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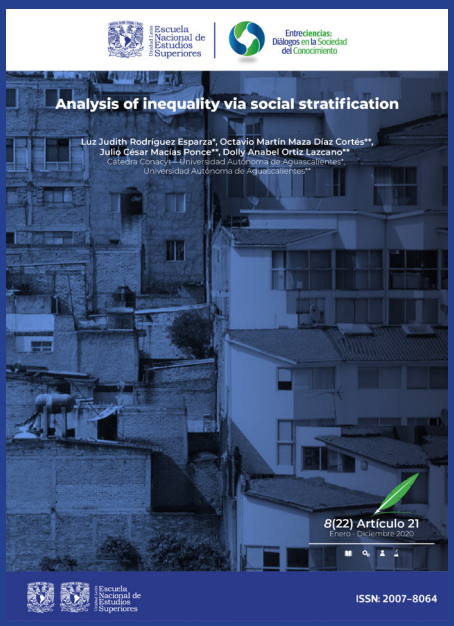

Analysis of inequality via social stratification

Análisis de la desigualdad a través de la estratificación social

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Resumen

Objetivo: analizar la contribución que provee la estratificación social a la desigualdad utilizando el índice de Gini como insumo.
Método: se utilizó la herramienta de diferencias compatibles para calcular el porcentaje del ingreso proporcionado por estratos sociales utilizando el índice de Gini; para verificar la eficiencia de la metodología propuesta, se consideraron datos reales de diferentes países.
Resultados: dado que se obtuvieron como resultados datos composicionales, se logró estimar y predecir la proporción de las contribuciones de los estratos a la desigualdad, evidenciando la importancia de la estratificación social en las clases.
Limitaciones: la medición de la desigualdad para construir el índice de Gini tiene diferentes metodologías a nivel mundial, lo que representó una dificultad para realizar comparaciones.
Principales hallazgos: con la metodología desarrollada en este artículo, se pudo cuantificar el peso que tienen diferentes estratos sociales en la desigualdad, esto es especialmente importante ya que puede ser una herramienta que ayude a los responsables de la toma de decisiones a tomar medidas más eficaces para contrarrestar la desigualdad.

Palabras clave: estratificación social, Índice de Gini, diferencias compatibles, datos composicionales, política redistributiva.

Abstract

Purpose: To analyze the contribution that social stratification provides to inequality using the Gini index as an input.
Methodology: The compatible differences tool was used to calculate the percentage of income provided by social strata using the Gini index; to verify the efficiency of the proposed methodology, real data from different countries were considered.
Results: Since compositional data were obtained as results, it was possible to estimate and predict the proportion of the contributions of the strata to inequality, evidencing the importance of social stratification in the classes.
Limitations: The measurement of inequality to construct the Gini index has different methodologies worldwide, which represented a difficulty in making comparisons.
Findings: The methodology that we developed in this article allowed us to know the weight that different social strata contributes to inequality; this is especially important since it can be a tool that helps decision-makers to take more effective measures to counteract inequality.

Keywords: Social stratification, Gini index, Compatible differences, Compositional data, redistributive public policy.

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Introduction

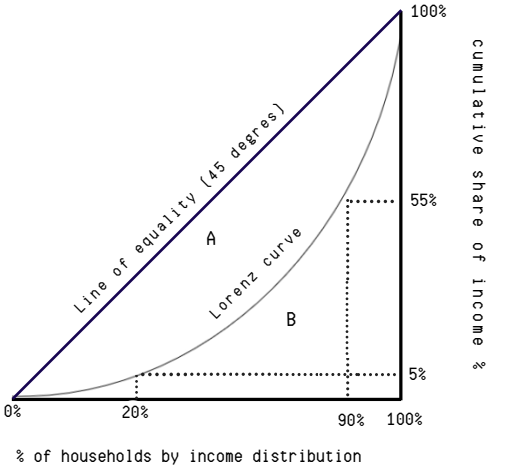
Inequality is defined as a social or economic disparity. Social inequality is the existence of unequal opportunities and rewards for different social positions within a society that encopasses several important dimensions: income, wealth, power, occupational prestige, schooling, ancestry, race, and ethnicity, among others. On the one hand, income is defined as the earnings derived from work or through investment activities, while wealth represents the total value of money and other assets owned. So, economic inequality is the unequal distribution of income and opportunities among different groups of individuals in a society. The fact that people are trapped in poverty with little or no chance to climb up the social ladder is a concern in almost all countries around the world. According with the Institute of Labor Economics (IZA) education, at all levels, enhancing skills, and training policies can be used alongside social assistance programs to help people get out of poverty and to reduce inequality. Several countries are also now exploring the idea of whether a universal basic income could be the answer (IZA, 2020, para. 1).

"Income is defined as household disposable income in a particular year. It consists of earnings, self-employment and capital income and public cash transfers; income taxes and social security contributions paid by households are deducted. The income of the household is attributed to each of its members, with an adjustment to reflect differences in needs for households of different sizes" (Organization for Economic Cooperation and Development [OECD], 2020, para. 1). Moreover, it also "includes the revenue streams from wages, salaries, interest on a savings account, dividends from shares of stock, rent, and profits from selling something for more than you paid for it. Unlike wealth statistics, income figures do not include the value of homes, stock, or other possessions" (Inequality ORG, s.f., para. 1).

According to OECD (2020, para. 1), there are five indicators to measure the income inequality among individuals: the Gini coefficient, which is based on the comparison of cumulative proportions by the population against cumulative proportions of income they receive; S80/S20 which is the ratio of the average income of the 20% richest to the 20% poorest; P90/P10 is the ratio of the upper bound value of the ninth decile (i.e. the 10% of people with the highest income) to that of the first decile; P90/P50 the upper bound value of the ninth decile to the median income; and P50/P10 of median income to the upper bound value of the first decile. The Palma ratio is the share of all income received by the 10% of people with the highest disposable income divided by the share of all income received by the 40% of people with the lowest disposable income.

The Gini index or Gini coefficient is a statistical measure of distribution and it is one of the most widely used indicators of social and economic inequality. The coefficient ranges from 0 to 1, with 0 representing perfect equality (Gini, 1914) (mathematically, this index is different from zero but tends to zero when the population increases and only one raises the wealth) and 1 is the representation of perfect inequality -when everyone has the same-. Values over 1 are not practically possible. The Gini index is often represented graphically through the Lorenz (1905) curve (see Figure 1), which shows the income distribution by plotting the population percentile by income on the horizontal axis and cumulative income on the vertical axis.

Figure 1. Lorenz curve



Source: Adapted from Lorenz, 1905, p. 208.

Let L:[0,1]→[0,1] be the wealth distribution function; that is, $L(x)$ measures the proportion of wealth accumulated by percent x of the population. Graphically, the Gini index is calculated as the ratio of two areas. If A is the cumulative area between the Lorenz curve and the

diagonal of the unit square (the graph of the function $f(x) = x$) and B is the area below the Lorenz curve, then the Gini index is calculated as $\frac{A}{A+B}$.

Sen (1973) defined the Gini index as a function G given by

$$G(\boldsymbol{t}) = \frac{1}{n}\left[n + 1 - 2\left(\frac{\sum_{i=1}^{n}(n+1-i)t_i^*}{\sum_{i=1}^{n} t_i^*}\right)\right]$$

where $\boldsymbol{t}$ is the wealth vector, $\boldsymbol{t}^*$ is $\boldsymbol{t}$ permuted with $t_i^* \leq t_{i+1}^*$, and n is the size of the population.

Notice that for this discrete version $0 \leq G(\boldsymbol{t}) \leq \frac{n}{n+1}$; however, the Gini index has a limitation in measuring inequality, it is sensitive to how the population is stratified.

Society is stratified into social classes based on wealth, income, educational attainment, and occupation. A social class refers to "a group of individuals who occupy a similar position in the economic system of production. Within that system occupation is very important because it provides financial rewards, stability, and benefits like healthcare" (What is social class?, s.f., para. 4). In broad terms, people are in similar positions, aware of each other.

In this paper, we aim to quantify the contribution of social classes (social stratification) to inequality considering compatible differences to calculate the percentage of the income provided by social classes. The results can be an important tool to help decision-makers opt for the most effective measures to counter inequality.

Herein lies the importance of knowing how a society is divided to any study that incorporates social items, therefore, we provide a real example showing how social stratification affects inequality. In addition to this, we will show a sensibility analysis -relative to the Gini index- when income is transferred between different social classes.

This article is organized as follows. In Section 1, we provide some background on social classes. In Section 2, we present our proposed methodology to quantify the contribution of each stratum to inequality. An application is given in Section 3, providing a prediction model using compositional data. Final comments are given in Section 4.

Background

In social sciences, the definition of classes can be especially difficult if it is taken into account the complexity of the subjects and the implications that it entails. The concept of social class has its foundations on Marx's work, in which he identified two well-differentiated groups: bourgeoisie and proletariat (Marx, 1968), thereby, the social position was determined by the control over the economic resources and means of production manifested in a duality between capital owners and workers. This conception of classes results in two large groups, although useful, heterogeneous, which complicates their study since the information generated from this division shows highly aggregated results.

The Marxist conceptualization limits the social aspect to the occupational part inasmuch as for Marx, the economic relations formed the material basis for the class struggle; hence, instinctively the social class is associated to the idea of the economic position of a group of people related to an income linked to the occupation, but as it will be seen, the social is also related to other characteristics; Bourdieu (2003), to give an example, thought on the class concept as relational substantial sets, as a result, there is a correspondence between practices and positions, between material attributes and conditions (Wright, 2015) that allows classifying the society through determinants (one of them the economic) and lifestyle.

Wright (1994) identifies three ways to approach class concept: Firstly, class as a set of attributes and living conditions of individuals (adopted by stratification studies), secondly, class based on the accumulation mechanisms determined by the control of economic resources (referred to Max Weber theory), defining the classes concerning the processes of "appropriation of opportunities" focused on three dimensions: economy, status, and power (Negrete and Romo, 2014); and finally, the Marxist point of view that studies the positions in the relations of domination in production. Wright integrates these three points of view since he does not consider them mutually exclusive, rather than interrelated, since the three processes operate in the society and are connected and in a permanent interaction (see Figure 2).

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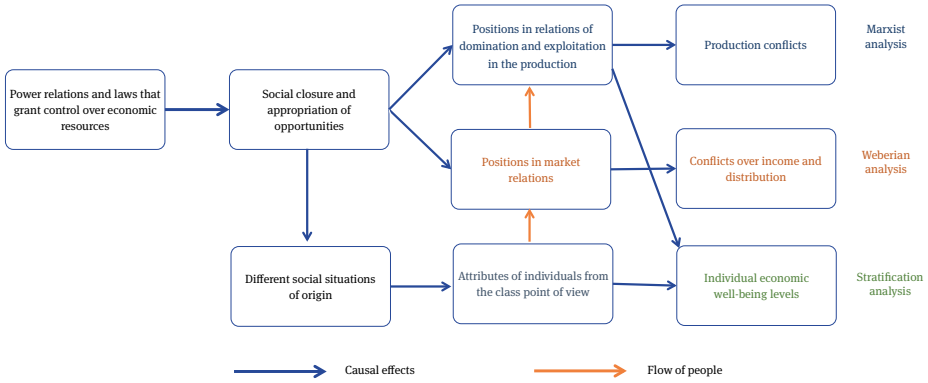
Figure 2. Combined analysis of classes: macro and micro processes



Source: Adapted from Wright, 2015, p. 27.

Grusky (Grusky and Weeden, 2008) suggests that the concept of social class has historically different meanings which affect the studies and the conclusions they reach, since the concept of which they are based on will measure and infer the reality (usually taken from a sociological or economic point of view), particularly in inequality studies; thus, he also proposes (in addition to conventional approaches such as measurement schemes based on the socio-economic, class or income) multidimensional models capable of capturing the different forms of inequality, including data derived from schooling, work experience, work conditions, and other factors.

This type of models allows to "calibrate" the typical concept of social class, incorporating attributes and endowments, which allow adding the micro-level (micro classes, or classes within classes) to the macro-level (the great concept of social class), close to Bourdieu's approach, who is the reference for the measurement of social class in several countries to identify social strata relating structural classes with class schemes that identify changes in the classification of the population over time, in order to capture phenomena such as social mobility, among others.

The concept of class in its simplest definition applies to a group of elements that have common characteristics, statistically also known as class interval, this group of elements are a set of characteristics that are subjectively defined by the interests of the researcher, so one of the most important questions raised for the identification of social classes is with regards to the criteria that must be taken into account to place an individual accurately in some social class. The United Kingdom criteria, for example, according to the Great British Class Survey (GBCS) (Savage *et al.*, 2013) take economic capital such as occupation, household income, household savings, value of the household, and also elements detailing cultural and social capital, for instance, leisure, use of the media, alimentation, among others, from which seven social classes are considered: elite, established middle class, technical middle class, new wealthy workers, traditional working class, emerging service workers, and precarious workers.

In the United States, social class is defined under the logic of social stratification, taking into account demographic data (Wodtke, 2016) with an occupational focus, considering the position of an individual within the technical division of labor, and the effects on its attitudes, behavior, and access to valuable resources which allows it to reach other capitals. Grusky (Grusky, 2014), however; it does not rule out the arise of new classes over time since social relationships (especially in employment subject) are in constant change.

Classes and inequity

Social class is an input to understand inequality, nevertheless, comparative studies on inequality should consider that the definition of class has different meanings; therefore, measuring inequality is not the same as measuring class inequality since the concept of class and the possible data derived from it assume different attributes that are not homogeneous in all countries, particularly those related to the history that

gives a specific initial context to each country, consequently, belonging to the upper class is not the same in China than in Argentina, as well as being poor in Germany than in Tanzania; however, it could be anticipated that the world elite (the 0.001% richest) can share characteristics regardless of their nationality, it is a homogeneous group, with similar economic and social resources, access to similar networks, capitals, and lifestyles. This group in 2019, according to the Global Wealth Report, was comprised of 168 thousand people worldwide who had fortunes of more than 50 million dollars (Credit Suisse Research Institute, 2019).

An important question to highlight is whether that small amount of ultra-rich people (in contrast to the world population), is considered a class or not, for example, in the United States that concentrated 40% of the cases in such status in 2019. The answer is no. In economies such as the Mexican, that participates with 173 people considered to be within that group, their condition would be statistically classified in the upper-upper class, which for the statistical institute are households with incomes greater than 100,000 pesos per month (USD $5,000 6% of households), so it would be expected that the data from a Gini index would be more unequal if measured by individuals and not by groups, being classes, deciles or percentiles, because the more aggregate the group is, the more inequality will be hidden.

In an attempt to typify the middle class in Mexico, Negrete (2014) estimates by a clustering method based on 17 variables taken from the household income-expenditure survey (ENIGH), among which the following stand out: housing size, occupation and household expenses on food, education and culture; that only 2.5% of households (1.7% of individuals) belong to the upper class with a monthly per capita expenditure of 15 thousand pesos (USD $ 625 per month), 42% of households (39% of individuals) belong to the middle class and 55% of households (59% of individuals) belong to the lower class, the latter data coinciding with official poverty data.

What seems interesting in a practical sense, is that the upper class, according to either both classifications, would have households with incomes of more than $5,000 per month sharing a stratum with households with an income of $100,000 per month, which, with households with $1 million per month income, etc., which hides a level of inequality within the classes that is difficult to perceive. In reference to the average household income in the upper class in Mexico, it could be classified as a middle class in high-income countries.

Methodology

In this section, we will propose a new methodology to quantify the contribution of social classes to inequality.

Consider the next problem on how to distribute a given amount x among a set of agents $N = \{1,2,...,n\}$ for $n \in \mathbb{N}$. We define $\{d_{ij}\}_{i,j \in N}$ as compatible differences if and only if

1) $d_{ii} = 0$,
2) $d_{ij} = -d_{ji}$, antisymmetric,
3) $d_{ij} + d_{jk} = d_{ik}$, for all $i, j, k \in N$

Let $\mathcal{M}_{nxn}(\mathbb{R})$ be the set of real matrices of dimension $n \times n$ with entries satisfying the before three conditions and let $\wp:\{(\boldsymbol{D},x):\boldsymbol{D}\in M_{nxn}(\mathbb{R}), x \in \mathbb{R}\}$. We can define $\varphi = (\varphi_1,\varphi_2,...,\varphi_n)$ where $\varphi_i: \wp \to \mathbb{R}$ for all i,as follows:

$$\varphi_i(\boldsymbol{D},x) := \frac{1}{n}\left(x + \sum_{j=1}^{n} d_{ij}\right); \qquad i = 1,2,\dots,n, \quad (1)$$

i.e., we can re-write $\boldsymbol{\varphi}$ as $\boldsymbol{\varphi}(\boldsymbol{D},x):=(\varphi_1(\boldsymbol{D},x),...,\varphi_n(\boldsymbol{D},x))$.

Since $d_{ij}=\varphi i(\boldsymbol{D},x) - \varphi j(\boldsymbol{D},x)$ for all j, we say that $\boldsymbol{D} = \{d_{ij}\}_{i,j \in N}$ preserves differences corresponding to $\boldsymbol{\varphi}(\boldsymbol{D},x)$ Moreover, being $\boldsymbol{D} = \{d_{ij}\}_{i,j \in N}$ a matrix of compatible differences, the unique vector that preserves differences is given by $\boldsymbol{\varphi}(\boldsymbol{D},x)$ which satisfies the following condition:

$$\sum_{i=1}^{n} \varphi_i(\boldsymbol{D},x) = x.$$

Therefore, $\varphi i(\boldsymbol{D},x)$ represents the amount given to the i-th agent.

On the other hand, let $\boldsymbol{c} = (c_1, c_2, \dots, c_n)$ such as $c_1 < c_2 < \cdots < c_n$ and define the following, the matrix $\boldsymbol{C}$:

$$\begin{pmatrix} 0 & c_1 - c_2 & c_1 - c_3 & \cdots & c_1 - c_n \\ c_2 - c_1 & 0 & c_2 - c_3 & \cdots & c_2 - c_n \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ c_n - c_1 & c_n - c_2 & c_n - c_3 & \cdots & 0 \end{pmatrix}$$

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i.e., $\boldsymbol{C} \in \mathcal{M}_{nxn}(\mathbb{R})$. Note that for a fixed row i

$$\sum_{j=1}^{n} c_{ij} = (n-1)c_i - \sum_{j\neq 1}^{n} c_j \ ,$$

then, we have

$$\varphi_i(\boldsymbol{C}, x) = \frac{1}{n}\left(x + (n-1)c_i - \sum_{j\neq 1}^{n} c_j\right) = \frac{1}{n}(x + nc_i - c_i - T + c_i);$$

where $T = \sum_{j=1}^{n} c_j$, thus

$$\varphi_i(\boldsymbol{C}, x) = \frac{1}{n}(x + nc_i - T), \qquad i = 1,2,\dots,n.$$

Now, let us consider this theory in a particular social context. Suppose a social stratification of four classes, i.e., *n=4*, given by:

1) Lower (L),
2) Middle (M),
3) Upper (U),
4) Bourgeoisie (B).

Let c_i be the income of the i-th social class for $i = 1,2,3,4$, and define $\boldsymbol{c} = (c_1, c_2, c_3, c_4)$ where $c_1 < c_2 < c_3 < c_4$. Thus,

$$\varphi_i(\boldsymbol{C}, x) = c_i + \frac{1}{4}\left(x - \sum_{j=1}^{4} c_j\right); \quad i = 1,2,3,4. \qquad (2)$$

This function satisfies that $\sum_{i=1}^{4} \varphi_i(\boldsymbol{C}, x) = x$. Thus, if x is the Gini index, the function (2) gives the contribution of the i-th social class of inequality.

Since $x \in [0,1]$ and the income of the social classes in a large value, such as $\sum_{j=1}^{4} c_j \gg x$, then $\frac{1}{4}\left(x - \sum_{j=1}^{4} c_j\right) \to -\frac{1}{4}\sum_{j=1}^{4} c_j = -\bar{\boldsymbol{c}}$, , where $\bar{\boldsymbol{c}}$ denotes the mean of vector $\boldsymbol{c}$ thus,

$$\varphi_i(\boldsymbol{C}, x) \approx c_i - \bar{\boldsymbol{c}}, \qquad i = 1,2,3,4. \qquad (3)$$

This means that we can calculate the contribution of the social classes to inequality without having the Gini index per se.

Observation 2.1 Note that for $i \in \{1,2,\dots,n\}$ and $\alpha_i \in \mathbb{R}^+$, $x, y \in \mathbb{R}$,

$$\varphi_i(\boldsymbol{C}^*, y) = \varphi_i(\boldsymbol{C}, x) + \alpha_i + \frac{1}{n}(y - x),$$

where the elements of the matrix $\boldsymbol{C}^*$ are given by $c_i^* = c_i + \alpha_i$.

This means, in terms of the Gini index, that if the income of some social class i is increased by α_i then, the contribution of this class to the "new inequality" equals the contribution given by the class before increasing, plus α_i and other value in $\left(-\frac{1}{n}, \frac{1}{n}\right)$. This interval depends on x and y and the number of analyzed classes, however, it is a small quantity compared to $\varphi_i(\boldsymbol{C}, x) + \alpha_i$, i.e., $\varphi_i(\boldsymbol{C}^*, y) \approx \varphi_i(\boldsymbol{C}, x) + \alpha_i$.

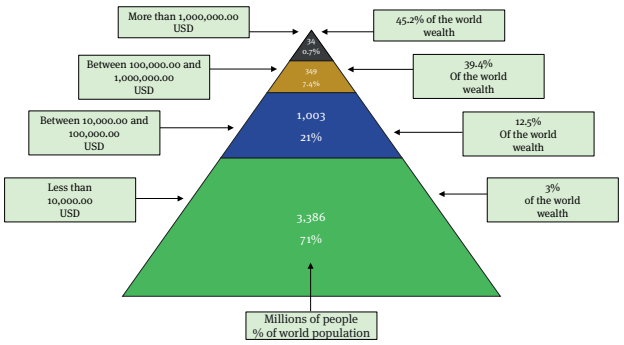
In order to provide the contribution to inequality of each social class in terms of percentage, we have

$$\%Class_i = \frac{|\varphi_i|}{\sum_{j=1}^{n}|\varphi_j|} \times 100, \qquad i = 1,2,\dots,n. \qquad (4)$$

Note that we used the absolute value, since each element φ_i is a real number.

Example 2. *Consider the global wealth pyramid presented in Figure 3.*

Figure 3. Global wealth pyramid



Source: Adapted from El País, cited in Instituto Mexicano para la Competitividad (IMCO), 2015, para 1.

Based on Figure 3 the percentage data are the following (we modified some values to obtain the 100%).

Table 1. Illustrative data example. Percentage of the population and income of four social classes

	Class	Population %	Income %
1	Lower	71	3
2	Middle	21	12.5
3	Upper	7.4	39.3
4	Bourgeoisie	0.6	45.2

Source: Authors' elaboration based on Figure 3.

Let us consider an illustrative example with a Population of 1000 persons and Income $10,000. We calculate the inequality contribution of each social class via equation (2). The results are presented in Table 2.

Table 2. Inequality contribution considering four social classes

Income								
L	M	U	B	Gini	φ_1	φ_2	φ_3	φ_4
300	1250	3930	4520	0.4995611	-2199.875	-1249.875	1430.125	2020.125

Source: Authors' elaboration.

The contribution in terms of percentage (see equation [4]) is presented in Table 3.

Table 3. Percentage contribution to inequality considering four social classes

%L	%M	%U	%B
31.88225	18.11413	20.72645	29.27717

Source: Authors' elaboration.

Thus, a major percentage of inequality is given by the lower class, followed by the bourgeoisie class, the upper, and finally the middle class.

In the following, we present five hypothetical cases, where the upper classes give income to lower classes (see for example Delajara, De la Torre, Díaz-Infante, Vélez [2018]).

2.1 Case 1: Middle class gives income to the Lower class

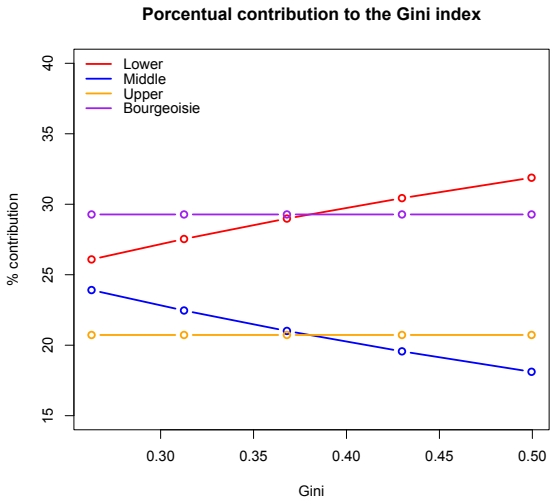
In this case, we fix the income for the Upper and Bourgeoisie classes and vary the income of the Lower and Middle classes (Middle class gives $100). The results of the inequality contribution considering four social classes are presented in Table 4 and Figure 4.

Table 4. Inequality contributions: Middle class gives to the Lower class

Income								
L	M	U	B	Gini	%L	%M	%U	%B
300	1250	3930	4520	0.50	31.88	18.11	20.72645	29.27717
400	1150	3930	4520	0.43	30.43	19.56	20.72620	29.27692
500	1050	3930	4520	0.37	28.98	21.01	20.72597	29.27670
600	950	3930	4520	0.31	27.54	22.46	20.72577	29.27649
700	850	3930	4520	0.26	26.09	23.91	20.72559	29.27631

Source: Authors' elaboration.

Figure 4. Percentage contribution to inequality considering Case 1



Source: Authors' elaboration.

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The contribution to inequality of the lower class decreases once getting income from the middle class, at some point this contribution is almost the bourgeoisie. Note that in this scenario, we can obtain a Gini index of at least 0.26.

2.2 Case 2: Upper class gives income to the Lower class

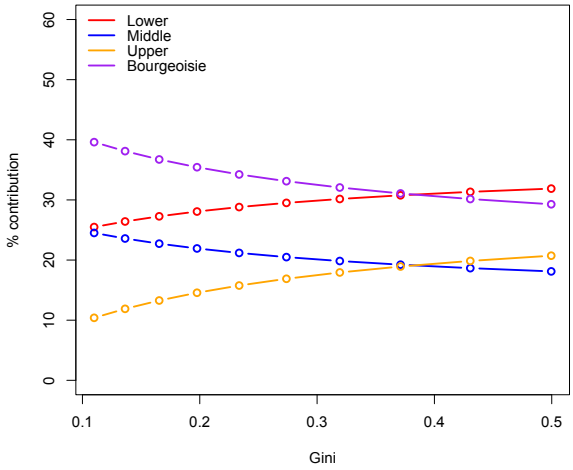
The Upper gives $100 to the Lower class. The results are presented in Table 5 and Figure 5.

Table 5. Inequality contributions: Upper class gives to the Lower class

Income								
L	M	U	B	Gini	%L	%M	%U	%B
300	1250	3930	4520	0.50	31.88	18.11	20.73	29.28
400	1250	3830	4520	0.43	31.34	18.66	19.85	30.15
500	1250	3730	4520	0.37	30.77	19.23	18.92	31.08
600	1250	3630	4520	0.32	30.16	19.84	17.94	32.06
700	1250	3530	4520	0.27	29.51	20.49	16.89	33.12
800	1250	3430	4520	0.23	28.81	21.19	15.76	34.24
900	1250	3330	4520	0.20	28.07	21.93	14.56	35.44
1000	1250	3230	4520	0.17	27.27	22.73	13.27	36.73
1100	1250	3130	4520	0.14	26.41	23.58	11.89	38.11
1200	1250	3030	4520	0.11	25.49	24.51	10.39	39.61

Source: Authors' elaboration.

Figure 5. Percentage contribution to the Gini index considering Case 2



Source: Authors' elaboration.

Compared to the previous case, the Gini index gets down to a value of 0.11, where the Lower and Middle classes contribute almost the same to inequality.

2.3 Case 3: Bourgeoisie class gives income to the Lower class

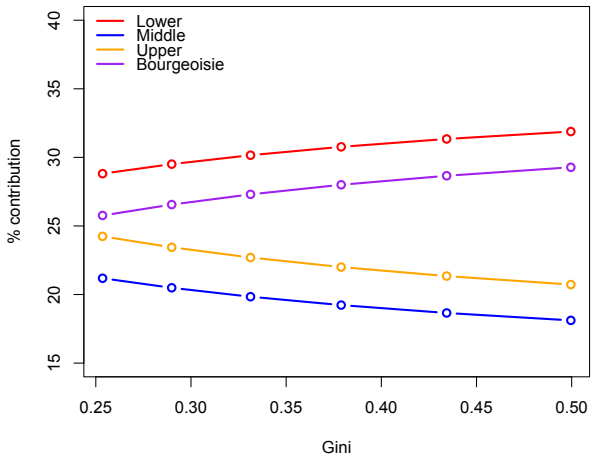
The Bourgeoisie gives $100. The results are presented in Table 6 and Figure 6.

Table 6. Inequality contributions: class Bourgeoisie gives to the Lower class

Income								
L	M	U	B	Gini	%L	%M	%U	%B
300	1250	3930	4520	0.50	31.88	18.11	20.73	29.28
400	1250	3930	4420	0.43	31.34	18.66	21.34	28.66
500	1250	3930	4320	0.38	30.77	19.23	22.00	28.00
600	1250	3930	4220	0.33	30.16	19.84	22.70	27.30
700	1250	3930	4120	0.29	29.51	20.49	23.44	26.56
800	1250	3930	4020	0.25	28.81	21.19	24.24	25.76

Source: Authors' elaboration.

Figure 6. Percentage contribution to the Gini index considering Case 3



Source: Authors' elaboration.

Note that in this case and in comparison to the two previous cases, there is no crossing of lines in the graph, that is, in all the scenarios the order of percentage contribution of social classes to inequality is maintained: Lower, Bourgeoisie, Upper, and Middle.

2.4 Case 4: Upper class gives income to the Middle and Lower classes

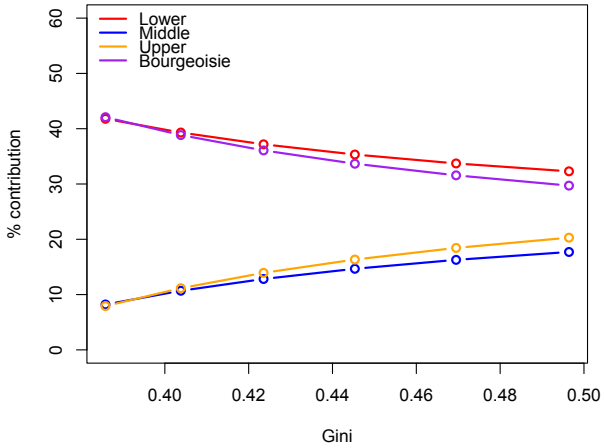
The Upper gives $200 in total, $162 (81%) to Middle, and $32 (19%) to Lower. The results are presented in Table 7 and Figure 7.

Table 7. Inequality contributions: Upper class gives to the Middle and Lower classes

Income								
L	M	U	B	Gini	%L	%M	%U	%B
304	1296	3880	4520	0.50	32.29	17.70	20.30	29.71
342	1458	3680	4520	0.47	33.72	16.28	18.44	31.56
380	1620	3480	4520	0.45	35.33	14.66	16.34	33.67
418	1782	3280	4520	0.42	37.18	12.82	13.93	36.07
456	1944	3080	4520	0.40	39.31	10.69	11.16	38.85
494	2106	2880	4520	0.39	41.79	8.21	7.92	42.09

Source: Authors' elaboration.

Figure 7. Percentage of the inequality contribution considering Case 4



Source: Authors' elaboration.

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This is another very special case, the contribution of the Lower and Bourgeoisie classes is very similar (more than 80% among them), while the Upper and Middle classes also contribute similarly but in a minimal way (approximately 20%). The Gini index reaches 0.39.

2.5 Case 5: Bourgeoisie class gives income to the Middle and Lower classes

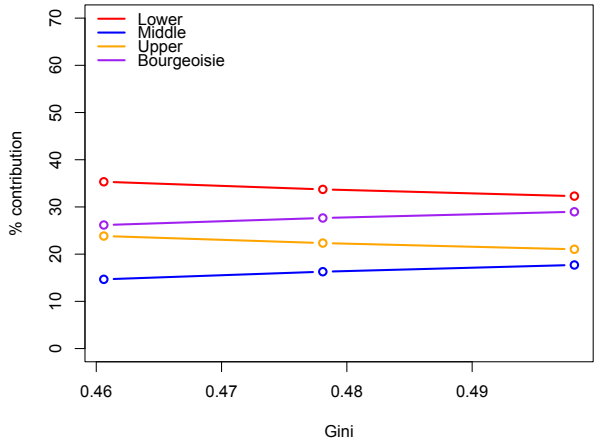
The Bourgeoisie gives $200 in total, $162 (81%) to Middle, and $32 (19%) to Lower. The results are presented in Table 8 and Figure 8.

Table 8. Inequality contributions: Bourgeoisie class gives to the Middle and Lower classes

Income								
L	M	U	B	Gini	%L	L	M	U
304	1296	3930	4470	0.50	32.29	17.70	21.30	28.97
342	1458	3930	4270	0.48	33.72	16.28	22.35	27.66
380	1620	3930	4070	0.46	35.33	14.66	23.84	26.17

Source: Authors' elaboration.

Figure 8. Percentage of the inequality contribution considering Case 5



Source: Authors' elaboration.

This is similar to case 3, where there is no line crossing and the contribution order is maintained. The Gini index reaches 0.46.

In Table 9 we present a summary of the cases.

Table 9. Analysis of the cases: percentage contribution to inequality

%	Case 1: M ⇒ L	Case 2: U ⇒ L	Case 3: B ⇒ L	Case 4: U ⇒ L, M	Case 5: B ⇒ L, M
Lower	↓	↓	↓	↑	↑
Middle	↑	↑	↑	↓	↓
Upper	≈	↓	↑	↓	↑
Bourgeoisie	≈	↑	↓	↑	↓

Source: Authors' elaboration.

In general, for the percentage of inequality contribution, we have the following:

1) When L class receives income from M, U, or B, its percentage to the inequality decreases (↓), but the percentage of the M class increases (↑).
2) When U or B class gives income to L and M classes, the percentage of the L class increases (↑) while the M decreases (↓).
3) If the U or B class gives income its percentage decreases (↓), if not, its percentage increases (↑).

Indeed, we can confirm that the extreme classes, in this case, the Bourgeoisie and the Lower, are the largest contributors to the inequality with a percentage in the interval (25%- 43%), as expected. Middle and Upper classes have a contribution percentage between 7% and 25%. In particular, the Middle class is the one that generally has the lowest contribution of all.

It is important to show these scenarios in order to quantify the contribution of social classes to inequality. Governments, decision-makers, and public policy providers must analyze different scenarios that can happen in the places they represent.

Application

The previous methodology can be replicated considering only 3 classes: Upper, Middle, and Lower. Let us consider a high-income country and a middle-low income country. For example, for Denmark, we have the data[1] presented in Table 10.

Table 10. Data from Denmark 2010

	Class	Population %	Income %
1	Lower	14	13.9
2	Middle	80	27.2
3	Upper	6	58.9

Source: Authors' elaboration based on O'Sullivan, 2017.

In 2010, Denmark had a Gini index of 0.272[2]. And using the φ function with 3 social classes, the percentage of contribution of the Gini index for each class is given by Lower ≈ 38% , Middle ≈ 12% , and Upper ≈ 50% . Thus, although the Middle class has a huge percentage of the population, the major contributor to inequality is the Upper class.

Another example is considering Mexico. The data are in Table 11.

Table 11. Data from Mexico 2014

	Class	Population %	Income %
1	Lower	60	9.3
2	Middle	34	29.3
3	Upper	6	61.4

Source: Authors' elaboration adapted from Diario Oficial de la Federación (2014).

For 2014, Mexico has a Gini index of 0.458. Applying the φ function also with 3 social classes, the percentage of contribution of the Gini index for each class is given by: the and L ≈ 43%, M ≈ 7%, U ≈ 50%.

As we can see in both examples, the Upper class is the major contributor to inequality, followed by the Lower class, and finally, the Middle class, although the example of the countries refers to two different income configurations, these are visible only in the middle and lower classes, where percentages have visible differences, but the upper class is made up of the same percentage of the population, concentrating almost the same amount of income, which is why it is suspected to be a pattern that economies with a similar concentration of income of the upper class can follow.

Consequently, the contribution of the upper class, due to the amount of income it concentrates, explains 50% of inequality, although the middle and lower classes behave in different ways, which causes the Gini value to decrease or increase, the upper-class income impacts in the same way on the Gini index construction; therefore, it is important to analyze the scenarios presented on redistributive best practices and their effect on reducing inequalities through the rise of the middle class.

The following subsection will analyze the percentage of contribution to inequality as compositional data. We present a real example with data from Mexico in order to analyze social stratification.

3.1 A predictive model for compositional data

In this section, we will consider a predictive model for compositional data using a hyperspherical transformation. Mathematically, a circular graph can be expressed as a compositional vector as follows:

$$\boldsymbol{x} = (x_1, x_2, \dots, x_n)' \in \mathbb{R}^n, for\ n \in \mathbb{N},\ and\ n \geq 1\,,$$

[1] https://www.citylab.com/life/2017/04/euro-vs-americam-middle-class/524193/
[2] https://data.worldbank.org/indicator/SI.POV.GINI?locations=DK

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such as $\sum_{j=1}^{n} x_j = 1, x_j > 0$. We will call $x_j, j = 1,2, \ldots, n$, as "part" and the set of all compositions will be called "simplex of n parts". Indeed, from equation (4) we can define each $x_j := \frac{|\varphi_j|}{\sum_{k=1}^{n}|\varphi_k|}$.

The concept of compositional data comes from Ferrers' work (Ferrers, 1866). In 1897, Pearson (1897) discussed the complexity of its theoretical properties and indicated that the property of which the components add 1, had been little or completely ignored.

The first systematic research on compositional data is found in Aitchison (1986), which uses normal logistic distribution and the log-ratio transformation for compositional data. For this research, Aitchison obtained the Research Medal of British Royal Statistical Academy in 1988.

Predictive model using a hyperspherical transformation

The following methodology is based on Wang, Lu, Mok, Fu, and Tse (2007).

Step 1. Transformation:

$$y_j{}^t = \sqrt{x_j{}^t}\ ;\ j = 1,2,\ldots,n;\ \ t = 1,2,\ldots,T;\ for\ \ n,T \in \mathbb{N}.$$

Let $\boldsymbol{y}^t = (y_1{}^t, y_2{}^t, \ldots, y_n{}^t)$, for $t = 1,2,\ldots,T$, thus $\|\boldsymbol{y}^t\|^2 = \sum_{j=1}^{n}(y_j{}^t)^2 = 1$. Then, the end of the vector $\boldsymbol{y}^t$ is on the surface of a n-dimensional sphere with radius 1 at any time t.

Step 2. Mapping. Map the Cartesian plane n-dimensional $\boldsymbol{y}^t = (y_1{}^t, y_2{}^t, \ldots, y_n{}^t) \in \mathbb{R}^n$ to hyperspherical coordinates $(r^t, \theta_2{}^t, \ldots, \theta_n{}^t)' \in \Theta^n$,

$$y_1{}^t, y_2{}^t, \ldots, y_n{}^t \ \Rightarrow\ \theta_2{}^t, \theta_3{}^t, \ldots, \theta_n{}^t$$

with the condition of $(r^t)^2 = \|\boldsymbol{y}^t\|^2 = 1$.

Thus, the transformations will be as follows:

$$\begin{aligned}
y_1{}^t &= \sin\theta_2{}^t \sin\theta_3{}^t \sin\theta_4{}^t \cdots \sin\theta_n{}^t \\
y_2{}^t &= \cos\theta_2{}^t \sin\theta_3{}^t \sin\theta_4{}^t \cdots \sin\theta_n{}^t \\
y_3{}^t &= \cos\theta_3{}^t \sin\theta_4{}^t \sin\theta_5{}^t \cdots \sin\theta_n{}^t \\
&\vdots \\
y^t_{n-2} &= \cos\theta^t_{p-2} \sin\theta^t_{n-1} \sin\theta_n{}^t \\
y^t_{n-1} &= \cos\theta^t_{n-1} \sin\theta_n{}^t
\end{aligned}$$

$$y_n{}^t = \cos\theta_n{}^t$$

where $0 \le \theta_j{}^t \le \frac{\pi}{2}, for\ j = 2,3,\ldots,n.$

Step 3. Inverse transformation. For $t = 1,2,\ldots,T$:

$$\theta_n{}^t = arccos\,(y_n{}^t)$$

$$\theta^t{}_{n-1} = arccos\left(\frac{y^t{}_{n-1}}{\sin\theta_n{}^t}\right)$$

$$\theta^t{}_{n-2} = arccos\left(\frac{y^t{}_{n-2}}{\sin\theta_n{}^t \sin\theta^t{}_{n-1}}\right)$$

$$\vdots$$

$$\theta_2{}^t = arccos\left(\frac{y_2{}^t}{\sin\theta_n{}^t \sin\theta^t{}_{n-1} \cdots \sin\theta_3{}^t}\right)$$

Step 4. Construct $n-1$ regressions models for each angle:

$$\hat{\theta}_j{}^t = \mathrm{f}_j(t) + \epsilon_j{}^t, j = 2,3,\ldots,n. \qquad (5)$$

Step 5. Use (5) to predict the angle at time $T+1$:

$$\hat{\theta}_j{}^{T+1} = \mathrm{f}_j(T+1), \qquad j = 2,3,\ldots,n. \qquad (6)$$

Step 6. Predict the values of $\hat{\boldsymbol{y}}^{T+1} = (\hat{y}_1{}^{T+1}, \hat{y}_2{}^{T+1}, \ldots, \hat{y}_n{}^{T+1})$ using equation (6) and Step 2.

Obviously, we should have $\sum_{j=1}^{n}(\hat{y}_j{}^{T+1})^2,\ j = 1,2,\ldots,n.$

Step 7. Finally, predict the values for each component:

$$\hat{x}_j{}^{T+1} = (\hat{y}_j{}^{T+1})^2, \qquad j = 1,2,\ldots,n.$$

We now present an example of how important the construction of social classes is. We present real data from a survey of Mexico.

Example 3.1 Importance of how social stratification is constructed.

In Mexico, the National Survey on Household Income and Expenditure (ENIGH, for its initials in Spanish), shows the current family income and the way they expend it. By

means of the ENIGH, we could obtain the percentage of quarterly historical income per family of the upper class (Decile 10), middle class (Decile 6- Decile 9) and lower class (Decile 1- Decile 5). Data is presented in Table 12.

Table 12. México Gini Value construction per social strata 1984-2014

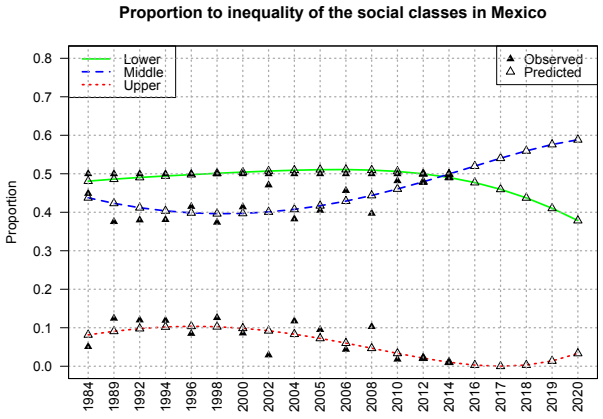
	Population %			Income %			
Year	L	M	U	L	M	U	Gini
1984	60	35	5	21.6	46.4	32.0	0.489
1989	51	41	8	19.0	44.1	36.9	0.480
1992	52	39	9	18.9	44.3	36.8	0.496
1994	50	40	10	19.2	44.1	36.7	0.503
1996	65	30	5	20.0	44.4	35.6	0.482
1998	62	32	6	18.8	44.2	37.0	0.487
2000	57	35	8	19.6	44.7	35.7	0.514
2002	54	39	7	20.2	45.7	34.1	0.490
2004	46	43	11	19.0	44.3	36.7	0.483
2005	49	41	10	18.8	45.1	36.1	0.489
2006	45	44	11	20.0	45.5	34.5	0.477
2008	45	44	11	19.4	44.4	36.2	0.446
2010	52	40	8	20.5	45.7	33.8	0.453
2012	55	38	7	20.7	45.4	33.9	0.454
2014	53	40	7	21.7	45.2	33.1	0.458

Source: Authors' elaboration with data from *the National Survey on Household Income and Expenditure* (Encuesta Nacional de ingresos y Gastos de Hogares, ENIGH), Inegi, 1984, 1989, 1992, 1994, 1996, 1998, 2000, 2002, 2004, 2005, 2006, 2008, 2010, 2012 y 2014.

So far, we have obtained the percentage of contribution to inequality for the social classes. This data can be interpreted as a proportion (compositional data), just dividing by 100, i.e., we obtain a value in (0,1). Note that when using deciles in social stratification, the Middle class has the major percentage of the income.

Using the predictive model with a hyperspherical transformation and the data from ENIGH, we can estimate and predict the proportion of inequality by social classes in Mexico. The results are presented in Figure 9.

Figure 9. Estimation and Predicted proportion of the contribution to inequality in Mexico



Note: As of 2016, it is a prediction.

Source: Authors' elaboration with data from *the National Survey on Household Income and Expenditure* (ENIGH), Inegi, 1984, 1989, 1992, 1994, 1996, 1998, 2000, 2002, 2004, 2005, 2006, 2008, 2010, 2012 y 2014.

Note in Figure 9, that opposite to what generally happens in the world, the extreme classes are the ones that contribute the most to inequality. In Mexico the middle class was thought to be the one that would contribute the most to inequality, according to the data obtained from the ENIGH. However, it has been pointed out by many authors the fact that there is under-reporting of income by households in this survey (Bustos, 2015) rendering it potentially inaccurate. This issue can be reflected in these results; but it could be a sign of shrinking of the

middle class as well, in which case, in the long term, could represent a large economic and social problem.

Therefore, the results show the importance of designing an appropriate survey and how social stratification is given, among other things, the deficiencies of the ENIGH, the fact that the high and low social class are those that contribute the least to inequality is reflecting the poor contribution that this type of surveys gives us. And this can be a serious problem since this survey is used in many statistics of the country.

Conclusions

In this paper, we have provided a methodology that helps us to analyze how important social stratification is, in order to study inequality. We have found that, in order to obtain more realistic results regarding this topic, different input data should be considered.

We have provided a tool to study the contribution to inequality from social classes in a given country. This analysis can help us to measure the effectiveness of fiscal and public spending, as well as to carry out more efficient redistribution practices and a design of public policies, focused on reducing inequalities through social spending in order to diminish the number of people living in poverty in a country, which seriously affects indicators of inequality.

This is an urgent and necessary objective as outlined in the United Nations 2030 agenda,. Nonetheless, the underlying question is: how should this expenditure be financed? By collecting taxes on the income of the middle classes?, or progressive taxes paying attention to the profits of capital, as well as the need to disaggregate the elite of the "high classes"?, since their contribution to public spending is diffuse or hidden in the social class or stratum in which they have statistically placed it.

Global experiences of countries pursuing aggressive fiscal policies to the middle class have caused their shrinking, reducing inequality through general impoverishment of the population, and reducing the level of income of the aforementioned class, hindering upward social mobility, making workers more vulnerable. As noted by the OECD (2019) the economic weight of the middle class has been drastically reduced in the world, proposing policies that shift tax pressure from income to work to income from capital, earnings, inheritances, and property; all these measures that the organization claims, would have an impact on economic growth and the reduction of inequality.

This article addresses the issue of inequality and its novelty lies in the analysis of the way in which it is composed, as a result, informed decisions can be made. In other words, public policies should be oriented based on an analysis in which the cost of the measures is clear. The proposals presented in the latest Cepal (2020) report make clear that in the face of the deep crisis experienced in Latin America, a State presence as a generator of equality is required.

In recent times in Mexico, a weak policy of support for the people in poverty has been carried out, but the attack on the middle classes has been heavy, in conjunction with the protection of the privileges of the upper class. Without a redistributive fiscal policy, resources cannot be obtained to implement social programs. The reduction of salaries of public officials and state spending are measures that are affecting the middle strata, and in the reports of Cepal (2020) are those civil servants that become part of the new poor, which will eventually lead to the shrinking of the middle class and therefore an increase in inequality.

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