EVALUATION OF THE EFFECTS OF MEXICAN TRADE POLICY ON THE MAIZE MARKET

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Abstract:

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The Texas Agricultural Market Research Center (TAMRC) *has been providing timely, unique, and professional research on a wide range of issues relating to agricultural markets and commodities of importance to Texas and the nation for over thirty years.* TAMRC *is a market research service of the Texas Agricultural Experiment Station and the Texas Agricultural Extension Service. The main* TAMRC *objective is to conduct research leading to expanded and more efficient markets for Texas and U.S. agricultural products. Major* TAMRC *research divisions include International Market Research, Consumer and Product Market Research, Commodity Market Research, Information Systems Research, and Contemporary Market Issues Research.*

EVALUATION OF THE EFFECTS OF MEXICAN TRADE POLICY ON THE MAIZE MARKET

Executive Summary

The Mexican trade policy allowing the entrance of duty-free maize imports beyond the quota established by the North American Free Trade Agreement (NAFTA) has been severely criticized because of its affects on Mexican production. To assess this and other trade policies on the Mexican maize market, as well as changes in the exchange rates and transportation costs, a model of spatial and intertemporal equilibrium is estimated and used.

The results indicate that if the quota established by NAFTA in 1998/2000 had been respected, the production would have increased by 1.2 million tons, consumer prices would have increased 13.5%, and consumption would have dropped by 1 million tons. In 1998/2000, a free trade policy would have put maize imports at 6.4 million tons. Consumer prices would have fallen 8.1% and production would have been 17.2 million tons, a figure that surpasses the reported production before NAFTA was implemented.

Because the maize market is strongly dependent on foreign trade, it is very sensitive to the exchange rate. In 1998/2000, a 25% devaluation of the Peso (relative to the U.S. Dollar) would place the 3.5 million ton imports in conditions for a total free trade. In contrast, an increase of 20% in costs of transportation from the ports of entry to the cities where the imports are consumed would have little effect on the maize market, although it would affect the composition of the imports by port and border. By the year 2008, when the maize market will be totally liberalized, it is expected that imports will ascend to 6.5 million tons.

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EVALUATION OF THE EFFECTS OF MEXICAN TRADE POLICY ON THE MAIZE MARKET

In the mid-eighties, the government of Mexico abandoned the interventionist model of import substitution to orient the economy toward foreign trade through liberalization. The reforms included trade liberalization via trade agreements with several countries in Europe and North and South America, elimination of subsidies, sale of government enterprises, and suspension of control over prices.

In the agricultural sector, the economic reforms covered numerous areas. Guaranteed prices of staple foods and the duties on some of them were eliminated. The Compañía Nacional de Subsistencias Populares (CONASUPO), which commercialized much of the agricultural production, was shut down. The system of granting subsidies underwent reform and subsidies to inputs, credit, and insurance disappeared while direct aid to production and subsidies to commercialization appeared.

In 1994, NAFTA established a plan for Mexico to liberalize trade in 10 to 15 years for some farm products. This plan fixed duties and import quotas and their yearly reduction over the period up to total trade liberalization. For maize, a tariff-quota plan was set up to substitute the maize import license, implicating the elimination of the government import license and its substitution by an *ad valorem* duty of 215%, or a set duty of $206 per ton. For maize imported from the United States and Canada, a quota of duty-free imports for the first year was fixed at 2.5 million and 1 thousand tons, respectively, and increased by 3% every year thereafter (SECOFI, 1994).

Previous the signing of NAFTA, predictions on its effects on the maize market foretold a drastic fall in the production of the grain (Levy and van Wijnbergen, 1992; STPS, 1994; Calva, 1995). Contrary to these predictions, there was a considerable increase after NAFTA. During the period 1990-1993 the average yearly production of maize was 14.84 million tons, while from 1994-2000, production rose to 18.12 million tons. (Comparison of 3-year production to 6-year production?) Several factors explain this growth including the direct aid granted to farmers through the PROCAMPO Program (Programa de Apoyos al Campo) and marketing policies backed by ASERCA (Apoyos y Servicios a la Comercialización Agropecuaria).

In spite of the high production achieved since NAFTA has been in effect, in some years, maize imports exceeded the quota set by the agreement. In 1993, 152 million tons of maize were imported and in 1994, maize imports were 2.22 million tons. The increase in consumption, the low international prices in 1994, and the low exchange rate are factors that explain the increase in buying from foreign markets. The devaluation of the Peso at the end of 1994 and the rise in international prices significantly increased the estimated cost of imports for 1995 for the various agents that were buying maize in foreign markets. For these reasons, the quota agreed upon for maize imports was complied with in 1995. The animal consumption growth from 6.69 million tons in 1995 to 8.26 million tons in

1996 shows that maize imports surpassed the NAFTA quota by 3 million tons. For 1997, the maize imports were 2.47 million tons, and for 1998, 1999, and 2000, the quota of 5 million tons was surpassed (SECOFI, 2000).

Along with an increase in production and imports, there was also an important rise in consumption, growing from 16.58 million tons in 1990-1993 to 22.15 million tons in 1994-2000. 3-year consumption compared to 6-year consumption. Several factors can explain this increment including the human population growth, but consumption as animal feed has been the most dynamic part of the increase in maize consumption.

Despite the considerable gain in maize production in the years NAFTA has been in effect, it has been suggested that the grain market, including maize, has lost the most within NAFTA because of the increase in imports (Cámara de Diputados, 2000; Senado de la República, 2000).

The increment in the quantity of maize imported, without the duty established by NAFTA, caused the Mexican government to be severely criticized. As of 1996, sovereignty and food self-sufficiency ceased being a goal within the framework of free trade for the government. By the third year under NAFTA, the designers of the agricultural policy had decided to eliminate the protection of maize that had been negotiated to remain until the year 2008 because it is a product that is sensitive to imports.

In 1996, the Mexican government allowed the importation of 5.82 million tons of duty-free maize: of which 5.63 million tons were from the United States, 155 thousand tons from South Africa, and 27 thousand tons from China. Mexico was obliged by NAFTA to allow entry of 2.65 million tons of duty-free maize from the United States, but the imports exceeding this quota would be protected by a 189.2% duty. The imports far surpassed the quota agreed on for year 14 of NAFTA (3.67 million tons), and, moreover, permitted duty-free imports from China and South Africa, which are not members of NAFTA.

The production and consumption of maize would have been different if the duties on imports exceeding the established quota had been charged. However, to what degree was consumption stimulated? And how much did production decrease because the tariff and quota were not observed as agreed on by NAFTA? With the inelasticity that characterizes human production and consumption, elements exist that make it possible to assume that the impact of establishing trade barriers would have been minimal. Likewise, it can be anticipated that social well being would have been less in a situation of more protection because of the contraction that would have occurred in consumption.

The sharp increase in imports and the social problems that have surfaced from the maize trade policies would suggest that Mexico is the loser in NAFTA dealings, at least in the market of maize. How certain is this observation? To answer these questions, it is necessary to evaluate alternate trade policies: the policy established by NAFTA, the policy that is actually put into practice, and a free trade policy. Because of the high costs of transportation from the U.S. ports to the Mexican consumer centers, and the low elasticity that characterizes the supply and demand of maize, it is expected that the effects of total trade liberation on production, consumption, and imports will not be highly significant.

In the long run, it is expected that imports will increase due to free trade and increased consumption. The U.S. Department of Agriculture predicts that maize sales to Mexico will increase to 6.5 million tons by the year 2008 (USDA, 2001). This points to a future in which supplying the needs of consumers will highly depend on foreign trade. It is this greater dependence that arouses interest in analyzing how the exchange rate and the costs of transportation impact domestic production and consumption, imports, and the trade flows. Because historically severe devaluations of the Peso relative to the U. S. Dollar have been accompanied by reductions in foreign trade, it is expected that maize imports are sensitive to changes in the exchange rate.

Objectives

The main objective of this study is to analyze the effects of alternate trade policies on production, consumption, and prices in order to compare the current policy implemented by the Mexican government with the NAFTA policy and a free trade policy. A second objective is to analyze how increases in the exchange rate (Pesos vs. U.S. Dollar) and rises in the costs of transportation from the entry points on the U.S. border and ports to the centers of domestic consumption in Mexico affect the maize market. A third objective is to be able to predict the situation of the maize market in the year 2008.

To obtain the first two objectives, a model of spatial and temporal distribution of the maize market is initially estimated and validated in production, consumption, prices, and imports by port and border for the "average year 1998/2000". In this base model, the trade policy implemented by the Mexican government that allows the entrance of duty-free maize imports beyond the quota established by NAFTA is considered; and this is introduced into the model by restricting imports according to the quantity registered in 1998/2000. The policy effects are determined by making the appropriate adjustments in the validated model, obtaining a new solution and comparing the results obtained with the base model. Several scenarios are examined. The trade policy established by NAFTA is introduced into the model by restricting imports according to their quota. The free trade policy is introduced into the model without restrictions placed on maize imports. Increases in the exchange rate of 15, 20, and 25%, were incorporated into the model by adjustments in the maize international price and a free trade policy is considered, that is, no restrictions were placed on imports in this scenario. Transportation cost increases of 20% were introduced into the model by adjustments in costs of insurance, ocean freightage, and domestic transportation from the entry points on the U.S. border and ports to the centers of domestic consumption. Rises in transportation costs were separately considered by borders, Gulf ports and Pacific ports. In this scenario imports registered in 1998/2000 were considered. The model solution represents: 1) trade policy established by NAFTA; 2) free trade; 3) increases in exchange rate and free trade; and 4) increase in transport costs. These were contrasted with the base model solution to estimate the impact on Mexican flow patterns, imports, production, consumption, and prices. Finally, the third objective is achieved by validating the model using information from the "average year 2007/2009".

Model and Data

Model

A model that permits the evaluation of alternate trade policies for the maize market in Mexico must consider several elements. The first of these elements is spatial segregation, the notion that production and consumption occur in separate places within the country and that the transportation of grain necessarily implicates a cost. Although maize is produced and consumed in all 32 states of the country, most of it is consumed in Mexico City and the surrounding metropolitan area, while most of the tradable surplus is concentrated in the northwestern and southern regions. The relatively large distances between the main producer-supplier regions and the main centers of consumption determine the importance of transportation costs.

The notion that production and consumption are realized over time is the second element. Maize production is characterized by its extreme seasonality: 75% of the domestic supply is harvested in November, December, January, and February. In contrast, consumption is relatively uniform throughout the year. This characteristic makes the cost of storage an important element in marketing the grain.

The degree of segregation of the market constitutes a third element. Producers, consumers, and importers of maize are all part of maize commercialization. (See original wording, did we interpret this right?) Segregating the different types of consumers that exist in the market is important because they respond differently to market stimuli and a given policy will have different effects on each of the agents. Trade barriers generally affect producers and consumers in opposite ways. The consumption of maize in Mexico can be classified by how it is used: human consumption, animal consumption, and industrial consumption, which includes consumption by seed and shrinkage losses.

A fourth element comprises the links the domestic market has with the international market since a good part of maize consumption is supplied by foreign grain. Because almost 100% of Mexican imports come from the United States, it is possible to contemplate domestic consumer centers and their connections to domestic supplier regions and U.S.-Mexico ports of entry, without including the rest of the world (Bivings, 1997).

The incorporation of the above elements into an economic model is possible when a model of distribution is constructed. Empirical studies that have used models of distribution to analyze the effects of policy on market variables, and have included Mexico, can be classified in the following manner: those that have used linear models of production and distribution; those that have used spatial equilibrium models; and those that have used spatial and intertemporal equilibrium models. Others use one of these modalities considering more than one product.

Nicholson (1996) uses a linear model of production and distribution to analyze trade liberalization in the milk sector of Mexico. Cramer, Wailes, and Shui (1993) studied the impacts of trade liberalization on the international market of rice. Boyd, Doroodian, and Abdul-Latif (1993) discussed the effect of free trade among the U.S., Mexico, and Canada

on production and trade flows of wood. Bivings (1997) studied the effect of sorghum market liberalization on production, demand, and imports of the grain in Mexico, applying a model of spatial and intertemporal equilibrium. Fuller, Fellin, and Salin (2000) analyzed the effects of liberalization on the U.S.-Mexico rice trade, using a model of multi-product spatial equilibrium. Gillis (1993) analyzed the economic effects of liberalization on the Mexico-U.S. onion trade, using a model of spatial equilibrium.

The spatial and temporal characteristics of the maize market determine the use of a model of spatial and intertemporal distribution to evaluate the effects of different trade policies on the maize market. Based on Takayama and Judge (1971) the target function of the model maximizes Net Social Payoff (NSP), which is equal to the areas below the demand curves, minus the areas below the supply curves, minus the value of the imports, minus costs of transportation and storage. The model of quadratic programming generates interregional trade flows and prices that result from maximizing consumer and producer surpluses minus the value of imports, costs of transportation, and costs of storage.

The model includes information on regional stocks and demands. In terms of availability, the production of 8 regions is considered, and, given the severe deficit of maize; it is permitted that the deficit be compensated by foreign imports that enter through some port or border. On the demand side, human, animal, and industrial consumption are considered; for purposes of balance, consumption of maize for seed and shrinkage losses are included in industrial consumption.

Both production and consumption enter as endogenous variables into the model, and linear functions of supply and demand are assumed. It is assumed, moreover, that supply and demand are intertemporally separable in price, that is, the supply and demand of maize from one period does not depend on the price in other periods.

An excess of supply in one producer region is linked to consumer centers through costs of transportation by truck or train. In a similar manner, the maize surpluses available in foreign markets are linked to consumer centers through costs of transportation by truck and train.

The model includes 8 supply and demand regions: Northwest[1], North, Northeast, West, Center, South, Gulf, and Peninsula. Eleven international ports/borders were included: Progreso, Veracruz, Tampico, Nuevo Laredo, Piedras Negras, Ciudad Juárez, Nogales, Mexicali, Guaymas, Mazatlán, and Manzanillo (Figure 1). The temporal analysis was done for the twelve months of the year.

Because maize production is characterized by extreme seasonality with consumption 12 months of the year, it is possible to introduce storage in maize producer regions. Due to the

[1] **Northwest** includes Baja California, South Baja California, Sonora, Sinaloa, and Nayarit; **North** includes Chihuahua, Coahuila, Durango, Zacatecas and San Luis Potosí; **Northeast** includes Nuevo León and Tamaulipas; **West** includes Jalisco, Michoacán, Colima, Aguascalientes and Guanajuato; **Center** includes State of Mexico, Federal District, Morelos, Hidalgo, Puebla, Tlaxcala and Querétaro; **South** includes Oaxaca, Chiapas and Guerrero; **Gulf** includes Veracruz and Tabasco; **Peninsula** includes Yucatán, Campeche and Quintana Roo.

lack of information on regional maize inventories, an estimation of initial inventories was made, and it was assumed that they were equal to final inventories. Storage of imports is also permitted at ports of entry; in this case it was assumed that initial and final inventories were equal to zero because imports of maize move more rapidly.

Because the government exerts control over maize imports through the Program of Import Quotas, the base model contemplates this situation with a restriction which establishes that the imports entering through different ports and borders in a given month must be equal to the permitted import quota in that month. This restriction is flexible in diverse scenarios that are constructed to evaluate the NAFTA and free trade policies. For the different scenarios, the same temporal distribution of the imports in the 12 months of the year is assumed. Because the exchange rate is necessary to calculate the maize international price in Pesos, the policy of exchange rates is introduced into the model through the international price (see target function in the Appendix).

The model solution is obtained using the MINOS, written in GAMS (General Algebraic Modeling Systems) programming language. The complete model, in its mathematical representation, is presented in the appendix.

Data

To estimate the spatial and intertemporal model it was necessary to estimate Mexican demand and supply equations, maize international prices, truck and train transportation costs from domestic supplier regions and entry borders/ports to domestic consumer centers, and maize storage costs.

Considerable effort was required to estimate model equations and parameters. For example, the 8 demand and supply regions in the maize model are individually represented by twelve (month) estimated inverse demand and supply equations. The supply and demand functions were calculated using the supply and demand price elasticity, prices to producer and consumer, and quantities supplied and demanded (Alston, Norton, and Pardey, 1995; Kawaguchi, Suzuki, and Kaiser, 1997).

Price elasticity of human and animal demand was taken from Garcia (1999), who econometrically estimated a model of simultaneous equations comprising six supply equations, two demand equations, four equations of price transmission, and three identities. Results reported by Garcia (1999) suggest price elasticity of human and animal demand of -0.041 and -1.29, respectively, for the period 1994-1996. This elasticity is used in the model for all regions and time periods. It was assumed that industrial demand price elasticity was the same as human demand price elasticity.

Supply price elasticity also came from Garcia (1999), who reported coefficients for three regions of Mexico (North, Center and South). In the spring-summer season supply price elasticities were 0.56, 0.51 and 0.44 in the North, Center, and South regions, respectively. As for the fall-winter season, the values were 0.83, 0.36 and 0.21 for the same regions, respectively. The demand and supply price elasticity at the national level reported by

Garcia (-0.32 and 0.55) are very close to that found by Sullivan, Wainio, and Roningen (-0.35 and 0.58).

The indicators used in the model refer to the average of three years. All average values for October to December were obtained from data observed in 1997, 1998, and 1999. From January to September all average values are from figures of 1998, 1999, and 2000. The year that runs from October to September of the following year is referred to as "average year 1998/2000."

Maize production by region and month from October 1997 to September 2000 came from predictions (do you say predictions when the time period has already passed?) from plantings and harvests estimated monthly by SAGARPA (2001). In 1998/2000 the primary maize producer regions were the West, South, Center, and Northwest with annual average production of 4.72, 3.96, 3.69, and 2.36 million tons, respectively. Maize inventories available at the beginning of October were calculated considering one month of human consumption, 15 days of animal consumption, and two months of industrial consumption (SAGAR, 1998).

Regional monthly consumption was calculated using the method proposed by Garcia (1999) and this estimates the maize consumed by humans, animals, and industry for each state, as well as that used for seed stock and shrinkage losses. Animal consumption is calculated with information on livestock production by state and ratios of conversion, while human and industrial consumption is estimated using information on industrial production of nixtamal milling, tortillas and starch. The information necessary for this calculation was obtained from SAGARPA (2001), SECOFI (2001), INEGI (1995), CANACINTRA (1996), and Fuller and Gutierrez (1992). In 1998/2000 the human, animal, and industrial consumption were 12.90, 7.97, and 2.05 million tons, respectively, and leading maize consumption regions are Center, West, and North with 7.06, 5.20, and 2.48 million tons, respectively.

Regional prices paid by the consumer and received by the producer were calculated using the international price of maize at the Mexican ports of entry. Shipping costs from port of entry to centers of consumption were added to the international price to obtain consumer prices. The maize average annual prices in the consumer regions ranged from $1,207 to $1,398 per metric ton. It was considered that the prices to producer were equal to consumer prices minus a margin of commercialization for transporting the grain from the farm to the consumer center. This margin of commercialization was calculated using the difference between maize wholesale price in the wholesale markets and the mean rural price received by the producers. Information for the mean rural price was obtained from SAGARPA (2000), and wholesale maize prices in the wholesale markets are from the Sistema Nacional de Información Integral de Mercados (SNIIM). The maize average annual prices in the supply regions ranged from $1,051 to $1,196 per metric ton.

Monthly and annual domestic import data, by port and border, came from SECOFI (2001). In 1998/2000 Mexican maize imports were 5.12 million tons: 55.7% enter via Gulf ports (Veracruz, Tampico, and Progreso); 43.4% enter via U.S./Mexico borders (Nuevo Laredo,

Piedras Negras, Ciudad Juarez, Nogales, and Mexicali); and only 0.9% enter via Pacific ports (Guaymas, Mazatlan, and Manzanillo).

International prices were imputed from U.S. Census data that related quantity and value of U.S. exports to Mexico by border crossing locations, and marine ports. The information came from U.S. International Trade Commission (USITC). The international price of maize considered the exchange rate, insurance, ocean freightage, cost of international financing, and entry costs. The import duty established by NAFTA was not included in any models since it has not been put into practice. The average annual international price for maize was $1,207 per metric ton for Gulf ports, $1,256 for Pacific ports, $1,046 for Ciudad Juárez, $1,178 for Nuevo Laredo and Piedras Negras, and $1,813 for Nogales and Mexicali.

The information on insurance and ocean freightage from ports on the Gulf of Mexico located in the United States to Mexican ports, as well as entry costs at ports and borders, was obtained from ASERCA (2000). Monthly insurance and ocean freightage ranged from $99 to $108 per metric ton. The average annual entry costs were $41 per metric ton for Gulf ports, $43 for Pacific ports, $48 for Mexicali, and $42 for Nuevo Laredo, Piedras Negras and Ciudad Juárez. The information on insurance and ocean freightage from U.S. ports on the Gulf of Mexico to ports located on the Mexican Pacific was obtained from the U.S. Department of Agriculture (USDA,). In this case monthly insurance and ocean freightage ranged from $133 to $162 per metric ton.

To calculate the cost of international financing, the libor rate was used, considering 15 days for entry through ports and one month for entry through borders. The libor rate and the exchange rate were obtained from INEGI (1999, 2000). The monthly libor rate ranged from 5.5% to 5.9% and the exchange rate ranged from 9.1 to 9.6 Mexican Pesos per U. S. Dollar.

Trucking costs were based on average fees paid to truckers during 1999 and 2000 (Dirección General de Tarifas (2000)). The truck transportation costs that linked production regions and entry borders/ports to consumer regions were estimated using a distance matrix and an average tariff of $0.5492 per ton/kilometer. Truck costs linking the Northwest, North, Northeast, South, and Peninsula regions to the Center Region were $903, $991, $652, $726, and $1,025 per metric ton, respectively, while costs from Gulf and West regions to the Center region were $291 and $393 per metric ton, respectively. The truck costs linking Nuevo Laredo, Piedras Negras, and Ciudad Juarez to the Center region were $809, $895, and $1,246 per metric ton, respectively, while costs from Veracruz and Tampico to the Center region were $291 and $357 per metric ton, respectively,

The cost of shipping by train from producing regions to consumer regions considers the freightage charged during 1999 and 2000 (Dirección General de Tarifas, 2000). Train transportation costs that linked supply regions to consumer centers were estimated using a distance matrix and an average tariff of $0.2908 per ton/kilometer. Truck costs linking the Northwest, North, Northeast, South, and Peninsula regions to the Center region were $408, $464, $268, $347, and $468 per metric ton, respectively, while costs from West and Gulf regions to the Center region were $173 and $122 per metric ton, respectively.

The cost of transporting imports by train from entry ports and borders to consumer centers was obtained from Transportacion Ferroviaria Mexicana (November 2001). Train costs that linked entry borders/ports to consumer centers were estimated using a distance matrix and the following tariffs: $0.463 per ton/kilometer for Nuevo Laredo-Northeast, $0.2531 for Nuevo Laredo-West, $0.2551 for Nuevo Laredo-Center, $0.4039 for Veracruz-Center, $0.2932 for Veracruz-West, $0.2945 for Tampico-West, and $0.3056 for Tampico-Center. Train costs linking Nuevo Laredo, Piedras Negras, and Ciudad Juárez regions to the Center region were $303, $319, and $499 per metric ton, respectively, while the train costs linking Veracruz and Tampico regions to the Center region were $169 and $266 per metric ton, respectively.

Finally, storage costs for importers and producers, which include handling at entry and exit, were obtained from ASERCA (June 2001). Storage costs were $52 per metric ton and this figure is used in the model for all regions, entry borders/ports, and time periods.

Information on yearly domestic consumption and production for the years 2007, 2008, and 2009 comes from the Committee of Agricultural Projections of the U.S. Department of Agriculture (USDA, November 2001). With this yearly data, monthly regional consumption and production were obtained, assuming a spatial and temporal distribution equal to the year 1998/2000. According to USDA's data, in 2007/2009 the Mexican maize consumption and production will be 27.03 and 20.54 million tons, respectively.

International price projections used to calculate consumer and producer prices were obtained from the Food and Agricultural Policy Research Institute (FAPRI). Since FAPRI reports annual prices, a monthly seasonal index of the international maize price was calculated to obtain the monthly international price in the years 2007, 2008, and 2009. With these monthly international prices, consumer and producer prices were calculated. The maize average annual price in the demand regions ranged from $1,440 to $1,656 per metric ton. It was assumed that from 1998/2000 to 2007/2009, transportation costs would have a growth rate similar to that registered for the international maize price. It was also assumed that the exchange rate, entry costs, international financing costs, and storage costs would remain at the same level as the average year 1998/2000.

Validation

The model was validated in consumption (human, animal, and industrial), production, prices, and imports per port and border. Since information is lacking on interregional trade flows and levels of storage, the model could not validate the replication of these indicators. Table 1 presents the results obtained with the model and the values observed in the year 1998/2000.

Except in a few cases, the model solution is very close to those levels observed in the year of analysis. The model overestimates production in the Northeast by 16.3%. However, the effect on total production is insignificant. Likewise, the model underestimates the consumer price in the South by 14.8% because an important percentage of the regional production is for home consumption and does not have a market value.

Table 1. Validation of Maize Model, 1998/2000.

Region	1998-2000	Base Model	Change	Change
	Thousand tons		%	
Production				
Northwest	2,356	2,412	56	2.4
North	1,211	1,240	29	2.4
Northeast	333	388	54	16.3
West	4,722	4,705	-17	-0.4
Center	3,691	3,716	26	0.7
South	3,958	3,776	-181	-4.6
Gulf	1,207	1,210	3	0.2
Peninsula	411	415	4	0.9
National Total	17,889	17,863	-26	-0.1
Consumption				
Northwest	2,137	2,200	62	2.9
North	2,484	2,401	-83	-3.4
Northeast	1,380	1,352	-28	-2.0
West	5,204	5,354	150	2.9
Center	7,056	7,008	-49	-0.7
South	1,784	1,817	33	1.9
Gulf	1,983	1,964	-19	-1.0
Peninsula	893	885	-7	-0.8
National Total	22,921	22,980	59	0.3
Imports				
Gulf	2,850	2,698	-152	-5.3
Border	2,219	2,325	106	4.8
Pacific	48	94	47	97.4
National Total	5,117	5,117	0	0.0
Consumer prices		Pesos per ton		
Northwest	1,344	1,258	-86	-6.4
North	1,212	1,271	59	4.9
Northeast	1,300	1,352	52	4.0
West	1,398	1,322	-76	-5.4
Center	1,376	1,396	20	1.4
South	1,256	1,069	-186	-14.8
Gulf	1,207	1,256	49	4.0
Peninsula	1,220	1,262	42	3.4
Average	1,289	1,273	-16	-1.2
Surplus		Million Pesos		
Consumer	250,500	251,144	644	0.3
Producer	21,034	20,991	-43	-0.2

Results

The Trade Policy Agreed upon by NAFTA

The NAFTA trade policy established duty-free maize imports at 2.81, 2.89, and 2.98 million tons in 1998, 1999, and 2000, respectively. The government should have applied a tariff of 172.2%, 163.4%, and 145.2 % in the same years, for maize imports beyond the quota established by NAFTA. However, in these three years annual imports of maize exceeded 5 million tons, on which importers did not pay any tax for acquiring maize in foreign markets.

The effects of this policy can be seen in Table 2. Because the government allowed entry of more than the 5 million ton quota, consumption was 1 million tons higher, totaling almost 23 million tons. The apparent losers were the producers since production dropped by 1.22 million tons. It should be mentioned that the areas where maize was not planted may have been planted with other more profitable crops, such as vegetables.

The demand for maize was greater in all of the regions due to the larger quantity of imports that was permitted. In absolute terms, the regions that consumed the largest amounts of maize were the Western and Center regions. The impact of the policy on maize production was much more variable, with production in the Northwest, West, Center, and South lowered by more than 200 thousand tons because of the effects of the policy.

An interesting result is the drop in prices at the consumer centers due to the larger quantity of imports at prices that were lower than the domestic market prices. On average, prices were 172 Pesos per ton lower. This allowed higher consumption and had important anti-inflationary effects. Due to its importance, maize has multiple effects on the rest of the economy; an increase in price can considerably affect inflation in the agricultural sector and the economy in general.

In conclusion, producers would have benefited from the NAFTA policy, and consumers, importers, and the society in general, would have been damaged. The effects on producers and consumers that puts a given policy into practice can be assessed by means of the producer and consumer surplus. If during 1998/2000 maize imports had been limited to the quota established by NAFTA, the producer surplus would have been 2,812 million Pesos more, while that consumer surplus would have been 3,570 million Pesos less, with respect to base model surpluses (Table 2).

Free Trade

Results under a free trade policy are presented in this scenario. Free trade policy is introduced into the model with no restrictions placed on maize imports. Total liberalization of the maize market has always been a highly debated issue in Mexico. Under free trade, the maize required in the consumer centers can be supplied from nearby places regardless of its origin. The importance of this scenario is the timeframe for reducing tariffs established by NAFTA allows total liberalization of the maize market for the year 2008.

The effects of a free trade policy are opposite those of a set import quota. Free trade favors consumption due to greater access to cheap imports while production is harmed as predicted before the implementation of NAFTA (Levy and van Wijnbergen, 1992; STPS, 1994; Calva, 1995). However, our model estimates that the harmful effects are minimal: maize production would have been 17.17 million tons in a situation of free trade, 693 thousand tons less than what was actually observed in the year of this analysis (Table 2). The effects of the policy are reduced because of the comparative advantages that exist in almost all of the domestic maize producer regions, among these is the nearness of centers of domestic production to centers of consumption.

An important aspect of a free trade policy is its effect on prices. With no restriction on imports, prices would have been 8.1% lower than the actual prices. The effects on a regional level would have been different: in the South region, prices would have been even lower. Several factors explain this greater decrease, but the most important of them is the relative isolation of the South region from the main center of consumption.

The lower prices would have permitted 23.60 million tons of maize to be consumed, that is, 623 thousand tons more that the quantity actually recorded in the average year. In all of the regions, consumption would have been higher, benefiting the North, West, and Center regions to a higher degree with a free trade policy (Table 2).

Lower production and higher consumption might have determined the importing of 6.43 million tons, that is, 25.7% more than in the average year 1998/2000. Of the imports, 52.3% would have entered through ports located on the Gulf of Mexico and 43.9% through the northern borders. This result leads to the conclusion that future consumption in Mexico will not depend on foreign imports; it will be supplied by domestic production. Indeed, USDA (2001) estimates that Mexico will import 6.5 million tons per year by the year 2008.

Consumers, importers, and the society in general benefited from this policy, and only producers lost. If during 1998/2000 Mexican maize imports had been free, the consumer surplus would have been 2,282 million Pesos more, while the producer surplus would have been 1,537 million Pesos less, with respect to base model surpluses. *This paragraph restates Paragraph 2 on page 11.*

Table 2. Maize Production, Consumption, Imports and Prices under NAFTA and Free Trade.

Region	Base Model	NAFTA	Free Trade	NAFTA	Free Trade
	Thousand tons			% Change	
Production					
Northwest	2,412	2,626	2,317	8.9	-4.0
North	1,240	1,327	1,171	7.0	-5.6
Northeast	388	429	368	10.6	-5.1
West	4,705	4,930	4,602	4.8	-2.2
Center	3,716	3,982	3,549	7.1	-4.5
South	3,776	4,059	3,596	7.5	-4.8
Gulf	1,210	1,276	1,169	5.5	-3.4
Peninsula	415	451	399	8.8	-3.8
National Total	17,863	19,080	17,170	6.8	-3.9
Consumption					
Northwest	2,200	2,077	2,267	-5.6	3.0
North	2,401	2,211	2,547	-7.9	6.1
Northeast	1,352	1,261	1,404	-6.8	3.9
West	5,354	5,119	5,476	-4.4	2.3
Center	7,008	6,762	7,171	-3.5	2.3
South	1,817	1,784	1,838	-1.8	1.2
Gulf	1,964	1,903	1,999	-3.1	1.8
Peninsula	885	858	900	-3.1	1.6
National Total	22,980	21,973	23,603	-4.4	2.7
Imports					
Gulf	2,698	1,566	3,365	-42.0	24.7
Border	2,325	1,271	2,824	-45.3	21.5
Pacific	94	57	243	-39.9	157.8
National Total	5,117	2,893	6,432	-43.5	25.7
Consumer Prices		Pesos per ton			
Northwest	1,258	1,416	1,172	12.5	-6.9
North	1,271	1,420	1,157	11.6	-9.0
Northeast	1,352	1,552	1,238	14.7	-8.5
West	1,322	1,427	1,267	7.9	-4.2
Center	1,396	1,571	1,280	12.6	-8.3
South	1,069	1,244	958	16.3	-10.4
Gulf	1,256	1,456	1,140	15.9	-9.2
Peninsula	1,262	1,478	1,152	17.2	-8.7
Average	1,273	1,445	1,170	13.5	-8.1
Surplus		Million Pesos			
Consumer	251,144	247,574	253,426	-1.4	0.9
Producer	20,991	23,803	19,454	13.4	-7.3

Sensitivity of Maize Imports to the Exchange Rate

The policy of exchange rate is introduced into the model through the international price. Increases in the exchange rate of 15, 20, and 25%, were considered, as is a free trade policy, meaning no restrictions were placed on imports.

Given that consumption of maize is highly dependent on acquisitions from outside the country, factors like the exchange rate have a strong impact on imports and, consequently, on the levels of production, consumption, and prices.

Table 3 presents the effects of a 15, 20, and 25% devaluation of the Peso relative to the U.S. Dollar. These effects would be similar to the effects of establishing an import quota. By making imports more expensive, devaluation serves to protect maize production and discourage consumption.

A 25% devaluation of the Peso in 1998/2000 would have put production and consumption at 18.75 and 22.26 million tons, respectively. In this case, production would have been 5% higher and consumption would have been 3.1% lower than the actual levels. The different response is explained because consumption is less elastic than production.

By making imports more expensive, devaluation raises prices in the different consumer centers. A devaluation of 25% would raise prices almost 10% above what they actually were. These changes reflect the harmful effects of devaluation on inflation.

Higher production and lower consumption cause imports to decrease. In 1998/2000 a 25% devaluation of the Peso would have put imports at 3.51 million tons, indicating that greater devaluation would cause the quantity of imports to be similar to the quota established by NAFTA.

Producers would have been the winners from this policy; consumers, importers, and the society in general would have been the losers. With devaluation of 25% and free trade, the consumer surplus would have been 2,623 million Pesos less, and producer surplus would have been 2,046 million Pesos more, with respect to surplus of the base model.

Table 3. Sensitivity of Maize Imports to the Exchange Rate.

Region	Base model	Free trade and devaluation of:					
		15%	20%	25%	15%	20%	25%
		Thousand tons			% Change		
Production							
Northwest	2,412	2,457	2,504	2,560	1.8	3.8	6.1
North	1,240	1,257	1,277	1,301	1.4	2.9	4.9
Northeast	388	395	405	417	1.9	4.5	7.4
West	4,705	4,751	4,803	4,859	1.0	2.1	3.3
Center	3,716	3,772	3,838	3,920	1.5	3.3	5.5
South	3,776	3,836	3,903	3,991	1.6	3.4	5.7
Gulf	1,210	1,224	1,240	1,260	1.2	2.5	4.2
Peninsula	415	421	433	443	1.5	4.5	6.9
National Total	17,863	18,114	18,402	18,752	1.4	3.0	5.0
Consumption							
Northwest	2,200	2,176	2,151	2,120	-1.1	-2.2	-3.6
North	2,401	2,368	2,320	2,272	-1.4	-3.3	-5.4
Northeast	1,352	1,335	1,312	1,288	-1.2	-3.0	-4.8
West	5,354	5,306	5,252	5,192	-0.9	-1.9	-3.0
Center	7,008	6,956	6,896	6,820	-0.7	-1.6	-2.7
South	1,817	1,810	1,802	1,792	-0.4	-0.8	-1.4
Gulf	1,964	1,951	1,934	1,917	-0.6	-1.5	-2.4
Peninsula	885	880	872	864	-0.6	-1.5	-2.4
National Total	22,980	22,781	22,538	22,264	-0.9	-1.9	-3.1
Imports							
Gulf	2,698	2,479	2,121	1,831	-8.1	-21.4	-32.2
Border	2,325	2,186	2,015	1,681	-6.0	-13.3	-27.7
Pacific	94	2	0	0	-97.9	-100.0	-100.0
National Total	5,117	4,667	4,136	3,512	-8.8	-19.2	-31.4
Consumer prices		Pesos per ton					
Northwest	1,258	1,289	1,321	1,361	2.5	5.0	8.1
North	1,271	1,297	1,334	1,372	2.0	4.9	7.9
Northeast	1,352	1,389	1,440	1,493	2.7	6.5	10.4
West	1,322	1,344	1,368	1,394	1.6	3.4	5.4
Center	1,396	1,433	1,475	1,530	2.7	5.7	9.6
South	1,069	1,107	1,147	1,201	3.5	7.3	12.3
Gulf	1,256	1,298	1,353	1,410	3.3	7.7	12.2
Peninsula	1,262	1,303	1,370	1,430	3.3	8.6	13.4
Average	1,273	1,307	1,351	1,399	2.7	6.1	9.9
Surplus		Million Pesos					
Consumer	251,144	250,409	249,528	248,521	-0.3	-0.6	-1.0
Producer	20,991	21,556	22,218	23,037	2.7	5.8	9.7

Sensitivity of Trade Flows to Changes in Transportation Costs

Imports from the United States enter mainly through ports on the Gulf of Mexico and cities located on the northern border, such as Nuevo Laredo. Given that the origin of maize is different, the prices often differ significantly between port and border crossing. Generally, the price of maize at the northern border is lower than the price at the Mexican Gulf ports. However, the cost of shipping from the northern border to Mexico City is generally higher than from Veracruz to Mexico City.

To analyze the maize market sensitivity to changes in the costs of transportation, three scenarios were constructed. The first includes an increase of 20% in insurance and ocean freightage from U.S. ports to Mexican ports on the Gulf as well as an increase in the costs of shipping from Mexican ports to domestic consumer centers. The second includes an increase of 20% in transportation costs from borders to domestic consumer centers. The third includes an increase of 20% in insurance and ocean freightage from U.S. ports on the Gulf to Mexican ports on the Pacific and an increase in shipping costs from Mexican ports to domestic consumer centers.

An increase in the costs of transporting imports that are supplied through ports on the Gulf of Mexico has a considerable effect on the magnitude and direction of the trade flows from the outside. If transportation costs from U.S. ports to domestic consumer centers increased 20%, traffic in this direction would decrease 10.8% relative to the average year 1998/2000. As a result, imports entering through the northern border of Mexico would increase 15.3%, which would be equivalent to an increase of 356 thousand tons (Table 4).

If the increase occurs in the transportation costs of maize that enters through the northern border of the country, imports through these points of entry would decrease 19.7%. As a result of these changes, maize imports entering through Pacific ports would increase by 448 thousand tons, while those entering through Gulf ports would increase 0.4% relative to those actually registered during the reference year. This is a result of the spatial distribution of consumption that determines that some of the regions can only be supplied by maize that enters through the northern border or, through Pacific ports.

Because of the reduction of maize imports through the Pacific ports, an increase in the costs of transporting maize entering through this via would have an insignificant effect on the composition of the imports by port of entry. The decrease in imports via the Pacific would increase imports that enter through the Gulf ports and the northern border by 0.7 and 3.0%, respectively (Table 4).

Table 4. Effect of Increases in Transportation Costs on the Maize Market.

Quantity	Base model	20% increase in transport costs of imports that enter through:					
		Gulf	Border	Pacific	Gulf	Border	Pacific
		Thousand tons			% Change		
Production	17,863	17,889	17,858	17,862	0.1	0.0	0.0
Consumption	22,980	23,006	22,975	22,979	0.1	0.0	0.0
Imports	5,117	5,117	5,117	5,117	0.0	0.0	0.0
Gulf	2,698	2,405	2,709	2,718	-10.8	0.4	0.7
Border	2,325	2,681	1,866	2,394	15.3	-19.7	3.0
Pacific	94	30	542	5	-67.9	474.6	-94.9
Surplus		Million Pesos					
Consumer	251,144	251,040	251,163	251,166	0.0	0.0	0.0
Producer	20,991	21,100	20,975	20,982	0.5	-0.1	0.0

Free Trade in the Year 2008

In 2008, it is planned for the market to become completely free, and it is expected that both consumption and production of maize will undergo changes. By 2008, the population of Mexico will reach 109.04 million inhabitants, according to data of the Consejo Nacional de Población (CONAPO, 1995), changing consumption dramatically.

The historical trend of maize yields indicates a significant increase in productivity per hectare. According to data of SAGARPA, from 1980 to 2000 the per-hectare yields of maize grew at an annual rate of 1.1% in the spring-summer season, and 3.85% in the fall-winter season. The Mexican government is concerned about the increasing productivity of maize; there are elements to support expectations that the trend will continue, reaching approximately 20 million tons by 2008.

On a long-term basis, it is expected that other factors such as the disappearance of PROCAMPO planned for the year 2008 will affect production; and possible increases in incomes will bring significant changes in the consumption of maize. Supply and demand estimations of the U.S. Committee on Agricultural Projections places consumption and production of maize at 27.03 and 20.54 million tons, respectively. Other predictions estimate that consumption and production will be 30.92 and 21.48 million tons, respectively (FAPRI).

Because demand will increase more than production, imports will total approximately 6.5 million tons. Validation of the model for the average year 2007/2009 is presented in Table 6. Except in rare cases, the solution of the validated model is very close to the levels projected in the year 1997/1998. Again, the model overestimates production in the Northeast by 15.2%; however, the effect on the total production is negligible.

The model overestimates imports by 10.8% because of the 2.8% overestimation in the demand. According to the model, maize imports for the average year would be 7.19 million tons, which falls within the range of the projections that USDA has used in

different scenarios (USDA, 1999; USDA, 2001). The composition of the imports by port or border would be similar to that of the year 1998/2000, with 51.6 % entering through the Gulf ports and 45.5% through the northern border.

Table 5. Validation of Maize Model, 2007/2008.

Region	2007-2009	Validation	Change	
	Thousand tons		%	
Production				
Northwest	2,706	2,795	90	3.3
North	1,390	1,405	15	1.1
Northeast	383	441	58	15.2
West	5,422	5,421	-1	0.0
Center	4,238	4,310	72	1.7
South	4,544	4,361	-183	-4.0
Gulf	1,385	1,373	-13	-0.9
Peninsula	472	484	12	2.6
National total	20,539	20,590	51	0.2
Consumption				
Northwest	2,521	2,666	146	5.8
North	2,929	3,000	71	2.4
Northeast	1,627	1,656	28	1.7
West	6,137	6,428	292	4.8
Center	8,321	8,450	128	1.5
South	2,103	2,162	58	2.8
Gulf	2,339	2,357	19	0.8
Peninsula	1,053	1,061	8	0.8
National total	27,030	27,780	750	2.8
Imports				
Gulf	3,615	3,707	91	2.5
Border	2,814	3,274	459	16.3
Pacific	61	209	149	245.3
National total	6,490	7,189	699	10.8
Consumer prices		Pesos by ton		
Northwest	1,593	1,402	-191	-12.0
North	1,429	1,378	-52	-3.6
Northeast	1,545	1,479	-67	-4.3
West	1,647	1,508	-139	-8.5
Center	1,618	1,527	-91	-5.6
South	1,505	1,182	-323	-21.5
Gulf	1,450	1,372	-77	-5.3
Peninsula	1,462	1,384	-78	-5.3
Average	1,531	1,404	-127	-8.3
Surplus		Million Pesos		
Consumer	350,958	354,769	3,811	1.1
Producer	26,865	26,959	94	0.3

Summary and Conclusions

The Mexican government's decision to allow duty-free imports beyond the quota set in NAFTA has caused severe criticism to be raised against free trade and has led to the conclusion that Mexico is the big loser in the agreement, at least where maize is concerned. However, considering the lower prices that were achieved through this policy, making higher levels of consumption possible, it can be said that even Mexico gains with the NAFTA policy. To this, the benefits to society must be added; these benefits were generated thanks to larger consumer surpluses.

A free trade policy would increase imports to 6.43 million tons. It is believed that this policy is desirable for its effects on prices and levels of consumption and because its effects on levels of production would not be significant. The total liberalization of the maize market would have put consumer prices 8.1% lower than those that were actually registered, and consumption would have reached 23.6 million tons. Contrary to the predictions that complete trade liberalization will have harmful effects on the production of maize, in a situation of free trade production will be 17.17 million tons. This figure is notably higher than the production registered before the signing of NAFTA. This significant result points out the existence of important comparative advantages in Mexican maize production, although it should be mentioned that the current policy of direct aid through PROCAMPO and subsidies to commercialization granted by ASERCA are decisive in maintaining this production figure. Thus, a policy of more food security would suggest that these programs should be kept up at least until 2008, when total trade liberalization will be put into practice.

Importation of maize, like production and consumption, are highly sensitive to the exchange rate. A 25% devaluation of the Peso relative to the U. S. Dollar would place imports at levels close to the level of the quota set by NAFTA. This result suggests that the maize market is heavily dependent on macroeconomic policy. More severe devaluations could totally obstruct maize imports. The scenarios of changes in the Peso-U. S. Dollar parity are realistic. Although in recent years there has been certain stability in the exchange rate, greater trade liberalization, which determines greater dependence on foreign economies, makes the amount of total reserves of foreign currency in the power of the Banco de Mexico uncertain, which makes the exchange rate also unpredictable. Confusing sentence.

With control over imports, the effects of increases in costs of transportation from the borders and ports to domestic consumer centers would not have significant effects on the maize market, but the effects on the composition of imports by port and border would be significant. Increases in transportation costs from the Gulf ports to domestic consumer centers would reduce imports through the Gulf and increase those entering across the northern border. In contrast, an increase in transportation costs for shipping maize from the borders to consumer centers would reduce imports that enter across the borders and increase imports entering from the Pacific ports, while imports via the Gulf would remain without significant change. This is a consequence of the spatial distribution of consumption, which makes it necessary for regions like the West and Northwest to be

supplied with maize entering through the northern border or Pacific ports, but not through Gulf ports because of the relatively large distances.

As a consequence of free trade and other factors that would affect supply and demand in the long term, it is expected that maize imports in the year 2008 will be approximately 6.5 million tons.

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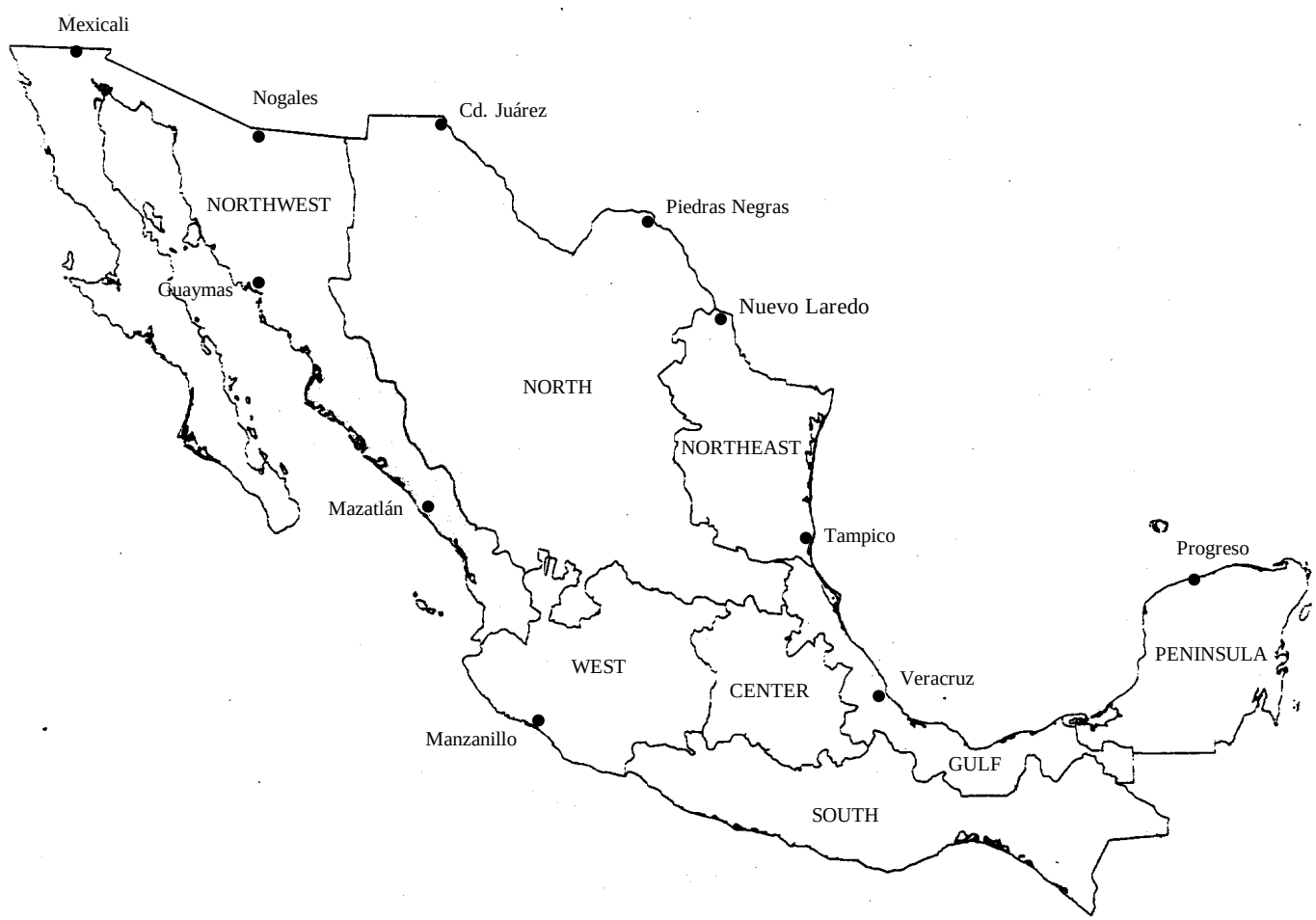
Figure 1. Mexican Maize Regions and Imports Ports.



Appendix

Considering *s(s=1,2…S=8)* maize producer regions, *d(d=1,2…D=8)* regions of human consumption, *a(a=1,2,3…A=8)* regions of animal consumption, *i(i=1,2,3…I=8)* regions of industrial consumption, *m(m=1,2…M=11)* ports of entry, and *t(t=1,2…T=12)* periods, the target function of the problem of maximizing NSP is formulated in the following manner:

$$
\begin{aligned}
MaxNSP = & \sum_{t=1}^{T} \pi^{t-1} \sum_{d=1}^{D} \left[\lambda_{dt} y_{dt} + \frac{1}{2} \omega_{dt} y_{dt}^{2} \right] + \sum_{t=1}^{T} \pi^{t-1} \sum_{a=1}^{A} \left[\lambda_{at} y_{at} + \frac{1}{2} \omega_{at} y_{at}^{2} \right] \\
& + \sum_{t=1}^{T} \pi^{t-1} \sum_{i=1}^{I} \left[\lambda_{it} y_{it} + \frac{1}{2} \omega_{it} y_{it}^{2} \right] - \sum_{t=1}^{T} \pi^{t-1} \sum_{s=1}^{S} \left[v_{st} x_{st} + \frac{1}{2} \eta_{st} x_{st}^{2} \right] \\
& - \sum_{t=1}^{T} \pi^{t-1} \sum_{m=1}^{M} \left[\left(\left(p_{mt} e_{t} \right) + c_{mt} \right) x_{mt} \right] - \sum_{t=1}^{T} \pi^{t-1} \sum_{s=1}^{S} \sum_{d=1}^{D} \left[p_{sdt}^{c} x_{sdt}^{c} + p_{sdt}^{f} x_{sdt}^{f} \right] \\
& - \sum_{t=1}^{T} \pi^{t-1} \sum_{m=1}^{M} \sum_{d=1}^{D} \left[p_{mdt}^{c} x_{mdt}^{c} + p_{mdt}^{f} x_{mdt}^{f} \right] - \sum_{t=1}^{T} \pi^{t-1} \sum_{s=1}^{S} \sum_{a=1}^{A} \left[p_{sat}^{c} x_{sat}^{c} + p_{sat}^{f} x_{sat}^{f} \right] \\
& - \sum_{t=1}^{T} \pi^{t-1} \sum_{m=1}^{M} \sum_{a=1}^{A} \left[p_{mat}^{c} x_{mat}^{c} + p_{mat}^{f} x_{mat}^{f} \right] - \sum_{t=1}^{T} \pi^{t-1} \sum_{s=1}^{S} \sum_{i=1}^{I} \left[p_{sit}^{c} x_{sit}^{c} + p_{sit}^{f} x_{sit}^{f} \right] \\
& - \sum_{t=1}^{T} \pi^{t-1} \sum_{m=1}^{M} \sum_{i=1}^{I} \left[p_{mit}^{c} x_{mit}^{c} + p_{mit}^{f} x_{mit}^{f} \right] - \sum_{t=1}^{T} \pi^{t-1} \sum_{s=1}^{S} \left[p_{st,t+1} x_{st,t+1} \right] \\
& - \sum_{t=1}^{T} \pi^{t-1} \sum_{m=1}^{M} \left[p_{mt,t+1} x_{mt,t+1} \right] \qquad 1)
\end{aligned}
$$

subjet to:

$$x_{st} + x_{st-1,t} - x_{st,t+1} \geq \sum_{d=1}^{D} \left[x_{sdt}^{c} + x_{sdt}^{f} \right] + \sum_{a=1}^{A} \left[x_{sat}^{c} + x_{sat}^{f} \right] + \sum_{i=1}^{I} \left[x_{sit}^{c} + x_{sit}^{f} \right] \qquad 2)$$

$$x_{mt} + x_{mt-1,t} - x_{mt,t+1} \geq \sum_{d=1}^{D} \left[x_{mdt}^{c} + x_{mdt}^{f} \right] + \sum_{a=1}^{A} \left[x_{mat}^{c} + x_{mat}^{f} \right] + \sum_{i=1}^{I} \left[x_{mit}^{c} + x_{mit}^{f} \right] \qquad 3)$$

$$\sum_{s=1}^{S} \left[x_{sdt}^{c} + x_{sdt}^{f} \right] + \sum_{m=1}^{M} \left[x_{mdt}^{c} + x_{mdt}^{f} \right] \geq y_{dt} \qquad 4)$$

$$\sum_{s=1}^{S} \left[x_{sat}^{c} + x_{sat}^{f} \right] + \sum_{m=1}^{M} \left[x_{mat}^{c} + x_{mat}^{f} \right] \geq y_{at} \qquad 5)$$

$$\sum_{s=1}^{S} \left[x_{sit}^{c} + x_{sit}^{f} \right] + \sum_{m=1}^{M} \left[x_{mit}^{c} + x_{mit}^{f} \right] \geq y_{it} \qquad 6)$$

$$x_{t} = \sum_{m=1}^{M} x_{mt} \qquad 7)$$

$$x_{s12,13} = x_{s0,1} \qquad 8)$$

and

$$y_{dt}, y_{at}, y_{it}, x_{st}\, x_{mt}, x^{c}_{sdt}, x^{f}_{sdt}, \ldots\ldots, x^{f}_{mit}, x_{st,t+1}, x_{mt,t+1} \geq 0 \qquad 9)$$

where:

π^{t-1} = $(1/1+i_t)^{t-1}$ = Discount factor with i_t equal to the rate of inflation in month *t*;
λ_{dt} = Intercept of the maize demand function in region *d* in month *t*;
ydt = Quantity of maize consumed in region *d* in month *t*;
ωdt = Slope of the maize demand function in region *d* in month *t*;
λat = Intercept of the maize demand function in region *a* in month *t*;
yat = Quantity of maize consumed in region *a* in month *t*;
ωat = Slope of the maize demand function in region *a* in month *t*;
λit = Intercept of the maize demand function in region *i* in month *t*;
yit = Quantity of maize consumed (industrial consumption) in region *i* in month *t*;
ωit = Slope of the maize demand function in region *i* in month *t*;
νst = Intercept of the maize supply function in region *s* in month *t*;
ηst = Slope of the maize supply function in region *s* in month *t*;
xst = Quantity of maize supply in region *s* in month *t*;
pmt = Import price, insurance and ocean freightage of maize through port *m* in month *t*;
et = Rate of exchange in month *t*;
cmt = International financial cost and entry ports through port *m* in month *t*;
xmt = Maize imports through port *m* in month *t*;
$pcsdt$ = Cost of transporting maize from region *s* to region *d* by truck in month *t*;
$xcsdt$ = Quantity of maize shipped from region *s* to region *d* by truck in month *t*;
$pfsdt$ = Cost of transporting maize from region *s* to region *d* by train in month *t*;
$xfsdt$ = Quantity of maize shipped from region *s* to region *d* by train in month *t*;
$pcmdt$ = Cost of transporting maize from port *m* to region *d* by truck in month *t*;
$xcmdt$ = Quantity of maize shipped from port *m* to region *d* by truck in month *t*;
$pfmdt$ = Cost of transporting maize from port *m* to region *d* by train in month *t*;
$xfmdt$ = Quantity of maize shipped from port *m* to region *d* by train in month *t*;
$pcsat$ = Cost of transporting maize from region *s* to region *a* by truck in month *t*;
$xcsat$ = Quantity of maize shipped from region *s* to region *a* by truck in month *t*;
$pfsat$ = Cost of transporting maize from region *s* to region *a* by train in month *t*;
$xfsat$ = Quantity of maize shipped from region *s* to region *a* by train in month *t*;
$pcmat$ = Cost of transporting maize from port *m* to region *a* by truck in month *t*;
$xcmat$ = Quantity of maize shipped from port *m* to region *a* by truck in month *t*;
$pfmat$ = Cost of transporting maize from port *m* to region *a* by train in month *t*;
$xfmat$ = Quantity of maize shipped from port *m* to region *a* by train in month *t*;
$pcsit$ = Cost of transporting maize from region *s* to region *i* by truck in month *t*;
$xcsit$ = Quantity of maize shipped from region *s* to region *i* by truck in month *t*;
$pfsit$ = Cost of transporting maize from region *s* to region *i* by train in month *t*;
$xfsit$ = Quantity of maize shipped from region *s* to region *i* by train in month *t*;
$pcmit$ = Cost of transporting maize from port *m* to region *i* by truck in month *t*;
$xcmit$ = Quantity of maize shipped from port *m* to region *i* by truck in month *t*;
$pfmit$ = Cost of transporting maize from port *m* to region *i* by train in month *t*;
$xfmit$ = Quantity of maize shipped from port *m* to region *i* by train in month *t*;

$pst,t+1$ = Cost of storage per unit of maize in region *s* from month *t* to month *t+1*;
$xst,t+1$ = Quantity of maize stored in region *s* from month *t* to month *t+1*;
$pmt,t+1$ = Cost of storage per unit of maize in port *m* from month *t* to month *t+1*;
$xmt,t+1$ = Quantity of maize stored in port *m* from month *t* to month *t+1*.