

Analysis of the economic effects on biopsychosocial homeostasis from a three-dimensional probability measurement system

Análisis de los efectos económicos en la homeostasis biopsicosocial a partir de un sistema de medición probabilístico tridimensional

Emilio Arch-Tirado^{1*}, Ana L. Lino-González², Jorge Loria-Castellanos³, Ángel A. Pérez-Calatayud⁴, Erandy Montes de Oca-García⁵, Miguel A. Collado-Corona¹ and Adolfo Albo-Márquez⁶

¹Neurological Center, ABC Santa Fe Medical Center, Mexico City; ²Clinical Neuroscience Department, Division of Neurosciences, Instituto Luis Guillermo Ibarra Ibarra National Rehabilitation Center, Mexico City; ³Division of Special Projects in Health, Mexican Institute of Social Security (IMSS), Mexico City; ⁴Critical Areas Division, Hospital General de México Dr. Eduardo Liceaga, Mexico City; ⁵Service Emergency Department, General Hospital 197, IMSS, Texcoco, State of Mexico; ⁶Association of Banks of Mexico, Mexico City, Mexico

Abstract

Objective: Describes the economic effects on bio-psycho-social homeostasis from a three-dimensional analysis of the joint interaction of biological, psychological and economic-social comorbidities, in order to know the probabilities of occurrence of these conditions simultaneously. **Method:** It is a cross-sectional study and random quota sampling. 353 men and women over 20 years of age participated, and answered a 27 questions application (bio-psycho-economic-social), the data was analyzed three-dimensionally in order to know the probability of occurrence of the variables studied and their possible location in the probabilistic unit cube. **Results:** Based on the unit cube proposal, it can be observed that in the block of people with incomes from 2200 to 6600 pesos in the group of men there is a probability of 12.9 per 1000 inhabitants of presenting debt problems, overweight and severe depression, while in the case of women, the probability is 2.08 per 1000 inhabitants. **Conclusions:** There is a priority axis that determines the change of the remaining variables, in this case it is the economic axis the one that determines the biological and psychological conditions.

Keywords: Multifactorial analysis. Economic vulnerability. Debt and Health.

Resumen

Objetivo: Describir los efectos económicos en la homeostasis biopsicosocial a partir de un análisis tridimensional de la interacción conjunta de la comorbilidad biológica, psicológica y económico-social, con la finalidad de conocer las probabilidades de ocurrencia a partir de estas condiciones de forma simultánea. **Método:** Estudio transversal y muestreo aleatorio por cuotas. Participaron 353 hombres y mujeres mayores de 20 años que contestaron un cuestionario con 27 preguntas (biopsicosociales-económicas). Se analizaron los datos tridimensionalmente con la finalidad de conocer la probabilidad de ocurrencia de las variables estudiadas y su posible localización en el cubo unitario probabilístico. **Resultados:** Con base en la propuesta del cubo unitario se obtiene que, en las personas con ingresos de 2200 a 6600 pesos, en los hombres existe una probabilidad

*Correspondence:

Emilio Arch-Tirado
E-mail: arch.tirado@gmail.com

Date of reception: 23-12-2020

Date of acceptance: 28-03-2021

DOI: 10.24875/CIRUE.M21000395

Cir Cir (Eng). 2022;90(3):386-394

Contents available at PubMed

www.cirugiaycirujanos.com

2444-0507/© 2021 Academia Mexicana de Cirugía. Published by Permanyer. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

de 12.9 por cada 1000 habitantes de presentar deudas, sobrepeso y depresión grave; en las mujeres, la probabilidad es de 2.08 por cada 1000 habitantes. **Conclusiones:** Existe un eje prioritario que determina el cambio de las variables restantes, en este caso el eje económico que determina las condiciones biológicas y psicológicas.

Palabras clave: Análisis multifactoriales. Vulnerabilidad económica. Deudas y salud.

*"No man ever steps in the same river twice,
for it's not the same river and he's not the same man."*
Heraclitus

Introduction

The World Bank defines poverty as the inability to reach a minimum level of life, that is, to have access to a standard of nutrition and other very basic needs¹. In 2018, it stated that approximately 50% of the total people who live in poverty is comprised by children, and that women represent the majority of poor people in most regions of the world. It also reported that more than 40% live in economies affected by fragility, conflicts, and violence, and this figure is expected to increase to 67% in the next decade. Furthermore, it is estimated that many people who had overcome extreme poverty may revert to it as a consequence of the COVID-19 pandemic (between 88 and 115 million people). It suggests that the new poor will possibly live in overpopulated urban areas and they will be employed in informal services and manufacturing activities².

In Mexico, according to the Consejo Nacional de Evaluación de la Política de Desarrollo Social (CONEVAL; National Committee for the Evaluation of Social Development Policy), in 2018 the population with income below the poverty line was 48.8% (61.1 million people), the population with income lower than the extreme poverty line was 16.8% (21 millions), and regarding the population that is in poverty was 41.9% (52.4 millions), while the population in a situation of extreme poverty was 7.4% (9.3 millions). In terms of vulnerable population by income, it was reported to be 6.9% (8.6 millions), vulnerable population due to social deficit (educational lag, lack of access to healthcare services, to social security, foods, quality, basic housing services and spaces) was 29.3% (36.7 millions), and population that is not poor and not vulnerable was 21.9% (21.9 millions)³.

According to the World Health Organization (WHO), poor health is both a cause and a consequence of poverty. It has stated that sickness can reduce family

economy, learning capacity, productivity, and quality of life, and this, in turn, creates or perpetuates poverty⁴. The Secretaría de Desarrollo Social in Mexico stated that the main cause of malnourishment in the population is the poor intake of food that provide energy and micronutrients (vitamins and minerals), related to poor eating habits, low income, and supply issues in rural areas. It states that, for a few years, Mexico has suffered a transformation in nutritional and food aspects characterized by the abandonment of traditional diets based on high consumption of cereal and root vegetables, and the adoption of diets high in energy, fat, and simple sugars; additionally, physical activity due to changes to the occupational structure and easier access to transportation, among other factors, increasing the number of overweight people and chronic conditions related to nutrition, such as hypertension, diabetes mellitus, and ischemic cardiopathy. An approximate daily per capita of 3100 kcal has been estimated, well above the required average, and, in addition, it has been reported that population with higher income, and possibly with intense work days and prolonged commute, tends to consume food out of the home, which implies higher consumption of foods rich in macronutrients⁵ (energy provision, carbohydrates, fat, and protein)⁶. Regarding the consumption of beverages, in 2008, it was reported that the poorer a household, the higher the expenditure on these products, that is, 5.4% of households with food poverty, and 3% in households with no poverty, which shows that the eating habits of the population do not exclusively depend on income or the nutritional content of food, but other attributes are taken into account, such as taste and smell. A consequence of this transformation is the increase in the levels of obesity, where a phenomenon known as "double load households" (malnourished children and obese mothers) has starting to emerge as a consequence of sedentary lifestyle and higher consumption of fats and sugars⁵. On the other hand, the *Encuesta Nacional de Ingresos y Gastos en los Hogares* (National Survey for Household Income and Expenses) in 2008, states that the ratio of women in poverty situations is higher

than that of men; 44.5% (24.4 millions) of women lived in multidimensional poverty (education, health, work, social security, housing, and general level of life)⁷. The CONEVAL has reported that participation in labor matters is higher in men than in women, and it is common for women who develop any subordinate work to lack contracts; it has also been seen a higher proportion of women who work but do not get paid or compensated. In connection to this, it is stated that the financial income of households comes primarily from men, who received approximately two thirds (65%) of household incomes, and lastly, that women who work receive lower incomes than men in practically all levels of education; and the salary differences between men and women is more evident in population with higher training⁸.

Currently, dynamic models are known and applied for the analysis and interpretation of economic, social, and biological phenomena. We can state that the probability of occurrence of identical events is impossible in time and space, and this is supported by the classic physical principle that two subjects cannot occupy the same space at the same time. Considering this property, it would be ideal to create, design, and implement multivariate measurement strategies that are independent for every subject and event. Based on this, it can be considered that each subject is a product of their environment, and even in parallel histories, such as in the case of siblings or even twins, it is expected for any type of evaluation to be the same. Dynamic systems are complex systems that are subject to great modifications based on minimal changes, as expertly exemplified by Lorenz⁹ with the “butterfly effect,” where minimal variations in the initial stages of a dynamic system generate great changes with time. In this way, it can be said that, in dynamic systems, external variables not only interact with the elements immersed in the system, but also with the relationships between them. It is known that some systems operate in a linear manner, as their actions can be predicted by the information regarding their starting point and their operating rules; however, many systems that are apparently deterministic, may result in extremely chaotic and unpredictable systems due to the complexity of the interaction and modification of their variables throughout time.

Chaos theory has two starting points regarding dynamic systems: the first one emphasized the hidden order that exists in a system called a chaotic system, and the second one refers to the spontaneous self-regulation and self-control processes⁹. The contribution

of Lorenz⁹ to the knowledge of complex systems and the condition that they can be chaotic is very important. Lorenz⁹ discovered, among other things, the essential characteristics of systems that help us better understand what we know as chaos; furthermore, he described the so-called strange attractors, which are famously exemplified as the “butterfly effect,” as a minimal variation in the initial conditions of a system, which may result in a completely unexpected effect, equivalent to the idea that “when this insect bats its wings in the Amazon, it could cause a storm a month later in Chicago.” These statements are based on the existence of several attractors in a specific system, which gradually generate more changes on the initial conditions: in this way, each system is liable to certain attractors, as is the case of the large amount of variables that exist in the environment, that in turn, directly and indirectly affect the system^{10,11}.

It is a priority to remember that reductionism is a school of thought based on the statement that “the whole is the sum of the parts;” thus, all factual element can be fragmented and studied in each of its parts without losing the content of its initial structure and function. It is hard to find any other system of objective reality in which this idea has been applied as intensely as the human body: the reduction of the system studied to simpler parts (systems, tissues, cells, protein compounds, molecules, atoms, etc.) that can be analyzed, which has been the medical paradigm for millennia. Isaac Newtown, the father of linearity, states in his third law that “for every action, there is an equal and opposite reaction,” which mean that there is one single cause for one single effect. Chaos theory breaks this linearity paradigm and Newtonian physics¹².

The key element in chaos theory is based on the fact that a large amount of independent variable will result in one single dependent variable, that is, there are many caused for a single effect to occur^{13,14}. Economist face this phenomenon almost everyday when analyzing economic trends. Since all complex systems behave in the same manner, these concepts can and should be applied to health sciences. In this way, we can state that, in dynamic systems, “small changes in the initial conditions of the system can generate great changes in the final result,” and, in the same way, in the superficial forms of its evolution, it is possible for them to follow different routes, such as self-organization, synchronization, unpredictability of final effect and small changes on initial conditions, as well as the existence of simplicity in some levels; in this way, chaos exists in other forms in fundamental concepts of complexity¹⁵.

Several time and space properties in complex systems arise spontaneously from interactions that occur in the system in question, which have a longitudinal impact throughout time, generating unexpected effects or properties on a particular system; these properties have been labeled as “emerging processes.”

The WHO defines health as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.” Therefore, the interaction of biopsychological and economic elements is decisive in homeostasis, in such a way that, the vulnerability of one of them is a cause for imbalance of the other two. This definition of illness was issued in the *Preamble to the Constitution of the World Health Organization*, adopted by the International Sanitary Conference, held in New York from June 19 to July 22, 1946, and signed on July 22, 1946 by the representatives of 61 States¹⁶, becoming effective on April 7, 1948. The definition has not been modified since then.

While reviewing the hypotheses on which Riemann's geometry (1826-1866) is based, it is worth noting that: “If, in one concept whose determinations constitute a continuous variety, we go from one determination to another, in a defined manner, the determinations traveled are one unidimensional variety whose essential characteristic is that only a continuous progression is possible in it from one point in two directions, forward or backward. Now, if we picture that this variety is transformed once more into a completely different one, that is once more defined, in such a way that each point is transformed into a certain point in the other, the totality of the determinations thus obtained form a two-dimensional variety. Similarly, we obtained a three-dimensional variety if we think of a two-dimensional variety transforming into a completely different one in a defined manner, and it is easy to imagine how to continue this construct. If, instead of thinking of this concept as subject to determinations, we consider its object as a variable, this construct can be designated as the composition of a variability of $n + 1$ dimensions from a variability of “ n ” dimensions and a variability of one dimension”¹⁷.

When considering the arguments of the chaos theory combined with the concepts for the ponderation of three-dimensional scales based on the definition of the WHO, simultaneous three-dimensional measurements can be generated to evaluate the probability of occurrence of certain event in a pathological process in a sample of subjects.

The purpose of this work is to describe the economic effects on the biopsychological homeostasis using a three-dimensional analysis of the interaction of

biological, psychological, social, and economic comorbidity with the purpose of understanding the probabilities of occurrence based on these conditions in a simultaneous manner.

Method

Cross-sectional study and random quota sampling. The study included 353 men and women over 20 years of age who were economically active and who agreed to answer a survey in the streets of Mexico City. The protocol was not subject to any research and ethics committee as it is a cross-sectional, descriptive study with no clinical or surgical complications.

Measurement instrument

A questionnaire with 10 questions was created and the Hamilton test was added for depression. The first five questions were financial and included information regarding monthly income, dependents, type of housing, employment status, and financial debts; based on these questions, it was determined whether the participants had debt. The next five questions were biological and structured with the purpose of determining if body weight was healthy, normal, or overweight, and if they had chronic conditions or not. In order to evaluate the emotional factor (psychological) the short version of Hamilton's depression test with 17 questions was used with the purpose of obtaining an intensity and severity measurement for depression.

Application of the measurement instrument

In order to perform the quota sampling, it was established that each one will include 10 participants, that is, intervals of 10 subjects were interviewed as they walked through an avenue in Mexico City; when a candidate refused to participate, the stable quota established in the samples started over. The interviewer was a medicine intern, who removed any participant that showed any pattern to consider that their answers were not truthful.

Proposed statistics instrument

Based on the article by Arch-Tirado et al.¹⁸ titled “Uncertainty, dynamic systems, principles of quantum mechanics and their relationship to the health-disease

process (analysis proposal),” the three-dimensional unit cube (bio-psycho-economic-social) was used starting from the axis (x, y, z) with the following conditions: the origin of the cube is (0,0,0), the limits by axis (1,1,1), and the unit in each axis is 0.1, in this manner, the areas by plane are limited by the axis (x, y) (x, z) and (y, z), and the total product of the planes (x)(y), (x)(z) and (y)(z) independently, with a total of 100 squares of 0.1². Furthermore, for the analysis of cubic areas, the result of product of the three axes (x) (y) (z) is observed, which is equal to 1000 cubes with an area of 0.1³. The axes are categorized in the following manner: x = psychological axis, y = biological axis, and z = economic and social axis, and they are all influenced by the environment and the moment in history of the subjects analyzed.

In order to weight the axes, the statistical dependency principle was used based on the sample size, calculating the likelihood of occurrence for an event based on its comorbidities by axis; in this manner, the higher the number of comorbidity, the value tends to zero by the probabilistic intersections principle, and vice versa, the lower the comorbidity number, the value tends to 1, so that it is $A \cap B$ closer to 1 than $A \cap B \cap C$, and so forth, until it $A \cap B \cap C \dots \cap X_i$ tends to 0, and in this way the probabilistic space by axis is $0 < (x, y, z) < 1$, as the case may be.

Tenets of the probabilistic unit cube

- No point is static: there can be movements in seconds, minutes, hours, etc., according to the environment and the manipulation of the variables depending on the moment when the measurement is taken.
- Pivot axis and tie effect: the axis where the variable is manipulated will impact the two other axes, with a strength proportional to the impact of the variable of the axis in question.
- The larger the number of intersections, the value tends to 0, and when one intersection is removed, the point moves towards 1, where the speed of the change is proportional to the value of the proportion of the interaction in question.
- Dynamic axes must be adapted to specific cases, evaluating the macro and micro-environments.
- Points by specific area will have a fractal behavior.
- The distance between 0 and 1 is infinite (property of actual numbers).

- There are three-dimensional probabilistic concentration areas, which delimit and facilitate the analysis of the sample studied (Fig. 1).

Data analysis

For the analysis, subjects interviewed were grouped according to their monthly income, that is, income lower than 2200 pesos, from 2200 to 6600 pesos, from 6600 to 13,320 pesos, from 13,320 to 20,000 pesos, from 20,000 to 26,640 pesos, from 26,640 to 33,300 pesos, from 33,300 to 40,000 pesos, from 40,000 to 50,000 pesos, and higher than 50,000 pesos. The proportion of subject was calculated for each income range, and decisions trees were built with the purpose of evaluating the conditional probability and statistical dependency for each branch. Finally, the probabilities obtained per variable were multiplied (biological, psychological, and economic-social), multiplying the results by 1000 with the purpose of determining the probability of occurrence of the three variables simultaneously, and their possible location on the probabilistic unit cube.

Results

The study was comprised on 353 subjects, 175 males (49.6%) and 178 women (50.4%), with an average age of 37.87 ± 10.1 years (mean $\pm$ standard deviation). Regarding the debts manifested by the subjects interviewed, the average monthly debt amount was $7,016.81 \pm 15,617.48$ pesos. The average salary percentage used to pay debts was $19.82 \pm 25.2\%$. Regarding body weight, 3 subjects (0.8%) had low weight, 116 (32.9%) normal weight, 142 (40.2%) overweight, 73 (20.7%) type I obesity, 13 (3.7%) type II obesity, and 6 (1.7%) type III obesity, where the trend was overweight. Regarding income, 16 subjects (4.53%) stated having income lower than 2220 pesos, 120 (33.99%) between 2220 and 6660 pesos, 108 (30.59%) 6660-13,320 pesos, 35 (9.91%) 13,320-20,000 pesos, 26 (7.36%) 20,000-26,640 pesos, 23 (6.51%) 26,640-33,300 pesos, 6 (1.69%) 33,300-40,000 pesos, 8 (2.3%) 40,000-50,000 pesos, and 11 (3.1%) income higher than 50,000 pesos, where the trend is from 2200 to 6600 pesos. On the other hand, 22.7% (n = 80) of the sample said they were smokers, 47% (n = 166) drank alcohol, 2% (n = 7) used drugs, 10.5% (n = 37) had diabetes, 11.04% (n = 39) had arterial hypertension, and 1.4% (n = 5) had cardiopathies.

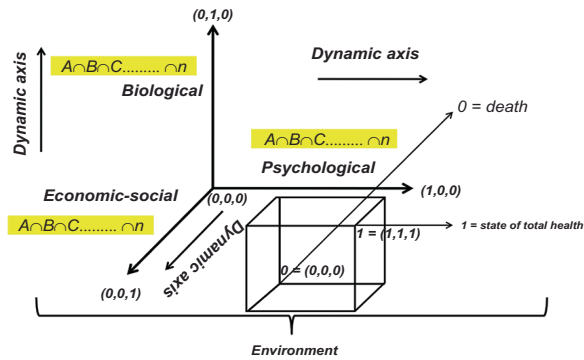


Figure 1. Probabilistic unit cube. It can be seen that, when values tend $(0,0,0)$ there is higher risk, which results from the higher number of comorbidity; and in the opposite case, when the value tends to $(1,1,1)$, when the health status is complete. (Figure created by the authors and previously published¹⁹).

Three-dimensional analysis based on the treediagram

Of the 353 subjects interviewed, 16 made less than 2200 pesos per month, that is, $\frac{16}{353} = 0.0453$ (4.53%), 10 of which were women and 6 men.

Using a decision tree construction based on the frequency of the variables of debt, overweight, diabetes mellitus, and depression, a table was built with the conditional probability calculations for each event in relation to the previous one, as well as the joint probability of all variables analyzed. It was found that the highest occurrence probability in this group of monthly income is 0.3112, that is, 31.1% probability of being a woman, with no debt, normal weight, no diabetes, and no depression. In terms of men in this group, 50% had debt, compared to women (40%) (Table 1).

When calculating the joint probability of the three axes (bio-psycho-economic-social) regarding the occurrence probability considering undesired comorbidity, 33.33% (0.3333) of men were overweight, 16.66% (0.1666) had severe depression, and 50% (0.5) had debt; in this way, $A \cap B \cap C = 0.027638$, based on the proposal of the unit cube. This result is multiplied times 1,000 in order to obtain a probability of 27.7328, that is, the probability that, 28 men per 1000 inhabitants are at risk of presenting these three conditions together. In women, the incidence of overweight was 20% (0.2), severe depression, 10% (0.1), and debt, 40% (0.4); in this way, $A \cap B \cap C = 0.008$, and multiplied times 1000 based on the

proposal of the unit cube, we obtain the probability that 8 out of 1000 women are at risk for these three characteristics together.

Regarding income between 2200 and 6600 pesos per month, 120 subject were identified, that is $\frac{120}{353} = 0.3399$ 33.99%, out of which 61 were women and 59 men, as in the previous case.

The dependency probability with the variables studied was calculated by construction a tree diagram, finding that, the larger the sample size, the nodes and branches increase significantly; thus, in order to obtain the probabilistic intersections, the product of each node must be calculated in relation to the length of the tree as follows:

Proportion (Gender) (Weight) (Diabetes) (Depression) = final Intersection.

For men:

$$\begin{aligned} R1 &= (0.4916)(0.4915)(0.2068)(0.66)(0.5) = 0.01648 \\ R2 &= (0.4916)(0.4915)(0.2068)(0.66)(0.5) = 0.01648 \\ R3 &= (0.4916)(0.4915)(0.2068)(0.33)(1) = 0.01648 \\ R4 &= (0.4916)(0.4915)(0.7931)(0.95)(0.36) = 0.06553 \\ R5 &= (0.4916)(0.4915)(0.7931)(0.95)(0.27) = 0.04915 \\ R6 &= (0.4916)(0.4915)(0.7931)(0.95)(0.18) = 0.03276 \\ R7 &= (0.4916)(0.4915)(0.7931)(0.95)(0.18) = 0.03276 \\ R8 &= (0.4916)(0.4915)(0.7931)(0.04)(1) = 0.00766 \\ R9 &= (0.4916)(0.5084)(0.166)(0.6)(1) = 0.02489 \\ R10 &= (0.4916)(0.5084)(0.166)(0.4)(1) = 0.01659 \\ R11 &= (0.4916)(0.5084)(0.166)(0.4)(1) = 0.01659 \\ R12 &= (0.4916)(0.5084)(0.833)(0.76)(0.78) = 0.12341^* \\ R13 &= (0.4916)(0.5084)(0.833)(0.76)(0.05) = 0.00791 \\ R14 &= (0.4916)(0.5084)(0.833)(0.76)(0.15) = 0.02373 \\ R15 &= (0.4916)(0.5084)(0.833)(0.24)(0.33) = 0.01648 \\ R16 &= (0.4916)(0.5084)(0.833)(0.24)(0.16) = 0.00799 \\ R17 &= (0.4916)(0.5084)(0.833)(0.24)(0.16) = 0.00799 \\ R18 &= (0.4916)(0.5084)(0.833)(0.24)(0.33) = 0.01648 \\ &\quad \Sigma 0.49936 \end{aligned}$$

In this manner, consider the highest (*) value obtained, it is established that, in the group of subjects with monthly income between 2200 and 6600 pesos, there is a probability of 0.12341 for men, with no debt, overweight, no diabetes, and no depression. Among the men in this group, 49.15% had debt, compared to 40.98% of women.

For women:

$$\begin{aligned} R19 &= (0.5083)(0.4098)(0.24)(0.83)(0.2) = 0.00829 \\ R20 &= (0.5083)(0.4098)(0.24)(0.83)(0.2) = 0.00829 \\ R21 &= (0.5083)(0.4098)(0.24)(0.83)(0.4) = 0.01659 \\ R22 &= (0.5083)(0.4098)(0.24)(0.83)(0.2) = 0.00829 \\ R23 &= (0.5083)(0.4098)(0.24)(0.16)(1) = 0.00799 \\ R24 &= (0.5083)(0.4098)(0.76)(0.89)(0.47) = 0.06622 \\ R25 &= (0.5083)(0.4098)(0.76)(0.89)(0.29) = 0.04085 \end{aligned}$$

Table 1. Income lower than 2200 pesos

Men						A∩B....∩N
R1	n = 6 (0.375)	WD (n = 3) = 0.5	NW (n = 1) = 0.33	W/oDb (n = 1) = 1	MDp (n = 1) = 1	0.061875
R2			OW (n = 2) = 0.66	WDb (n = 1) = 0.5	SDp (n = 1) = 1	0.061875
R3				W/oDb (n = 1) = 0.5	MDp (n = 1) = 1	0.061875
R4		WD (n = 3) = 0.5	NW (n = 1) = 0.33	W/oDb (n = 1) = 1	WDp (n = 1) = 1	0.061875
R5			OW (n = 2) = 0.66	W/oDb (n = 1) = 0.5	W/oDp (n = 1) = 1	0.061875
R6				WDb (n = 1) = 0.5	W/oDp (n = 1) = 1	0.061875
Women						
R7	n = 10 (0.625)	WD (n = 4) = 0.4	NW (2) = 0.5	WDb (1) = 0.5	MDp (1) = 1	0.0625
R8				W/oDb (1) = 0.5	W/oDp (1) = 1	0.0625
R9			OW (2) = 0.5	W/oDb (2) = 1	W/oDp (1) = 0.5	0.0625
R10					WDp (1) = 0.5	0.0625
R11		W/oD (n = 6) = 0.6	NW (n = 6) = 1	WDb (n = 1) = 0.16	W/oDp (1) = 1	0.06
R12				W/oDb (n = 5) = 0.83	W/oDp (5) = 1	0.31125
Σ	16					0.9925

WD: with debt; WDb: with diabetes; WDp: with depression; SDp: severe depression; MDp: mild depression; MDp: moderate depression; NW: normal weight; W/oD: without debt; W/oDb: without diabetes; W/oDp: without depression; OW: overweight.

$$\begin{aligned}
 R26 &= (0.5083)(0.4098)(0.76)(0.89)(0.17) = 0.02395 \\
 R27 &= (0.5083)(0.4098)(0.76)(0.89)(0.05) = 0.00704 \\
 R28 &= (0.5083)(0.4098)(0.76)(0.1)(0.5) = 0.00791 \\
 R29 &= (0.5083)(0.4098)(0.76)(0.1)(0.5) = 0.00791 \\
 R30 &= (0.5083)(0.5901)(0.22)(0.87)(0.57) = 0.03272 \\
 R31 &= (0.5083)(0.5901)(0.22)(0.87)(0.14) = 0.00803 \\
 R32 &= (0.5083)(0.5901)(0.22)(0.87)(0.14) = 0.00803 \\
 R33 &= (0.5083)(0.5901)(0.22)(0.87)(0.14) = 0.00803 \\
 R34 &= (0.5083)(0.5901)(0.22)(0.12)(1) = 0.00791 \\
 R35 &= (0.5083)(0.5901)(0.77)(0.82)(0.43) = 0.08143^* \\
 R36 &= (0.5083)(0.5901)(0.77)(0.82)(0.08) = 0.01515 \\
 R37 &= (0.5083)(0.5901)(0.77)(0.82)(0.17) = 0.03219 \\
 R38 &= (0.5083)(0.5901)(0.77)(0.82)(0.3) = 0.05681 \\
 R39 &= (0.5083)(0.5901)(0.77)(0.17)(0.6) = 0.02355 \\
 R40 &= (0.5083)(0.5901)(0.77)(0.17)(0.4) = 0.0157 \\
 &\quad \Sigma 0.49288
 \end{aligned}$$

Considering the group with the same income and the highest (*) value obtained, it is established that there is a probability of 0.08143 for women, no debt, overweight, no diabetes, and no depression.

In terms of the highest occurrence probability, for the group with an income range between 2200 and 6600 pesos per month, in case of men, it was found that 29/59 have debt, 23/59 are overweight, and 4/59 have severe depression, therefore $A \cap B \cap C = (0.3898)(0.0677)(0.4915) = 0.01297 \times 1000 = 12.97$, which

means that 12.97 men per 1000 inhabitants are at risk. For the sample size, $59/353 = 0.1671$ or 16.71%.

In women, the highest occurrence probability was 25/61 with debt, 19/61 overweight, and 1/61 with severe depression, so that $A \cap B \cap C = (0.3114)(0.0163)(0.4098) = 0.00208 \times 1000 = 2.08$, which means that 2.08 women per 1000 inhabitants are at risk. For the sample size, $61/353 = 0.1728$ or 17.28%.

Using the same methodology, when analyzing the group with an income range between 6600 to 13,320 pesos, it was found that the sample was comprised of 108 (30.59%) subjects, of which 40 (37.035%) were men and 68 (62.96%) were women. When considering the highest occurrence probability, it was found that the most relevant intersections were in men with this range of income, with debt, overweight, and with depression, so that $A \cap B \cap C \cap D = 0.0339$, and in this way $(0.0339)(1000) = 33.9$; that is, there is an estimated 33.9% of men per 1000 at risk for this joint comorbidity. For women with the same conditions, the estimation is 22.6 per 1000.

For the income range between 13,320 to 20,000 pesos, the sample was comprised of 35 (9.91%) participants, of which 18 (51.42%) were men, and 17 (48.57%) were women. The most representative results for this group were income within this range,

make, with debt, overweight, and with depression, then $A \cap B \cap C \cap D = 0.0226$, in such a way that there is an estimated 22.6 men per 1000 at risk for this joint comorbidity. For women with the same conditions, the estimation was 5.6 per 1000.

For the range of income between 20,000 to 26,640 pesos, the sample was comprised of 26 (7.36%) participants, 11 (42.3%) were men, and 15 (57.69%) were women. The most representative results show that 9 (81.81%) men and 11 (73.33%) women had debt; given the sample size in this income range, the comorbidity estimation is not representative.

In the income range from 26,640 to 33,300 pesos, the sample was comprised of 23 (6.51%) participants, of which 16 (69.56%) were men, and 7 (30.43%) were women. In this group, 13 (81.25%) men and 5 (71.42%) women had debt; as in the previous income range, the data does not support an estimate per 1000 inhabitants.

In the income range between 33,300 to 40,000 pesos, the sample was comprised of 6 (1.69%) participants, all men with debt. For the income range between 40,000 and 50,000 pesos, the sample was comprised of 8 (2.26%) men, all with debt. Lastly, for those with income higher than 50,000 pesos, the sample was comprised of 11 (3.11%) participants, all men with debt.

With the data observed, we can see a trend of value lower than the mean, which reflects income inequality in Mexico.

Discussion

The results of this work describe the effects of debt on the biopsychosocial balance. The average monthly debt payment is 7016.81 ± 1561.48 pesos, with a average percentage in relation to the accrued salary of $19.82 \pm 25.2\%$; in this manner, the confidence interval of 95% of the proportions with these values is $0.1567 < p < 0.2397$, that is, from 15.67% to 23.97% in relation to the total sample studied, where the distribution of the intervals is biased to the left, as 69.11% of subjects make less than 13,320 pesos per month. Thus, in this group, debt repayment may even take up 100% of total income.

67.1% of the sample studied was overweight, or had some type of obesity as the result of low income, possibly due to the low cost of highly caloric and low-protein diets. In the sample studied, 10.5% had diabetes and 11.04% detected arterial hypertension.

Based on the established ranges and the three-dimensional analysis, it can be seen that, starting at the income range of 2200 to 2600 pesos, debt increases,

and consequently, so does the comorbidity. In this range, 49.15% of men and 40.98% of women had debt. Among them, 79.31% of men and 76% of women were overweight.

The proposed analysis allows us to evaluate three variables that occur at the same time. The most representative studies were for the range of 2200 to 6600 pesos, obtaining a probability that 12.97 out of 1000 inhabitants are men with debt, overweight, and with severe depression, and for women with the same conditions, the probability is 2.08 out of 1000 inhabitants. It is worth noting the vulnerability of the male gender in this range. For the range between 6600 and 13,320 pesos, for males, there was a probability of 33.9 subjects out of 1000 to have this joint comorbidity; for women with the same conditions, the estimation is 22.6 out of 1000. According to the sample size, these two intervals are the most representative. It is worth mentioning that the population in the range of 6600 and 13,320 pesos is the most vulnerable, possibly increased due to the erroneous perception of credit cards that are considered as salary extensions, and thus increasing in a non-proportional way to the accrued income.

Conclusions

Multivariate analysis models must be used simultaneously, such as the one proposed in this work.

There is a priority axis that determines the change in the remaining variables, in this case the economic axis, which determines biological and psychological variables.

There are no statics in the measurements. If this three-dimensional model was placed on an arrow of time, changes in the studied variables would be seen, even in very short periods of time, and this is why the stochastic and chaos theory in this type of analysis.

Mathematical and statistical model that break the linearity paradigm must be generated and validated.

Funding

The authors declare that they have received no funding.

Conflicts of interest

The authors declare they have no conflicts of interest.

Ethical disclosures

Protection of people and animals. The authors declare that no experiments have been made on human beings or animals for this research.

Data confidentiality. The authors declare that no patient data appears in this article.

Right to privacy and informed consent. The authors declare that no patient data appears in this article.

References

1. World Bank. World Development Report 1990: Poverty. 2020. (Viewed on 21-12-2020.) Available: <https://openknowledge.worldbank.org/handle/10986/5973>
2. Banco Mundial. Pobreza. Panorama General. 2020. (Viewed on 21-12-2020.) Available: <https://www.bancomundial.org/es/topic/poverty/overview>
3. Consejo Nacional de Evaluación de la Política de Desarrollo Social. Medición de la pobreza. Pobreza en México. Resultados de pobreza en México 2018 a nivel nacional y por entidades federativas. 2018. (Viewed on 20-12-2020.) Available: <https://www.coneval.org.mx/Medicion/Paginas/PobrezaInicio.aspx>
4. World Health Organization. Pobreza y salud. Informe de la Directora General. 1999. (Viewed 21-12-2020.) Available: https://apps.who.int/gb/archive/pdf_files/EB105/se5.pdf
5. Secretaría de Desarrollo Social. Diagnóstico sobre la población en condiciones de pobreza vulnerable a los efectos de la desnutrición. 2010. (Viewed on 21-12-2020.) Available: https://www.gob.mx/cms/uploads/attachment/file/32231/Diagnostico_Licons_1_.pdf
6. Organización de las Naciones Unidas para la Alimentación y la Agricultura. Macronutrientes y micronutrientes. 2015. (Viewed on 20-12-2020.) Available: http://www.fao.org/elearning/Course/NFSLBC/es/story_content/external_files/Macronutrientes%20y%20micronutrientes.pdf
7. Instituto Nacional de la Mujeres. Pobreza y género. Una aproximación a la forma diferencial en que afecta la pobreza a mujeres y hombres en México, 2010. 2010. (Viewed on 21-12-2020.) Available: http://cedoc.inmujeres.gob.mx/documentos_download/101180.pdf
8. Consejo Nacional de Evaluación de la Política de Desarrollo Social. Pobreza y género en México. Hacia un sistema de indicadores. 2012. (Viewed on 19-12-2020.) Available: https://www.coneval.org.mx/Informes/Coordinacion/INFORMES_Y_PUBLICACIONES_PDF/PobrezayGeneroenweb.pdf
9. Arch-Tirado E, Rosado-Muñoz J. Ciencias de la complejidad y caos como herramientas en el análisis de la proliferación de vectores y zoonosis. *Cir Cir*. 2009;77:341-50.
10. Grenfell BT. Chance and chaos in measles dynamics. *J R Statist Soc B*. 1992;54:383-98.
11. Nowak M, Sigmund K. Chaos and evolution cooperation. *Proc Nat Acad Sci USA*. 1993;90:5091-4.
12. Sametband MJ. Entre el orden y el caos. La complejidad. México: Fondo de Cultura Económica/SEP/CONACyT/La Ciencia para Todos 167;1999.
13. Philippe P. Chaos, population biology, and epidemiology: some research implications. *Hum Biol*. 1993;65:525-46.
14. Thiéart RA, Forgues B. Chaos theory and organization. *Organiz Sci*. 1995;6:19-31.
15. Pearce N, Merletti F. Complexity, simplicity and epidemiology. *Int J Epidemiol*. 2006;35:515-9.
16. World Health Organization. ¿Cómo define la OMS la salud? 2020. (Viewed on 15-12-2020.) Available: <https://www.who.int/es/about/who-we-are/frequently-asked-questions#:~:text=La%20cita%20procede%20del%20Pre%20C3%A1mbulo%20de%20la%20Constituci%C3%B3n,en%20vigor%20el%207%20de%20abril%20de%201948>
17. Hawking S. Dios creó los números. Barcelona: Crítica; 2010.
18. Arch-Tirado E, Collado-Corona MA, Lino-González AL, Terrazo-Lluch J. Incertidumbre, sistemas dinámicos, principios de mecánica cuántica y su relación con el proceso salud-enfermedad (propuesta de análisis). *Rev Esp Salud Publica*. 2020;94:e11-11.