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Ilich L. M.
Doctor of Economics, Associate Professor,
Borys Hrinchenko Kyiv University, Ukraine;
e-mail: ilyich_l@meta.ua; ORCID ID: 0000-0002-8594-1824
Hlushak O. M.
Ph. D. in Pedagogy, Associate Professor,
Borys Hrinchenko Kyiv University, Ukraine;
e-mail: o.hlushak@kubg.edu.ua; ORCID ID: 0000-0001-9849-1140
Semenyaka S. A.
Ph. D. in Physical and Mathematical Sciences, Associate Professor,
Borys Hrinchenko Kyiv University, Ukraine;
e-mail: s.semeniaka@kubg.edu.ua; ORCID ID: 0000-0001-5083-1433

MODELING OF EMPLOYMENT STRUCTURAL TRANSFORMATIONS

Abstract. The article presents the modelling of structural transformations in the employment of the population by the algorithm: 1) forming a database and establishing the type of mathematical model; 2) identification of variables; 3) exploring the forms of correlation between factor features and the resulting variable; 4) parameterization of data; 5) drawing up the regression equation; 6) economic interpretation of the results, in particular, the calculation of elasticity coefficients; 8) validation of the model for adequacy (calculation of errors of approximation, correlation coefficients and determination); 9) validation of the model for statistical significance (Fisher criterion and Student's *t*-test); 10) forecasting: calculation of confidence intervals.

It is formed the statistical research base of the level dependence of the Ukrainian population employment (selected regions) on a number of factors (share of full-time workers with higher education in % to accounting number; growth rate of labor productivity; growth rate of average wages; capital investment index; coverage ratio). The research was made due to data of the State Statistics Service of Ukraine in the period of 2000—2016 in the Dnipropetrovsk, Kharkiv, Kyiv and Vinnytsia regions. The dynamics of growth of selected factors for each region for the period 2000—2016 is considered.

It is established and determined the economic and mathematical models of the level dependence of the Ukrainian population employment (region) on the influence of selected factors for Dnipropetrovsk, Kharkiv, Kyiv and Vinnitsa regions. The comparative analysis of the obtained results is carried out.

It is established that the determinants that influence the dynamics of employment growth for the industrial regions of Dnipropetrovsk and Kharkiv regions are the factors reflecting the share of full-time employees with higher education, growth rate of labor productivity and the coefficient of export coverage. It is made a comparative analysis of the built regional models (Dnipropetrovsk, Kharkiv, Kyiv and Vinnytsia regions) with a mathematical model of multiple regression for the analysis of structural changes in the employment of the population of Ukraine.

Keywords: regional economy, structural transformation, employment, econometric modeling.

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Ільїч Л. М.
доктор економічних наук, доцент,
Київський університет імені Бориса Грінченка, Україна;
e-mail: ilyich_l@meta.ua; ORCID ID: 0000-0002-8594-1824
Глушак О. М.
кандидат педагогічних наук, доцент,
Київський університет імені Бориса Грінченка, Україна;
e-mail: o.hlushak@kubg.edu.ua; ORCID ID: 0000-0001-9849-1140
Семеняка С. О.
кандидат фізико-математичних наук, доцент,
Київський університет імені Бориса Грінченка, Україна;
e-mail: s.semeniaka@kubg.edu.ua; ORCID ID: 0000-0001-5083-1433

МОДЕЛЮВАННЯ СТРУКТУРНИХ ТРАНСФОРМАЦІЙ У ЗАЙНЯТОСТІ НАСЕЛЕННЯ

Анотація. Представлено моделювання структурних трансформацій у зайнятості населення за алгоритмом: формування бази даних і встановлення виду або типу математичної моделі; ідентифікація змінних; дослідження форм зв'язку між факторними ознаками та результативною змінною; параметризація даних; складання рівняння регресії; економічна інтерпретація результатів, зокрема розрахунок коефіцієнтів еластичності; перевірка моделі на адекватність (розрахунок похибок апроксимації, коефіцієнтів кореляції та детермінації); перевірка моделі на статистичну значущість (критерій Фішера і критерій Стьюдента); прогнозування; обчислення довірчих інтервалів.

Сформовано статистичну базу дослідження залежності рівня зайнятості населення України (обраних регіонів) від низки факторів (частки штатних працівників з вищою освітою у відсотках до облікової чисельності; темпу зростання продуктивності праці; темпу зростання середньої заробітної плати; індексу капітальних інвестицій; коефіцієнта покриття експортом імпорту) за даними Державної служби статистики України у період 2000—2016 роки у Дніпропетровській, Харківській, Київській і Вінницькій областях. Розглянуто динаміку росту обраних факторів для кожного регіону за період 2000—2016 роки.

Побудовано і досліджено економіко-математичні моделі залежності рівня зайнятості населення України (регіону) від впливу обраних факторів для Дніпропетровської, Харківської, Київської і Вінницької областей. Проведено порівняльний аналіз отриманих результатів.

Установлено, що визначальними факторами, які впливають на динаміку росту рівня зайнятості, для промислових регіонів Дніпропетровської та Харківської областей є фактори, що відображають частку штатних працівників із вищою освітою, темп зростання продуктивності праці та коефіцієнт покриття експортом імпорту. Здійснено порівняльний аналіз побудованих регіональних моделей (Дніпропетровської, Харківської, Київської та Вінницької областей) з математичною моделлю множинної регресії для аналізу структурних зрушень у сфері зайнятості населення України.

Ключові слова: економіка регіону, структурна трансформація, зайнятість, економетричне моделювання.
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Ильич Л. Н.
доктор экономических наук, доцент,
Киевский университет имени Бориса Гринченко, Украина;
e-mail: ilyich_l@meta.ua; ORCID: 0000-0002-8594-1824
Глушак О. М.
кандидат педагогических наук, доцент,
Киевский университет имени Бориса Гринченко, Украина;
e-mail: o.hlushak@kubg.edu.ua; ORCID: 0000-0001-9849-1140

Семеняка С. А.
кандидат физико-математических наук,
Киевский университет имени Бориса Гринченко, Украина;
e-mail: s.semeniaka@kubg.edu.ua; ORCID: 0000-0001-5083-1433

МОДЕЛИРОВАНИЕ СТРУКТУРНЫХ ТРАНСФОРМАЦИЙ ЗАЙНЯТОСТИ НАСЕЛЕНИЯ

Аннотация. Представлено моделирование структурных трансформаций в занятости населения. Построены и исследованы экономико-математические модели зависимости уровня занятости населения Украины (Днепропетровской, Харьковской, Киевской и Винницкой областей) от ряда факторов (доли штатных работников с высшим образованием в процентах к учетной численности; темпа роста производительности труда; темпа роста средней заработной платы; индекса капитальных инвестиций, коэффициента покрытия экспортом импорта). Представлен сравнительный анализ полученных результатов. Произведено сравнение построенных региональных моделей с математической моделью множественной регрессии для анализа структурных изменений занятости населения Украины.

Ключевые слова: экономика региона, структурная трансформация, занятость, эконометрическое моделирование.

Формул: 7; рис.: 5; табл.: 1; библ.: 13.

Introduction. In the system of socio-economic research, the considerable attention is paid to the research of regional differences by major macroeconomic indicators and their sensitivity to the influence of exogenous and endogenous factors. Such approach to the study of the meso-level markets is, first, connected to the fact that the economies of the regions directly influence the competitiveness of the national economy, and the last may in its turn affect the development of certain sectors of specific regions, which inevitably affects the employment of the population. Among the domestic scientists who devoted their research to the interrelation of structural changes of macro- and meso-level of economics and employment of the population it should be noted A. Balashov (research of problems of estimation of regional disparities of social development) [1]; T. Burbela (estimation of influence of structural changes in economy on production efficiency) [2]; L. Ilich (modeling of educational and qualification imbalances between labor supply and demand) [3]; A. Kramarenko (analysis of structural changes in the world economy and employment due to the evolution of technological structures) [4]; Marshavina Yu. (modelling the relationship between employment and the most important factors of demand) [5]; V. Reutova (determining regional disproportion in structural changes in the economy) [6] and others.

Among the outstanding works of foreign scientists devoted to the study of the relationship between regional socio-economic development and employment are the researches of Grimes PW, Ray MA [7], D. C. Knudesen [8], D. Wadley, P. Smith [9], A. M. Mulligan, A. Molin [10], B. Batóg, J. Batóg [11], J. A. Brox, E. A. Carvalho [12].

Analysis of research and statement of the problem. The labor market is a factor market, on the relationship and evolution of the basic elements depend the nature and specificity of both economic and social processes. Being the most specific subsystem of the economy and at the same time its driving force, the labor market determines the prospects for sustainable economic and innovative development, which are primarily related to the quality characteristics of the workforce and decent working conditions. More current issue is the estimation of employment sensitivity to macroeconomic factors, which will allow to improve qualitatively the macroeconomic forecasting in this area.

The purpose of the article is to develop a methodology for economic and mathematical modelling of structural changes in the employment of the population of Ukraine (region), depending on the impact of the share of highly educated workforce; dynamics of labor productivity; average wages; capital investments; export and import of goods and services.

The research is based on the use of economic and mathematical scientific methods using MS Excel, including methods of correlation analysis, mathematical modelling, tabular and graphical methods of analysis. The modelling is made in several stages: 1) the forming a database and establishing the type or type of mathematical model; 2) identification of variables; 3) exploring the forms of correlation between factor features and the resulting variable; 4) parameterization of data; 5) drawing up the regression equation; 6) economic interpretation of the results, in particular, the calculation of elasticities; 8) validation of the model for adequacy (calculation of error estimation, correlation coefficients and determination); 9) validation of the model for statistical significance (Fisher criterion and Student's t-test); 10) forecasting: calculation of confidence intervals.

Results of the research. To identify the sensitivity of employment of the population of the country (region) to changes in the economic system, let us use the method of mathematical modelling, which is widely used in applied economic researches.

It is clear that there are many factors that determine the multidirectional vectors of structural changes in employment, but we should remember that the economic and mathematical model must meet the objectives of the research, to reflect the strong relationship between the variables, have practical use, be adequate and simple in use. An economic-mathematical model, which is capable to satisfy all of the above conditions, will be able not only to objectively estimate the dependence of employment on structural changes in factor features, but also to forecast the possible changes what create the preconditions for creating a reliable information base to support the decision acceptance of management decisions on socio-economic development of the country (region) and the development of appropriate strategies.

The purpose of the econometric model is to establish and research the relation between the employment level of the population of Ukraine (region) on the influence of macroeconomic factors. The choice of factors was made on the basis of possible relationship between them and the availability of statistical information sufficient to perform the econometric modelling. To achieve the research goal, there are the following tasks: to investigate the relationships between selected factors at the country and region level; to determine their impact on the employment of the population of the country and the region; to conduct a comparative analysis of the results.

As the research object it was identified the industrial regions dominated by material-intensive and energy-intensive industries with low added value and extensive use of workforce (Dnipropetrovsk region). The production potential basis of this region consists of enterprises of high-tech industries: energy mechanical engineering, electrical engineering, electronics, radio engineering, aerospace industry (Kharkiv region), where the construction is dominated, real estate operations and financial services (Kyiv region), and the region dominated by the agro-industrial complex and the food industry (Vinnytsia region). The diversity of this sample, which covers the main directions of economic development of the country, will allow making a comprehensive approach to the task of analysing the dynamics of employment at the regional and national levels.

The task of building an economic and mathematical model that reflects the dependence of the employment of population of the region on the influence of the selected factors in each of the selected areas will be solved with the help of the application software MS Excel. To calculate mathematically the possible relationship between employment and the above factors, let us use the statistics of the State Statistics Service of Ukraine for the period 2000—2017.

The initial phase for building an econometric model is to identify the variables. According to the identification results we get: Y — employment rate of the population in the corresponding region; x_1 — share of full-time employees with the higher education; x_2 — growth rate of labor productivity; x_3 — growth rate of average wages; x_4 — capital investment index; x_5 — the export coverage ratio of imports.

The dynamics of the selected factors for each region for the period 2000—2017 are shown in the *Fig. 1—5*. From the Figure 1 we can see that the regions selected for the analysis show us an increase of share of the workforce with higher education. Informatization of the economy requires the increasing involvement in the production of highly skilled labor, which gradually displaces the less skilled labor force. The higher employment rates of people with higher education in Kharkiv

and Kyiv regions, compared to other regions, are resulted not only from the economic development but also from the attractiveness of these regions for young people, who are mainly focused on higher education.

Ukraine has not yet recovered from the crisis of 2007 and 2013 and has low productivity rates (*Fig. 2*). Although, overall, both in the country as a whole and in most regions, labor productivity has increased comparing to previous years, but it still could not reach the levels of pre-crisis 2007. Primarily, because of the low share of high-tech industries on the regions, which are based on the results of intellectual work, innovation and the creation of new knowledge (Kyiv and Vinnitsa regions).
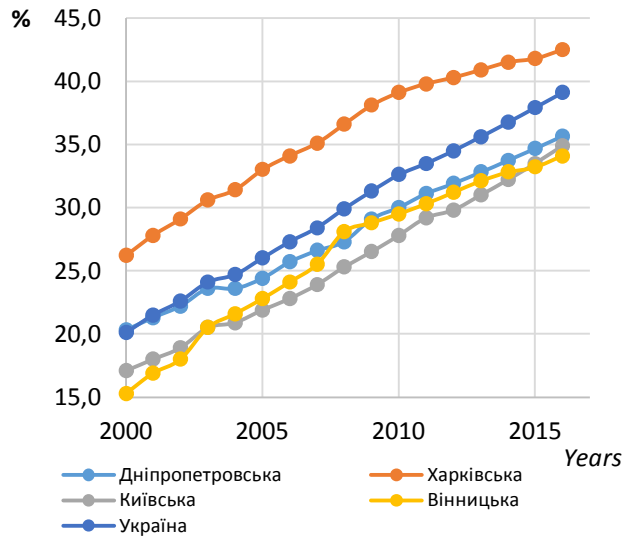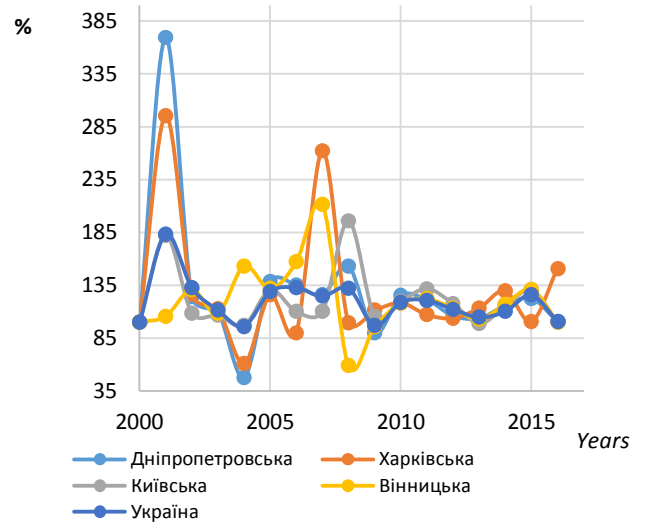

Fig. 1. Share of employees with higher education   Fig. 2. The productivity growth rate

Source: Designed by the authors.

On the other hand, it is not necessary to minimize the high proportion of low-productivity jobs in the economy and the retention of hired workers on part-time or administrative holidays.

There is an organic relationship between productive employment and payment for it. Both indicators are conditioned by the nature of socio-economic processes. On the one hand, without a rise in productive employment, it is impossible to ensure a wage increase, and on the other hand, the level of wages and the rate of its growth (*Fig. 3*) significantly affect the productive employment. First of all, this is due to the fact that the salary is more than half of the total household income of these regions. It is a major income source for the employed, part of the family budget and sometimes income for the whole family.

The capital investment index is a kind of indicator of the region's financial attractiveness. The undulating dynamics of this indicator is a consequence of the fact that our country has an unstable business environment because of the crisis and the conflict on the Donbass, trade and transit wars. For the period 2013—2015, Ukraine lost almost a third of capital investments of pre-crisis level. The increasing dynamics of capital investment in all analyzed regions is a testament to the confidence of the internal investors in the future. It should be noted that it was capital investments that accounted for more than 85 % of gross fixed capital formation and showed the highest growth rates as a result of 2018, exceeding the level of 2012 by 15,2 % (the last year of growth before the period of investment decline during 2013—2015).
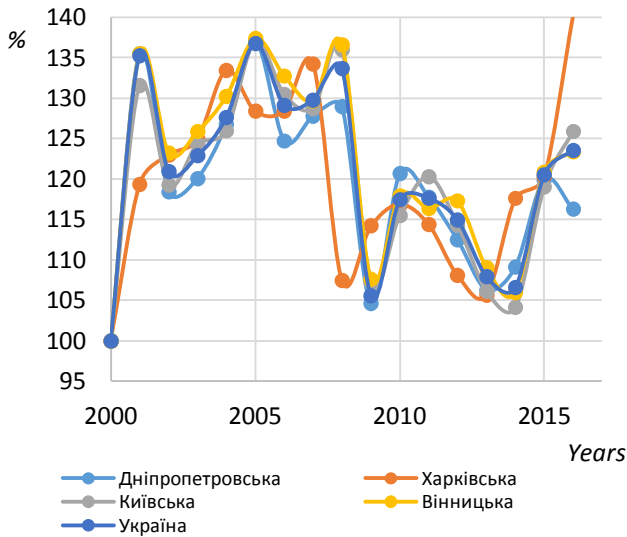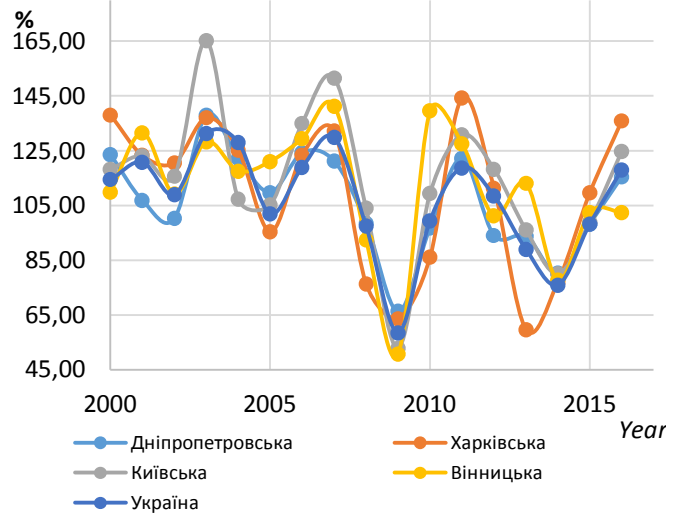
Fig. 3. Growth temp of the average wage
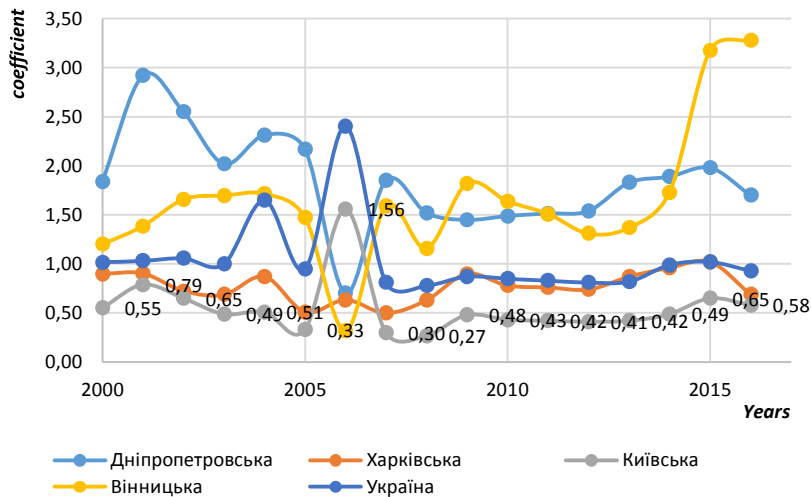

Fig. 4. Capital investment index

Fig. 5. Import-export coverage ratio

Source: Designed by the authors.

The import-export coverage ratio reflects the region's (country) potential for the foreign trade and has a significant impact on employment, because it stimulates an economic growth through the need for increased production, work places creation, accelerated growth in the average wage, and poverty reduction. At the same time, it should be noted that in some cases the region may become a hostage to a well-established production structure, and even if resources will be efficiently used, it will not increase the labour productivity. There is a close relation between foreign trade, employment and labour productivity in regions, which show a steady positive growth. The export acceleration stimulates the labour productivity, wage growth, increasing the competitive advantage and improving the life quality. Therefore, the export orientation of the region's economy may have a dual effect on employment.

Model specification is the second stage of development, which involves establishing a relationship between the effective and factor variables. At this stage, there is a formation of correlation field depending on the employment rate of the population on each factor using a point diagram in MS Excel. We use the trend line to determine the optimal type of relationship. With the help of dialog box of the trend line format, we determine the coefficient of determination for each of the diagrams. Comparing the coefficients of determination R^2 for each type of dependence, we choose the most optimal, that is, those for which the value of R^2 gets the maximum value possible.

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Based on the above research, it was established the linear relationship between the relevant factors of the econometric model:

$$Y = a_0 + a_1 X_1 + a_2 X_2 + a_3 X_3 + a_4 X_4 + a_5 X_5 + u, \qquad (1)$$

The next stage in model building is the parameterization stage: finding parameter for estimation $\hat{a}_i$ $(i = \overline{0,5})$ and formation of appropriate regression equation. This stage can be implemented in MS Excel in several ways. One way is purely mathematical, and involves estimating parameters using the smallest squares method and using the formula

$$\hat{A} = (X^T X)^{-1} \times X^T Y, \qquad (2)$$

where $\hat{A}$ — the vector column of the estimates of the coefficients of the equation, X^T — transported matrix to the matrix X, $(X^T X)^{-1}$ — the inverted matrix to the product of two matrices.

As a result of the calculations, economic and mathematical models were obtained.

For Dnipropetrovsk region:

$$\hat{Y} = 52,74 + 0,2 X_1 + 0,02 X_2 - 0,02 X_3 - 0,003 X_4 + 0,005 X_5.$$

$$(3)$$

For Kharkiv region:

$$\hat{Y} = 52,19 + 0,13 X_1 + 0,014 X_2 + 0,002 X_3 - 0,006 X_4 + 0,005 X_5$$

$$(4)$$

For Vinnytsia region:

$$\hat{Y} = 59,31 - 0,25 X_1 - 0,03 X_2 + 0,04 X_3 + 0,04 X_4 + 0,006 X_5 \qquad (5)$$

For Kyiv region:

$$\hat{Y} = 53,015 + 0,069 X_1 + 0,029 X_2 - 0,008 X_3 + 0,006 X_4 + 0,001 X_5 \qquad (6)$$

The developed models are adequate, as evidenced by the average values of the relative errors of the calculated regression values, which are within 10 %. For Dnipropetrovsk region the relative error becomes a value $\overline{A}$ = 1,05 %, for Kharkiv region $\overline{A}$ = 1,5 %, for Vinnytsia region $\overline{A}$ = 5,5 %, for Kyiv region $\overline{A}$ = 1,7 %.

Another criterion for model adequacy is related to the value of the correlation coefficient R and the determination coefficient R^2. The closer to R and R^2 to the one, the more significant is the linear relationship between the variables, it means the change in the effective variable is mostly explained by the change in the factor variable and only insignificant changes by other factors. For Dnipropetrovsk region the correlation coefficient becomes a value R = 0,98, and for Kharkiv one — R = 0,79, for Vinnytsia one — R = 0,84, and for Kyiv one — R = 0,63.

It seems that the difference between the correlation coefficients is resulted from the fact that by estimation the effects on the employment rate in Kharkiv and Kyiv regions it was not taken into account the factor that has a significant influence on the dynamics of growth of the effective variable in these regions. From there, we can conclude that, despite some similarities in the economic development of these regions, the relevant models are purely local and require an individual selection of influential factors to analyze the employment levels.

Equally important for the analysis and interpretation of the results are the coefficients of elasticity E_i and the total elasticity E. The coefficients of elasticity E_i are calculated for each factor variable X_i: $E_i = \hat{a}_i \cdot \dfrac{\overline{x}_i}{\overline{y}}$, $(i = \overline{1,5})$ and indicate on how many percent will be changed Y (it will be increased with $E_i > 0$ and decreased with $E_i < 0$) if the corresponding value X_i increases by 1 %. The total elasticity of E $\left(E = \sum\limits_{i=1}^{5} E_i \right)$ indicates on how many percent the result Y will change if all factors are increased by 1 % at the same time.

There are presented the corresponding values of elasticity coefficients of factor variables of the researched regions in the *Table*.

Table

Elasticity coefficients for regional models

The elasticity of the factor variable	Regions			
	Dnipropetrovsk	Kharkiv	Vinnytsia	Kyiv
E1	0,092020158	0,087141233	-0,115593638	0,0382687
E2	0,049380033	0,028421467	-0,074040428	0,07947792
E3	-0,030796305	0,012723109	0,079986009	-0,000259188
E4	-0,006098188	-0,011623465	0,073019974	-0,002224995
E5	0,015025198	0,006345181	0,017122241	-0,014434259
E	0,119530896	0,123007525	-0,019505843	0,100828177

Source: Designed by the authors.

Analyzing the developed models (3)—(6) on the totality of the found parameter estimates, it should be noted that the determinants that influence the dynamics of employment growth for the industrial regions of Dnipropetrovsk and Kharkiv are the factors that reflect the share of staff with higher education and rate of growth of labor productivity. The positive dynamics has also the factor that characterizes the import — export coverage ratio. The findings on these regions overlap with the results for Kyiv region, although, noting the coefficients value, the growth rate of higher education workers in the Kyiv region does not have a significant impact on the employment rate increase as in the Dnipropetrovsk and Kharkiv regions.

The situation is quite different in the Vinnytsia region, where the rate of growth in average earnings and the capital investment index have a significant impact on the positive dynamics of employment, while the factor of higher education availability does not contribute to the intensive growth of employment rate.

It is interesting to compare the developed regional models with the mathematical model of multiple regression for the analysis of structural changes in the population employment of Ukraine. This model was used in the research of Glushak O. and Semenyak S. [13]:

$$\hat{Y} = 45,723 + 0,506 X_1 - 0,00002 X_2 - 0,002 X_3 - 0,016 X_4 + 0,886 X_5. \qquad (7)$$

As we can see, the specificity of economic development of regions and the dynamics of influence of determining factors on some indicators, which is monitored in equations (3)—(6), «smoothed out» in the Ukrainian model (7) that shows the locality (regionality) of practical use of the corresponding econometric models for research study of structural changes in the employment, especially when forecasting.

The constructed models are adequate and statistically significant, therefore suitable for point and interval forecasts. Comparing the research results of employment rates in Ukraine with regional ones — in Dnipropetrovsk, Kharkiv, Kyiv, Vinnytsia regions, we can make the following conclusions: the level of education and investment growth are determining factors that influence the employment growth in the whole country. At the same time, for the Dnipropetrovsk region, the impact of investment is not reflected positively in the employment area, what is primarily connected to the strengthening of the technical equipment of the region's production and labor leakage. A growth of export-import coverage ratio and the labor productivity rate has positive changes.

Conclusions. Information on the employment situation of the population is the basis for the creation and implementation of an effective strategy of socio-economic development of the individual region and the state as a whole. In this context, it is essential to evaluate and analyze the population employment that requires further application of statistical methods of research to determine the condition and patterns of employment development in the regional and macroeconomic aspects.

Based on the conducted analysis of the labor market it is established the qualitative relationships between structural changes in macro- and mezzanine levels and population employment. It is made a selection of the main factors influencing the employment dynamics. It is built the econometric model of multiple regression to research the dependence of the employment rate of the population of Dnipropetrovsk, Kharkiv, Kyiv and Vinnytsia regions on higher education of the employed population, growth rates of labor productivity and average wages, capital investment index, the value of export coverage ratio. With the help

of the variance-correlation analysis of the constructed models, it is estimated the general influence of factor variables on the effective variable, and it was determined the statistical significance of the models. The application of the proposed model contributes not only to the comparative analysis of the employment dynamics of the population, but also to the determination of its elasticity to the macroeconomic factors, both at the regional level and in Ukraine. The prospects for further developments in this area will be related to the research of the impact of the development dynamics on the workforce structure.

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