

UDC 330.5

DOI: 10.31651/2076-5843-2020-1-82-89

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CORRELATION-REGRESSION ANALYSIS OF GDP AND AVERAGE WAGE INDICATORS IN UKRAINE

The article explores the relation between GDP per employee and average wage. The calculations were made on the basis of the data of the State Statistical Service of Ukraine for a 24-year period (from 1995 to 2018). The studied indicators are reduced to 1995, which is taken as the baseline, and also adjusted for cumulative coefficients of consumer price indices for each year in relation to the base year to obtain real values of indicators in the prices of the base period - 1995.

Using correlation-regression analysis, the work outlines trends and the degree of correlation between GDP per employee and average wage. It is proved that there is a direct linear dependence and a close relation between the studied variables. Since wages are the main form of income of our country's population, we can say that there is also a regression between the real average monthly GDP per employed person and the level of household income. Estimation of the extent of this regression, correlation coefficients and determinations will be explored in our future work.

Keywords: *average monthly GDP per employee; the average monthly salary; consumer price index; regression coefficient; correlation coefficient; coefficient of determination; statistical significance; Fisher's F-test; Student's t-test.*

Introduction. The transformations that have taken place in the Ukrainian economy in recent decades have led to significant changes in the level and quality of life of the population, one of the most important characteristics of which is population income. Their level, structure, sources of income, degree of differentiation are among the most important indicators of both economic and social well-being of society.

Population income is an indicator of events that occur in the national economy. Together with the main macroeconomic indicators, they are an indicator that characterizes the level of socio-economic development of the country, gives an assessment of the current economic policy and the effectiveness of the reforms. That is why the concepts of «income», «income of population», «household income» and the scientific and methodological basis of income generation are always the focus of the scientific community.

The main component of the income of the majority of the population of our and other countries of the world is wages. Scholars of the Center for American Progress, M. Madowitz and S. Hanlon, note that with the exception of the richest people in the country, almost all working Americans have such incomes and standards of living that are determined by their wages [1]. Therefore, the study of the process of wage formation and factors affecting its level does not lose relevance in our country and in other countries of the world.

Literature review. The study of these issues has received considerable attention in contemporary economic literature. The first scientific attempts to clarify the issues related to the nature and formation of wages were made by representatives of the classical school of political economy F. Kene, W. Petty, A. Smith, D. Ricardo, K. Marx and others. When formulating the first wage definitions, they often reduced their wages to a living wage. In this sense, D. Ricardo emphasized that no attempt by the state to raise wages above the subsistence minimum would lead to an improvement in the welfare of the people. Wages above the subsistence level will cause a rise in fertility, and therefore an increase in the labor supply, which, according to market laws, will reduce the level of wages to a minimum [2]. Described by the representatives of the classical school, the theory of wages,

being an integral part of the theory of income, has evolved over the centuries with the development of economic science and methods of theoretical research.

Today, domestic and foreign experts are researching issues related to wages, their place and importance in the structure of the population's income. A fundamental study on the quality of life of the population, poverty factors, problems of income generation, issues of determining wages and income is presented in the works of Nobel Prize winner 2015 A. Ditton [3]. Various aspects of the formation of income, the problem of poverty in countries that have undergone transformational changes are studied by the Russian economist R. Nureyev [4]. The works of Ukrainian scientists G. Karmelyuk, G. Senov analyzes the interconnection between GDP and social indicators of life of the population, including minimum wage, subsistence minimum and others [5]. G. Kulikov investigates aspects of wage formation in a crisis period [6]. Using the category "revenue generation system" K. Gubin explores the main structural problems of this system in Ukraine, paying much attention to the analysis of real and average wages and their relationship with the level of GNI and GDP of Ukraine [7, 8]. Discussion issues of income generation and their economic content are investigated in the works of I. Khovrak [9].

Despite a considerable amount of research into the problems of income generation in general and wages in particular, we believe that further study of the impact of GDP on the average wage does not lose its relevance. Especially, when the growth of minimum and average wages does not lead to economic growth and vice versa, when GDP growth does not lead to an increase in the level of real wages.

Wages in the process of macroeconomic circulation are formed as a result of GDP creation and its subsequent distribution (GDP calculation method by income, or distribution method); so there must be a strong correlation between the average wage and the GDP per employee, which we want to explore in this work.

The purpose of the article is to research the dynamics of GDP per employed and average wage in Ukraine, to determine the direction and degree of correlation between these indicators using correlation regression analysis.

Results and discussion. For the purpose of the survey we will use the data of the State Statistical Service of Ukraine [10]. The following are identified and selected as indicators of the work being investigated:

- average monthly GDP per employee (GDP); author's calculations have been made to determine it based on the data of the State Statistical Service of Ukraine;
- average monthly wage (RF); the source of information is the data of the State Statistical Service of Ukraine.

Before conducting the correlation analysis, the data on the indicators were transformed with the following features:

- 1) the study period is 24 years, from 1995 to 2018;
- 2) the base year for the calculations was 1995, so the surveyed indicators are reduced to that period; the choice of the year is related to the formation of relative price stability after hyperinflation of 1992-1994;
- 3) in order to eliminate the inflationary impact on the indicators under study, their adjustments to the cumulative coefficients of the consumer price indices for each year relative to the base are made; thus the real values of the indicators in the prices of the base period, 1995 were obtained.

The necessary data for the study within the selected period and the estimated gross domestic product per employee are shown in Table 1.

We will use correlation-regression analysis to test for the correlation between these indicators.

This method is used to visualize the form of communication between the studied economic indicators.

Table 1

**Consumer price index, GDP, employment and average annual wage
in 1995-2018**

Year	CPI, %	GDP, billion UAH.	Employment, million per.	Average annual wage, UAH / month	GDP per employee, UAH/month
1995	100,0	54,5	24125,1	73	188
1996	139,7	81,5	24114,0	126	282
1997	110,1	93,4	23755,5	143	328
1998	120,0	102,6	22998,4	153	372
1999	119,2	130,4	19947,8	178	545
2000	125,8	176,1	20175,0	230	727
2001	106,1	211,2	19971,5	311	881
2002	99,4	234,1	20091,2	376	971
2003	108,2	277,4	20163,0	462	1146
2004	112,3	357,5	20295,7	590	1468
2005	110,3	457,7	20680,0	806	1844
2006	111,6	565,0	20730,4	1041	2271
2007	116,6	751,1	20904,7	1351	2994
2008	122,3	990,8	20972,3	1806	3937
2009	112,3	947,0	20191,5	1906	3908
2010	109,1	1120,6	19180,2	2250	4869
2011	104,6	1349,2	19231,1	2648	5846
2012	99,8	1459,1	19261,4	3041	6313
2013	100,5	1522,7	19314,2	3282	6570
2014	124,9	1586,9	18073,3	3480	7317
2015	143,3	1988,5	16443,2	4195	10077
2016	112,4	2385,4	16276,9	5183	12212
2017	113,7	2983,9	16156,4	7104	15391
2018	109,8	3558,7	16360,9	8865	18126

Source: compiled and calculated by the author based on the data of the State Statistical Service of Ukraine www.ukrstat.gov.ua

To do this, in the rectangular coordinate system plot, the y-axis defines the individual values of the resultant sign Y, and the x-axis - the individual values of the factor sign X. In our researching, we take the average wage for the productive characterization and the GDP per employee for the factor characterization (Table 2).

Based on the correlation field, it is possible to hypothesize (for the general population) that the relation between all possible values of X and Y is linear. That is, there is a direct link between GDP per employee and average wage levels.

The linear regression equation has the following form:

$$y = bx + a. \quad (1)$$

The estimated regression equation (based on sample data) will following form:

$$y = bx + a + \varepsilon, \quad (2)$$

where a and b - are respectively estimates of the parameters α and β of the regression model to be found; ε - is a random error (deviation).

Since the deviations ε_i for each particular observation i in the sample are unknown, therefore:

- 1) observations x_i and y_i can be obtained only estimates of the parameters α and β ;
- 2) the estimates of the parameters α and β of the regression model are, respectively, values a and b, which are random because they correspond to a random sample.

To estimate the parameters α and β , we use the OLS (ordinary least squares method), which gives the best estimates of the parameters of the regression equation. But only if certain preconditions for the random term (ε) and the independent variable (x) are fulfilled.

Table 2

GDP per employee and average annual wage at the base period prices in 1995-2018, UAH / month

Year	Cumulative CPI 1995 = 100%	GDP per employee, UAH/month	Average annual wage, UAH / month
1995	100,0	188,3	73,0
1996	139,7	201,7	90,2
1997	153,8	212,9	93,0
1998	184,6	201,4	82,9
1999	220,0	247,7	80,9
2000	276,8	262,8	83,1
2001	293,7	300,1	105,9
2002	291,9	332,7	128,8
2003	315,8	363,0	146,3
2004	354,7	413,9	166,3
2005	391,2	471,5	206,0
2006	436,6	520,2	238,4
2007	509,1	588,2	265,4
2008	622,6	632,4	290,1
2009	699,2	559,0	272,6
2010	762,8	638,3	295,0
2011	797,9	732,8	331,9
2012	796,3	792,8	381,9
2013	800,3	821,0	410,1
2014	999,5	732,0	348,2
2015	1432,3	703,6	292,9
2016	1609,9	758,6	321,9
2017	1830,5	840,8	388,1
2018	2009,9	901,9	441,1

Source: compiled and calculated by the author based on the data of the State Statistical Service of Ukraine www.ukrstat.gov.ua

The aggregate of points of the resultant and factor signs is called the correlation field (fig. 1).

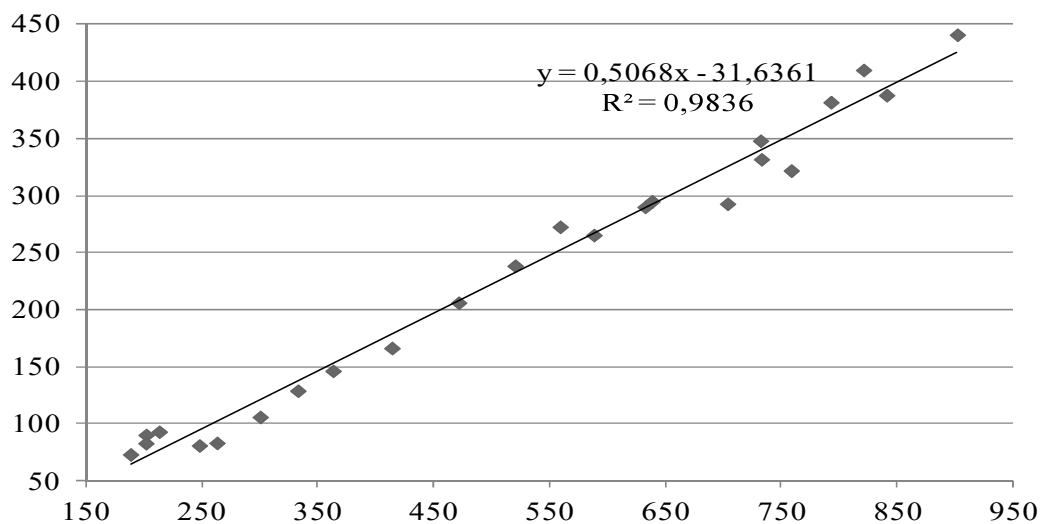


Fig. 1. The field of correlation between GDP per employee and average annual wage, UAH / month.

Formally, the OLS criterion can be written as follows:

$$S = \sum (y_i - y^*_i)^2 \rightarrow \min, \quad (3)$$

and the system of normal equations is:

$$a * n + b * \sum x = \sum y$$

$$a * \Sigma x + b * \Sigma x^2 = \Sigma y * x. \quad (4)$$

Using a spreadsheet with the required data, mathematical methods of study, including the method of algebraic addition, you can calculate the regression parameters.

It should be noted that the empirical regression coefficients (a) and (b) are only estimates of the theoretical coefficients β_i , and the equation reflects only the general trend in the behavior of the variables under consideration.

We obtain empirical regression coefficients: $b = 0,5068$, $a = -31,6361$. Therefore, the linear regression equation has form:

$$y = 0,5068 x - 31,6361.$$

The coefficients of the linear regression equation can be given an economic sense. The regression coefficient $b = 0,5068$ shows the average change in the resultant index (in units of measure Y) with increasing or decreasing factor X per unit of measure. In this research, with an increase in GDP per employee 1 unit, the average wage increases by an average of 0,5068 units.

The coefficient $a = -31,6361$ formally shows the predicted level Y, but only if $X = 0$ is close to the sample values. But if $X = 0$ is far from the sample values of X, a literal interpretation can lead to incorrect results, and even if the regression line accurately describes the value of the observed sample, there is no guarantee that this will be the case with extrapolation left or right.

Substituting the corresponding values of X into the regression equation, one can determine the aligned (predicted) values of the resultant y (x) for each observation.

Next, we calculate the indicator of bond closeness using the linear paired correlation coefficient $r_{x,y}$. The linear pairwise correlation coefficient can be determined either through a selective linear correlation coefficient or through a regression coefficient b.

The values of the linear pair correlation coefficient can take values from -1 to +1, characterizing a weak or close relationship between the traits. In our study, the coefficient $r_{x,y}$ is 0,992, which indicates a fairly high correlation between the average wage rate and GDP per employee.

The direction of connection between Y and X determines the sign of the regression coefficient b (if > 0 is a direct relations, otherwise it is a reverse). In our case, the coefficient is positive (0,992), and therefore the relations is straight.

Next, we analyze the significance of the correlation coefficient obtained and test the hypotheses for linear regression coefficients using the following methods:

- 1) t-statistics. Student's test;
- 2) F-statistics. Fisher's test.

1. Using ordinary least squares method, we only obtained estimates of regression equation parameters that are specific to a particular statistical observation (a specific set of x and y values). To assess the statistical significance of the regression and correlation coefficients, a Student's t-test is calculated.

As the main (null) hypothesis, we put forward the hypothesis that the parameter or statistical characteristic in the general population differs insignificantly from zero. Along with the main hypothesis, we put forward an alternative hypothesis about the inequality of zero parameter or statistical characteristic in the aggregate.

If the actual value of the t-criterion is greater than the tabular one (modulo), then the main hypothesis is rejected and it is believed that with probability $(1-\alpha)$ the parameter or statistical characteristic in the general population is significantly different from zero.

If the actual value of the t-criterion is less than the tabular one, there is no reason to reject the main hypothesis, that is, the parameter or statistic in the general population is slightly different from zero at the significance level α .

$H_0: r_{xy} = 0$, no linear interconnection between the variables;

$H_1: r_{xy} \neq 0$, there is a linear interconnection between the variables.

In order to test the null hypothesis about the equality of zero of the general correlation coefficient of the normal two-dimensional random variable at the competing hypothesis $H_1 \neq 0$, at the level of significance α , it is necessary to calculate the observed (actual) value of the criterion and on the table of the Student's critical points of distribution, by the given level of significance α and the number of degrees of freedom $k = n - 2$ find the critical point t_{crit} of the bilateral critical region.

t_{actual} according to our calculations is 36,341.

According to the Student's table with significance level $\alpha = 0,05$ and degrees of freedom $k = 22$ we find the t_{crit} :

$$t_{\text{crit}} = (n-m-1; \alpha/2) = (22; 0,025) = 2,074.$$

Since $|t_{\text{actual}}| > t_{\text{crit}}$, we reject the hypothesis of equality of 0 correlation coefficient. In other words, the correlation coefficient is statistically significant.

Similarly, we test the hypothesis H_0 about the equality of the individual regression coefficients of zero (alternatively - H_1 is not equal) at the significance level $\alpha = 0,05$.

$H_0: b = 0$ - there is no linear dependence between the variables X and Y in the general population;

$H_1: b \neq 0$ - there is a linear dependence between the variables X and Y in the general population.

To do this, we use the already determined indicator $t_{\text{crit}} = (n-m-1; \alpha/2) = (22; 0,025) = 2,074$ and compare it with the indicators t_b and t_a , which we will calculate below.

$$t_b = 0,507 / 0,0139 = 36,34$$

Since $36,34 > 2,074$ the statistical significance of the regression coefficient (b) is confirmed (we reject the hypothesis that the coefficient is zero).

$$t_a = -31,636 / 7,91 = 4$$

Since $4 > 2,074$, the statistical significance of the regression coefficient (a) is confirmed (we reject the hypothesis of zero equality of this coefficient).

2. To test the significance of the regression model, we perform an analysis using the Fisher F-test, the calculated value of which is the ratio of the variance of the original series of observations of the studied indicator and unbiased estimation of the residual sequence variance for this model.

A model is considered significant if the calculated value with $k_1 = (m)$ and $k_2 = (n-m-1)$ degrees of freedom is greater than the table value at a given level of significance (where m is the number of factors in the model).

First, we hypothesize that the equation as a whole is statistically insignificant:

$H_0: R_2 = 0$ at the α level of significance.

Second, we determine the actual value of the F-criterion. In our study, it is equal to $F = 1320,65$.

Next, we define the tabular value of the F-criterion. If the actual value of the F-criterion is less than the table criterion, then it is said that there is no reason to reject the null hypothesis. Otherwise, the null hypothesis is rejected and the $(1-\alpha)$ probability is assumed to be an alternative hypothesis of the statistical significance of the equation as a whole.

The tabular value of the criterion with degrees of freedom $k_1 = 1$ and $k_2 = 22$ equals $F_{\text{table}} = 4,3$.

Since the actual value of $F > F_{\text{table}}$, we can declare the statistical significance of the coefficient of determination (the found estimate of the regression equation is statistically reliable).

The degree of accuracy of the regression equation is estimated using the coefficient of determination R^2 , which shows the fraction of variation of the resultant trait, explained by the variation of the factor trait and represents the square of the (multiple) correlation coefficient. Most often, when interpreting the coefficient of determination, it is expressed as a percentage.

$R^2 = 0,9836$, that is, in 98,36% of cases, changes in GDP per employee lead to changes in the average wage. In other words, the accuracy of regression equation selection is high. But, as we can see, there remains 1,64% of change in Y, which is not related to the change in GDP, and is explained by factors that are not taken into account in the model (as well as specification errors).

Conclusions. Based on the research, we can say that there is a close relations between the variables studied, namely, between the average wage and GDP per employee. The existence of a direct linear dependence is proved by the correlation-regression analysis that was performed in the work.

The statistical dependence of Y on X was studied. At the specification stage, a pairwise linear regression was selected. It estimated its least squares parameters. The statistical significance of the equation is verified using the Fisher coefficient and determination; the statistical significance of the coefficients obtained using the Student's t-test.

It is established that 98.36% of the total variability of Y in the study situation is explained by the change in X. It is also established that the model parameters are statistically significant. An

economical interpretation of the model's parameters indicates that an increase in X by 1 unit of measurement results in an increase in Y by an average of 0,5068 units of measurement.

Thus, there is a direct linear regression between the real average monthly GDP per employee and the average wage per employee. Since wages are the main form of income of our country's population, we can say that there is also a regression between the real average monthly GDP per employed person and the level of household income. The estimation of the degree of this regression, the correlation coefficients and the determinations will be explored in our future work.

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КОРЕЛЯЦІЙНО-РЕГРЕСІЙНИЙ АНАЛІЗ РІВНЯ ВВП ТА СЕРЕДНЬОЇ ЗАРОБІТНОЇ ПЛАТИ В УКРАЇНІ

Проблема. Основною складовою доходу більшості населення нашої та інших країн світу є заробітна плата. Незважаючи на достатню кількість досліджень проблем формування доходів населення в цілому та заробітної плати зокрема, вивчення впливу ВВП на рівень середньої заробітної плати не втрачає своєї актуальності, особливо в умовах, коли зростання мінімальної та середньої заробітної платні не призводить до економічного зростання, та навпаки, коли зріст ВВП не призводить до підвищення рівня реальної заробітної плати.

Мета статті - дослідження напрямку та ступеню взаємного зв'язку між рівнем ВВП на одного зайнятого та рівнем середньої заробітної плати в Україні

Методи дослідження. Зв'язок між рівнем ВВП на одного зайнятого та середньою заробітною платою досліджено за використанням методу кореляційно-регресійного аналізу. Для цього за допомогою економіко-статистичних методів дослідження зібрано та розраховано необхідні показники. Використання математичних методів дослідження, зокрема методу алгебраїчного додавання, дозволило розрахувати параметри регресії.

Результати. Аналіз зв'язку між досліджуваними показниками здійснено на основі даних за 24 роки (з 1995 по 2018). Показники, що досліджуються, зведені до 1995 року, який прийнято базовим роком для розрахунків. Проведено коригування показників на кумулятивні коефіцієнти індексів споживчих цін для кожного року по відношенню до базового. Отримані реальні значення показників у цінах базисного періоду (1995 року). Проведено статистичну перевірку наявності взаємозв'язку між ВВП на одного зайнятого та середньою заробітною платою методом кореляційно-регресійного аналізу. Проаналізовано значимість отриманого коефіцієнта кореляції та перевірено гіпотези щодо коефіцієнтів лінійного рівняння регресії за допомогою методів *t*-статистика (критерій Ст'юдента) та *F*-статистика (критерій Фішера). Оцінено ступінь точності рівняння регресії за допомогою коефіцієнта детермінації.

Наукова новизна. Встановлено, що в досліджуваній ситуації 98,36% загальної варіабельності рівню середньої заробітної плати пояснюється зміною рівню ВВП на одного зайнятого. Доведено, що параметри моделі статистично значущі. Економічна інтерпретація параметрів моделі свідчить про те, що зі збільшенням ВВП на одного зайнятого на 1 одиницю, рівень середньої заробітної плати підвищується в середньому на 0,5068 од.

Висновки. Доведено, що існує пряма лінійна регресія між реальними середньомісячними показниками ВВП на одного зайнятого та показниками середньої заробітної плати одного працюючого. Оскільки заробітна плата є основною формою доходів населення нашої країни, можна стверджувати, що між реальними середньомісячними показниками ВВП на одного зайнятого та рівнем доходів домогосподарств теж існує регресія. Оцінку ступеню цієї регресії, коефіцієнти кореляції та детермінації буде досліджено в нашій подальшій роботі.

Ключові слова: середньомісячний ВВП на одного зайнятого, середньомісячна заробітна плата, індекс споживчих цін, коефіцієнт регресії, коефіцієнт кореляції, коефіцієнт детермінації, статистична значущість, *F*-критерій Фішера, *t*-критерій Ст'юдента.

Одержано редакцією: 17.11.2019
Прийнято до публікації: 24.01.2020