https://doi.org/10.33271/nvngu/2024-1/175

O. I. Babchynska[*1],
orcid.org/0000-0001-6377-6242,
O. H. Vagonova[2],
orcid.org/0000-0001-6553-7771,
V. M. Nyzhnyk[3],
orcid.org/0000-0002-8624-6444,
O. A. Posvalyuk[3],
orcid.org/0009-0004-8153-7471,
O. M. Lozovskyi[1],
orcid.org/0000-0002-9979-6832

1 – Vinnytsia Institute of Trade and Economics of State University of Trade and Economics, Vinnytsia, Ukraine
2 – Dnipro University of Technology, Dnipro, Ukraine
3 – Khmelnytskyi National University, Khmelnytskyi, Ukraine
* Corresponding author e-mail: olena.babchinska@ukr.net

GROSS REGIONAL PRODUCT IN UKRAINE: TWO-DIMENSIONAL ANALYSIS OF REGULARITIES AND TERRITORIAL FEATURES

Purpose. Carrying out an analysis of panel data on individual indicators of the development of the regions of Ukraine in general and their aggregates, distinguished by territorial location and profitability in order to establish the main regularities and specific features of changes in their gross regional product.

Methodology. On the basis of a sample of statistical indicators of the socio-economic development of the regions of Ukraine for the period from the beginning of the Russian-Ukrainian war (2014) to the full-scale invasion, the authors created panel series of data with the separation of regional groups according to territorial and income criteria. For each group panel series of data, random effects regression models were built in order to determine the presence of regularities and specific features of regional development in different groups.

Findings. An analysis of scientific developments and practical results in the issue of determining the key factors of the formation of the gross regional product was carried out. Given the uncertainty in views on the key factors of regional development, an attempt was made to determine them using a two-dimensional analysis of panel data. For this purpose, a sample of statistical information on the main indicators of socio-economic development of each of the regions of Ukraine was formed and their grouping was carried out according to two criteria: territorial location and profitability according to the indicator of the gross regional product per capita. In general, five groups of oblasts were formed based on territorial characteristics and four groups of oblasts based on income characteristics, and a panel regression model was constructed for each of these groups, including the total set of regional panel data. The received specifications of the models made it possible to form a list of key regularities in the formation of the gross regional product in Ukraine, as well as to determine specific factors of influence on the resulting indicator for each of the groups of oblasts.

Originality. On the basis of the given approach to the panel analysis of factors of regional development and, in particular, the formation of the gross regional product, based on a combination of statistical methods for grouping (clustering) regions according to various criteria and panel regression models, the hypothesis regarding the presence of common regularities of regional development in certain groups of oblasts of Ukraine was confirmed. The key factors and specific features of changes in the indicator of the gross regional product in Ukraine in general and in individual regional clusters are determined.

Practical value. The possibility of practical use of the obtained results as key risk factors in the process of forming plans for the economic development of individual oblasts in the long term, as well as the application of the proposed approach to the study on key factors of the formation of other indicators of regional development.

Keywords: *gross regional product, analysis of panel data, factors of regional development*

Introduction. Sustainable regional development is a guarantee to the continuous development of the state's economy in general, which requires special attention to the issues of its provision due to the targeted influence on the key factors of its activation as well. At the same time, in Ukraine, achieving the goals of sustainable development and, in particular, the strategic goal of ensuring sustainable sectoral and regional development [1], economic development vectors in the direction of "regional development" [2] is not only unattainable within the specified time, but also impossible due to a significant change in the basic input conditions. According to experts, the consequence of the modern Russian-Ukrainian war will be "a 20-year setback of the country's development" [3]. Thus, under modern conditions, the need for in-depth analytical studies on the processes of regional development of Ukraine both as a whole and in relation to individual consolidated regions or oblasts grouped according to different criteria is actualized, one of the components of which can be a two-dimensional analysis of regularities and specific features of regional development.

Literature review. The use of panel data analysis in economic research has become widespread in the world scientific community over the past decades and has been widely covered in the works by L. Anselin [4], B. Baltagi [5], C. Hanck [6], A. Garrat [7], J. Elhorst [8], T. Petersen [9], Z. Townsend [10].

Among the Ukrainian research scientists of the practical aspects of the application of econometric analysis in the modeling of economic processes, it is worth noting the works by M. Oliskevych [11].

Studying of processes, regularities, specifics, etc. of regional development in Ukraine using multidimensional analysis models is not a common practice, although some researchers turn to them in their developments. Therefore, it is worth mentioning the works by O. Raievnieva [12] regarding the multidimensional analysis of indicators of the development of the regions of Ukraine in the aspect of determining the main sources of its unevenness, and Ye. Matviishyn [13] about the use of the possibilities of econometric analysis in order to build models of demographic forecasting in the aspect of developing regulatory mechanisms for regional labor markets, etc. At the same time, in the context of our study, the works by I. Turskyi [14], O. Riadno [15], and D. Novikov [16] are of greater interest. In particular, the classic multifactorial regression modeling carried out by I. Turskyi made it possible to state that the gross regional product (GRP) depends linearly on the volume of products sold and the number of economically active population. According to D. Novikov's estimates, the cumulative financial result of industrial enterprises of the region from ordinary activities to taxation has the maximum positive impact on the indicator of the gross regional product, whereas the maximum negative impact is due to the factor of the introduction of progressive technological processes in industry. That is, in this case, it has been proven that industry (the real sector of the economy) is the determining factor influencing the dynamics of the gross regional product indicator in Ukraine. Other authors [17], based on the analysis of panel data on regional development, conclude that the general factors affecting the gross added value of the region are the turnover of retail trade, the share of the population with an average per capita equivalent total income below the subsistence minimum, the export-to-import ratio, and the ratio of migration increase (reduction) of the population.

Unsolved aspects of the problem. It is worth paying attention to the fact that all researchers of the factors affecting the regional gross product in the process of modeling neither grouped nor clustered regions according to individual characteristics, which made it possible to obtain only generalized results of a theoretical nature. As for more modern studies, M. Bril [17], using models of multiple canonical correlations in order to form a balanced system of indicators of regional differentiation, substantiates the insignificance of the indicator of retail trade turnover in the context of the study on the state of socio-economic development of the region. V. Hryniv [18] emphasizes the necessity to group regions based on a preliminary ranking by a certain indicator in the context of further construction of reliable predictive models. V. Holovachov [19], using correlation-regression analysis, makes an attempt to determine the influence of the integral indicator of the development and implementation of the multi-purpose cadaster on the gross regional product. Although in this case even the very formulation of the question is not entirely appropriate, since the applied technique allows one to note the presence of common trends in dynamics, but not their mutual influence. In turn, at the level of national administration [3], the volume of foreign investments, budget indicators and real gross domestic product are understood as key factors of regional development.

Thus, given the uncertainty in views on the key factors of regional development and the actualization of the need to develop new strategies and approaches to it, taking into account the trends of wartime and the long-term consequences of the influence of hostilities, the identification of general regularities and specific territorial features in the development of regions is particularly important.

Purpose and task statement. The purpose of the work is to carry out a two-dimensional analysis of panel data on individual indicators of the development of the regions of Ukraine in general and their aggregates, separated on the basis of territorial location and profitability in order to establish the main regularities and specific features of changes in their GRP.

In view of the set purpose, the following were the key tasks of the research:

1. To group the regions of Ukraine according to the territorial and income criteria.

2. Based on a sample regarding the dynamics of the set of indicators for each of the oblasts of Ukraine, to form panel data series and build regression models for a continuous panel series of data and for separate groups of regions of Ukraine formed on the basis of the defined criteria.

3. To establish clear regularities, specific features and factors of the formation of the gross regional product both in relation to the totality of the regions of Ukraine and in relation to their individual groups.

Research methodology (structure, sequence). In the process of research, methods of statistical data analysis, as well as theoretical methods of comparative analysis, synthesis and logical generalization were used. The information base of the research was made up of statistical materials of the State Statistics Service of Ukraine, as well as scientific works on the issues raised in the work. Thus, on the basis of a sample regarding the dynamics of the set of indicators for each of the regions of Ukraine, panel data series were formed, for which fixed and random effects regression models were built in order to determine the presence of regularities – common parameters that define the change in the volume of the gross regional product to the greatest extent. The objects of observation are the regions of Ukraine (24 objects). The observation interval is 1 year and the considered period is 8 years (2014–2021) for all variables. The total number of observations is 192 units, and the indicator of the gross regional product is chosen as the dependent variable. The grouping of the oblasts of Ukraine for the purposes of the study according to the profitability criterion was carried out using statistical and graphical methods of constructing interval distribution series.

Basic materials and obtained scientific results. The main task of our research is not to build completely reliable regression dependencies for forecasting indicators of regional development, but to establish the presence of clear regularities, specific features and factors of the formation of the gross regional product both in relation to the totality of the regions of Ukraine and in relation to individual homogeneous groups that are similar to each other in certain features. In particular, for the purposes of our research, two such groups were singled out:

1. Territorially oriented: northern, southern, central, eastern and western oblasts.

2. Income-oriented: five regions, distinguished on the basis of the indicator of the gross value added in the region per person.

As for the observation interval, its limits were chosen taking into account significant changes in the Ukrainian socio-economic space in connection with the beginning of the war with Russia and the loss of part of the territories in 2014. Thus, in fact, within the framework of our research, it will be possible to determine the presence of regularities and specific features of formation of the gross regional product in the state throughout the entire period of the country's functioning in the conditions of a local war up to a full-scale military invasion based on the analysis of regional statistics indicators [20].

The list of indicators of regional development that were used in the construction of regression models for panel data series is given in Table 1.

Thus, we focused on the study on the influence of the general socio-economic parameters and individual indicators of the labor market of the regions in the context of formation of the volume of their gross added value.

When forming the regional distribution of Ukraine's oblasts, we used the standard division of the country's territory

Table 1

List of indicators of regional development used in the study

Indicator	Unit of measurement	Reference designation in models	Indicator	Unit of measurement	Reference designation in models
Gross regional product	mln UAH	N 1	Average monthly salary	UAH	N 11
Gross regional product per person	UAH	N 2	Consumer price index (December to December of the previous year)	%	N 12
Output* at basic prices	mln UAH	N 3	Capital investments	mln UAH	N 13
Volume of output* in extractive industries	mln UAH	N 4	Number of available population	people	N 14
Volume of output* in the processing industry	mln UAH	N 5	Labor force aged 15–70	thsd. people	N 15
Gross value added in the processing industry	mln UAH	N 6	Number of people employed in industry aged 15–70	thsd. people	N 16
Share of the processing industry in output	%	N 7	Unemployed population aged 15–70	thsd. people	N 17
Employed population aged 15–70	thsd. people	N 8	Average number of full-time employees	thsd. people	N 18
Population income per person	UAH	N 9	Number of pensioners of all categories	people	N 19
Population expenditure per person	UAH	N 10			

* "output" in accordance with the statistical terminology adopted in Ukraine means "the value of goods and services resulting from the production activity of resident units in the reporting period"

into: Northern (Zhytomyr, Kyiv, Sumy, and Chernihiv oblasts); Southern (Mykolaiv, Odesa, Kherson, Zaporizhzhia oblasts); Western (Volyn, Transcarpathian, Ivano-Frankivsk, Lviv, Ternopil, Rivne, Khmelnytskyi, Chernivtsi oblasts); Eastern (Donetsk, Luhansk, Kharkiv) and Central (Vinnytsia, Dnipro, Kropyvnytskyi, Poltava and Cherkasy oblasts).

When distinguishing groups of oblasts based on income-oriented characteristics, the easiest way would be to use the method of constructing interval series of distribution with equal intervals, according to which "the number of intervals is determined according to the Sturges' rule" [21]. However, with such an approach, for the aggregate we studied – 24 regions – the number of intervals is 5 and the obtained distribution of regions (Fig. 1) is not uniform.

Taking into account the fact that under the given approach, almost half of the oblasts will be in one interval according to the gross income indicator, and one or two oblasts – in the others, we used a graphical method to group the regions of Ukraine according to income-oriented characteristics (Fig. 2).

So, the graphical presentation of the average values of the gross regional income per capita for the eight-year period in each of the studied regions of Ukraine allowed determining the upper and lower threshold limits, that is, the levels of the studied indicator, which make it possible to distinguish groups of regions with the lowest and highest values.

With this approach, we can distinguish two clearly defined groups of regions:

1) oblasts with the minimum value of the studied indicator: Transcarpathian, Luhansk and Chernivtsi;

2) oblasts with the maximum value of the studied indicator: Vinnytsia, Dnipro, Kyiv, and Poltava. All remaining regions were divided into two additional groups;

3) with high values of the studied indicator: Zaporizhzhia, Mykolaiv, Odesa, Kharkiv, Cherkassy oblasts;

4) with average values of the studied indicator: Volyn, Donetsk, Zhytomyr, Ivano-Frankivsk, Kropyvnytskyi, Lviv, Rivne, Sumy, Ternopil, Kherson, Khmelnytskyi, Chernihiv oblasts.

Subsequently, regression models were built for the entire panel series of data and for each of the separately defined groups of regions, which, in a generalized form, have the following form for the panel series of data [6]

$$X_{it} = Z_{it} \cdot a_{it} + \varepsilon_{it}; \quad i = 1, ..., N; \quad t = 1, ..., T,$$

where i stands for the index of the economic object; t is a point in time; a_{it} denotes coefficients of independent variables Z_{it} at the point in time t for the object i; ε_{it} is the corresponding error; X_{it} is the forecast (calculated) value of the dependent variable for the i^{th} economic object at the point in time t.

The specificity of panel data is the presence of two dimensions, according to which the research is conducted. One dimension is individual economic units, that is, in our case, the regions of Ukraine, and the other corresponds to any given point in time.

The balance of panel data is determined by their availability for each parameter, that is, the absence of missing data. Since in our case all studied data are available for each period and for each region, there are reasons to speak of fully balanced panel data.

In the course of panel studies, it is advisable to use fixed effects models in cases when individual objects of observation that have a set of individual characteristics are available, and random effects models – in case of forming a sample randomly from a larger aggregate. However, since such differentiation

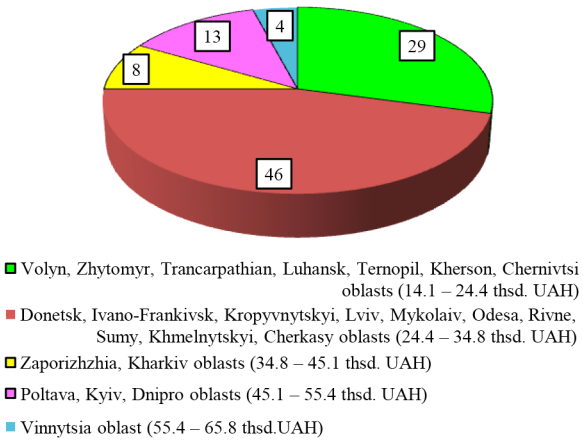

Fig. 1. The share of regions that are included in each of the defined intervals according to the indicator of gross regional income per capita, %

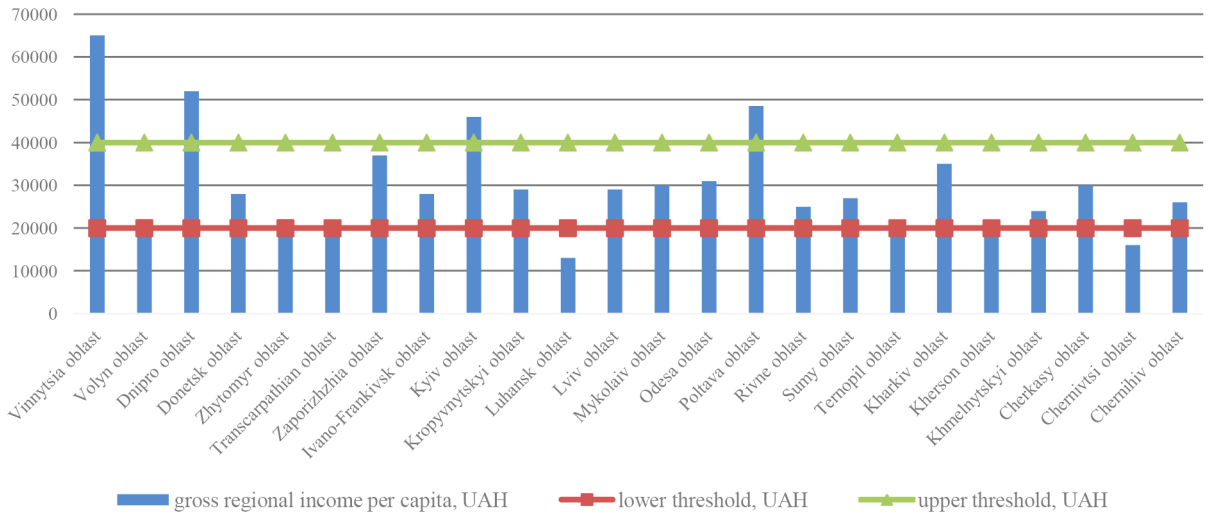

Fig. 2. Graphical method of grouping regions of Ukraine according to the indicator of the gross regional income per capita, UAH

does not always make sense, first of all, we tested the determined panel data for the choice of the panel regression construction method – the use of fixed or random effects (Table 2).

The analysis carried out using Gretl software environment made it possible to draw several main conclusions. First, for all studied groups of regions, a higher level of significance and a larger number of indicators with high significance are present precisely under the conditions of application of the random effects regression model. The only exception is the 4^{th} group of oblasts grouped by income-oriented characteristics, that is, the group with average values of the GRP indicator per capita.

The second important conclusion is that some of the most significant indicators in the context of change in the studied parameter are common to the vast majority of isolated groups of Ukraine's oblasts. At the same time, the only indicator that demonstrates the highest level of significance in absolutely all cases is N 3, i. e. the output at basic prices.

The smallest number of indicators with a high level of significance is present in the group of regions of Ukraine "East" and in the group of regions with high values of the gross regional product per capita, but even in these cases, when applying the random effects regression model, its previous specifications are better, which allows to precisely use them in the process of further analysis.

Since insignificant variables were present in each of the variants of the regression models built by us, their successive extraction was applied in order to establish all possible significant parameters for the formation of GRP in the regions of Ukraine. The obtained results for the entire totality of oblasts of Ukraine are shown in Table 3.

The actual sequential removal of redundant variables was carried out using the classical method of least squares (LSM) in Gretl environment. Thus, each of the studied independent variables belonged to the category of insignificant in the case when the chance probability of the relationship between it and the dependent variable exceeded 10 % (0.1). At the same time, one-by-one sequential removal of redundant variables with subsequent verification of the level of significance of the remaining ones was carried out until at least one non-significant variable remained in the resulting model. Similarly, in the process of building panel regression models, regressors were ex-

Table 2

The results of evaluating the significance of regression models for different groups of regions

Group of regions	Fixed effects model	Random effects model
All regions in general	N 3***; N 5***; N 10**; N 4***; N 6***	Const*; N 3***; N 4***; N 5***; N 6***; N 10**; N 11*; N 14*; N 17**
North	N 3***; N 11***; N 9*	N 3***; N 11***; N 9**
South	N 3***; N 6*; N 8**; N 9***; N 17***	N 3***; N 6*; N 8***; N 9***; N 10*; N 14**; N 17***
West	N 3***; N 13***; N 19***	N 3***; N 7*; N 10**; N 13***; N 19***
East	N 3**	N 3***
Centre	Const***; N 3***; N 4***; N 5***; N 6***; N 8**; N 10**; N 12**; N 14***; N 15**; N 17**	Const***; N 3***; N 4***; N 5***; N 6***; N 8***; N 10***; N 12**; N 14***; N 15***; N 17***
Groups of oblasts based on income-oriented characteristics		
1) group	N 3**	N 3***; N 5*; N 10*; N 18*
2) group	N 3***; N 4***; N 9*; N 12*; N 11**; N 14*	N 3***; N 4***; N 9**; N 11**; N 12**; N 14**
3) group	N 3***	N 3***; N 4*
4) group	Const**; N 3***; N 4***; N 5***; N 6**; N 10***; 12*; N 16***; N 17***; N 18***	Const**; N 3***; N 4***; N 5***; N 6***; N 10***; N 16***; N 17**; N 18***

* statistical significance at the 0.1 level;
** statistical significance at the 0.05 level;
*** statistical significance at the 0.01 level

Table 3

The random effects panel regression model for the indicator of the gross regional product in Ukraine

Indicator	Coefficient	Standard error	Z	P-value	Significance
const	–6,249.21	1,258.64	–4.965	6.87e–0,7	***
output at basic prices	0.4755	0.00712	66.76	0.0000	***
volume of output in extractive industries	0.1744	0.01418	12.30	8.94e–035	***
volume of output in the processing industry	–0.5287	0.02963	–17.85	3.04e–071	***
gross value added in the processing industry	1.82699	0.157136	11.63	3.01e–031	***
population expenditure per person	0.121719	0.02026	6.009	1.87e–09	***
number of available population	0.00379	0.000604	6.275	3.50e–010	***
Estimation indicators of the model					
Indicator		Value	Indicator		Value
Average of dependent variables		104,223.4	Standard deviation of residual variables		84,557.08
Sum of quadratic residues		1.83e+09	Standard model error		3,137.735
Log-likelihood		–1,815.230	Akaike criterion		3,644.459
Schwarz criterion		3,667.262	Hannan-Quinn criterion		3,653.694
Rho parameter		–0.198877	Durbin-Watson statistic		2.031920

cluded for which the presence of multicollinearity – linear dependence – was detected. In this case, the calculation was carried out using the VIF (variance inflation factor) criterion, which makes it possible to estimate the increase in variance due to the linear dependence of the factor (independent variable) on other independent variables. So, with a VIF value > 10, the independent variable was subject to exclusion as characterized by pronounced multicollinearity with respect to the other regressor (regressors).

The greatest impact on the indicator of the gross regional product, if we talk about Ukraine in general, is carried out by a change in the indicator of the gross added value in the processing industry, which is explained by the very methodology of calculating the studied indicator. The indicator of the number of available population has the least influence on the volume of GRP, although its dynamics also has the highest significance level in terms of the influence on the change in the studied indicator. The expression of the inverse dependence between the volumes of GRP and output in the processing industry of each of the studied oblasts is another interesting point. In other words, an increase in the volume of output in the processing industry leads to a decrease in the volume of the gross regional product. Of course, the reliability of the given model is not indisputable and too high values of the Schwarz, Akaike and Hennan-Quinn information criteria indicate the need for its further improvement, but such results require further in-depth research of the specified issue.

In addition, although the given regression dependence provides the possibility of forecasting the studied indicator with an average percentage error of 0.08 %, however, for certain oblasts – Dnipro, Lviv, Kyiv, Odesa and Cherkasy – when it is applied, the forecast residues will exceed the size of the standard error by 2.5 times, and, therefore, there are other – specific – factors of influence on the volumes of formation of the gross regional product, which can be revealed in the process of researching individual regional groups.

As already noted, we used the territorial grouping of oblasts of Ukraine into five groups, distinguishing the northern, southern, central, eastern and western oblasts. A similar panel regression modeling was carried out for each group of oblasts, the results of which are presented in Table 4.

The conducted research made it possible to note that for the country's oblasts grouped according to the principle of territorial location, not only the key factors in the constructed regression dependencies are differentiated, but also their number. In particular, the smallest number of significant factors for the resulting indicator, that is, for the GRP indicator, was found regarding the central and northern oblasts, and the largest number – in the eastern oblast. So, while the panel regression model for the gross regional product of the central oblasts includes only five indicators, together with the constant, the similar model for the group of oblasts in the east of our country already contains 12 indicators. This situation can be explained, first of all, by the high level of differentiation in the oblasts of the East in terms of the spectrum of the investigated indicators.

For the northern oblasts of the country, an important factor of the change in the volume of the gross regional product, as evidenced by the data of the obtained calculation models, is the number of the workforce. It is this factor and, to a lesser extent, the average monthly salary in the oblasts of this group that have the greatest influence on the studied variable. At the same time, while an increase in the salary indicator positively affects the dynamics of GRP, the per capita income indicator, on the contrary, has a strong inverse effect: its growth leads to a decrease in the indicator of the gross regional product. The factor of the number of available population also has a negative impact on the studied indicator in the northern oblasts, the growth of which also negatively affects the indicator of the gross regional product.

On the other hand, in the south of Ukraine, the spectrum of significant factors in the formation of GRP is much wider, as the conducted research showed. Here, first of all, it is worth noting the very considerable inverse relationship between the number of the unemployed population and the studied variable: an increase in the number of the unemployed is accompanied by a decrease in the gross regional product.

At the same time, a strong inverse relationship also occurs with regard to the indicator of the employed population in the studied region, the growth of which is inevitably accompanied by a decrease in the GRP indicator. Such a situation allows us to assume that for the gross regional product of the South of Ukraine, shadow employment, in which workers are not included in the category of economically active population, is very significant.

Another important factor for the southern oblasts is the share of the processing industry in the output. Thus, even minor changes in this indicator can lead to significant direct changes in GRP. The southern region of Ukraine is not very powerful in terms of industrial development, although, as the data obtained show, the development of industry in this region is one of the most important factors for the growth of the gross regional product.

Table 4

Random effects panel regression models for the indicator of gross regional product of the regions of Ukraine, grouped by territorial characteristics

Indicator	Coefficient	Standard error	Z	P-value	Significance
Northern oblasts					
const	2,433.78	2,225.19	1.094	0.2741	
output at basic prices	0.447926	0.0051	87.11	0.0000	***
population income per person	–0.7654	0.1476	–5.187	2.13e–07	***
average monthly salary	5.89464	0.925781	6.367	1.93e–010	***
number of available population	–0.0418	0.01249	–3.350	0.0008	***
labor force aged 15–70	92.9018	28.2816	3.285	0.0010	***
Southern oblasts					
const	12,687.4	4,306.63	2.946	0.032	***
output at basic prices	0.4053	0.0100	40.18	0.0000	***
volume of output in extractive industries	0.744326	0.303722	2.451	0.0143	**
gross value added in the processing industry	–0.506848	0.194565	–2.605	0.0092	***
share of the processing industry in output	427.310	163.375	2.616	0.0089	***
employed population aged 15–70	–312.514	74.9712	–4.168	3.07e–05	***
population income per person	0.722249	0.09524	7.584	3.36e–014	***
population expenditure per person	–0.2093	0.06842	–3.059	3.98e–06	***
number of available population	0.158945	0.03446	4.612	3.98e–06	***
unemployed population aged 15–70	–1,060.39	175.349	–6.047	1.47e–09	***
Western oblasts					
const	9,264.24	4,446.77	2.083	0.0372	**
gross regional product per person	–0.162125	0.0351899	–4.607	4.08e–06	***
output at basic prices	0.487908	0.00606881	80.40	0.0000	***
average monthly salary	–0.904411	0.477579	–1.894	0.0583	*
capital investments	426.06	80.0494	5.322	1.02e–07	***
number of available population	0.0117760	0.00172	6.814	9.48e–012	***
number of pensioners of all categories	–0.03672	0.00532	–6.892	5.52e–012	***
Eastern oblasts					
const	–81,981.9	15,085.6	–5.434	5.50e–08	***
gross regional product per person	2.03608	0.182177	11.18	5.32e–029	***
gross value added in the processing industry	2.21886	0.200875	11.05	2.29e–028	***
population expenditure per person	0.287828	0.116780	2.465	0.0137	**
consumer price index	251.277	69.4448	3.618	0.0003	***
number of available population	0.0346570	0.00667	5.194	2.05e–07	***
labor force aged 15–70	–19.5039	3.13307	–6.225	4.81e–010	***
number of people employed in industry aged 15–70	–309.471	80.1366	–3.862	0.0001	***
average number of full-time employees	29.3103	10.1528	2.887	0.0039	***
number of pensioners of all categories	–0.054414	0.01265	–4.300	1.71e–05	***
employed population aged 15–70	61.9794	15.7884	3.926	8.65e–05	***
population income per person	–0.333981	0.19028	–1.755	0.0792	*
Central oblasts					
const	–10,161	2,873.32	–3.536	0.0004	***
gross regional product per person	0.302543	0.027398	11.04	2.38e–028	***
output at basic prices	0.358	0.00706	50.65	0.0000	***
volume of output in extractive industries	0.177215	0.021132	8.386	5.05e–017	***
number of available population	0.00654	0.00156	4.205	2.61e–05	***

The panel regression model for the western oblasts of Ukraine made it possible to establish that capital investment is one of the determining factors of GRP growth in the region. So, it is this factor that has the greatest direct influence on the value of the studied variable, that is, even its minor fluctuations are accompanied by significant deviations of the final GRP sums. In addition, three inversely related coefficients are present in the regression model for the western oblasts: the gross regional product per person, the average monthly salary, and the number of pensioners of all categories. This situation, from our point of view, is associated with significant rates of reduction in the number of the available population, as a result of which there is a discrepancy in the dynamics of GRP indicators and gross regional product per capita. The inverse relationship between GRP and salary is a result of a relatively lower level of shadowing of economy of the western regions, during which the growth of expenses for the maintenance of production personnel is reflected in the costs attributed to the cost price, and, therefore, negatively affects the indicator of gross added value.

The constructed regression model for the eastern oblasts, as noted earlier, contains the largest number of coefficients, although this group includes only three oblasts. Therefore, such a result indicates significant differences in the development and formation of the gross regional product in the studied regions. The greatest importance for the GRP of the East of the country is the number of people employed in industry, even a slight reduction of which is accompanied by a noticeable decrease in the total volume of the studied indicator. It is also important to note that the GRP indicator in these oblasts has a strong direct relationship with the values of the consumer price index.

Another important point to note is the presence of a strong direct relationship between GRP and the employed population, as well as a strong inverse relationship of the labor force indicator. Thus, the increase in the level of employment in the region rather positively affects the growth of the analyzed indicator, but the inverse relationship of the labor force indicator in this case can be explained by the increase in its composition of the unemployed population in the region. Also, a very important factor for the formation of the gross regional product of the eastern oblasts is the average number of full-time employees. That is, we can say that the eastern oblasts are regions of a high level of industrial development, for which the key element in increasing GRP is maintaining a high level of employment. So, although the industry of the eastern regions is highly developed, it is not at all characterized by a high level of technological development, because the results of its activity are clearly related to the number of people employed in production.

For the central oblasts of the country, the constructed regression model has the smallest number of coefficients and, at the same time, does not contain indicators with a high or negative level of influence. In this case, the greatest connection can be observed between GRP indicators and output volumes of extractive industries, as well as gross regional product per person. In this context, we should point out that the oblasts assigned to this group are too different in socio-economic conditions of development, which did not make it possible to build a more reliable model. In addition, forecasting GRP using the given coefficients is impossible for Dnipro oblast, since in this case the forecast residues will exceed the size of the standard error by 2.5 times.

Additional parameters of the given regression models, as well as values of test scores and criteria, are summarized in Table 5.

The given data prove the insufficient reliability of the developed models specifically for predictive calculations, however, at the same time, they are quite reliable for explaining the most important factors and processes of influence on GRP, based precisely on the main indicators of socio-economic development and the labor market of the oblasts. In addition, and what is quite important, the result of the Durbin-Watson statistic made it possible to note the absence of autocorrelation in the selected sets of indicators – its worst value (1.43) is only for the group of central oblasts.

The regression models for the northern and eastern oblasts of the country are the most reliable, considering the given test-scores, and the results obtained for the group of western oblasts have the least reliability.

So, while for the North and the East the average percentage error of the forecast is –0.007 and 0.07 %, respectively, for the group of western oblasts it is –4.93 %. Furthermore, the values of the Schwarz, Akaike and Hannan-Quinn information criteria, which should go to zero, exceed 1,300 exactly for the group of western oblasts. That is why additional modeling was carried out using an income-oriented feature when grouping the oblasts. The specifications of the obtained regression models are summarized in Table 6.

A preliminary analysis of all presented models for certain groups of oblasts allowed us to note that in each of them there is

Table 5

Specifications of random effects panel regression models for the indicator of the gross regional product of the regions of Ukraine, grouped by territorial characteristics

Indicator	North	South	West	East	Centre
Average of dependent variables	93,154.72	106,678.3	68,505.38	138,951.4	147,426.5
Sum of quadratic residues	39,179,133	1.11e+08	2.54e+09	49,470,223	3.59e+08
Log-likelihood	–269.6927	–286.4	–650.7	–208.52	–376.94
Schwarz criterion	560.1799	607.5	1,330.5	455.2	772.33
Akaike criterion	551.39	592.85	1,315.4	441.04	763.9
Hannan-Quinn criterion	554.3	597.7	1,321.4	444.8	766.9
Standard deviation of residual variables	64,412.05	62,618.77	51,654.46	91,305.03	120,496.2
Standard model error	1,204.6	2,201.6	6,619.1	1,950.74	3,156.96
Average percentage error	–0.007	–0.36	–4.93	0.07	0.10
Durbin-Watson statistic	2.14	2.06	1.82	1.90	1.43
Rho parameter	0.154296	–0.2351	–0.0147	0.0038	0.12
Intergroup variance	720,429	2.02275e+006	6.80713e+007	1.41258e+006	1.56066e+006
Intragroup variance	735,406	836,264	979,936	1.1805e+006	7.7283e+006
Corr (y, yhat)^2	0.999697	0.999448	0.98749	0.999742	0.999366

Table 6

Random effects panel regression models for the indicator of the gross regional product of the regions of Ukraine, grouped by territorial characteristics

Indicator	Coefficient	Standard error	Z	P-value	Significance
oblasts with the minimum GRP value per person					
const	–1,673.71	718.349	–2.330	0.0198	**
output at basic prices	0.613522	0.0237	25.88	1.10e–147	***
volume of output in the processing industry	–0.977234	0.1465	–6.669	2.57e–011	***
gross value added in the processing industry	3.47400	0.55033	6.313	2.74e–010	***
population income per person	–0.06414	0.0377	–1.700	0.0892	*
oblasts with the maximum GRP value per person					
const	–29,031.9	15,998.1	–1.815	0.0696	*
output at basic prices	0.329055	0.01754	18.76	1.56e–078	***
volume of output in extractive industries	0.2878	0.04236	6.795	1.08e–011	***
average monthly salary	5.25785	0.6734	7.808	5.82e–015	***
number of available population	0.124244	0.03848	3.228	0.0012	***
labor force aged 15–70	–284.99	75.95	–3.75	0.0002	***
unemployed population aged 15–70	–333.052	87.93	–3.79	0.0002	***
average number of employees	123.205	27.03	4.56	5.17e–06	***
consumer price index	194.39	91.16	2.132	0.0330	**
oblasts with high GRP values per person					
const	–7,613.40	3,035.54	–2.508	0.0121	**
output at basic prices	0.459583	0.01292	35.57	3.95e–277	***
volume of output in extractive industries	0.250085	0.04837	5.169	2.35e–07	***
gross value added in the processing industry	–0.999685	0.07601	–13.15	1.67e–039	***
population income per person	27.5615	7.82009	3.524	0.0004	***
average number of full-time employees	0.29645	0.06901	4.296	1.74e–05	***
oblasts with average GRP values per person					
const	–4,558.79	1,283.52	–3.552	0.0004	***
output at basic prices	0.476438	0.01175	40.55	0.0000	***
volume of output in the processing industry	–0.2582	0.05160	–5.003	5.63e–07	***
gross value added in the processing industry	1.06938	0.309805	3.452	0.0006	***
population expenditure per person	0.105052	0.0163945	6.408	1.48e–010	***
number of people employed in industry aged 15–70	–81.5747	18.5373	–4.401	1.08e–05	***
unemployed population aged 15–70	–107.640	31.1990	–3.450	0.0006	***
average number of full-time employees	61.4747	8.91588	6.895	5.39e–012	***

a direct relationship between the volume of output at basic prices and the studied indicator. At the same time, whereas in groups of oblasts with minimum and average values of GRP per capita there is a connection of the studied indicator with the volume of output in the processing industry, in groups of oblasts with high and maximum volumes of GRP per capita – with the volume of output in extractive industries. There is one more important aspect – in regions with lower indicators of GRP per capita, the relationship between the volume of gross regional product and the volume of output in the processing industry is inverse, while in more profitable regions – the relationship between GRP and the volume of output in extractive industries is direct. Therefore, we can conclude that the active development of extractive industries is one of the key factors of high profitability of the regions. As for other aspects of the formation of the gross regional product, they differ for each of the isolated groups of oblasts.

Thus, for example, in the group of regions with the maximum value of GRP per person, there is a strong inverse connection with indicators of the labor force and the unemployed population, as well as a close direct relationship with the average number of full-time employees and the consumer price index. This, again, is indirect evidence of a not too high technological level of production activity, the volume of which depends more on the number of production personnel than on technological development and automation of production processes. In the regions with high values of GRP per person, the indicator of population income per person has the greatest influence on the formation of the analyzed indicator, which shows a significant increase in the volume of commercial activity, the added value of which is formed due to mark-ups, and the final sums of gross profit are formed owing to consumers spending their income. In the regions with average values of GRP per person, on the other hand, indicators of the unemployed population, the average number of full-time employees and the number of people employed in industry have the greatest influence on its formation.

In any case, the analysis of panel data and the models obtained as a result are not absolutely reliable in the context of the formation of GRP, as evidenced by their individual test scores (Table 7). Although autocorrelation was not detected in rela-

Table 7

Random effects panel regression models for the indicator of the gross regional product of the regions of Ukraine, grouped by GRP per capita

Indicator	oblasts with the minimum GRP value per person	oblasts with the maximum GRP value per person	oblasts with high GRP values per person	oblasts with average GRP values per person
Average of dependent variables	38,591.17	193,120.4	131,962.0	79,441.40
Sum of quadratic residues	14,067,229	3.97e+08	3.10e+08	2.82e+08
Log-likelihood	–193.4302	–306.7523	–374.0209	–851.0648
Schwarz criterion	402.75	644.6962	770.1750	1,738.644
Akaike criterion	396.86	631.5046	760.0417	1,718.13
Hannan-Quinn criterion	398.42	635.8772	763.7056	1,726.42
Standard deviation of residual variables	15,162.34	118,813.5	70,575.36	54,528.59
Standard model error	838.6665	4,068.020	2,976.040	1,779.656
Average percentage error	0.11	–0.06	–0.10	0.05
Durbin-Watson statistic	1.9093	2.32	1.9353	1.9764
Rho parameter	–0.15097	–0.2523	–0.1687	468,389
Intergroup variance	14,227.1	3.96415e+006	391,246	2.54799e+006
Intragroup variance	577,030	1.00234e+007	7.44199e+006	0.363794
Corr (y, yhat)^2	0.99734	0.999092	0.9984	0.999002

tion to the panel series of data used in the modeling, and the average percentage error in forecast calculations does not exceed 0.11 %, the values of the information criteria remain too high, as well as the size of the standard error of the model. It indicates the need for further research both in the direction of selecting groups of oblasts, and in relation to the set of analyzed indicators to ultimately obtain a reliable predictive model.

At the same time, the conducted research made it possible to point out the presence of clear dependencies and specific features in the formation of the gross regional product in the oblasts of Ukraine and, in particular, to establish an extremely high level of direct connection between the indicators of the real economy and the volume of GRP. Of course, each region is characterized by its own specific features of development which have a significant impact on the scope of the studied indicator and which are difficult to detect within the framework of a panel analysis. However, this approach makes it possible to determine group characteristics and regularities of development and, based on this, to more carefully approach the formation of the regional development program. In addition, the obtained results are of particular importance in the context of the formation of strategies and programs for the post-war economic recovery of the regions and, in particular, the forecasting of possible consequences both in terms of the loss of human, industrial or agricultural potential for the territories where hostilities were directly fought, and in terms of a significant population growth and changes in the structure of the economy of the regions located far from the front.

Conclusions. The conducted two-dimensional analysis of panel data on individual indicators of the development of the regions of Ukraine in general and their aggregates, separated by territorial location and profitability, made it possible to note that the results of functioning of extractive industry enterprises have a significant weight in the context of formation of GRP. Precisely those oblasts where there is a close connection between the values of the studied variable and output in the extractive industries are also characterized by the highest levels of gross regional product per capita. The dynamics of some individual labor market indicators are also important for certain groups of oblasts in the context of the GRP formation.

In general, the specifications of panel regression models obtained in the course of the study made it possible to determine the list of the most significant in the context of formation of the gross regional product of one or another group of oblasts parameters, key factors and specific features of the change in the GRP indicator. In the future, they can be used as the key ones in forecasting indicators of the development of individual regions, as well as in the process of forming programs and plans for improving the indicators of socio-economic development of individual regions.

At the same time, since the given panel regression models are not perfect, in further studies it is necessary to refine them using a wider range of indicators of regional development or to expand the list of criteria for grouping oblasts of Ukraine in order to establish general regularities and group features of the dynamics of the studied indicators.

References.

1. *Strategy of sustainable development of Ukraine until 2030* (2017). UNDP Ukraine. Retrieved from https://www.undp.org/sites/g/files/zskgke326/files/migration/ua/UNDP_Strategy_v06-optimized.pdf.

2. *Vectors of economic development of Ukraine 2030* (2021). Kyiv: Kabinet Ministriv Ukrainy. Retrieved from https://nes2030.org.ua/docs/doc-vector.pdf.

3. *UNDP Resilience and Recovery Programme: Responding to the War in Ukraine* (2022). Retrieved from https://www.undp.org/uk/ukraine/prohrama-proon-iz-pidvyshchennya-stiykosti-ta-vidnovlennya.

4. Anselin, L. (2013). *Spatial econometrics: methods and models*. Dordrecht: Springer, Science and Business Media. ISBN: 978-90-481-8311-1.

5. Baltagi, B. H. (2010). *Econometric analysis of panel data*. New York: John Wiley & Sons Inc. ISBN: 0-470-01456-3.

6. Hanck, C., Arnold, M., Gerber, A., & Schmelzer, M. (2020). *Introduction to Econometrics with R. Essen. Duisburg-Essen*. Retrieved from https://www.econometrics-with-r.org/index.html.

7. Garrat, A., Lee, K., Pesaran, M., & Shin, Y. (2011). *Global and National Macroeconometric Modelling. A long Run Structural Approach*. Oxford: University Pres. ISBN: 978-0199296859.

8. Elhorst, J. P. (2010). Specification and estimation of spatial panel data models. *International Regional Science Review, 26*(3), 244-268. https://doi.org/10.1177/0160017603253791.

9. Petersen, T. (2014). *Analyzing Panel Data: Fixed- and Random-Effects Models: Handbook of Data Analysis*. Sage publications, Ltd., Retrieved from: https://sk.sagepub.com/reference/handbook-of-data-analysis.

10. Townsend, Z., Buckley, J., Harada, M., & Scott, M. (2015). The Choice between Fixed and Random Effects. In *The SAGE Handbook of Multilevel Modeling*, (pp.73-88). Retrieved from http://agfda.userweb.mwn.de/ALD_2015/downloads /Uebung2/Townsend_et_al_2013.pdf.

11. Oliskevych, M. O. (2015). *Econometric modeling of dynamic processes of labor market development in Ukraine: monograph*. Lviv: LNU imeni Ivana Franka. ISBN: 978-617-10-0235-7.
12. Raievnieva, O. V., & Bobkova, O. Yu. (2012). Determination of the sources of uneven development of the regions of Ukraine based on the decomposition of the Teil index. *Aktualni problemy ekonomiky*, *2*(128), 200-210.
13. Matviishyn, Ye. H. (2012). Application of the demographic forecasting model to regulate the labor market in the region. *Efektyvnist derzhavnoho upravlinnia*, *33*, 302-311.
14. Turskyi, I. V. (2017). Modeling the dependence of the gross regional product on the development of entrepreneurship in the regions of Ukraine. *Naukovyi Visnyk Khersonskoho Derzhavnoho Universytetu*, *25*(2), 77-81.
15. Riadno, O. A., & Berkut, O. V. (2017). Econometric modeling of gross regional product formation based on panel data. *Naukovyi Visnyk Mizhnarodnoho Humanitarnoho Universytetu*, *27*, 67-71.
16. Novikov, D. A. (2014). Economic-mathematical modeling of the influence of indicators-factors of labor potential on the gross regional product of industrial regions of Ukraine. *Visnyk Ekonomiky Transportu i Promyslovosti*, *47*, 19-23.
17. Bril, M. (2020). Methodology of forming a balanced system of indicators of regional differentiation. *BiznesInform*, *4*, 133-142.
18. Hryniv, V. (2021). Assessment of the potential of socio-economic development of regions. *Ukrainskyi zhurnal prykladnoi ekonomiky ta tekhniky*, *6*(4), 147-152.
19. Holovachov, V. V. (2022). Mathematical modeling of regional development. *Zbirnyk naukovykh prats' UkrDUZT, 202*, 48-61.
20. Derzhavna sluzhba statystyky Ukrainy (n.d.). *Regions of Ukraine: statistical collections for 2014–2021.* Retrieved from https://ukrstat.gov.ua/druk/publicat/kat_u/publ2_u.htm.
21. Scott, D. W. (2010). Sturges' rule. *Wiley Interdisciplinary Reviews: Computational Statistics*, *1*(3), 303-306.

Валовий регіональний продукт в Україні: двовимірний аналіз закономірностей і територіальних особливостей

О. І. Бабчинська[*1], *О. Г. Вагонова*[2], *В. М. Нижник*[3], *О. А. Посвалюк*[3], *О. М. Лозовський*[1]

1 – Вінницький торговельно-економічний інститут Державного торговельно-економічного університету, м. Вінниця, Україна
2 – Національний технічний університет „Дніпровська політехніка“, м. Дніпро, Україна
3 – Хмельницький національний університет, м. Хмельницький, Україна
[*] Автор-кореспондент e-mail: olena.babchinska@ukr.net

Мета. Здійснення аналізу панельних даних щодо окремих показників розвитку регіонів України в цілому та їх сукупностей, виокремлених за ознакою територіального розташування й дохідності з метою встановлення основних закономірностей і специфічних особливостей зміни їх валового регіонального продукту.

Методика. На основі вибірки статистичних показників соціально-економічного розвитку областей України за період з 2014 року й до повномасштабного вторгнення авторами були сформовані панельні ряди даних з виокремленням регіональних груп за територіальним і дохідним критеріями. Для кожного групового панельного ряду даних побудовані регресійні моделі з випадковими ефектами з метою визначення наявності закономірностей і специфічних особливостей регіонального розвитку в різних групах.

Результати. Здійснено аналіз наукових напрацювань і практичних результатів у питанні визначення ключових чинників формування валового регіонального продукту. З огляду на невизначеність у поглядах на ключові чинники регіонального розвитку, здійснена спроба визначити їх за допомогою двовимірного аналізу панельних даних. З цією метою сформована вибірка статистичної інформації щодо основних показників соціально-економічного розвитку кожної з областей України та проведене їх групування за двома критеріями: територіального розташування та дохідності за показником валового регіонального продукту на душу населення. У цілому виокремлені п'ять груп областей за територіальною ознакою і чотири групи областей за ознакою дохідності і для кожної з цих груп, включно із загальною сукупністю регіональних панельних даних, була побудована модель панельної регресії. Отримані специфікації моделей дали можливість сформувати перелік ключових закономірностей у формуванні валового регіонального продукту в Україні, а також визначити специфічні фактори впливу на результуючий показник для кожної з груп областей.

Наукова новизна. На основі наведеного підходу до панельного аналізу чинників регіонального розвитку і, зокрема, формування валового регіонального продукту, базованого на поєднанні статистичних методів групування (кластеризації) областей за різними критеріями й моделей панельної регресії була підтверджена гіпотеза щодо наявності спільних закономірностей регіонального розвитку в окремих групах областей України. Визначені ключові чинники та специфічні особливості зміни показника валового регіонального продукту в Україні в цілому та в окремих регіональних кластерах.

Практична значимість. Можливість практичного використання отриманих результатів в якості ключових факторів ризику у процесі формування планів економічного розвитку окремих областей у довгостроковій перспективі, а також застосування запропонованого підходу до дослідження ключових чинників формування інших показників регіонального розвитку.

Ключові слова: *валовий регіональний продукт, аналіз панельних даних, чинники регіонального розвитку*

The manuscript was submitted 01.08.23.