSION

Figure 1 shows the current and the potential spatial distribution of producing and consuming municipalities. The current geographic distribution is characterized by a high concentration of municipalities where improved seed is produced and consumed in the Districts of Atlacomulco and Toluca. Meanwhile, the Districts of Zumpango, Valle de Bravo, Tejupilco, and Coatepec Harinas do not have municipalities that produce certified seed.

Table 1 presents some economic indicators related to the production and distribution of improved seed in the base model. Income, production costs, and distribution costs amounted to 15,359, 4,520, and 876 million pesos, respectively, which resulted in a profit of 9,865 million pesos.

Scenario 1 considers the same producing municipalities as the base scenario, but the number of consuming municipalities increases from 15 to 22 (17 municipalities that currently consume certified seed plus five potential consumers). In this scenario, the production of improved seed remains constant and, therefore, production costs do not change; however, more consuming municipalities results in a 12.6% increase in distribution costs. Higher costs, together with a lower income, reduced the profits by 57,000 pesos: a drop of 0.6% in relation to the profits observed in the base model.

Scenario 2 considers the same producing and consuming municipalities as scenario 1, but takes into account 50% more shipments outside the state than the base scenario. This involves sending part of the production outside the State of Mexico, while the rest is distributed among the potential consuming municipalities. The results of scenario 2 show an 0.2% income increase regarding the base scenario. Production costs remain unchanged, while distribution costs increase by 3.0% in relation to the base model. The increase in income is canceled by the increase in distribution costs, resulting in the same profits as in the base model.

The income in scenario 3 drops by 43,000 pesos, which entails a decrease of 0.3% in relation to the base model. Production costs decrease by 0.8% as a result of the type of hybrid suggested in the new municipalities, based on the weather conditions of the proposed areas. Given their location, distribution costs increase by 9.2%, which means that circulating the seed among producing and consuming municipalities within the state is more expensive than sending the seed to municipalities outside the state.

Table 1. Income, costs, and profits of certified seed production and distribution in the State of Mexico, 2019 (thousands MXN).

Scenario	Municipalities		TUSM %	Yield t ha^{-1}	Income	Costs		Profit
	producers	consumers				production	distribution	
					thousands MXN			
Base model	8	17	greater than 40	greater than 4	15,359	4,522	877	9,865
Scenarios								
1	8	22	25 y 40		15,316	4,522	987	9,808
2	8	24	25 y 40		15,382	4,522	903	9,868
3	10	22	25 y 40	between 2.5 and 4	15,316	4,484	957	9,875
4	10	24	25 y 40	between 2.5 and 4	15,382	4,484	903	9,995
Change with respect to the baseline situation								
1	0	5	-	-	−43	0	110	−57
2	0	7	-	-	23	0	26	3
3	2	5	-	-	−43	−38	80	10
4	2	7	-	-	23	−38	26	130
Change in % with respect to the baseline situation								
1	-	-	-	-	−0.3	0.0	12.5	−0.6
2	-	-	-	-	0.1	0.0	3.0	0.0
3	-	-	-	-	−0.3	−0.8	9.1	0.1
4	-	-	-	-	0.1	−0.8	3.0	1.3

Source: Developed by the authors based on the results for the base model and the four scenarios.

Income in scenario 4 increases by 0.2% regarding the base model. Production costs drop by 0.8%, while distribution costs increase by 0.3%. In this scenario, profits were 1.3% higher than in the base model.

Profits do not change significantly from one scenario to the other. This was as expected, since the production of certified seed remains constant; however, we must point out that if certified seed producers took the initiative to produce in these areas, their profits would remain the same. Nevertheless, both accessibility for producers and availability of the certified seed would increase.

These results indicate that changes in the distribution logistics of production and supply (in this case, certified seed) frequently have positive and negative effects on variables such as income, production and distribution costs, and profits for producers. García-Salazar and Skaggs (2015) show similar effects regarding distribution costs after yellow corn replaced white corn in a given area, as a consequence of a change in consumption. When roads or transport routes are in poor conditions or the areas are difficult to access, distribution costs are frequently higher, potentially increasing the time and cost needed to reach the consuming areas (Ayllon-Benítez *et al.*, 2015). This situation affects producers with less accessibility and lower consumption levels. Preference is given to nearby areas (in this case, in adjacent states), thus hindering the growth of consuming areas within the state. Similarly, seed costs for grain producers can vary significantly if distribution costs are reduced and accessibility is improved.

CONCLUSIONS

Currently, the geographic distribution of improved seed production and consumption is notably concentrated in the RDDs of Atlacomulco, and Toluca, and to a lesser extent in Texcoco. Some municipalities have the potential to become certified seed producers and consumers, which indicates that dispersing the municipalities that already produce and consume certified seed is possible.

The solution of a spatial equilibrium model applied to the certified seed market in the State of Mexico indicates that a better spatial distribution of production and consumption —by means of a geographical dispersion of municipalities with the potential to produce and consume improved seed— would improve distribution costs, but would not have any effects on producers' profits. If the certified seed were sold in regions outside the State of Mexico, the seed-producing companies would see moderate increase in their profits.

The geographic dispersion of the certified seed production in the different municipalities would entail an improvement in the access of producers to the improved seed, which would encourage its use and dissemination, and would therefore lead to an increase in the use rate of certified seed. Bringing the producing and consuming areas closer would also improve prices, encouraging producers to change from low potential seeds to seeds with a higher production potential.

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