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Article

Economic effects of the possible entry of African swine fever into Mexico from the United States of America

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Abstract:

Mexico has never experienced outbreaks of the African swine fever virus, but it poses a significant threat to its pork industry; therefore, it is necessary to assess the economic impact of its possible entry into the country. The objective was to evaluate the economic effects of the possible entry of the virus into Mexico from the United States of America using data from 2024 and non-linear programming, in eight producing-consuming regions and two import entry points. The results indicated that, under optimal conditions, national and regional production were overestimated by 0.92 %, a difference of 15,008 t between what was observed and the model; national and regional consumption were overestimated by 0.6 %, with a Net Social Value of 8,929.9 million pesos. If the virus entered Mexico from the United States of America, the country would not import pork, and national production and consumption would decrease by 0.3 and 49.8 %, respectively, compared to the optimal model. Producer and consumer prices would experience average increases of 3.5 % in regions from the center to the north of the country, whereas in those from the center to the peninsula, they would decrease by 6.3 % on average; likewise, the well-being of society would decline by 18.5 %. It is concluded that if the virus were to enter Mexico from the United States of America, there would be negative impacts on production from the center to the south of the country, as well as on prices; the entire pork market would be affected relative to the optimal model.

Keywords: Pork, Optimization, African swine fever, Zero imports, Total social benefit.

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Introduction

For Mexico, pork ranks second, both as a preferred source of protein, after poultry, and in production value, only after cattle. In 2024, the country generated 1,812.4 thousand tonnes (t) of carcass pork, led by Jalisco, Sonora, Puebla, and Yucatán, which accounted for 71 % of the total; 180.3 thousand t were exported, leaving 1,632 thousand t in the country[(1)]. In the same year, 1,620 thousand t were purchased from abroad (51.4 % of national consumption), with 82.7 % coming from the United States of America (USA); this resulted in a total demand of 3,252 thousand t, equivalent to 24.7 kg per person[(1,2)]. Thus, Mexico ranked sixth in the world in pork production, only after the USA, Brazil, China, Argentina, and Australia, and tenth as an exporter[(1)].

The country's consumption is supplied by external purchases, which are monitored to prevent any pathogenic agent, such as African swine fever (ASF), from entering the national territory, affecting domestic production and consumption and, consequently, harming consumers in terms of prices[(3,4)]. To date, Mexico has never experienced outbreaks of ASF[(5)], but it continually poses a serious threat to its pork industry[(6)]. In this context, one cause that determines the entry of imports of a livestock product into the country, such as pork, is, in fact, ASF, which is conceived as a viral disease of importance in farm and wild pigs[(7)], and has become a global threat to its production since 2007[(8)]. The virus responsible for the disease belongs to the family *Asfarviridae* and is complex and strong[(7,9)].

The virus that causes ASF was detected in China in 2018, where it spread before the outbreak was officially recognized. Since then, ASF has been reported in domesticated pigs and wild boars in South Asian countries, and the virus appears to be rapidly spreading in parts of Asia and Europe [(9)]. In the Americas, the disease has been detected in Cuba (1971), Brazil (1980), the Dominican Republic (1978)[(10)], and Haiti (1979). In 2010, a report described the search for the ASF virus in wild boars in Iran; nevertheless, there is no evidence to indicate its presence in the Middle East[(11)]; more recently, it was reported in the Dominican Republic (first case detected in April 2021)[(12)], a situation that has put the entire American continent on alert[(4)].

Mexico is free of ASF[(4)]; however, it has always been necessary to control the entry of pigs and fresh pork, as well as to improve biosecurity strategies in livestock farms. Some studies on the effects of ASF, as a non-tariff trade policy on Mexican pork imports, include that of the Federal Government[(5)], which disseminated the economic impact of the possible entry of the disease into Mexico, with rates of reduction in domestic production of 10, 30, and 50 % of its herd; for their part, other authors[(13)] evaluated losses associated with ASP in China and neighboring nations, evidencing a lack of actions that help reduce its impact. An additional study[(14)] analyzed the economic impacts of the introduction of ASF in Europe on trade patterns in the German commercial sector; another study[(15)] applied a method to assess the probabilities of entry and spread of the ASF virus in countries in the region of influence.

Therefore, the objective was to evaluate a scenario of the possible entry of ASF into Mexico from the United States[(16)] via the entry of pork, with simulation of the elimination of imports on production, consumption, producer and consumer prices by region and, on the measure of societal well-being, known as Net Social Value (NSV), based on an optimal model. The hypothesis states that, without distortions, the estimated or optimal model maximizes the NSV in relation to data from 2024, and that the cancellation (border closure) of pork imports due to the entry of ASF into Mexico from the northern neighbor reduces production, but also leads to a decline in both consumption and producer and consumer prices, and lowers the level of social welfare through the NSV.

Material and methods

The spatial price equilibrium model incorporated supply and demand, which depend on both demanded and supplied quantities, referred to as inverse demand and supply functions[(17,18)]. Thus, the inverse pork demand equation corresponding to region i was: $P_{di} = P_{di}(Q_{di}) = \alpha_{di} + \beta_{di}Q_{di}$; $\beta < 0$; where: P_{di} = consumer price of carcass pork for region i, in Mexican pesos per tonne ($/t). Q_{di} = quantity of carcass meat demanded in region i, expressed in t. α

= intercept of the carcass pork demand equation for region i. β = slope of the pork demand equation for region i.

On the other hand, the inverse supply function of pork was: $P_{si} = P_{si}(Q_{si}) = \alpha_{si} + \beta_{si}Qs_{di}$; where: P_{si} = producer price of carcass pork in region i, in \$/t. Q_{si} = quantity supplied of carcass pork in region i, in t. α = intercept of the carcass pork supply equation for region i. β = slope of the pork supply equation for region i. Similarly, it must be ensured that: $\frac{\partial P_{di}(Q_{di})}{\partial Q_{di}} \leq 0$ for the inverse demand equation and $\frac{\partial P_{si}(Q_{si})}{\partial Q_{ds}} \geq 0$ for the inverse supply equation.

The quasi-social well-being was estimated using the surplus generated by the demand and supply of pork, which was as follows: $W_i(Q_{si}^*, Q_{di}^*) = \int_0^{Q_{di}^*} P_{di}(Q_{di})dQ_{di} - \int_0^{Q_{si}^*} P_{si}(Q_{si})dQ_{si}$. When introducing the costs of mobilization between the n regions of the study, the quasi-social well-being (NSV) function was expressed as follows: $NW = \sum_{i=1}^{n} W_i(Q_{si}^*, Q_{di}^*) - \sum_{i=1}^{n}\sum_{j=1}^{n} C_{ij}T_{ij}$; where: C_{ij} = cost of moving the product from the producing region i to the consuming region j, in \$/t. T_{ij} = quantity distributed from the region i to the region j, in tonnes of product. Additional elements, part of the programming model, included restrictions on the demand and supply of pork. Regarding demand constraints, it was required that the sum of the quantity of pork transported from region d to region i be greater than or equal to the demand of that area. That is: $Q_{di} \leq \sum_{j=1}^{n} T_{ij}$ for all i. For the restrictions on the supply of pork, it was essential that the sum of the quantity of pork transported out of region i be less than or equal to the total pork production in that region. Consequently, $Q_{si} \geq \sum_{j=1}^{n} T_{ij}$ must hold for all i. In the modeling of the national pork market, the existence of areas that offer, acquire, and trade the same good (carcass pork) was considered. Thus, each region was made up of a different market separated by transportation costs[17,18]. The transport costs were considered in physical units and were independent of the volume traded.

Data

For the base model, the pork production and import data from 2024 were generated by each state[1,2], then exports were subtracted from the production of the states that reported the data, and the result of this difference was added to the production of the states that made up each of the regions to obtain the production for each region. Nevertheless, in the scenario of the possible entry of ASF into Mexico, the base model was modified by removing the import figures. The demand and supply functions were obtained using observed information available in 2024, along with transportation costs. The estimation of consumption (demand) for each region required information on the population (of human beings) by state for the year 2024, which was extracted from the National Population Council[19]; subsequently, the national pork production was divided by the total population, which resulted in the *per capita* consumption without imports, and this figure was multiplied by the population of each state that made up the region, resulting in the total consumption of that region.

The producer price of carcass meat by region was obtained using data from each state within the region and weighted by the respective production; these data were taken from the official source[2]. On the other hand, the consumer price was obtained from Mexican official sources[20,21]. The price of pork entered (corresponding to the points of entry into the country and for the base model) was obtained from government institutions[20], whereas the international price of pork at points of entry 1 and 2 was 1,969 US dollars per t (USD/t)[22], at an exchange rate of 18.36 Mexican pesos per US dollar ($MX/USD)[23]. Data on transport costs, per t-kilometer (km) ($/t/km), came from multimodal land transport companies with national coverage[24,25]. The mathematical formulation included a nonlinear objective function of the pseudo-quadratic type[17], focused on optimizing net economic surpluses (consumer and producer), considering transportation costs and linear market equilibrium constraints:

$$Max \sum_{i=1}^{n} \left[\int_{0}^{Q_{di}^{*}} P_{di}(Q_{di}) dQ_{di} - \int_{0}^{Q_{si}^{*}} P_{si}(Q_{si}) dQ_{si} \right] - \sum_{i=1}^{n} \sum_{j=1}^{n} C_{ij} T_{ij}$$

Subject to: $Q_{di} - \sum_{j=1}^{n} T_{ij} \leq 0$ for all *i*; $-Q_{si} + \sum_{j=1}^{n} T_{ij} \leq 0$ for all *i*, and $Q_{di}, Q_{si}, T_{ij} \geq 0$ for all *i* and *j* (understood as conditions of non-negativity of the model). The model considered eight consuming regions[26,27]: Northwest (NW): Baja California (BC), Baja California Sur (BCS), Sonora (Son), Sinaloa (Sin), and Nayarit (Nay); North (NR): Chihuahua (Chih), Coahuila (Coah), Durango (Dgo), San Luis Potosí (SLP), and Zacatecas (Zac); Northeast (NE): Nuevo León (NL) and Tamaulipas (Tams); Central-West (CW): Aguascalientes (Ags), Colima (Col), Guanajuato (Gto), Jalisco (Jal), and Michoacán (Mich); Central-East (CE): Mexico City (CDMX), Hidalgo (Hgo), State of Mexico (Edo Mex), Morelos (Mor), Puebla (Pue), Querétaro (Qro), and Tlaxcala (Tlax); South (SU): Chiapas (Chis), Guerrero (Gro), and Oaxaca (Oax); East (EA): Tabasco (Tab) and Veracruz (Ver); Yucatán Peninsula (PE): Campeche (Camp), Quintana Roo (QRoo), and Yucatán (Yuc).

Ten were included as producing regions, of these, eight were consumers: NW, NR, NE, CW, CE, SU, EA, PE, and the rest were two points of entry of pork; entry point 1 (PE1) consisted of the customs of Colombia (NL), Nuevo Laredo and Reynosa (Tams), Piedras Negras (Coah). PE1 accounted for the entry of 91 % of imported pork, whereas point of entry 2 (PE2), made up of customs of Mexicali and Tijuana (BC), Nogales and San Luis Rio Colorado (Son), and Ciudad Juárez (Chih)[1,28], recorded the entry of the remaining 9 %. In addition, the model without imports did not consider PE1 and PE2, both in the supply equations and in the transportation cost matrix. The solution, in terms of a feasible equilibrium, involved verifying that the mathematical functions of demand had a negative slope coefficient and those of supply had a positive slope. In this optimization problem, the conditions[21] were expressed by the set of equations: $\frac{\partial Z}{\partial Q_{di}} = P_{di} - \lambda_{di} \leq 0, \left(\frac{\partial Z}{\partial Q_{di}}\right) Q_{di} = 0, Q_{di} \geq 0$. These equations cause the demand price of pork in region *i* to be equal to its shadow price, expressed by λ_{di}, conditioned on the quantity of pork demanded being positive. On the other hand, the set of equations: $\frac{\partial Z}{\partial Q_{si}} = P_{si} - \psi_{si} \leq 0, \left(\frac{\partial Z}{\partial Q_{si}}\right) Q_{si} = 0, Q_{si} \geq 0$, requires that the supply price of pork in zone *i* be the same as its shadow price, shown by ψ_{si}, provided that the supply of pork is greater than zero; in addition: $\frac{\partial Z}{\partial T_{ij}} = -C_{ij} + \lambda_{dj} - \psi_{si} \leq 0, \left(\frac{\partial Z}{\partial T_{ij}}\right) T_{ij} = 0, T_{ij} \geq 0$.

In these equations, it was required that the demand price (λ_{di}) in region *i* must be equal to the average of the supply prices (ψ_{si}) of pork in region *i* and regions *j*, plus the transport costs indicated by the variable (T_{ij}), provided that the quantity of pork transported is greater than zero. The optimal solution to the problem expressed the solution matrix in terms of quantity of supply (Q_{si}) and consumption (Q_{di}) by region, trade between two different regions (T_{ij}, where *i* is different from *j*), and trade within the same region (T_{ij}, where *i* is equal to *j*). For its part, the equilibrium price in each zone was found in the dual variables (P_{di} and P_{si}). In addition, the relationships between equilibrium prices and regions are: a) if region *i* absorbs all its demand generated there ($T_{ii} = Q_{di} > 0$), then the price difference between demand and supply of pork is equal to the cost of transportation ($P_{di} = C_{ii} + P_{si}$); b) if region *i* sends pork to region *j* ($T_{ij} > 0$), then the cost of transportation of the region *i* plus the supply price of region *j* is equal to the demand price in region *i* ($P_{dj} = P_{sj} + C_{ji}$). If region *j* does not send pork to region *i*, it is because the supply price of carcass pork in region *j* was higher than the demand price of region *i*; consequently, that trade route from region *j* to region *i* was not activated, or that distribution route was not present in the results output ($P_{di} < C_{ji} + P_{sj}$).

There are two estimators of the demand and supply functions: the first is the intercept (α_i) and the second is the slope (β_i), which were generated with the elasticities, prices, and quantities produced and demanded, using the formula: $\varepsilon_{pi} = \left(\frac{\partial Q_i}{\partial P_i}\right)\left(\frac{P_i}{Q_i}\right)$. Where ε_{pi} refers to the price elasticity of the supply function or the demand function of region *i*. In the same vein, due to the scenario of the possible entry of ASF into Mexico from the United States, the data corresponding to the volume of imports was removed from the model; thus, the information referring to producing regions remained unchanged, but that corresponding to the consuming regions did change. To structure the demand and supply functions for each region, it was necessary to use the data on both the respective price elasticities[29] and those from the points of entry into the country by imports[30,31]. The results of the validation of the model, with the elimination of imports due to ASF, were compared with those of the base model, and the effects of the entry of ASF into Mexico were subsequently analyzed. The solution was obtained by running the MINOS solver, part of the GAMS (General Algebraic Modeling System) programming language, version 24.4.2 for Windows 8, Office 2013[32].

Results

Table 1 shows the contrast of what was observed in 2024 (i.e., pork production by area, imports by point of entry into the country, and regional consumption) and what the model optimized for the same variables; the regional effect on the production, consumption, and NSV variables resulting from the simulated cancellation of pork imports due to the possible entry of ASF into Mexico is also observed. On the production side, the impact of canceling imports would be noticed only in geographical areas from the center of the country to the peninsula; in contrast, from the center to the north, increases in this variable would be expected. For its part, the policy in question would reduce national and regional consumption by almost 50 %; consequently, the well-being of society would decrease by 18.5 % relative to the base model.

Table 1: Pork market in Mexico, 2024. Base model (optimization) and model without imports

Region	Observed	Optimization	No imports
	Production (t)		
Northwest	273,636	273,510	273,559
North	55,820	56,023	56,138
Northeast	31,218	31,339	31,502
Central-West	652,063	652,374	652,364
Central-East	182,407	184,597	184,452
South	85,339	85,645	85,580
East	180,288	190,663	186,668
Yucatán Peninsula	171,322	172,950	171,924
Subtotal	1’632,093	1’647,101	1’642,187
	Imports (t)		
Point of entry 1	1’474,076	1’479,597	0
Point of entry 2	145,788	144,280	0
Subtotal	1’619,864	1’623,877	
	Consumption (t)		
Northwest	303,862	304,149	152,624

North	339,758	344,079	172,036
Northeast	240,313	241,205	120,264
Central-West	552,795	572,410	287,382
Central-East	1’072,289	1’075,268	539,841
South	341,073	338,412	170,300
East	270,067	263,468	133,389
Yucatán Peninsula	131,799	131,987	66,351
Subtotal	3’251,956	3’270,978	1’642,187
NSV (BP)	8,930	8,929.9	7,275.0

Source: Base model, 2024. NSV= net social value. BP= billions of pesos.

In addition, the effect on prices resulting from simulating border closures on the entry of pork into the country is shown in Table 2. Compared to the base model, pig farmers in the center-north would expect a higher price for the commercialization of the product, but this would not be the case for farmers in the rest of the regions; however, the price that the country’s demanders will have to pay will be higher compared to that of the optimal model.

Table 2: Effects on producer and consumer prices of pork resulting from eliminating imports due to an ASF outbreak, 2024

Prices ($/t)				
	Optimal model		**No imports**	
Region	**Productor**	**Consumer**	**Producer**	**Consumer**
Northwest	49,514	55,790	51,112	57,380
North	55,841	58,550	58,924	61,690
Northeast	56,281	56,580	61,433	61,460
Central-West	58,096	59,450	57,878	59,230
Central-East	60,763	61,230	60,092	61,010
South	61,113	64,240	58,291	61,420
East	61,998	63,770	57,616	59,390
Yucatan Peninsula	58,848	60,010	54,466	55,620

Source: results of running the model without imports, using data from 2024.

Discussion

The optimization of the model confirmed that the adjustment or calibration between what was observed and estimated was in the range of 0 to 10 %[33], which is sufficient to analyze the impacts of simulating the import elimination policy. The NSV was 0.002 % above that observed in 2024, implying that production and imports were overestimated by 0.92 and

0.25 %, respectively; the latter, higher by 0.37 % for PE1 and lower by 1.03 % for PE2. Consumption was overestimated by 0.002 %, with emphasis in the CE and CW regions; in contrast, in the rest (SU and EA), it was lower than in 2024.

The effect of the model on the PE was minimal due to its geographical location; it is even considered self-sufficient since the 100 % produced is consumed within that region, and it has a surplus left to redistribute(34) (Table 1). To supply its domestic market, Mexico acquired 1,619.9 thousand t of the product, mainly from the United States(34,35). Therefore, ASF can spread via imports both to this and to other countries(6), with the capacity to break into the trade of live pigs and their derivatives(36) and, although the nation is free of this disease, recent outbreaks in the Dominican Republic keep the Americas on alert(37); hence, under this scenario of the possible outbreak of ASF in Mexico, in this work, it was resorted to total cancellation of imports(38,39,40) due to the effect of the virus (Table 2), which were discounted from national consumption.

The results of the model show that eliminating imports due to a possible outbreak of ASF in the United States of America would have adverse economic effects in Mexico, as it is under possible threat of entry of the virus(6); in terms of production, the central-southern regions of the country would be more affected, whereas the north could partially compensate for the supply. This regional behavior is consistent with the internal redistribution observed in European countries in the face of ASF outbreaks(36,40); on the consumption side, the fall in this market variable by almost 50 % and the reduction in social well-being by 18.5 % show the vulnerability of the pork market to commercial disruptions. This finding coincides with what was reported for Mexico(41) and with studies carried out in Europe and Asia, where ASF has generated similar disruptions in production and trade(37,42,43).

In relation to prices, a restriction on imports due to the effects of ASF(40) suggested moderate increases for producers and consumers in half of the country. Nonetheless, in regions such as the south and the Peninsula, consumer price reductions are observed, possibly associated with social fear of acquiring potentially contaminated pork, aligning with what was documented in other findings(36,40,44); thus, the perception of reduced prices received by producers and paid by consumers in the aforementioned areas was relevant to a study on the economic effects of ASF in China(39). Price pressure could intensify in the near term, but the need for animal protein would eventually cause a rebound. This adjustment cycle has been reported in ASF-affected markets, where price recovery depends on health and trade response capacity. Although the model focused on economic variables, the results should be interpreted in conjunction with health measures. The absence of specific treatment for ASF makes it necessary to consider biosecurity, quarantine, and sanitary culling strategies as an integral part of the response. The scientific literature supports that effective containment of the virus depends more on prevention than on correction(5,37,39).

Conclusions and implications

The simulation of the entry of the African swine fever virus (ASF) into Mexico from the United States of America, with total elimination of pork imports, revealed predominantly negative effects on the domestic market. A surplus of the product was observed in only four regions, along with a nearly 50 % fall in national consumption, moderate increases in producer and consumer prices in half of the country, and a significant loss of social well-being, as measured by the reduction in net social value. Such findings suggest that a government decision to close borders to imported pork, without a comprehensive health strategy, would be detrimental to society; therefore, in the event of an ASF outbreak, it is essential to implement immediate containment and mitigation measures, such as the following: strict quarantine in affected farms and risk areas, minimizing the movement of animals, products, and vehicles; slaughter of infected or exposed animals with animal welfare and biosecurity protocols; deep disinfection of facilities, equipment, and transport units, with epidemiological monitoring; strengthening epidemiological surveillance through rapid diagnosis, traceability, and inter-institutional communication; education and training for producers, technicians, and transporters focused on biosecurity practices and early detection. Incorporating such strategies into simulation models would make it possible to estimate, in addition to economic impacts, the costs and benefits of health responses, so it is suggested that future research integrate epidemiological variables and response protocols to offer more robust scenarios that are useful for public decision-making.

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