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Contaduría y Administración
Accounting & Management

Contaduría y Administración 65 (5), Especial COVID-19, 2020, 1-23

Impact of social deprivation on the number of deaths from and infections by COVID-19 in Mexico: Analysis with artificial neural networks using information at the municipal level

Impacto del rezago social en el número de muertes y contagios por COVID-19 en México: análisis con redes neuronales artificiales empleando información a nivel municipal

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Received August 19, 2020; accepted October 28, 2020
Available online August 8, 2020

Abstract

The situation that Mexico is going through, due to the COVID19 pandemic, has evidenced the vulnerability of certain localities because of the deficiencies related to health services access, education, and basic services in households (electricity, water and sewer system). This research aims to analyze the impact of the lack of those services, on the number of COVID19 cases and deaths. To achieve that purpose, Artificial Neural Network approach is employed, using the municipal Social Lags Index, published by the National Council of Social Development Policy Evaluation (CONEVAL) and the number of cumulative COVID19 deaths and cases reported by Mexican government. Findings suggest that structural deficiencies related to lack of sanity conditions and access to water are the main determinates of the number of contagions and deaths by the pandemic.

JEL Code: C45, I14, I18, I24, I32
Keywords: contagion and death by COVID19; socioeconomic variables; artificial neural network; México; pandemia

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Peer Review under the responsibility of Universidad Nacional Autónoma de México.

http://dx.doi.org/10.22201/fca.24488410e.2020.3020

Resumen

La situación que atraviesa México, a raíz de la pandemia del COVID19, ha puesto en evidencia la vulnerabilidad de ciertas regiones propiciada por carencias relacionadas con acceso a servicios de salud, educación y servicios básicos de la vivienda (electricidad, agua y drenaje). El presente trabajo analiza el impacto que la falta de dichos servicios tiene en la incidencia de contagio y muerte por COVID19. Para ello, se utiliza la metodología de redes neuronales artificiales con datos a nivel municipal del Índice de Rezago Social, publicado por el Consejo Nacional de Evaluación de la Política de Desarrollo Social (CONEVAL) y datos de muertes y contagios acumulados reportados por el Gobierno de México a través de la plataforma COVID19. Los resultados revelan que las carencias estructurales, relacionadas con la falta de condiciones de saneamiento y acceso al agua, son los principales determinantes del número de contagios y muertes por la pandemia.

Código JEL: C45, I14, I18, I24, I32
Palabras clave: contagio y muerte por COVID19; variables socioeconómicas; redes neuronales artificiales; México; pandemia

Introduction

Based on data reported by the Government of Mexico on the COVID-19 platform,[1] as of June 27, there had been 216,682 confirmed cases and 26,648 deaths due to the SARS-COVID virus. Of the confirmed cases, 45.23% were female and 54.77% male, while 33.99% of the deaths were female and 66.01% male. In those infected, related diseases have been detected: 20.09% suffered from hypertension, 19.52% from diabetes, 16.44% from obesity, and 7.77% were smokers. Of the main comorbidities associated with the deaths, 41.94% suffered from hypertension, 36.87% from diabetes, 24.93% from obesity, and 8.73% were smokers.

Furthermore, research by Gun, Ni, and Hu (2020), Yang, Yu, and Xu (2020), and Zhang, Dong, and Cao (2020) confirms the relationship between coronavirus death and 32 comorbidities, most notably hypertension and diabetes.

Grotto, Huerta, and Sharabi (2008)and Leng, Jin, Li, Chen, and Jin (2015) indicate socioeconomic determinants, such as education, status, occupation, and income, which are associated with the prevalence of hypertension. Possible explanations include awareness of disease prevention and control, better accessibility to health services, adherence to medical treatment among higher socioeconomic groups, and low birth weight and work stress in lower socioeconomic levels.

Similar evidence has been found for diabetes. Saydah and Lochner (2010) note that low educational levels and belonging to a family with an income below the poverty line are associated with a higher level of diabetes mortality. Tang, Chen, and Krewsky (2003) found that the prevalence of diabetes

[1] https://coronavirus.gob.mx/datos/

increases with decreasing income and educational levels for both genders.

Based on the above, it is clear that there is a link between infection and death from COVID-19 and chronic diseases related to socioeconomic factors.

In addition to the above, the link between health and socioeconomic variables has been repeatedly confirmed in the literature (Subramanian, Smith, and Subramanyam, 2006; Dowd, Zajacova, & Aiello, 2009; Paula *et al.*, 2012; Kivimäki *et al*., 2020). Specifically, it has also been established that there is a relationship between educational level and health (Groot & Van Den Brink, 2007; Silles, 2009; Kaestner, Schiman, & Ward, 2020).

Thus, this study aims to analyze the impact that social deprivation and lack of access to education, health, and basic housing services (water, electricity, and drainage) have on the rate of infection and deaths caused by COVID-19 at the municipal level in Mexico. The methodological proposal consists of a cross-sectional analysis through artificial neural networks. The data used include the cumulative number of deaths and infections caused by COVID-19, the percentages of the population with low levels of education and without access to health services, and the percentage of homes without basic services. All of these variables are given by municipality.

This study contributes to demonstrating the main factors of social deprivation related to the impact of the pandemic and seeks to address these needs of the population, thereby reducing the impact that future health crises may have.

The study is structured as follows: the second section describes the relationship between socioeconomic variables and health, specifically, vulnerability to infection and death from COVID-19. The third section reviews the related literature, and section four details the data and methodology used. Section five presents and analyzes the empirical evidence, and the sixth section presents a discussion linking the relationship between the results obtained and Mexico's socioeconomic structural problems. Finally, the last section presents the conclusions.

Socioeconomic variables and the COVID-19 pandemic

Among the socioeconomic variables considered in this study are access to education and health services and household access to basic services, such as access to the public piped water supply, electricity, drainage, and dirt floors in homes.

Access to water is a basic service on which proper sanitation and hygiene practices depend. Compliance with both conditions is critical to reducing disease and promoting health (Moe & Rheingans, 2006). Particularly in the context of the pandemic, in which handwashing has been intensively and extensively promoted globally as a basic measure for reducing the infection rate, access to this service is

of fundamental importance (Van Bavel *et al*., 2020).

As for drainage services, the fact that latrines or toilets are not connected to a sanitation system implies exposure to feces, enabling the bacteria and parasites found in them to spread diseases, inhibiting the response capacity of individuals (Kumar & Joseph, 2012).

Electricity supply is a critical factor in providing health services and meeting the goal of universal health coverage and access to clean water and ventilation systems (Adair-Rohani *et al*., 2013). Lack of access to this service has been identified as one of the main barriers to fulfilling human potential and well-being (Markandya & Wilkinson, 2007). With lower well-being, individuals are more vulnerable to viruses such as COVID-19.

Electricity, in terms of sanitation, makes it possible to extend the shelf life of food by refrigerating and freezing it and to pump water from reservoirs (wells and springs), facilitating the supply of clean water even if there is no access to the public water supply network (Velo García, 2006).

Access to electricity also makes it possible to extend the hours dedicated to various activities without natural light. It increases efficiency in performing various tasks within the home using electrical and electronic devices. It also promotes comfort, gives access to information through TV and radio, enables using technology, and facilitates remote work and learning (Pillajo Lincango, 2015).

Concerning the last point, during the lockdown decreed after the outbreak of the COVID-19 pandemic, almost all labor and educational activities continued remotely through Information and Communication Technologies. Thus, people without access to electricity during the pandemic have seen their possibilities of entering or continuing to participate in the labor market or receiving education limited. Thus, the United Nations Development Program for Latin America states that only one out of every five workers can work from home (UNDP, 2020).[2] The remaining 80% lost their jobs or saw their income reduced because of cuts to their wages.

Regarding the relationship between education and health, the interrelations between both variables have been extensively documented. A higher level of education i) influences the way individuals think and decide (Ross & Wu, 1995); ii) makes possible a higher level of income and access to a better standard of living (Tsakos *et al*., 2009); iii) has positive effects on well-being, such as access to cultural experiences, eating habits, and hygiene patterns (Michalos, 2008; Brunello *et al*., 2011); iv) promotes creativity and innovation, facilitating problem-solving (Hofman *et al*., 2013; Hammond *et al*., 2011); and v) makes it possible to have access to greater knowledge, skills, concepts, rules, attitudes, and behaviors, improving productivity and competitiveness in the labor market (Fabra & Camisón, 2009). In general, a higher educational level promotes healthier behaviors and gives access to higher income and better living

[2] UNDP webpage "Working during a pandemic: Only one out of five workers in Latin America and the Caribbean can work from home. Available at: https://www.latinamerica.undp.org/content/rblac/es/home.html Consulted July 2, 2020.

standards, promoting health (Ortiz, Sosa, & Díaz, 2015).

Finally, access to health services makes it possible to keep individuals under supervision and monitor various indicators, facilitating the practice of preventive medicine and reducing the probability of developing chronic diseases. In terms of emergency care, it facilitates timely attention, preventing the patient's situation from worsening and the damage from becoming greater or irreversible.

Literature review

Given the importance of health within the dimensions of economic development and well-being, the relationship of that issue to socioeconomic factors has been extensively studied (Adams *et al.*, 2003; Haas, 2008; Dowd, Zajacova, & Aiello, 2009; Cherlin, 2018; Currie & Goodman, 2020).

In particular, authors such as Andronie (2005) and Amin, Raja, and Abro (2018) have analyzed the transmission of viral diseases and their relationship with socioeconomic factors. They examine the link between social and economic variables and the epidemiology of Hepatitis B and C viruses. Meanwhile, Mokhtar and Abd (2017) and Mohidem *et al*. (2018) investigate the social determinants of tuberculosis transmission in Malaysia. All these studies corroborate that socioeconomic variables are determinants of the transmission of viral diseases. The factors that have been frequently identified in the transmission of viral diseases are income, level of education/instruction, housing characteristics, and space (rural/urban).

In terms of research on socioeconomic variables and health-related situations at the municipal level in Mexico, Duarte-Gómez *et al*. (2015) stand out. They study the socioeconomic determinants of infant mortality in municipalities with a low Human Development Index. The results indicate that the average determinants are living conditions and access to health services, especially preventive care and delay in care.

Regarding the relationship between the COVID-19 virus and socioeconomic variables, there has been extensive analysis of the topic of risk perception based on socioeconomic issues and social network use (Huynh, 2020), beliefs and attitudes (Caria *et al*., 2020), behavioral economics (Haushofer & Metcalf, 2020), and behavioral response (Shabu *et al*., 2020).

Following the above, Muñiz and Corduneanu (2020) investigated the perception of risk and media consumption during the beginning of the COVID-19 pandemic in Mexico. The results indicated that the population was interested and concerned but with a low perception of the risk of contagion.

Continuing with the documents on COVID-19 in Mexico, the UNDP (2020) analyzes the health and economic challenges that the pandemic has imposed on Mexico; it also points out that the conditions of economic weakness and inequalities prevailing before the arrival of the pandemic have aggravated the

effects of the containment measures in economic terms. Thus, it investigates the effects of the pandemic in terms of informal and formal income, poverty, consumption, industrial production, oil prices, exports, and remittance income.

Closely related to the present study, Barraza *et al*. (2020) use the Multidimensional Poverty Index to identify the pre-existing poverty conditions that affect the level of vulnerability of certain households to the pandemic in El Salvador. The factors they use, analogous to those used in the present study, are access to drinking water, health services, overcrowding, access to sanitation, underemployment, and social security. The results indicate that more than 85% of the population suffers from at least one type of deprivation. This situation exposes them to greater risk and puts them at a disadvantage.

This research adds to that previously carried out, highlighting the conditions and lack of access to basic services of the Mexican population that increase the risk of infection and death in the face of the COVID-19 pandemic. The results are of utmost importance to demonstrate the socioeconomic determinants of COVID-19 infection, helping implement measures focused on mitigating these vulnerability factors.

Data and methodology

The analysis of the socioeconomic determinants of the cumulative number of COVID-19 infections and deaths at the municipal level is based on the number of infections and deaths per municipality[3] as of June 23, 2020, published by the Government of Mexico on the COVID-19 website. On that day, 656 municipalities were free of infection and deaths from COVID-19.[4] The municipality with the highest number of infections was Iztapalapa (7587 infections and 944 deaths), followed by Gustavo A. Madero (5568 infections and 872 deaths) and Puebla (5064 infections and 511 deaths). It should be noted that the study is carried out in municipalities with a positive number of infections and deaths due to COVID-19.

As for socioeconomic variables, the Social Gap Index (IRS) published by the National Council for the Evaluation of Social Development Policy (CONEVAL) for 2015 (the most recently published) is taken as a reference. It includes the variables: population 15 years old and over illiterate, population 6 to 14 years old not attending school, population 15 years old and over with incomplete basic education, population without entitlement to health services, housing with dirt floor, housing without toilet or sanitary services, housing without piped water from the public supply, housing without drainage, housing without electricity, housing without washing machine, housing without a refrigerator.

[3]Municipal data were chosen because this is the highest level of disaggregation, which makes it possible to obtain more information on the aggregate (national) relationship between the lack of basic services and the impact of COVID-19.
[4]See note 1 above

The effects of certain variables are implicit in other more general variables; for example, there is no need for electrical appliances such as washing machines and refrigerators without electricity. Therefore, this study has taken those variables that include the information of interest: population 15 years of age and older with incomplete basic education, population without access to health services, housing with dirt floors, housing without piped water from the public supply, housing without sewage, and housing without electricity.

In general terms, the Social Gap Index for 2015 reveals that, on average, 52.63% of the population aged 15 and over have incomplete basic education; 31.45% do not have the right to health services; 8.8% do not have access to piped water from the public supply; 18.7% do not have drainage; 2.5% do not have electricity. The municipalities with the lowest social lag (lowest deprivation) are Benito Juárez, CDMX (-1.68) and San Pedro Garza García, Nuevo León (-1.65), while those with the highest IRS are Batopilas, Chihuahua (4.87), and Mezquital, Durango (5.12).

Methodology

An Artificial Neural Network (ANN), also called a connectionist system, is a set of processing elements (nodes or neurons) interconnected by connections with a numerical and alterable value called weight. The processing of this network consists of adding the values of the inputs it receives from other units connected to it, comparing this amount with the threshold value. If it equals this value or is higher, it sends the activation to the output layer of the connected units (Montano, 2017).

An ANN can be defined as a directed graph that has the following characteristics (Larrañaga, Inza, & Moujahid, 2003):

i) Each node (neuron) i is linked to a state variable X_i.

ii) Each interconnection (i, j) between nodes (neurons) i and j is associated with a weight $w_{ij} \in \mathbb{R}$

iii) To each node (neuron) i is related a threshold $\theta_i \in \mathbb{R}$

iv) For each node i a function $fi(Xi, \ldots, Xn, W_{i1}, \ldots, W_{in}\ \theta_i)$ is required, which depends on the weights of its connections, the threshold, and the states of the nodes j that are connected to node i. The value of this function supplies the new state of the node.

These types of networks can define both linear and non-linear parameters, schematized from input to output, of type $Y = Y(X; W, A)$, which is a continuous function of both the inputs and the parameters W and the network architecture (A) (MacKay, 2003). Networks can be trained to perform regression, classification, and prediction tasks.

The input layer of an ANN is made up of a set of neurons that receive data and information from the environment. This type of layer comprises neuron structures that do not have input synapses, only output synapses. In the second plane are the hidden layers, which have no direct connection with the environment but collect information and data from the input layer; this is where they try to estimate, model, and represent the characteristics of the environment (Díaz & Aroche, 2020). This layer is the only one that is neither input nor output and has the following form:

$$\text{Hidden layer: } a_j^1 = \sum_l W_{jl}^1 X_l + \theta_j^1 ; h_j = f^1(a_j^1) \tag{1}$$

Finally, the output layer comprises the sets of neurons that provide the network response. This type of layer has no output synapses.

$$\text{Output layer: } a_j^2 = \sum_l W_{jl}^2 X_l + \theta_j^2 ; h_j = h^2(a_j^2) \tag{2}$$

An important difference between the existing classifications of artificial neural networks is the number of layers that make up the learning processes (hidden layers). A larger number of layers makes it possible for more complex processes to be approximated. Such a network is known as a multilayer perceptron (MLP).

Multilayer perceptrons enable the capture of a wide range of functional relationships, even if they are non-linear. An MLP network is a pre-fed network, i.e., a type of network that reacts to changes in its environment to preserve some particular system state (Bishop, 1995).

The training of the neuron is carried out with a subset of data $D = \{X^{(n)}, t^{(n)}\}$, fitting W of the input function and minimizing the error of the function by the "gradient descent" method given by the function:

$$E_D(w) = \frac{1}{2}\sum n \sum i \left((t_i^{(n)} - y_i(x^{(n)}; w)\right)^2 \tag{3}$$

The results of the ANN do not make it possible to directly analyze the sensitivity of the result (estimated variable) to each factor. Therefore, the Variable Importance Analysis must be performed to find out what the MLP has learned from the value of the weights and the activation values of the neurons. That is, it makes it possible to know each input variable's effect on the network's output (Díaz & Aroche, 2020).

This paper estimates multilayer perceptron networks, specifically presenting the results of two

ANNs, both with a hidden layer. For the first ANN, the output variable is the number of infections per municipality, while for the second network, the output variable is the number of deaths per municipality. For both networks, the input layer variables are: i) population aged 15 years and older with incomplete basic education, ii) population without access to health services, iii) dwellings with dirt floors, iv) dwellings without piped water from the public supply, v) dwellings without drainage, and vi) dwellings without electricity.

The choice of the methodology is due to the benefits of Neural Networks in comparison with other approaches: i) they produce a higher proportion of correct classifications than other methodologies, such as multiple regression for the prediction of a quantitative variable, discriminant analysis, logistic regression models for binary classification problems, and discriminant analysis for non-binary classification problems (Pitarque, Roy, & Ruiz, 1998); ii) they capture both linear and non-linear relationships (MacKay, 2003); iii) they capture the dynamic behavior of the relationships between variables; and iv) they can be trained to perform regression, classification, and prediction tasks (Diaz-Rodriguez, & Fidel-Aroche, 2020).

Results

Network information

Table 1 contains the information on the first network. It presents the variables in the input layer, the number of hidden layers (one), and the activation function found within the latter, which is of the hyperbolic tangent type. In the output layer, the variable to be estimated is the number of infections, the scaling method for the scale dependents is standardized, the activation function is of the identity type, and the error function is the sum of squares.

Table 2 presents the results of the ANN to analyze the determinants of the number of deaths, which is similar to the previous network. Thus, this study lists the six variables that make up the input layer, the number of hidden layers (one), and the activation function found within the latter, which, as for the first network, is of the hyperbolic tangent type. In the output layer, the variable to be estimated is the number of deaths, the scaling method for the scale dependents is standardized, the activation function is of the identity type, and the error function is the sum of squares.

Table 1
ANN information: analysis of the determinants of the number of infections

Network information			
Input layer	Factors	1	Population 15 years of age and older with incomplete basic education
		2	Housing with dirt floors
		3	Population not entitled to health services
		4	Housing without piped water from the public water supply
		5	Housing without sewage systems
		6	Housing without electric power supply
Hidden layers	Number of units[a]		6689
	Number of hidden layers		1
	Number of units in hidden layer 1[a]		11
	Activation function		Hyperbolic tangent
Output layer	Dependent variables	1	Confirmed
	Number of units		1
	Scale change method for scale dependents		Standardized
	Activation function		Identity
	Error function		Sum of squares

Source: created by the author with estimation data

Table 2
ANN information: analysis of the determinants of the number of deaths

Network information			
Input layer	Factors	1	Population 15 years of age and older with incomplete basic education
		2	Population not entitled to health services
		3	Housing with dirt floors
		4	Housing without piped water from the public water supply
		5	Housing without sewage systems
		6	Housing without electric power supply
Hidden layers	Number of units[a]		6689
	Number of hidden layers		1
	Number of units in hidden layer 1[a]		10
	Activation function		Hyperbolic tangent
Output layer	Dependent variables	1	Deaths
	Number of units		1
	Scale change method for scale dependents		Standardized
	Activation function		Identity
	Error function		Sum of squares

Source: created by the author with estimation data

Network predictive capability

The ultimate goal of the estimation of the Neural Network is to train it to predict the value, in this case of infections/deaths, by municipality based on the data of the variables found in the input layer. Figure 1 presents the dispersion of the cases estimated by the network against the observed cases, i.e., those that occurred: infections and deaths

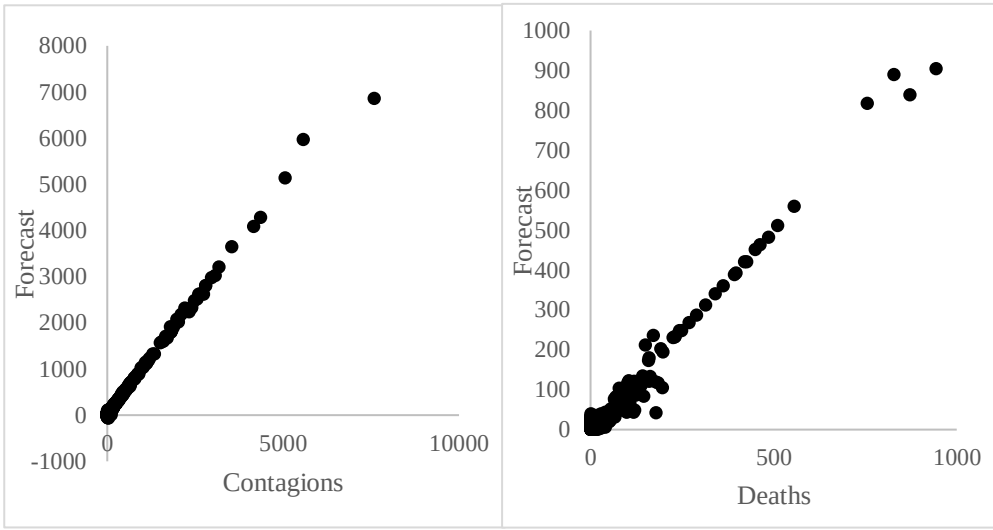

Figure 1. Scatterplot: observed vs. estimated cases
Source: created by the author based on estimation data.

Figure 1 indicates that the first network, whose output variable is the number of infections, presents a high level of assertiveness in its results, coinciding almost completely with the values presented. In the case of the network whose output variable is the number of deaths, for the municipalities with less than 200 cases, the error is greater than for the municipalities with between 200 and 600 cases, which could be due to the existence of unobserved variables that could affect the number of deaths.

After verifying the predictive power of the network and the fit of the data estimated by the network concerning the cases presented, the variable importance analysis is presented, which makes it possible to know the effect or significance of each input variable on the network output. Table 3 and Figure 2 present the values of this analysis comparatively.

The analysis of the importance of the variable indicates that the main determinant for the number of infections and the number of deaths due to COVID-19 is lack of access to drainage, indicating that the sanitary conditions caused by the lack of this service are crucial for health conditions. This result is consistent with the recommendation made by the World Health Organization (2020), which is that patients with COVID-19 should have their own toilet or latrine with a separate door from the patient's room. This device should be properly functioning and contain drain traps. The toilet should be flushed with the lid down to avoid splashing and aerosol clouds. If individual use of the bathroom is not possible, trained and properly protected personnel should disinfect it twice a day.

Table 3
Analysis of the importance of the variable

	Infection	Death
Incomplete education	70.9%	83.7%
Lack of electric power	80.5%	95.8%
Dirt floor	85.1%	85.4%
No access to health services	95.6%	91.1%
Lack of piped water	97.4%	93.4%
No access to drainage	100.0%	100.0%

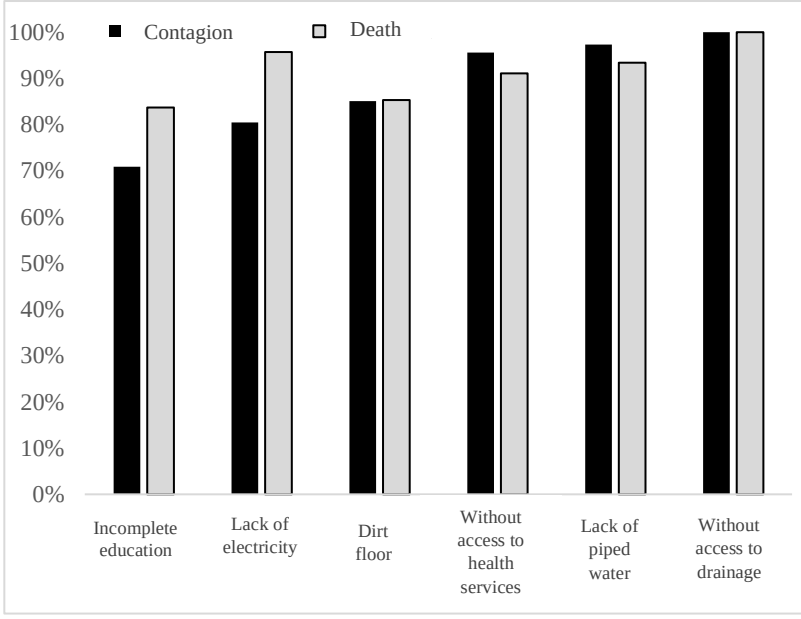

Figure 2. Analysis of the importance of the variable.
Source: created by the author based on estimation data.

This recommendation warns about the risk of contagion due to exposure to excrement. Lack of access to sewage puts at risk the household members of an infected person and the entire community, extensively and intensively, that is, for an extended period and constantly.

In the case of contagion, the second most important variable is the lack of piped water, which is explained by the hygiene and sanitation measures that must be followed based on the health authorities' recommendations. It is almost impossible to follow these recommendations if there is no access to the vital liquid.

Third, there is the lack of entitlement to health services, which makes it impossible to monitor the conditions of individuals, the practice of preventive medicine, and awareness of certain eating habits, hygiene, or physical activity, which reduce the propensity to chronic diseases, such as diabetes or hypertension.

Regarding the number of deaths, the second and third determining variables are the lack of electricity and the unavailability of piped water. Although the order of the factors associated with infection and death due to COVID-19 is different, the results indicate that, beyond access to health services, the lack of access to basic services promotes conditions that jeopardize the health of individuals, increasing their susceptibility to infection during the pandemic.

It should be noted that the lack of access to basic services is related to other factors. Suppose a household does not have water, electricity, or sanitation access. In that case, it is unlikely that it will have the means to acquire (a) hygiene and sanitation products (antibacterial gel, sanitizing liquid, and cleaning products, among others), (b) protective accessories (masks and gloves), (c) balanced diet, (d) medicines and food supplements and some other goods and services that could lessen the risk of contagion or increase the body's response capacity.

It is important to address those communities with a high index of social deprivation, trying to correct deficiencies related to basic issues and promoting dignified living conditions that mitigate the effects of a pandemic and do not become a breeding ground for contagion of other diseases.

Discussion

Recent forecasts indicate that the impact of the COVID-19 crisis could lead to an increase in global poverty for the first time since the 1998 Asian crisis. Estimates indicate that the number of people living in extreme poverty on less than USD 1.90 a day will increase by 7.75%, or 49 million people, out of 681 million people worldwide (Gerson Mahler et al., 2020). The situation in Mexico is discouraging. Although income distribution has improved in recent decades, it is still one of the most unequal countries in the world. The Gini index for 2018 is 45.4 (World Bank, 2020). What is more, 1% of the richest population earns 21% of the national income, and the four richest people possess 9% of the national wealth, situations not found in any other country worldwide (Esquivel Hernández, 2015).

In a similar vein, a recent study conducted by the National Council for Social Development Policy (CONEVAL) indicates that sectors of the population face the COVID-19 crisis with many disadvantages. It highlights women, workers, both in the formal and informal sectors, unemployed people, agricultural day laborers, children and children affected by the digital divide in their homes and the lack of connectivity in their communities, and micro, small, and medium-sized enterprises, which generate

72% of employment and 52% of the national product in Mexico (ibid.).

Due to the pandemic, income poverty could increase by between 7.2% and 7.9%, meaning that about 8.9 to 9.8 million people would be added to the population with insufficient income to purchase the basic food basket, goods, and services. Furthermore, the total number of people living in extreme income poverty would increase between 4.9% and 8.5%, equivalent to between 6.1 and 10.7 million people. Due to the impact of the crisis, people who were not poor or vulnerable may find themselves in conditions of poverty or vulnerability (CONEVAL, 2020).

According to a survey conducted by the Universidad Iberoamericana in May of this year, 8.4 million people had lost their jobs, were temporarily suspended from work, or could not go out to look for work due to the COVID-19 pandemic. 14.6% of the economically active population was in this situation. In addition, 2 out of every 3 of the jobs lost were in the informal sector, affecting mainly women with low levels of remuneration (Universidad Iberoamericana, 2020).

The relationships between the variables of social deprivation with the infections and deaths due to the COVID-19 pandemic, found with the artificial neural network analysis, reflect their negative impacts and their basic underlying causes: poverty, social-economic inequality, and marginalization, as highlighted above.

The relationship of incomplete education with infections and deaths is an encouraging indicator of the importance of education (albeit incomplete) to confront negative events that occur in society. However, it is also an early warning of the attention that should be paid to the development of education from basic education to higher education, especially because of the negative impact of the suspension of face-to-face classes. Virtual education is not a perfect substitute for children and young people from poor and marginalized households. According to the Social Gap Index, the relationship between the lack of electricity and infections, especially those resulting in deaths, is high. Households lacking electricity lack light and basic household goods, television sets, and digital media.

Therefore, information campaigns on the measures to follow to prevent contagion and deaths are null and void, as are educational programs on television or digital platforms. At the beginning of the 2019-2010 school year, around 25 million students returned to school in basic education; however, 20 million came from poor households. Moreover, prior to the health crisis, the dropout rate in higher secondary education in Mexico was high, 16.9%, and at the higher level, 8.3% (INEGI, 2020), rates that will surely increase due to the crisis, and it is necessary to address the resulting lags. Relevant measures in this regard are i) to increase the scope and number of scholarships for students, granted by the Benito Juárez National Coordination of Scholarships for Welfare; and ii) to consolidate the Internet for All Program, designed to offer internet connections to 101,000 public spaces such as schools, hospitals, and public offices. Particular emphasis should be placed on closing the digital divide between urban and rural

public places.

Clear manifestations of poverty and social inequality, particularly in the "lost cities" of urban and semi-urban municipalities, are precarious housing, lack of piped water, and unavailability of access to drainage variables. According to empirical evidence, these are highly related to contagion and deaths due to the COVID-19 pandemic. The housing of the poorest family strata is poorly constructed, lacks services, and has cramped spaces, resulting in overcrowding (Ziccardi, 2016; Roy, Bernal & Lees, 2020).

Most of these new urban centers result from migration from the countryside to the cities, subsequent invasions of communal or state properties, and the construction of "cardboard houses" and corrugated metal roofs in very irregular spaces. In urban and suburban centers with self-construction the use of good quality materials is already common. Nevertheless, the lack of services remains as a palpable legacy of their irregular origin. In the country's south, one-third of the population lives in precarious houses, as described above, and a high percentage have dirt floors (UNAM, 2020).

It is difficult to comply with health authorities' recommendations to prevent COVID-19 problems in these conditions. Lockdowns and social distancing are incompatible with the precariousness of their housing and the high number of family members. Likewise, frequent handwashing and other hygiene norms are unfeasible due to the lack of piped water and drainage (UNAM, 2020).

The impact of poor housing on health conditions is magnified by the existence of an equally poor health system. The high rates of infection and deaths due to the COVID-19 pandemic have highlighted its limitations. Due to decades of persistent deterioration and corruption, the current system discriminates between the poor and the rich (who have access to private health services), between the entitled and the non-entitled, and between urban and rural sectors. Around 20 million people lack affiliation to health services; six out of every 20 employed people do not have access to health services because of their work, as more than 34 million work in the informal sector. This problem is aggravated in the country's south in municipalities with social deprivation and Indigenous communities (Acción Ciudadana Frente a la Pobreza, 2020).

Conclusions

This study presents the relationship between the availability of basic services and the number of deaths and infections due to COVID-19. It concludes that the two variables with the greatest impact on the number of infections are lack of access to drainage and unavailability of piped water from the public supply. Both factors demonstrate that the lack of basic sanitary conditions increases exposure to diseases, especially viral diseases such as COVID-19. Regarding the number of deaths, the two variables most closely related are lack of access to drainage and unavailability of electricity. Both variables reflect

structural deficiencies that prevent the population from ensuring their well-being, inhibiting their development opportunities.

This study contributes by highlighting the factors that should be addressed to reduce contagion and deaths due to the pandemic, thus decreasing the vulnerability of at-risk groups. However, it must be taken into consideration that, on the one hand, the shortcomings indicated have a structural nature that prevents the response from being immediate since they require significant investment in infrastructure for the supply networks of electricity, water, and drainage. On the other hand, the State has strong limitations in terms of its budget, in addition to the various pressures due to the present crisis.

Among the recommendations, taking into account the above restrictions and identifying vulnerable areas, are: implementing piped water supply schemes or installing washing and disinfection areas in communities without access to drinking water. Another option would be to identify at-risk areas, especially where there is a high concentration of people over 60 years of age, and install temporary containment centers with adequate basic services infrastructure. In addition, mobile health units could be installed to treat those infected and carry out prevention and awareness campaigns on COVID-19 measures.

The COVID-19 pandemic has demonstrated that economic and health adversity has a greater impact on certain regions of the country, particularly those lacking access to elementary services and basic housing conditions. The effects of the economic and health crisis are not only immediate. They will also have repercussions on opportunities and standards of living in a differentiated manner for the population in the medium and long term.

In many cases, the health crisis reduced family income and increased expenses in other areas: hygiene products, telecommunication services, medicines, and medical services. In addition, it has caused some heads of households to fall ill or die, affecting the long-term economic capacity of households. The economic crisis also generates job losses and reduced consumption possibilities, affecting the population's food and health conditions.

Although there were forecasts of recession for 2020, the pandemic significantly exacerbated the effects of the economic crisis, creating new situations that are much bleaker than those projected. Thus, the challenge is to flatten the contagion curve and lessen the economic effect, trying to find a balance. This challenge is especially difficult for economies such as Mexico's, which has high levels of informality, vulnerable populations lacking basic services, high economic and financial dependence, and economic inequality, among others.

As for future lines of research, the pandemic and the crisis unleashed by COVID-19 have left academics and scientists with countless problems to analyze and attempt to solve from different perspectives. Many variables influence the number of infections and deaths caused by the pandemic, such

as the adoption of hygiene measures, income and savings levels, poverty levels measured by the multidimensional poverty index, and well-being measured by the human development index, among other factors. The main limitation is the availability of information and the coincidence in its level of disaggregation. Considering some of these variables is necessary to undertake a more complete and comprehensive analysis.

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