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MULTIVARIATION OF INNOVATIVE APPROACHES TO EVALUATION AND MODELING OF POPULATION INCOME INEQUALITY

Abstract. The problem of inequality is perceived as a challenge to modern society, since the growth of inequality leads to the deepening of migration processes, increasing social tensions, creating prerequisites for changing the social system, fundamentalization of religious groups, political instability and military conflicts, economic and humanitarian wars.

This article is an analytical summary of scientific methods for assessing economic inequality. The purpose of the article is to evaluate the inequality of the population of Ukraine by sources of income. In accordance with the set goal, the dynamics of changes in the Gini index by the amount of monetary income were analyzed. The general scientific methods of scientific research and the basic provisions of the theories of socio-economic inequality, economic growth and innovative management became the methodological tools of the conducted research. To determine the degree of inequality of the population in terms of income, the entire spectrum of variation indicators (coefficient of variation, mean square deviation, etc.) was used. At the same time, special coefficients were analyzed, which make it possible not only to assess the degree of income inequality but also to measure the influence of factors on this phenomenon. These are primarily the Lorenz coefficient and the Lorenz curve, the Atkinson index, the Theil index, the decomposition of the specified coefficients, the coefficient of funds, the coefficient of differentiation, and the coefficient of contrasts.

The article decomposes the Gini index by sources of income and identifies the main sources of income that have the greatest impact on the growth of inequality in the distribution of income of the population of Ukraine.

The determination of economic inequality in the distribution of incomes of the population was carried out on the basis of the dynamic stochastic model of general equilibrium (DSGE). In the course of building the DSGE model of inequality of income distribution, three macroeconomic subjects operating in a closed economy were identified, namely households, firms and the state. The total amount of capital invested in a specific sphere of the economy and the total number of the economically active population, which is a parameter of the labour force in the production function, were also used. The obtained results are useful in the study of the issue of determining the causes of the influence of certain factors on the level of income distribution and the possibility of reducing the level of stratification of the population of Ukraine. The results of the conducted research can also be useful for calculating the basic indicators of the socio-economic development of the regions and the country in general.

Keywords: population income, dynamic stochastic general equilibrium model, economic inequality, Theil index, Atkinson index, Gini coefficient, coefficient of differentiation, Lorenz curve, income inequality

Formulas: 14, tabl.: 3, fig.: 1, bibl.: 36

JEL Classification: C13, D31

Introduction. The innovative development and reform of the economic system of Ukraine during the period of its independence is accompanied by many negative social phenomena. In particular, crisis phenomena in the socio-economic sphere are associated with the formation of a polarized society with various forms of economic inequality. The sustainability of the national economy and the national innovation system depends on a complex of factors that interact with each other and shape this indicator to one degree or another. One of these factors is differentiation in the distribution of incomes of the population. In connection with the strengthening of destabilization processes in the world economy, there is a deepening of the problem of inequality of income distribution between different groups of people.

A significant differentiation of the population in terms of financial status and uneven distribution of income is a problem for Ukraine, which has deepened in recent years. These processes are connected, first of all, with the annexation of Crimea by russia in 2014 and the armed conflict in Donbas, and in recent years - with the COVID-19 pandemic and the military aggression of the russian federation.

The problem of overcoming social inequality in terms of income requires in-depth study and the search for mechanisms for the redistribution of the population's income. This is a search for factors that increase differentiation, determination of the extent of their influence on income differentiation, research of income components and their influence on the differentiation of total incomes

Inequality is a multifaceted phenomenon, and it manifests itself in all spheres of social life, but there is no single general methodology for its measurement. Therefore, in the conditions of sustainable development, there is a need to improve the methodology and innovative models for assessing the level of inequality and justifying the mechanism of coordination of activities on the problems of its reduction.

However, today there are practically no materials in which the assessment of the level of income inequality according to different approaches would be indicated. It should be noted the low level of application of modelling theory in the context of income inequality, that is, the selection of the most accurate estimate of the analyzed indicator because practice shows that most often, the Gini index or its graphical representation by the Lorenz curve are used for comparison, which takes into account only basic indicators. while ignoring other important factors.

Literature review and the problem statement. Issues of inequality have recently been addressed by leading experts in economics, sociology, and political science, in particular, T. Piketty (2014), considered the historical dynamics of the distribution of wealth, income and various manifestations of inequality; L.M. Grigoryev (2016) noted that the nature of the distribution of wealth among citizens determines income inequality and becomes the reason for maintaining and maintaining income inequality over time; B. Milanovic (2016) analyzed the largest international database on inequality "all Gini indices" and tracked the long-term evolution of inequality in Western countries; Zh. G. Palma (2006) assessed the inequality in the distribution of national income in the era of globalization and established the discrepancy in the distribution of income between the richest 10% and the poorest 40% of the population

in different countries; S. I. Jones (2015) investigated the reasons for the growth of income inequality.

Despite the great attention to the problem of inequality, there are still a number of unsolved problems regarding its theoretical justification, search for forms, sources and methods of inequality assessment and their optimization.

The problem of income inequality is quite relevant not only in Ukraine but also outside its borders. Today, there are many scientists who research and try to find out the main reasons for the differentiation of the population's incomes. Among domestic economists, the research of E. Libanova (2020), V. Semenov (2008), V. Bulavynets, O. Zaklekta (2017), N. Kholod (2009), A. Hvelesiani (2009), I. Lavruk, S. Todoriuk, V. Kyfiak (2019), O. Prymostka (2016). In their publications, scientists suggest ways to overcome financial inequality in society both at the state and global levels.

Many works by domestic and foreign scientists are devoted to the issue of population inequality by income (Shcherba (2013); Yitzhaki and Schechtman (2013); Dmytryshyn (2013); Kostrobii, Kavalets and Hnativ, (2013)), which examine approaches to measuring population differentiation and polarization using income inequality indicators. In their work, scientists use well-known statistical indicators of relative inequality - Gini, Palm, Atkinson, Theil indices, decile (quintile) differentiation coefficients, income contrast coefficient and a number of others.

In particular, in the works of Yitzhaki and Schechtman (2013), Dmytryshyn (2013), Kostrobii, Kavalets and Hnativ (2013), the Gini index is used to differentiate the population by income, and both statistical and mathematical methods are used to find it. In order to find factors of differentiation, to determine the impact of structural components of income on the general level of differentiation of the population, the above-mentioned authors proposed to decompose income by population groups using the Gini index. However, questions regarding the reliability of calculating the Gini index by known methods and its use in assessing population inequality remain unresolved.

Methods. The methodological basis of this article is the basic theories of socioeconomic inequality, economic growth and innovative management. To calculate the inequality of the population by sources of income, special coefficients were analyzed, which make it possible not only to estimate the degree of inequality by income but also to measure the influence of factors on this phenomenon. These are primarily the coefficient and the Lorenz curve, the Gini coefficient, the Atkinson index, the Theil index, the decomposition of the specified coefficients, the coefficient of funds, the coefficient of differentiation, and the coefficient of contrasts.

Lorenz curve

According to the Pareto principle (80-20 rule), 80% of the consequences of many phenomena are caused by 20% of the causes (20% of criminals commit 80% of crimes, 20% of drivers create 80% of accidents, 20% of buyers give 80% of profits). This principle, discovered by J. M. Juran and named after V. Pareto, who found out that 80% of property in Italy belongs to 20% of its population, is the empirical basis for the fundamental conclusion of the theory of inequality regarding the feedback between the size of incomes and the number of their recipients. Graphically, this conclusion is illustrated by the Lorenz curve (Fig. 1). which is built in a square, on the X-axis of which the percentage of people receiving income is set, and on the Y-axis - the share of the received income from the total. The bisector of the third quarter characterizes the distribution of income under conditions of absolute equality. So, the Lorenz curve is a line that reflects inequality in society due to the action of the cumulative effect, that is, it reflects the ratio

of the percentages of all incomes and the percentages of all their recipients. Thus, the deviation of the Lorenz curve from this bisector will reflect the amount of income inequality.

In the case of uniform distribution of income, the paired shares of the population and income should coincide and be located on the diagonal of the square, which means the complete absence of concentration of income, that is, absolute equality in their distribution. Line segments connecting the points correspond to accumulated frequencies and increasing percentages of income and create a broken concentration line (Lorenz curve). The more this line differs from the diagonal (the more concave it is), the greater the unevenness of income distribution, and accordingly, the higher their concentration.

The Lorenz curve reflects the actual quantitative relationship between the share of income recipients in the total population and the share of total income they receive over a certain period of time (usually a year). At the same time, the first point of the curve shows that the poorest 10% of the population receive 3.7% of the total income, the second point shows that the poorest 20% receive 9.0% of the total income, etc. At the same time, the richest 10% receive 22.6% of the income.

In a society with absolute equality, every 10% of the population receives 10% of total income, 20% - respectively 20%, etc. In this case, the Lorenz curve takes the form of a straight line (diagonals of a square, lines of uniform distribution). However, in reality, one cannot expect complete equality in the distribution of income among the population, and the curve always differs from the diagonal. For example, in Ukraine in 2019, the poorest 10% of the population accounted for only 4.4% of total income, and the richest 10% - 21.4%. In the case of absolute inequality, the entire population except for one person (one household) has no income, and this one person (or household) receives all the income. Then the curve is transformed into two straight lines.

The area of deviation from a uniform distribution (absolute inequality), that is, the segment created by the Lorenz curve and the diagonal of the square, indicates relative inequality in income distribution.

But another form of the Lorenz curve is also possible when the line of non-uniform distribution is located above the line of uniform distribution. This case describes the distribution of resources, consumption volumes, etc. between population groups ranked by the values of another indicator. For example, if the dependence of the consumption of cheap food products on the income level of the population is investigated: the shares of the poorest population (lower decile groups) exceed the shares of the wealthy (higher decile groups).

Lorenz coefficient

The Lorenz coefficient as a relative characteristic of inequality in income distribution is determined by the formula:

$$L = \frac{|Y_1 - X_1| + |Y_2 - X_2| + |Y_3 - X_3| + |+\ldots+| + |Y_n - X_n|}{n} = \frac{\sum_{i=1}^{n} |Y_i - X_i|}{n} \qquad (1)$$

where Yi is the share of income concentrated in the i-th social group of the population;
Xi - the share of the population belonging to the i-th social group in the total population;
n - the number of social groups.

The Lorenz coefficient varies in the range 0 < L1 < 1; L = 0 for complete equality in income distribution; L = 1 for complete inequality, when all incomes are concentrated in one household.

Concentration coefficient (Gini coefficient)

The main and most convenient, and therefore the most common indicator of differentiation of the population according to the level of income (expenditure, consumption) is the index of concentration of income (expenditure, consumption), or the Gini coefficient, which reflects the nature of the distribution of the total amount incomes of the population between its individual groups.

The basis of the Gini coefficient, which is based on the Lorenz curve, is the idea that the extreme positions in the distribution of income between groups of individuals are egalitarian (in which all participants receive absolutely equal shares) and polar (when one participant receives all the income). The first case describes complete equality, the second - absolute inequality in distribution. The Gini coefficient is calculated based on data on the distribution of households (population) by the level of average income (expenses).

Given the essence of the Lorenz curve, the Gini coefficient measures the part of the figure's area that is limited by the lines of uneven distribution and the area of the triangle that encloses it.

The Gini coefficient can be calculated without constructing the Lorenz curve by the formula:

$$G = \frac{2}{\bar{c}N^2}\sum_{i=1}^{N}\left(r_i - \frac{N+1}{2}\right)c_i \tag{2}$$

where $\bar{c}$ is the total average income of households:

$$\bar{c} = \frac{\sum_{i=1}^{N} c_i}{N} \tag{3}$$

N - the number of units of the population;
r_i - household rank by income;
c_i - income of the i-th household.

The Gini coefficient varies in the range 0 < G < 1; G = 0 for complete equality and G = 1 for complete economic inequality of the population.

It is worth noting that the Gini coefficient to some extent underestimates the degree of inequality, as it ignores the extreme (on both sides) groups of households.

In the methodological guidelines of the State Statistics Service of Ukraine (2021), the Gini index for discrete income (expenditure) distributions is calculated using the formula:

$$G = 1 - 2\sum_{i=1}^{n} X_i \cdot cum\, Y_i + \sum_{i=1}^{n} X_i \cdot Y_i \tag{4}$$

where X_i is the share of the population of the i-th group in the total population;
У, - the share of income of the i-th population group;
x = cum X_i - cumulative share of the population of the ith group;
x = cum Y_i - cumulative share of income of the ith group;
n – the number of groups.

To calculate the Gini index, society is divided into 5 (quintiles) or 10 (deciles) parts containing the same number of elements (families or people). This method of calculating the Gini index does not require the construction of the Lorenz curve, which

The integral formula for finding the Gini index looks like this:

$$G = 2\int_0^1 \big(x - y(x)\big)\,dx \tag{5}$$

where y(x) is the function of population distribution by income (Lorenz curve);
y = x is a function of the uniform distribution of the population by income.

Atkinson index

In addition to the Gini coefficient, the use of the Atkinson index is common in the practice of statistical measurement of income inequality:

$$A = 1 - \frac{1}{\bar{c}}\left(\frac{1}{N}\sum_{i=1}^{N} c_i^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}, \varepsilon \in [0,1) \tag{6}$$

where ε is a parameter that estimates the expected level of stratification.

The Atkinson index ranges from 0 to 1 and is interpreted in the same way as the Gini coefficient.

Along with the Lorenz curve or the Gini index, the *Robin Hood index* (also known as the Hoover index, the Schutz index) is calculated. This indicator consists in determining the amount of total income that should be redistributed between the parts of the population with the highest and lowest incomes in order to equalize them. Graphically, the Robin Hood index corresponds to the largest deviation of the Lorenz curve from the bisector of a right angle drawn from the reference point.

In addition, income inequality is characterized by the Theil index, which is a measure of information entropy and is calculated according to the formula:

$$T_1 = \frac{1}{N}\sum_{i=1}^{N} \frac{c_i}{\bar{c}} ln \frac{c_i}{\bar{c}} \tag{7}$$

Theil index (log mean deviation) is also used to assess inequality. This indicator is calculated according to the formula:

$$T_0 = \frac{1}{N}\sum_{i=1}^{N} ln \frac{c_i}{\bar{c}} \tag{8}$$

It is believed that Theil indicators have certain advantages compared to other indicators of inequality since they can be decomposed into components related to different population groups, that is, they are nothing more than a weighted sum of indices for different groups.

Also, to measure economic inequality, various statistical methods are used, which consist in determining the arithmetic mean, median or modal income of the population, and coefficients of variation. Another method used by economists and statisticians is to group the population by income level and compare the average levels of the extreme groups with each other. In this case, methods of measuring income through quartile, quintile, decile financial indices, etc. are common (Prymostka, 2016).

Decile (quintile) coefficient of differentiation (coefficient of funds)

This coefficient is one of the most common indicators of inequality due to the simplicity of both calculations and interpretation. The idea of the coefficient is to compare the incomes (or another indicator of well-being) of the richest and poorest groups of the population, the same in number. So, if we are talking about decile groups, the average incomes in the tenth and first groups are compared, that is, in the 10% of the richest and 10% of the poorest households/ persons. If information is available by quintiles, the incomes of the fifth and first 20 per cent of the population are compared, respectively.

But in view of the need to eliminate so-called anomalous observations (for example, a family of millionaires falls into the richest group, the income of which significantly changes the average level of the group), often not average values by groups are compared, but so-called threshold values. For example, in the case of using data by decile groups, the ratio of incomes of families (households, individuals) that occupy 90% places in the ranked series (that is, lower incomes are received by 89.99% of families, and higher incomes by 9.99%) and 10% (9.99% of families receive lower incomes, and 89.99% receive higher incomes"). In particular, the decile coefficients of income differentiation are calculated as the ratio of two limits: between the ninth and tenth decile groups and between the first and second, that is, it is the ratio between the minimum income of the population (households) of the higher decile and the maximum income of the lower one. Quintile coefficients of differentiation are calculated similarly.

Therefore, the coefficient of differentiation or coefficient of funds (β), which is the ratio of the average values of the characteristic within the limits of the upper and lower deciles, is calculated according to the formula:

$$\beta = \frac{Y_{10}}{Y_1} \tag{9}$$

where Y_10 is the income of the household, which in the distribution series is located at the lower limit of the tenth decile group, or the ninetieth percentile;
Y_1 - household income, which in the distribution series is located at the upper limit of the first decile group, or the tenth percentile.

When using data by quintiles, 80% and 20% are used, respectively. The quintile coefficient is always smaller than the decile coefficient, as it involves the exclusion from the calculations of a twice as large share of the population with incomes (expenditures) that are the most different from the average level.

Under absolute equality, the decile (quintile) coefficient of differentiation is equal to 0, under absolute inequality it is unlimited, that is, it can be as large as economic inequality is. In reality, the decile coefficient does not exceed 10-12, and the quintile coefficient - 6-7.

Income contrast ratio

The difference in the incomes of the richest and poorest strata of society is measured using the coefficient of income contrasts, which depends on the level of average per capita income and on the degree of concentration of the population in groups with high and low incomes. In this case, the criterion for assigning a household to the extreme group is not the level of income, according to which the household belongs to a certain decile (quintile), but the ratio between income and the subsistence minimum. Accordingly, the groups of households that form the rich and poor subsets may be unequal in number.

The coefficient of income contrasts between the population group with high (for example, more than 5-6 subsistence minimums) and low (less than subsistence minimum) incomes is the product of two coefficients. The first is the ratio between the levels of average per capita incomes of individual population groups. The second is the ratio between the numbers of the two specified groups.

Research results. Let's find the Lorenz function based on statistical data on the distribution of monetary income by decile population groups, for example, for the year 2020 (Table 1). We will look for the Lorenz function in the form of a polynomial.

When using polynomials of high degrees, computational difficulties arise. Therefore, we will use spline interpolation. Let's apply polynomials of the fourth degree on the corresponding intervals:

$$y_1 = a_4x^4 + a_3x^3 + a_2x^2 + a_1x \quad 0 \le x \le 0{,}4$$

$$y_2 = b_4x^4 + b_3x^3 + b_2x^2 + b_1x + b_0 \quad 0{,}4 \le x \le 0{,}7$$

$$y_3 = c_4x^4 + c_3x^3 + c_2x^2 + c_1x + c_0 \quad 0{,}7 \le x \le 1$$

Table 1. Distribution of monetary income by decile (10%) population groups in 2020

Population group	x_i	y_i	x_i=cum x_i	y_i=cum y_i
The first (with the lowest incomes)	0.1	0.04	0.1	0.04
Second	0.1	0.055	0.2	0.095
Third	0.1	0.065	0.3	0.16
Fourth	0.1	0.074	0.4	0.234
Fifth	0.1	0.082	0.5	0.316
Sixth	0.1	0.093	0.6	0.409
Seventh	0.1	0.105	0.7	0.514
Eighth	0.1	0.12	0.8	0.634
Ninth	0.1	0.145	0.9	0.779
Tenth (with the highest incomes)	0.1	0.221	1	1

Source: compiled and calculated according to State Statistics Service, 2021

The unknown parameters of the polynomials can be found by solving the systems of equations (equality of the values of the functions and their first derivatives):

$$\begin{cases} y_1(0.1) = 0.04, \\ y_1(0.2) = 0.095, \\ y_1(0.3) = 0.16, \\ y_1(0.4) = 0{,}234, \end{cases} \begin{cases} y_2(0.4) = 0.234, \\ y_2(0.5) = 0.316, \\ y_2(0.6) = 0.409, \\ y_2(0.7) = 0.514, \\ y_2(0.4) = y_1(0.4) \end{cases} \begin{cases} y_3(0.7) = 0.514, \\ y_3(0{,}8) = 0.634, \\ y_3(0.9) = 0.779, \\ y_3(1) = 1, \\ y_3(0.7) = y_2(0.7) \end{cases}$$

The following polynomials were obtained:

$$y_1 = 1.67x^4 - 1.83x^3 + 1.18x^2 + 0.3x \text{ при } 0 \le x \le 0.4$$

$$y_2 = -3.89x^4 + 8.72x^3 - 6.66x^2 + 2.93x - 0.33 \text{ при } 0.4 \le x \le 0.7$$

$$y_3 = 25.83x^4 - 79.33x^3 + 92.19x^2 - 46.8x + 9.11 \text{ при } 0.7 \le x \le 1$$

Applying formula (4), we get the value of the Gini index:

$$G = 1 - 2\left(\int_0^{0.4} y_1 dx + \int_{0.4}^{0.7} y_2 dx + \int_{0.7}^{1} y_3 dx\right) = 0.272$$

The results of calculations of the Gini index for the period 2010-2022, as well as data from the World Bank (Giny index according to the World Bank) and the State Statistics Service of Ukraine, are given in Table. 2.

Table 2. The value of the Gini index for Ukraine in 2010-2022

Year	World Bank	All households (Statistics of Ukraine)	including those who live		Calkulated by the autors	Absolute change, ΔG, %	Shorrocks method
			in urban settlements	in the countryside			
2010	0.266	0.278	0.266	0.256	0.282		
2011	0.253	0.277	0.274	0.246	0.279	-0.36	0.204
2012	0.248	0.271	0.269	0.248	0.275	-2.17	0.195
2013	0.246	0.263	0.259	0.239	0.266	-2.95	0.257
2014	0.247	0.248	0.242	0.232	0.25	-5.70	0.225
2015	0.246	0.251	0.252	0.22	0.253	1.21	0.221
2016	0.24	0.24	0.241	0.223	0.236	-4.38	0.202
2017	0.255	0.243	0.243	0.231	0.253	1.25	0.212

2018	0.25	0.244	0.246	0.228	0.248	0.41	0.220
2019	0.26	0.256	0.258	0.241	0.265	4.92	0.240
2020	0.261	0.261	0.263	0.24	0.262	1.95	0.249
2021	0.266	0.265	0.263	0.246	0.272	1.53	0.258
2022	–	0.285	0.282	0.268	0.286	7.55	0.276

Source: compiled and calculated according to the State Statistics Service, 2021; Giny index according to the World Bank

The data in Table 2 shows that the values of the Gini index obtained from different sources differ slightly. It is characteristic for Ukraine that until 2016 there was a decrease in the Gini index and starting from 2017 - its increase. It increased significantly in 2022 - by 7.55%. The Gini index is higher for the population living in urban settlements than in rural areas, which is explained by the greater differentiation of incomes in cities.

Using the latest data from the World Bank, based on the value of the Gini index in 2020, it can be noted that South Africa, Namibia, Sri Lanka, and China are among the most unequal countries in terms of income distribution. At the same time, Ukraine is in this rating alongside Holland, Slovakia, and Belgium, which are among the most equal countries in the world. Numerous sociological studies claim that the more democratic a country is, the less income inequality it has. There is greater inequality in developing countries than in developed countries.

During the last 15 years, with a Gini index value of about 0.25, Ukraine is among the European countries. However, in reality, Ukrainian society is very stratified. Obviously, this assessment of inequality is ambiguous; if you do not rely only on financial indicators, but also evaluate the standard of living, then the result will be different. In particular, according to the World Happiness Report 2021, Ukraine ranks 110th among 149 countries (World Happiness Report 2021). These results are based, for example, on indicators of GDP per capita, expected standard of living, attitude to corruption.

The reasons for the discrepancy are the low quality of domestic statistical data on the incomes of the richest and poorest strata of the population because a significant part of their income is not declared and has a shadow character; in Ukraine, there is practically no middle class that would balance the imbalance between the number of poor and rich.

Scientists often in their work propose methods for calculating the Gini index, in which it is adjusted. In particular, in the work of Kostrobii, Kavalets and Hnativ, 2013, the authors use the statistical distribution of the population according to the level of average per capita total income of the population for calculations. This approach does not take into account the total share of income received by each population group in this distribution. Thus, the conducted research for 2012 shows that the Gini index after applying the proposed method increased from 0.262 to 0.424.

The Gini index is convenient to use to compare the studied characteristic (income, expenses, tax deductions) in aggregates with different numbers of elements (for example, regions with different populations) or to compare the distribution of the characteristic in different population groups (for example, the Gini index for the rural population and the index Gini for the urban population) or in different countries. It supplements data, for example, on GDP, average per capita income. However, there are also disadvantages of the Gini index. For example, it does not take into account sources of income.

In numerous scientific studies, the search for factors that affect inequality in society is carried out. Such factors include, for example, the level of economic development of the country, un-

employment, poverty, the success of the market, social and political reforms, and others. Note that the Gini index does not have a close correlation with various economic indicators.

If we compare the dynamics of changes in the Gini index in Ukraine with the dynamics of economic development, it is noticeable that at the same time as the economic downturn, there was a significant increase in inequality from 0.297 in 1992 to 0.39 in 1995. It can be assumed that the inconsistent economic reforms during the transition period led to the decline of the economy and, accordingly, a significant increase in income inequality. In the period of economic growth in 2000-2006, inequality stabilized at the level of 0.29, probably thanks to the economic reforms implemented in those years. And for the period 2009-2017, the level of inequality was approximately 0.25, although there was a decline in the economy in 2009 and 2015.

There has been an annual increase in inequality over the last five years, especially in 2020 with a simultaneous 4% fall in GDP in the same year, an increase in unemployment and poverty since 2015. Such processes can be objectively connected with the political and economic crisis of 2014, the large flow of forced migrants from Donbas and Crimea worsened the situation with the uneven distribution of the population's income. Many residents of Donbas suddenly lost their property and financial sources of livelihood as a result of hostilities. More than 5 million residents of Eastern Ukraine fell into the group of impoverished people.

Since 2020, another factor has appeared, which, according to the assumption, has a negative effect on the income inequality of the population. This year, the economy of Ukraine was hit by the COVID-19 pandemic. Quarantine restrictions have caused an economic downturn in some sectors of the economy, especially in all service sectors. Therefore, a significant share of the economically active population of Ukraine lost their jobs and, accordingly, their incomes. The poverty rate in 2020 for expenses below the actual living wage was 51%.

With the start of full-scale hostilities and the associated migration of the population, loss of jobs in the East of the country, as well as mass emigration of Ukrainians abroad, the poverty level in 2022, based on expenses below the actual subsistence minimum, amounted to 53% (Figure 1).

The disadvantage of such an indicator is that the Gini coefficient is given without describing the grouping of populations, does not take into account sources of income (income is provided at the expense of hard work or at the expense of property, business) and unofficial taxes, the level of corruption, etc. According to the Report on Human Development [6, p. 206–209] countries with a low value of the Gini coefficient: Ukraine (24.1), Slovenia (25.6), the Czech Republic, Slovakia (26.1), Kazakhstan (26.3), Iceland (26.9), Finland (27.1), etc. The highest value is observed in South Africa (63.0), Namibia (61.0), Haiti (60.8), Botswana (60.5), Colombia (53.5), Paraguay (51.7), Brazil (51.5), that is, these are the countries of the South that belong to the countries, that are developing.

The world average value of this indicator is 37.9% (2015) and is observed in such countries as Japan, Tanzania, Cambodia, Israel and others.

A decrease in the Gini coefficient indicates a fairer distribution of goods among people, but it has remained relatively constant for many years in most countries. Therefore, although the Gini coefficient belongs to the traditional indicators of the income distribution, it was not included in the list of indicators of the UN system in the field of Sustainable Development Goals (hereinafter referred to as SDGs).

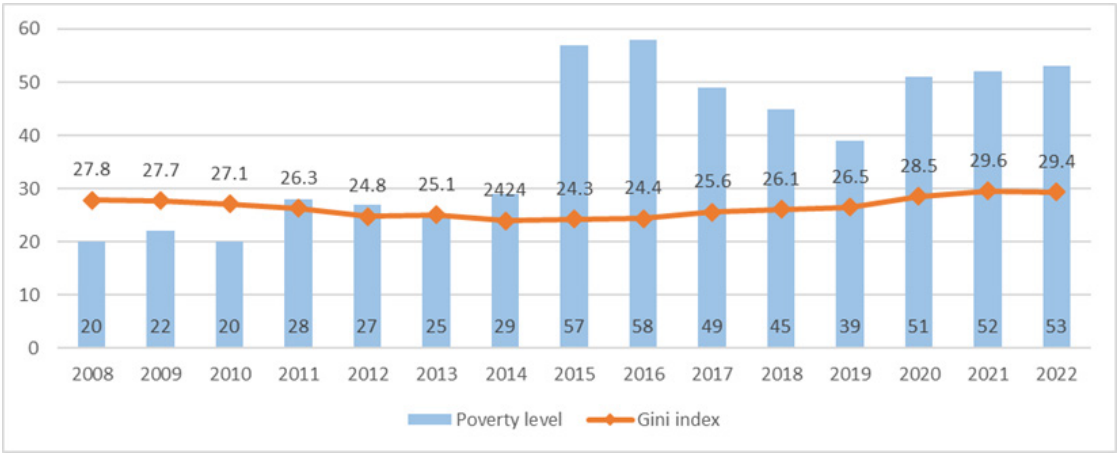

Figure 1. Dynamics of the Gini index (by the amount of monetary income) and the poverty level (by expenses below the actual subsistence minimum) during 2008-2022

Source: compiled and calculated based on the State Statistics Service, 2022), Borodchuk and Cherenko, 2021)

That is, the Gini coefficient will not be used as a global indicator, but it remains the most widely used and widely available official indicator of income inequality in some regions of the world (Prymostka, 2016). Instead, the list of indicators of inequality in the Central Bank included such indicators as "growth rates of household expenses or income per capita among the least well-off 40% of the population and among the population as a whole"; "the share of people with an income below 50% of the median income, broken down by age group, gender and disability"; and "share of working people's income in GDP, including wages and social security transfers" and others.

Having only the value of the Gini index, it is impossible to determine the cause and factors that affect the uneven distribution of incomes of the population. To determine the source of income, which makes the greatest contribution to the overall inequality of income distribution, we will use the method proposed by E. Shorrocks (1982), income decomposition. This method was developed to measure the weight of wages, and transfer payments (payments to the population under social insurance programs, cash benefits and benefits), which are components of income.

The possibility of quantifying the contributions of individual components to the formation of the general economic inequality of the population is provided by the decomposition method of the Gini coefficient. The contribution of each source of income to total inequality, measured by the Gini coefficient, is the product of pseudo-Gini coefficients (a simple concentration coefficient for a separate component) for each type of income and the share of this type of income (weight) in total income.

Formally, the concentration coefficient Gk for each specific k-th component of income (expenditure, consumption) is described by the equation:

$$G_k = \frac{2}{n^2 \mu_k} \sum_{i=1}^{n} \left(r_i - \frac{n+1}{2} \right) y_i^k \qquad (10)$$

where *n* is the number of groups of households;

y_i^k - component of the *k*-th income of the *i*-th group of households (UAH);

μ_k - average per capita income on the *k*-th component (UAH);
$r_i - i$ -th rank of households on the scale of total income (for households with the lowest level of income r_1=1, and with the highest r_n=n).

The Gini index is equal to the sum of the products of the concentration coefficient of the corresponding component of the aggregate

$$\frac{\mu_k}{\mu}$$

monetary income and the share of the latter in total income, i.e.:

$$G = \sum_{k=1}^{m} \frac{\mu_k}{\mu} G_k \tag{11}$$

where *r* is the number of income components;
μ - the average amount of cash equivalent income per capita (UAH).

The proportional contribution of the *k*-th source of income to total inequality can be calculated using the formula:

$$S_k = \frac{cov\left(Y^k, \bar{Y}\right)}{\sigma^2(\bar{Y})}, Y^k = \left(y_1^k, y_2^k, \ldots y_n^k,\right), \bar{Y} = (\bar{Y}_1, \bar{Y}_2, \ldots, \bar{Y}_n), k = \overline{1,m} \tag{12}$$

where $\bar{Y}_i (i = \overline{1,n})$ is the average per capita income of the *i*-th population group (UAH).

The elasticity of the Gini index in relation to the i-th component of income is calculated by the formula (Nivorozhkina, 1998):

$$\varepsilon_k = \frac{\mu_k}{G\mu}(G_k - G), k = \overline{1,m} \tag{13}$$

A slightly modified method of calculation, which is also based on the elasticity of the Gini coefficient, is illustrated by the formula:

$$\lambda = \frac{1}{G}\left(Y_k(G_k - G)\right) \tag{14}$$

where *G* is the Gini coefficient;
Y_k - the share of the k-th component of income in its total amount;
G_k is the Gini coefficient for the k-th component of income.

Now let's decompose the Gini coefficient by the source of population income. For this, based on the data of the State Statistics Service, we will distinguish the following components of sources of income that form the total income of households: y^1 - wages; y^2 - income from the entrepreneurial activity and self-employment; y^3 - income from the sale of agricultural products; y^4 - property income; y^5 - pensions; y^6 - scholarships; y^7 - benefits, subsidies and compensatory payments provided in cash (unemployment benefit, help for the poor, child support, subsidies for housing, electricity and fuel); y^8 - monetary assistance from relatives and other persons; y^9 - alimony; y^{10} - other monetary incomes. When finding the Gini index, we will not take into

account non-monetary income. All households are divided into decile (10%) groups depending on the amount of average per capita equivalent cash income. The obtained results of the decomposition of the Gini index are shown in Table. 3.

Table 3. Results of the decomposition of the Gini index by components of monetary income for 2010-2022

	Year	Components (on average per month per household, UAN)									
		y^1	y^2	y^3	y^4	y^5	y^6	y^7	y^8	y^9	y^{10}
$\frac{\mu_k}{\mu}$ *100, %	2016	53.56	5.73	3.58	1.07	25.09	0.75	3.70	4.89	0.32	1.33
	2017	52.85	6.12	3.81	1.26	23.89	0.68	3.67	6.12	0.29	1.33
	2018	54.32	6.06	3.48	1.68	22.57	0.58	3.63	6.03	0.22	1.47
	2019	59.89	5.11	3.38	1.57	19.60	0.39	3.10	5.15	0.26	1.55
	2020	60.58	6.66	2.79	1.46	19.48	0.34	2.28	4.48	0.25	1.71
	2021	62.32	7.12	2.61	1.15	17.79	0.30	2.60	4.14	0.30	1.68
	2022	63.27	6.14	1.81	0.22	19.38	0.26	3.48	4.00	0.24	1.27
S_k*100, %	2016	70.73	12.66	2.71	0.91	11.11	-0.12	-2.73	3.64	0.05	1.04
	2017	67.34	15.53	4.38	0.65	7.63	-0.23	-1.58	5.49	-0.07	0.86
	2018	75.92	13.15	2.92	1.09	0.89	0.31	-1.84	6.22	-0.05	1.39
	2019	84.84	9.20	2.64	0.20	-1.29	-0.11	-1.46	4.26	-0.07	1.79
	2020	82.59	12.14	1.16	0.14	2.38	0.07	-1.53	1.43	-0.02	1.64
	2021	82.98	14.07	0.98	-0.17	0.37	-0.03	-1.83	1.49	-0.01	2.14
	2022	85.44	10.40	1.26	0.44	-0.46	-0.02	-1.34	1.46	0.05	2.76
ε_k %	2016	0.182	0.047	-0.007	-0.001	-0.129	-0.008	-0.067	-0.012	-0.002	-0.003
	2017	0.158	0.071	0.005	-0.004	-0.151	-0.008	-0.055	-0.007	-0.004	-0.005
	2018	0.210	0.058	-0.002	-0.003	-0.202	-0.003	-0.053	0.000	-0.002	-0.002
	2019	0.262	0.031	-0.007	-0.012	-0.208	-0.005	-0.049	-0.012	-0.003	0.001
	2020	0.231	0.044	-0.013	-0.012	-0.178	-0.002	-0.038	-0.029	-0.002	-0.001
	2021	0.225	0.058	-0.015	-0.013	-0.181	-0.003	-0.045	-0.026	-0.002	0.002
	2022	0.227	0.032	-0.005	0.002	-0.193	-0.003	-0.047	-0.025	-0.002	0.013

Source: compiled and calculated according to the State Statistics Service, 2022

According to the received numerical results of the study, the main contribution to the differentiation of the population's income is made by the payment of labour. Its share in the structure of aggregate income and proportional contribution to inequality has been constantly growing and in 2020 amounted to 63.27% and 85.44%, respectively. This suggests that in order to reduce inequality, it is necessary to create conditions for increasing the incomes of the employed population.

The share of income from entrepreneurial activities has remained unchanged in recent years (approximately 6%).

In the period from 2016 to 2022, the share of pensions in the income structure decreases (from 25.09% to 19.38%), with a rather low proportional contribution to the inequality of income distribution. However, in Ukraine, pension provision is carried out almost entirely from the solidarity system, which does not provide for a significant difference in the amount of pensions.

Mandatory savings insurance has not yet been introduced in Ukraine, and voluntary pension insurance is not widespread, which could affect pension provision.

It should be noted that income component y^7 (benefits, subsidies and compensatory payments provided in cash) has a downward effect. The purpose of the system of social transfers is to reduce inequality. In all periods, social transfers have contributed, albeit insignificantly, to the reduction of income inequality in society. This dynamic of structural changes in income inequality is a consequence of a clearer direction (targeting) of social transfers to support low-income strata.

Sources of income such as pensions, scholarships, and alimony have had both positive and negative effects on income redistribution in different years. Despite their small share in the structure of total income (about 1%) in 2022, these income components contributed to the reduction of income inequality when the economy of Ukraine weakened.

We propose to determine the economic inequality in the distribution of the population's income on the basis of the dynamic stochastic model of general equilibrium (DSGE).

Currently, DSGE models are models of the general equilibrium of the economy, which, based on endogenous and exogenous factors of the environment in which the system functions, determine its development and changes (Miroshnichenko, 2011). The general equilibrium of this type of model is related to the initial position of the optimum point, where the supply is equal to the demand. In DSGE models, it is achieved due to the distribution of resources and prices that balance markets and satisfy the conditions for optimizing the activities of the main economic agents (Yitzhaki and Schechtman, 2013).

The simplest example of the DSGE model consists of three equations, each of which characterizes a separate block of macroeconomic subjects: the dynamic IS equation (reflects aggregate demand, models national income), the neo-Keynesian Phillips curve (corresponds to aggregate supply, taking into account inflation expectations and current real marginal costs) and Taylor's rule (replaced the LM curve, describes the equilibrium in the money market, models the interest rate) (Bazhenova, 2009).

The practical application of dynamic stochastic models began at the Central Bank of Sweden (the RAMSES II model), and later this forecasting method was used by the European Central Bank (NAWM), the US Federal Reserve System (SIGMA), the Norwegian Bank (NEMO) (Workshop "The applying dynamic stochastic models of general equilibrium (DSGE) in central banks", 2018). To date, DSGE models have become widely used, in addition to the systems listed above, in the central banks of Great Britain (BEQM), Canada (ToTEM), Peru (MEGA-D), Romania, the Czech Republic, Chile (MAS), in the development of the IMF world economy model (GEM, GIMF), where they are used as basic analysis and forecasting systems (Tovar, 2008).

In the course of building the DSGE model of inequality of income distribution, three macroeconomic subjects operating in a closed economy were identified, namely households, firms and the state. The determination of objective functions for each of the subjects was carried out based on the purpose of the model. So, for households, instead of the usual equation of maximizing utility, the basis is the mechanism of forming their budget (*Income*). In this case, household incomes were calculated according to their type of employment: hired workers (*work*) or entrepreneurs (*entrepr*), - taking into account the type of economic activity (W_i, a_i) within which the subjects function. It is also advisable to take into account the third category of the population, which make up the economically inactive part of the population. To a greater extent, this includes the unemployed population of retirement age and those who cannot work due to various objective reasons (*dotation*). In this case, their income is determined by the amount of

the corresponding social payments from the state. Regardless of the sources of income formation described above, rent (*R*), capitalization of interest on deposits (deposit, i_{dep})) received by subjects other than their main type of income should also be considered. In addition, we will add state transfers and subsidies to consumers' income. Other one-time types of income in the form of inheritance, lottery winnings, etc. are not taken into account. To obtain the final result, we apply the tax rate to the defined income function, the amount of which is determined by another market entity - the state (tax_j).

The next characteristic of households is the function of wealth (*Wealth*), which is determined by adding to the incomes of consumers, tangible and intangible assets available to them, accumulated in previous periods (*savings*), as well as access of households to the market (*lamp*).

When analyzing the consumption function (*Consumption*), we take into account the peculiarities of the behaviour of households, which is determined by their decision, which share of income to spend (π_{cons}) and which to save, as well as consumer expectations regarding future prices (ξ_{cons}), taking into account this dynamic of inflation.

Firms will be characterized according to the wages they set, price formation and total profit. In the context of modelling profit differentiation of firms (*Profit*), we will further consider this group of economic entities, dividing them according to (Hayashida, Nanba, Yasuoka, Ono, 2017), (Bondarenko, 2018) into producers of final (*fc*) and intermediate goods (*ic*). The basis for the first group of firms is the CES production function for all intermediate goods (Hayashida, Nanba, Yasuoka, Ono, 2017). For the second group - the Cobb-Douglas two-factor production model.

Another function of firms is pricing (*Price*). According to Calvo's model, let's divide all subjects into two parts: those that quickly respond to cyclical changes in the market and will influence the formation of the price (θ_p), and those that cannot quickly adjust to a new production system (Barnett, Ellison, 2005).

Similarly, let's determine the wage (*Wage*), based on the marginal costs of the firm (Holmes, 2014).

The state, as the third subject of the system, performs management functions, determines the tax policy (*Tax*) and controls the balance on the market. Thus, we will take into account the tax assessment system for each country separately, the amount of social benefits, etc.

As a result, the following rules must be observed in the model: maximization of the total utility of the economy, the profit of the firm, and the fulfilment of the balance when determining the state budget. Fulfilment of these conditions will ensure the adequacy of the built model, due to which it will be possible to use the obtained indicators of consumer incomes for the analysis of their differentiation.

Finally, we will determine the differentiation in income distribution for the period t through the decile coefficient, having previously sorted all households according to the level of wealth (*Inequality*). In addition, we will consider all interrelationships within the system not only from the point of view of its division into subjects but also taking into account dynamic development. Thus, we will take the (*t-1*) period as the basis of the model, relative to which we will determine the change in indicators in the t period.

So, the final model looks like this:

- income function of a separate household in the period *t*:

$$Income_{i,t} = \begin{pmatrix} W_{i,t}\left(1 - tax_{wage\ ,t}\right) \cdot \tau_{wage} + cap_{i,t} \cdot \alpha_{i_{entepr}} \cdot \left(1 - tax_{cap,t}\right) \cdot \tau_{cap} + \\ + R_{i,t}\left(1 - tex_{rent\ ,t}\right) \cdot \tau_{rent} + deposit_{i,t} \cdot i_{dep\ ,t}\left(1 - tax_{dep,t}\right) \cdot \tau_{dep} + \\ + dotation_{i,t} \end{pmatrix}$$

- a function of total household wealth in the period *t*:

$$Wealth_{i,t} = (Income_{i,t} + savings_{i,t})^{lamp}$$

- household consumption functions in the period *t*:

$$Consumption_{i,t} = Income_{i,t} \cdot \pi_{i_{cons}}^{\xi_{cons}} \rightarrow max$$

- profit function of the firm in the period *t*:

$$Profit_{i,t} = \left(\begin{pmatrix} \pi_{i_{firm},t} \cdot A \cdot \left(\delta \cdot cap_{i,t}^{-\varepsilon} + (1-\delta) \cdot lab_{i,t}^{-\varepsilon}\right)^{\frac{\delta}{\varepsilon}} \cdot Price_{i,t} + \\ + \left(1 - \pi_{i_{firm},t}\right) \cdot Price_{i,t} \cdot \sum_{j} Q_{j,t} - W_{i,t} \cdot lab_{i,t} - cap_{i,t} \end{pmatrix} \cdot \right)$$
$$\cdot \left(1 - tax_{cap,t}\right) \cdot \tau_{cap} + dotation_{i,t}$$

- function of pricing on the market in the period *t*:

$$Price_t = \left(Price_{t-1} + \frac{\partial(W_t \cdot lab_t + cap_t)}{\partial Q_t} - \frac{\partial(W_{t-1} \cdot lab_{t-1} + cap_{t-1})}{\partial Q_{t-1}}\right)^{\xi_{profit,t}}$$

- function of wage formation in the period *t*:

$$W_{i,t} = \left(1 - \theta_{W_{i,t}}\right) \cdot W_{i,t-1} + \theta_{W_{i,t}} \cdot (1-\varepsilon) \cdot \frac{Q_{i,t}}{lab_{i,t}}$$

- function of replenishment of the national budget through taxes in the period *t*:

$$Tax_t = Consumption_t \cdot tax_{cons} \cdot \tau_{cons} + W_t \cdot tax_{wage} \cdot \tau_{wage} + Profit_t \cdot tax_{profit} \cdot \tau_{profit}$$

- inequality in income distribution during the period *t*:

$$Inequality_t = \sum_{i=1}^{0,1n} Wealth_{i,t} \Big/ \sum_{i=0,9n}^{n} Wealth_{i,t}$$

The model also uses the total amount of capital invested in a specific sphere of the economy and the total number of the economically active population, which is a parameter of the labour force in the production function. Another component of the model is subsidies allocated by the government to support producers and workers.

Conclusions. Inequality is perceived through the prism of relativity and differences in development opportunities. Therefore, indicators of the concentration of income, wealth, and assets are traditionally used to assess it: the Gini coefficient, the Palma coefficient, decile and quintile indicators, the generalized entropy index, the happiness index, GDP per capita, etc. Different representations of inequality differ significantly and sometimes contradict actual data (happiness rating, etc.).

Based on data from household income surveys, we calculated the Gini index for the monetary incomes of the population of Ukraine. At the same time, the Lorenz function is constructed in the form of polynomials using spline interpolation. The obtained values are quite close to the

values of the Gini indices calculated by the Shorrocks method, the World Bank and the State Statistics Service of Ukraine.

The model considered by us in the work is universal and can be applied to other regions of the world, in the regional section of countries, under the conditions of preliminary calibration of the parameters. Further improvement of the model consists in its expansion through the introduction of additional sources of income in order to obtain more accurate results. In addition, a transition to an open type of economy is possible through the addition of one more subject - the external sector.

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