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DIGITAL TRANSFORMATION OF THE ECONOMY AND REGIONAL FACTORS OF YOUTH UNEMPLOYMENT IN KAZAKHSTAN

In the context of the accelerated digital transformation of the economy, the problem of youth unemployment is becoming one of the significant challenges to the sustainable socio-economic development of the regions. The spread of digital technologies, the development of online employment platforms and changes in the demand structure for professional competencies are creating new conditions for the integration of young people into the labor market, while increasing interregional differences in the unemployment rate.

The purpose of the study is to identify and quantify regional socio-economic factors influencing the level of youth unemployment in the context of the digitalization of the economy, as well as to substantiate the directions of its reduction, taking into account regional specifics. The methodological basis of the research consists of methods of economic and statistical analysis. The empirical basis was the official data of the Bureau of National Statistics (BNS). The work uses an analysis of the dynamics of labor market indicators, comparative regional analysis, correlation analysis and econometric modeling based on panel data. The results of the study showed that the level of economic activity of young people, the level of socio-economic development of regions, as well as the development of digital infrastructure and the availability of digital services have a statistically significant impact on the level of youth unemployment. It has been established that regions with a more developed digital environment are characterized by lower rates of youth unemployment.

The results obtained expand the scientific understanding of the impact of digitalization on the transformation of regional labor markets and can be used in the development of state youth policy, improvement of regional employment programs and the development of digital competencies of youth.

Keywords: digital transformation of the economy, youth unemployment, regional development, labor market, youth employment.

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Экономиканың цифрлық трансформациясы және Қазақстандағы жастар жұмыссыздығының өңірлік факторлары

Экономиканың жеделдетілген цифрлық трансформациясы жағдайында жастар арасындағы жұмыссыздық проблемасы өңірлердің орнықты әлеуметтік-экономикалық дамуындағы елеулі сын-қатерлердің біріне айналууда. Цифрлық технологиялардың таралуы, онлайн жұмыспен қамту платформаларының дамуы және кәсіби құзыреттерге сұраныс құрылымындағы өзгерістер жұмыссыздық деңгейіндегі өңіраралық айырмашылықтарды күшейте отырып, жастардың еңбек нарығына интеграциялануы үшін жаңа жағдайлар жасайды.

Зерттеудің мақсаты – экономиканың цифрландыру жағдайында жастар арасындағы жұмыссыздық деңгейіне әсер ететін өңірлік әлеуметтік-экономикалық факторларды анықтау және сандық бағалау, сондай-ақ өңірлік ерекшелікті ескере отырып, оны төмендету бағыттарын негіздеу. Зерттеудің әдіснамалық негізі экономикалық және статистикалық талдау әдістері болды. Эмпирикалық база Ұлттық статистика бюросының (ҰСБ) ресми деректері болды. Жұмыста еңбек нарығы көрсеткіштерінің динамикасын талдау, салыстырмалы аймақтық талдау, корреляциялық талдау және панельдік деректерге негізделген эконометрикалық модельдеу қолданылады. Зерттеу нәтижелері жастардың экономикалық белсенділік деңгейі, өңірлердің әлеуметтік-экономикалық даму деңгейі, сондай-ақ цифрлық инфрақұрылымды дамыту және цифрлық қызметтердің қолжетімділігі жастар арасындағы жұмыссыздық деңгейіне статистикалық маңызды әсер ететінін көрсетті. Цифрлық ортасы анағұрлым дамыған өңірлер жастар арасындағы жұмыссыздық көрсеткіштерінің төмендеуімен сипатталатыны анықталды.

Алынған нәтижелер цифрландырудың өңірлік еңбек нарықтарының трансформациясына әсері туралы ғылыми түсінікті кеңейтеді және мемлекеттік жастар саясатын әзірлеу, өңірлік жұмыспен қамту бағдарламаларын жетілдіру және жастардың цифрлық құзыреттерін дамыту кезінде пайдаланылуы мүмкін.

Түйін сөздер: экономиканың цифрлық трансформациясы, жастар арасындағы жұмыссыздық, аймақтық даму, еңбек нарығы, жастарды жұмыспен қамту.

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Цифровая трансформация экономики и региональные факторы молодежной безработицы в Казахстане

В условиях ускоренной цифровой трансформации экономики проблема молодежной безработицы становится одним из существенных вызовов устойчивому социально-экономическому развитию регионов. Распространение цифровых технологий, развитие онлайн-платформ трудоустройства и изменения в структуре спроса на профессиональные компетенции создают новые условия для интеграции молодежи на рынок труда, одновременно усиливая межрегиональные различия в уровне безработицы.

Целью исследования является выявление и количественная оценка региональных социально-экономических факторов, влияющих на уровень молодежной безработицы в условиях цифровизации экономики, а также обоснование направлений ее снижения с учетом региональной специфики. Методологическую основу исследования составили методы экономического и статистического анализа. Эмпирической базой послужили официальные данные Бюро национальной статистики (БНС). В работе используется анализ динамики показателей рынка труда, сравнительный региональный анализ, корреляционный анализ и эконометрическое моделирование на основе панельных данных. Результаты исследования показали, что уровень экономической активности молодежи, уровень социально-экономического развития регионов, а также развитие цифровой инфраструктуры и доступность цифровых услуг оказывают статистически значимое влияние на уровень молодежной безработицы. Установлено, что регионы с более развитой цифровой средой характеризуются более низкими показателями молодежной безработицы.

Полученные результаты расширяют научное понимание влияния цифровизации на трансформацию региональных рынков труда и могут быть использованы при разработке государственной молодежной политики, совершенствовании региональных программ занятости и развитии цифровых компетенций молодежи.

Ключевые слова: цифровая трансформация экономики, молодежная безработица, региональное развитие, рынок труда, занятость молодежи.

Introduction

Unemployment remains one of the key socio-economic problems affecting the economic stability and efficiency of the labor market. In the context of digital transformation, structural changes in the demand for labor and the spread of digital employment platforms significantly affect the employment opportunities of young people.

A special place in the labor market is occupied by youth as a socio-demographic group that is at the stage of initial inclusion in economic activity. The level of youth employment (YE) largely determines the formation of competitive human capital and long-term prospects for economic growth. At the same time, young people remain one of the most vulnerable categories in the labor market due to a lack of professional experience, inadequate edu-

cational training to the requirements of the digital economy, as well as limited employment opportunities in certain regions.

Despite the implementation of government programs to support employment and develop youth entrepreneurship, the problem of youth unemployment (YU) remains relevant. The digitalization of the economy strengthens the regional differentiation of the labor market, which is manifested in differences in the level of youth employment, job availability, the development of digital infrastructure and the level of economic activity of the regions. In this regard, there is an increasing need for a comprehensive analysis of regional socio-economic factors that determine the level of YU.

In Kazakhstan, in 2022, the age category of youth was expanded to 15-34 years, which affects the interpretation of statistical indicators of the labor market.

The object of the research is the youth labor market in the context of the digital transformation of the economy. The subject of the study is regional socio-economic and institutional factors influencing the youth unemployment rate (YUR). The purpose of the study is to identify regional socio-economic factors that determine the level of YU, as well as to assess the possibilities of its reduction based on methods of economic and statistical modeling, taking into account the processes of digitalization of the economy.

To achieve this goal, the following tasks are being solved: theoretical approaches and results of domestic and foreign research on YU are analyzed; the dynamics and regional features of YU in 2020-2024 are investigated; key socio-economic factors affecting the level of YUR are identified; correlation and regression analysis of the dependence of YUR on selected factors is carried out; a forecast scenario is developed and determined directions for improving the regional YE policy.

The methodological basis of the research consists of methods of economic and statistical analysis, including analysis of the dynamics of indicators, comparative regional analysis, correlation analysis and econometric modeling based on panel data.

The scientific novelty of the study is a comprehensive economic and statistical analysis of the impact of socio-economic and digital factors on YU in the regions of Kazakhstan. Unlike previous studies, the article uses panel data on 17 regions and 3 cities of national significance for the period 2020-2024, the econometric model includes indicators of digital development, and scenario modeling of the impact of key factors on YU is applied.

The practical significance of the research lies in the possibility of using the results obtained in the development of regional youth employment programs, the formation of state youth policy, as well as in the development of measures to develop digital competencies and increase youth adaptability to the digital economy.

Literature review

The development of human capital and its impact on the functioning and transformation of the labor market have received fundamental justification in the works of representatives of neoclassical economic theory. Within the framework of this approach, education, vocational training and accumulation of skills are considered as key factors for increasing labor productivity, competitiveness

of workers and their employment (Shults, 1961; Besker, 1987). The theory of human capital suggests that investments in education and the development of professional competencies increase the likelihood of employment and contribute to a more efficient allocation of labor resources in the economy.

In modern conditions of global economic instability and the accelerating digital transformation of the economy, there is a significant transformation of the factors determining the level of employment and unemployment. The development of digital technologies, automation and artificial intelligence tools leads to structural changes in the labor market and the formation of new requirements for the professional competencies of employees. On the one hand, digitalization contributes to the growing demand for young professionals with digital skills, the ability to innovate and high adaptability to technological changes. On the other hand, technological progress and automation of certain types of activities can lead to a reduction in traditional jobs and increased structural unemployment (Autor, 2015; Frey & Osborne, 2017).

Research shows that the impact of technological change on employment is mixed. On the one hand, digital transformation creates new employment opportunities related to the development of digital platforms, remote work and online entrepreneurship. On the other hand, automation and technological changes can reduce the demand for traditional jobs. Modern research highlights that digitalization is significantly transforming the structure of the labor market and employment mechanisms (Acemoglu & Restrepo, 2020). As a result, the importance of digital competencies and continuing education as key factors of youth competitiveness in the labor market is increasing.

A number of research show that digital infrastructure and the level of digital skills of the population are becoming important factors for the competitiveness of workers in the modern labor market and can have a significant impact on the employment rate of young people (Başol *et al.*, 2023; OECD, 2023). At the same time, digitalization leads to structural changes in the demand for labor and increases the importance of human capital, professional skills and adaptability of workers.

In recent years, considerable attention in the scientific literature has been paid to the development of platform employment, which is one of the key forms of employment in the digital economy. Platform services and online platforms create new employment opportunities, allowing employees to offer services

in the global labor market. Research shows that digital platforms can act as an alternative employment channel for young people, providing job flexibility, reducing the transaction costs of job search and access to new forms of economic activity. At the same time, platform employment is characterized by a high degree of instability and limited social protection for workers (Insebayeva & Beyssembayev, 2023; Jones & Sen, 2025).

Despite the existing risks, the development of the platform economy is considered by many researchers as an important factor in the transformation of modern labor markets and the formation of new employment models. The analysis of the dependence of employment on the phases of the business cycle and the level of economic activity is of considerable scientific interest. In modern literature, it is noted that the impact of macroeconomic fluctuations on different age groups of the population varies significantly. Empirical research shows that for older workers, age restrictions are the main barriers to finding work, while for young people, fluctuations in business activity, the level of economic growth and the state of regional labor markets play a key role. In this regard, the need to develop differentiated instruments of public employment policy is emphasized, including the use of flexible mechanisms for regulating the minimum wage, tax incentives and employment support programs for different age groups of the population (Axelrad *et al.*, 2018).

An important place in the scientific literature is occupied by the analysis of regional factors affecting YE. The researchers emphasize the need to improve regional policy aimed at developing infrastructure, stimulating industrial production and supporting modern high-tech sectors of the economy. In this context, the growth of the gross regional product (GRP) is considered as one of the key factors in reducing YU and ensuring the sustainable development of regional labor markets (Parida & Pattayat, 2024).

Platform employment has become an important form of labor relations in the digital economy, providing new employment opportunities for young people, but often characterized by instability and limited social protection (Brynjolfsson & McAfee, 2014; World Bank, 2021).

In recent years, researchers have also noted the increasing influence of technological factors and the digital transformation of the economy on YE processes. The digitalization of the economy creates new jobs in the field of information technology, remote employment and online services, which can

help reduce YU (Kozallik & Kozallik, 2025; Zinich *et al.*, 2023). The analysis of YU in modern conditions requires taking into account not only traditional socio-economic factors, but also indicators of digital development of regions.

Based on the theoretical analysis of previous studies and the identified determinants of youth unemployment, the following research hypotheses (*H*) have been formulated:

H1. The level of economic activity of young people has a negative impact on the unemployment rate among young people. Increasing youth participation in the labor market helps to reduce youth unemployment.

H2. YE significantly reduces YU in the regions.

H3. The development of digital infrastructure, including household Internet access, contributes to reducing youth unemployment.

H4. The use of digital services and online platforms increases employment opportunities for young people and has a negative impact on youth unemployment.

H5. The digital transformation of the regional economy has a statistically significant impact on youth unemployment.

The verification of these hypotheses is carried out using econometric modeling based on panel data for the regions. Thus, the conducted review of scientific research indicates the multifactorial nature of YU and the lack of a unified approach to interpreting its causes. At the same time, existing studies rarely consider the combined impact of socio-economic and digital factors on YU at the regional level using panel data analysis. In this regard, it seems advisable to expand existing approaches by taking into account the impact of the digital transformation of the economy and the regional specifics of labor market development, which will identify the key determinants of YU and substantiate effective mechanisms for its regulation.

Methodology

The theoretical part of the research was based on the analysis of scientific publications by domestic and foreign authors using the methods of logical analysis, generalization and a systematic approach, which allowed to form the conceptual foundations of the research and identify key theoretical approaches to the research of youth unemployment.

The analytical part at the initial stage of the research included conducting continuous statistical and comparative analysis aimed at identifying com-

mon trends and forming the context of the problem under research.

The empirical research base is based on official statistical data from the NBS. The econometric assessment was carried out on the basis of a panel regression model. The Hausmann test was performed to select the characteristics of the model. The results supported a model with constant effects due to the correlation between individual regional characteristics and explanatory variables. The use of stable effects made it possible to balance the influence of regional features that remained unchanged over time.

The criterion for including a region in the sample is the availability of comparative official statistical data on all analyzed indicators for the specified period. Since administrative and territorial changes took place in 2022 (the creation of new regions), the principle of a single territorial entity within each reporting year was used to ensure comparability of panel data. The data for 2020-2021 is comparable to the retrospective distribution of indicators in accordance with the official publications of the statistical authority. In the absence of individual observations, linear interpolation methods were used or officially recalculated indicators were used.

At the first stage of the research, a descriptive statistical and comparative analysis of the dynamics of YU in the regions in 2020-2024 was carried out, which made it possible to identify the impact of the pandemic and the post-pandemic period on regional labor markets.

At the second stage, the main determinants of the YUR were identified, after which a quantitative assessment of the influence of the selected factors was carried out using correlation and regression analysis methods. The YUR (%), determined in accordance with the methodology of the International Labour Organization (ILO), was used as a dependent variable.

In this research, YU refers to the proportion of unemployed people aged 15 to 34 in the economically active youth population in accordance with the ILO methodology. YE represents the number of employed people in a given age group and is used as an explanatory variable reflecting the state of the regional labor market.

The "unemployed" include people between the ages of 15 and 34 who, during the period under review, did not have a paid job or a profitable occupation, were actively looking for work, and were ready to start work in the near future.

"YE" is considered as the number of young people aged 15 to 34 years employed in the economy

(employees, self-employed and entrepreneurs), and is used in the article solely as an explanatory factor characterizing the state of the regional labor market, and not as an alternative indicator of unemployment. Thus, in the research, the YUR is a dependent variable, while indicators of YE and economic activity are used to analyze factors that determine its dynamics and regional differences.

At the next stage, the main determinants of the YUR were identified, after which, using the methods of correlation and regression analysis, the influence of the selected factors on its level was assessed based on the interpretation of the corresponding coefficients.

The final stage of the research was the application of economic and statistical modeling methods to predict the dynamics of YU and develop practice-oriented recommendations aimed at reducing it in the medium term.

Microsoft Excel and Stata programs were used to implement these methods.

Results and discussions

The research assessed the impact of changes in the socio-economic environment of the country and its regions on the level of youth unemployment. This allowed us to form the basis for building a strategic model, within which the dependent variable was defined and key independent determinants were identified. The analysis procedure was carried out in stages and included several consecutive analytical stages.

At the first stage, a descriptive dynamic analysis was performed. In the course of the research, the main indicators of the socio-economic development of the country's regions over a five-year period were studied and selected, which made it possible to assess general trends and regional differences.

According to official statistics, the number of young people in 2024 amounted to 5759.8 thousand people, of which 2911.5 thousand were men and 2848.3 thousand were women. The largest number of young people in 2024 is observed in Almaty (696 thousand people), Turkestan region (503 thousand people) and Astana (456 thousand people).

At the same time, there is a significant decrease in the number of young people in a number of regions. So, in the Turkestan region in 2024, compared with 2023, the decrease was about 151 thousand people, in the East Kazakhstan region – 119 thousand people, in the Mangystau and North Kazakhstan regions – 99 and 69 thousand people, re-

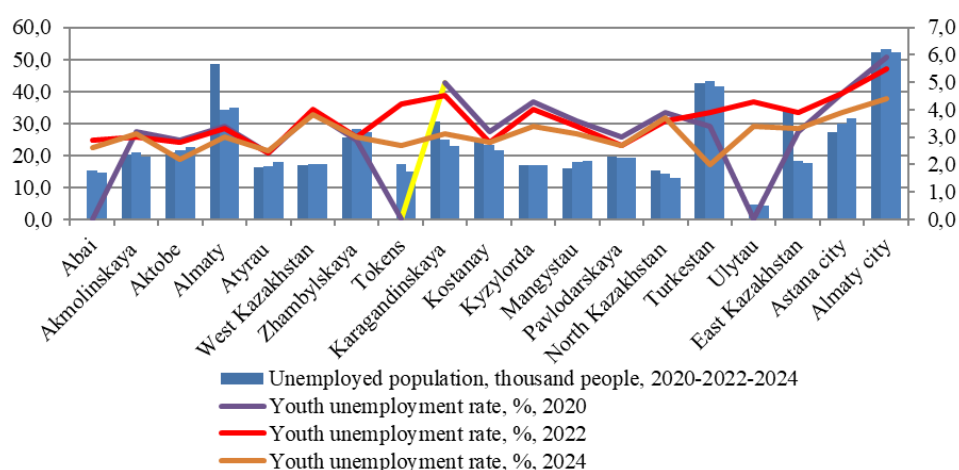
spectively. It should be noted that in 2023, compared with 2022, on the contrary, there was a noticeable increase in the number of young people in the North Kazakhstan region (from 99 to 134 thousand people) and in the Mangystau region (from 150 to 231 thousand people). This dynamic is largely due to intensive internal migration processes associated with the movement of young people to large cities and economically more developed regions with better socio-economic opportunities. In addition, the demographic situation is influenced by a gradual decrease in the birth rate and an increase in natural population decline in certain regions of the country.

According to the forecasts of the research centers, the decline in the number of young people may continue in the period from 2021 to 2029. At the same time, positive dynamics is expected mainly due to an increase in the number of the age group of 15-19 years, associated with the transition to the

youth category of new age cohorts. At the same time, negative dynamics may persist if the migration outflow of young people from the country continues (Official Website of the BNS, 2020-2024). The persistence of such trends can lead to a decrease in the capacity of the domestic labor market, increased competition between employers for labor resources and the formation of a shortage of personnel.

An analysis of the dynamics of YU shows that in 2021, there was an increase in this indicator at the national level due to the consequences of the pandemic and the associated economic constraints. At the same time, a relationship is revealed between the level of youth unemployment, the density of the youth population in the regions and changes in the age boundaries of the youth category. In subsequent years, the indicators have stabilized at a level below 4%, which indicates the relative stability of the national labor market (Figure 1).

Figure 1
Regional structure of YU



Note: compiled by the author based on the source (Official Website of the BNS, 2020-2024)

The increase in unemployment in 2021 reflects the effects of the pandemic shock, which had a significant impact on the functioning of the labor market. In subsequent years, there has been a gradual stabilization of indicators at a level below 4%, which indicates the recovery of regional labor markets and the adaptation of young people to changing employment conditions, including those related to the development of the digital economy and the emergence of new forms of work.

The largest share of YU was recorded in Almaty (44.6% of the total number of unemployed in the

region), as well as in Almaty and Turkestan regions and Astana (38.3%). The high rates of YU in these regions are largely due to the significant concentration of young people. Thus, the cities of Almaty and Astana are the largest educational and innovation centers in the country, attracting students and young professionals, while the Turkestan region is characterized by high demographic indicators. This concentration of young people increases competition in the labor market. At the same time, the development of digital technologies, the expansion of digital services and the emergence of new forms of employ-

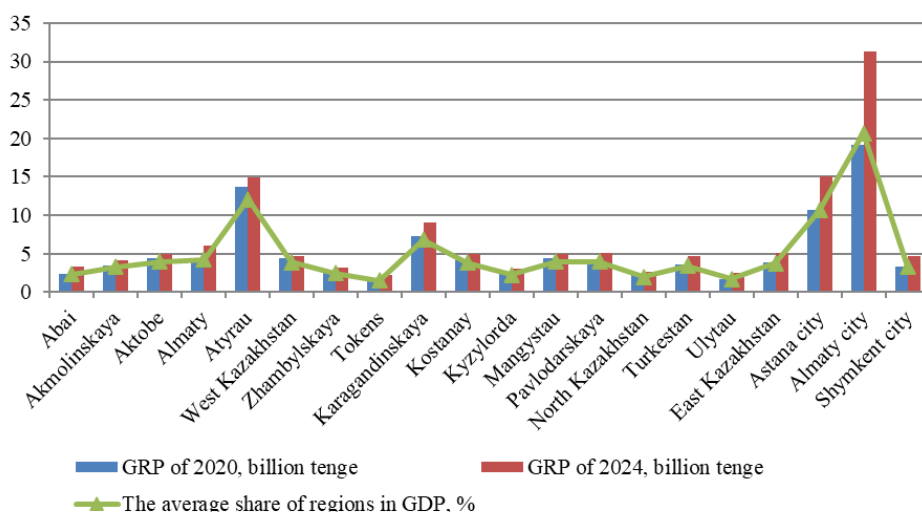
ment are gradually transforming the structure of labor demand, creating additional employment opportunities for young professionals.

In the republic as a whole, there has been a downward trend in YU over the period under review. The positive dynamics is largely due to the implementation of state employment support programs, the development of entrepreneurial competencies among young people, as well as the formation of new sectors of the economy. Digital and technological sectors, including information technology, green energy, creative industries, startup ecosystem and digital employment platforms, play a special role in this process. In addition, flexible forms of employment such as project work, internships, remote employment and freelancing are growing in popularity among young people, which

are actively developing in the context of the digitalization of the economy.

The GRP has a significant impact on YE, as it reflects the scale of economic activity in the region and the potential for creating new jobs. In regions with a high level of GRP, as a rule, a more developed economic infrastructure is being formed, high-tech industries are expanding and the demand for young professionals with modern professional and digital competencies is increasing. On the contrary, in regions with a lower level of economic development and limited digital infrastructure, employment opportunities remain less diverse, which contributes to an increase in youth unemployment. Thus, the dynamics of GRP is one of the key factors determining the state and development of regional labor markets for young people (Figure 2).

Figure 2
Dynamics of GRP



Note: compiled by the author based on the source (Official Website of the BNS, 2020-2024)

The dynamics of GRP reflects increased interregional differentiation, in which economic growth is concentrated mainly in raw materials and agglomeration regions, forming an asymmetry of YE opportunities. Oil and gas producing regions are traditionally attractive to young people due to high salaries and vacancies in engineering and technical specialties, given that 60% of the total grants are allocated to engineering and technical areas of research (Minister's Order dated 03/18/2024). However, rising inflation (2020 – 6.72%, 2024 – 14.72%) reduces the real incomes of the population and consumer

demand for regional products, which may limit the profitability of companies and their ability to create new jobs for young professionals (official website of the BNS).

The development of digital infrastructure and the active use of digital technologies by the population have a significant impact on the formation of YE and youth unemployment. In today's world, digitalization creates new employment opportunities, including remote work, freelancing, participation in startups and online projects. The high level of digital literacy and access to the Internet allow young

people to learn new competencies faster, adapt to changing labor market conditions and reduce competition for traditional jobs. Thus, digitalization indicators are an important factor complementing the

traditional socio-economic determinants of YE. The analysis of the BNS data shows that Kazakhstan demonstrates a steady increase in digitalization over the period 2020-2024 (Table 1).

Table 1
Digitalization of Kazakhstan

Indicators	2020	2021	2022	2023	2024
Percentage of households with Internet access, %	92,4	93,8	94,9	95,6	96,4
Percentage of the population using the Internet (16-74 years old), %	85,9	88,1	90,3	93,1	96,2
Share of mobile Internet users among households, %	88	90,6	92,5	94,8	95,5
Share of the population using a computer (PC/laptop/tablet), %	78,7	82,4	85,5	88,7	90,9
Level of digital literacy of the population, %	82,1	84,8	87,3	89,3	92,8
Percentage of the population buying goods and services online, %	17	20,5	23,9	26,8	28,5
Mobile Internet subscribers per 100 inhabitants	86	92	98	103	109

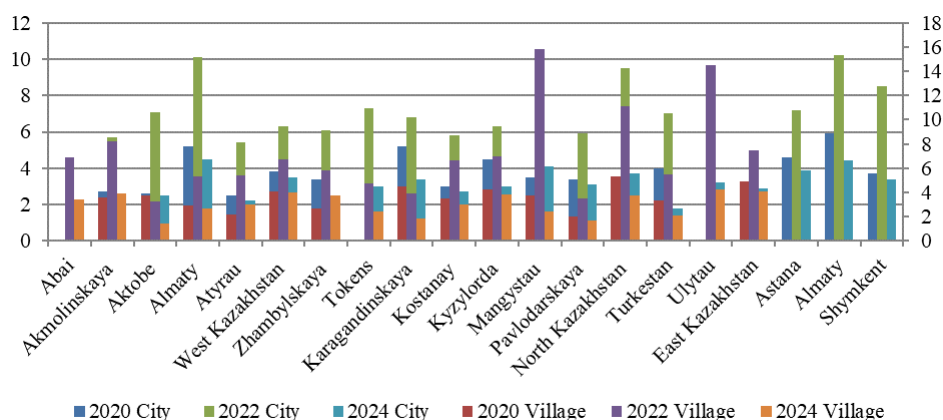
Note: compiled by the author based on the source (Official Data Request to BNS, 2020–2024)

During the period under review, there has been a steady increase in digitalization. These trends reflect an increase in the digital competence of the population and create new employment opportunities for young people in the digital economy.

Despite the high overall level of digitalization, there are significant interregional differences: in megacities (Almaty, Astana, Shymkent), Internet access and the use of digital services are approaching 99%, the level of digital literacy is high, and young people are actively involved in the digital economy. At the same time, in rural and remote regions (for example, North Kazakhstan and Ak-

mola regions), the indicators are lower – access to the Internet and the use of digital services are limited by infrastructural barriers and lower digital literacy. For a more detailed analysis, it is useful to break down the data by urban and rural areas. Such a regional section makes it possible to take into account differences in economic activity, infrastructure, and the level of digitalization between large cities and rural areas, identify areas with the greatest vulnerability of young people in the labor market, and build a panel regression model assessing the impact of socio-economic and digital factors on YU (Figure 3).

Figure 3
YU according to the ILO methodology



Note: compiled by the author based on the source (Official Website of the BNS, 2020–2024)

In 2020, the YUR in urban areas was higher than in rural areas in some regions (for example, Almaty, Karagandinskaya), due to the concentration of young people and high competition for jobs. By 2022, there is an increase in unemployment in both urban and rural areas, partly reflecting the effects of the pandemic shock and economic instability. By 2024, most regions are showing a decrease in youth unemployment, especially in cities, which may be due to the adaptation of young people to new working conditions and increased employment in the digital and service sectors. The highest unemployment in urban areas was observed in large megacities and regions with a high concentration of young people: Almaty, Astana, Mangystau (2022). In rural areas, the highest increase in unemployment was recorded in some remote areas, such as Ulytau and North Kazakhstan (2022), indicating limited employment opportunities and weak development of digital and industrial infrastructure. The reduction in unemployment by 2024 is more pronounced in urban areas than in rural areas, which highlights the continuing digital and economic inequalities between regions.

The data show significant inter-regional differences and the gap between urban and rural areas, which confirms the need to take regional effects into account in the panel regression model. The data obtained will help identify the key determinants of youth unemployment, as well as assess which regions require priority support through government and digital initiatives for youth. This heterogeneity creates unequal employment opportunities: young people in cities are faster learning new digital professions and projects, while in rural areas the digital gap persists, which may hinder adaptation to modern labor markets.

An analysis of descriptive statistics shows that the average YUR in the research period was about 3.8%, with the minimum value reaching 2.1% and the maximum value reaching 6.4%. The average level of youth economic activity was 63.5%, while the YE rate was about 60%. Indicators of socio-economic development of regions show significant differentiation: the gross regional product per capita varies from KZT 1.98 to 15.43 thousand, reflecting differences in the level of economic development of the country's regions. The analysis of digital indicators indicates a fairly high level of digital infrastructure development. Thus, the average share of households with Internet access is about 93.7%, and the share of the population using the Internet is 89.4%. At the same time, there is a certain regional differ-

entiation, which may have an impact on the formation of employment opportunities, especially among young people.

Econometric modeling was carried out using the method of multiple linear regression based on panel data. At the preliminary stage, correlations between variables were evaluated and the model was diagnosed for the presence of multicollinearity, which made it possible to clarify the composition of explanatory factors. The use of the panel approach made it possible to increase the explanatory ability of the model, reduce the error in estimating coefficients and obtain more stable results compared with cross-sectional analysis.

Economic and statistical modeling of YU requires a reasonable selection of factors reflecting both macroeconomic and socio-institutional features of regional development. To quantify the impact of socio-economic and digital factors on YU in the regions, a panel regression model was built that allows taking into account both the temporal dynamics of indicators and interregional differences. The use of panel data provides a more accurate assessment of the relationships between variables by combining temporal and spatial observations. Before constructing the econometric model, the descriptive statistics of the studied variables were analyzed, presented in Table 2.

Table 2
Model of the factors

Designation	Factors
Y	YUR, %
X_1	the level of economic activity of young people, %
X_2	YE rate, %
X_3	indicator of socio-economic development of the region (GRP per capita), thousand KZT
X_4	the level of digital infrastructure development (percentage of households with Internet access), %
X_5	the level of use of digital services by the population (percentage of the population using the Internet), %

Note: compiled by the authors

Next, a correlation analysis was performed using the Pearson correlation coefficient, which made it possible to estimate the strength and direction of linear relationships between dependent and explanatory variables (Table 3).

Table 3
The Pearson correlation coefficient matrix

Factors	Y	X ₁	X ₂	X ₃	X ₄	X ₅
Y	1.00	-0.62	-0.74	-0.41	-0.38	-0.45
X ₁	-0.62	1.00	0.81	0.39	0.33	0.37
X ₂	-0.74	0.81	1.00	0.42	0.35	0.40
X ₃	-0.41	0.39	0.42	1.00	0.46	0.51
X ₄	-0.38	0.33	0.35	0.46	1.00	0.72
X ₅	-0.45	0.37	0.40	0.51	0.72	1.00

Note: calculated by the authors

The data obtained show a negative relationship between the YUR and most explanatory variables. The strongest inverse correlation is observed between the level of YU and the level of YE ($r = -0.74$), as well as youth economic activity ($r = -0.62$). This indicates that increasing the level of youth involvement in economic activity helps to reduce unemployment. In addition, a moderate negative relationship was found between the level of YU and indicators of digitalization, such as access to the Internet and the level of use of digital services by the population. This result confirms the assumption that the development of digital infrastructure and the spread of digital technologies can help expand YE opportunities, including through the emergence of new forms of employment, remote work and the development of the digital economy.

At the next stage, a regression analysis was performed to quantify the impact of the identified factors. The model of multiple linear regression based on panel data was used as the basic one, using the indexes i – region/city of national significance (units of observation) and t – time period (year), which allow taking into account both spatial and temporal differences, which makes the model panel-based (1):

$$Y_{it} = \alpha + \beta_1 X_{1it} + \beta_2 X_{2it} + \beta_3 X_{3it} + \beta_4 X_{4it} + \beta_5 X_{5it} + \mu_i + \varepsilon_{it} \quad (1)$$

where:

- α – constant that reflects the basic level of youth unemployment, when all factors X_1 – X_5 = 0;
- β – measures the “net” effect of a particular factor X on the level of youth unemployment;
- μ_i – individual regional effect;
- ε_{it} – random error reflecting the influence of factors unaccounted for in the model.

The model was evaluated using fixed and random effects. The results of the Hausman test ($p < 0.01$) confirmed the preference for the fixed-effects model, which indicates the presence of stable inter-regional features affecting the level of youth unemployment. The final results of the regression analysis are presented in Table 4.

Table 4
Results

Factors	Coef.(β)	Std.Err.	t-stat.	p-value
α	7.214	1.542	4.68	0.000
X ₁	-0.031	0.012	-2.58	0.011
X ₂	-0.067	0.015	-4.47	0.000
X ₃	-0.00008	0.00003	-2.41	0.018
X ₄	-0.021	0.009	-2.33	0.022
X ₅	-0.028	0.010	-2.71	0.008
R ²	0.71			

Note: calculated by the authors

The results show that most of the factors included in the model have a statistically significant impact on the YUR.

The strongest influence is exerted by the level of YE (X_2). The coefficient β_2 has a negative value (-0.067), which indicates that an increase in YE by 1% leads to a decrease in YU by an average of 0.067%, all other things being equal.

The economic activity of young people (X_1) also has a statistically significant impact on the unemployment rate. The negative value of the coefficient β_1 (-0.031) indicates that the increase in youth participation in economic activity contributes to a decrease in the unemployment rate (Y).

The indicator of socio-economic development of the region, represented by GRP per capita (X_3), also demonstrates a negative relationship with the YUR of β_3 (-0.00008). This means that in economically more developed regions there is a more favorable labor market situation associated with the creation of new jobs and the expansion of employment opportunities.

Of particular interest are the results related to the influence of digital factors. Coefficients for variables characterizing the development of digital infrastructure and the level of use of digital services by the population have a negative and statistically significant value. This confirms the hypothesis that

the development of the digital economy contributes to the expansion of YE opportunities.

In particular, an increase in the proportion of households with Internet access (X_4) by 1% is associated with a decrease in YU (Y) by an average of 0.021%. Similarly, an increase in the level of use of digital services by the population (X_5), by 1%, leads to a decrease in the YUR(Y) by about 0,028%.

Thus, the results of the econometric analysis indicate that the development of digital infrastructure and the expansion of the use of digital technologies can be important factors in reducing YU and improving the efficiency of regional labor markets.

To increase the reliability of the results obtained, additional tests were conducted to verify the stability and correctness of the constructed panel regression model.

Diagnostic tests were conducted to verify the reliability of the model. The Hausman test confirmed the preference for the fixed-effects specification. The diagnosis of multicollinearity ($VIF < 5$) showed the absence of a strong correlation between the independent variables. Tests for heteroscedasticity and autocorrelation were performed, and reliable standard errors were applied to ensure the stability of the estimates.

Thus, the performed diagnostic procedures confirm the stability of the results obtained and allow us to conclude about the statistical reliability of the constructed model. This gives reason to assert that the revealed dependencies between the level of YU and socio-economic and digital factors are stable and reflect the real patterns of functioning of regional labor markets.

The results of the econometric analysis allow us to confirm the hypotheses put forward in the study. The obtained regression coefficients show that the level of youth economic activity has a statistically significant negative impact on the YUR, which con-

firms the H1 that an increase in youth participation in the labor market contributes to a decrease in unemployment.

The analysis also shows that the YE has a significant negative impact on YU, which confirms the H2. The coefficient of the variable characterizing the level of household access to the Internet is negative and statistically significant, which indicates the positive impact of the development of digital infrastructure on reducing YU (H3).

The indicator of the use of digital services by the population also demonstrates a statistically significant relationship with YU, confirming the H4 that the development of digital services expands employment opportunities for young people. Collectively, the indicators of digital development included in the model confirm the H5 about the significant impact of the digital transformation of the regional economy on the formation of YU.

The results obtained indicate the important role of both socio-economic and digital factors in shaping regional labor markets and youth employment. Based on the obtained regression model, it is possible to build a forecast of YU by region and at the national level using a scenario approach. We will propose a forecast based on three scenarios: basic, educational and complex, taking into account the dynamics of key factors. Then the basic model of multiple linear regression based on panel data and analysis results will have the following form (2):

$$Y = 7,214 - 0,031X_{lit} - 0,067X_{2it} - 0,00008X_{3it} - 0,021X_{4it} - 0,028X_{5it} \quad (2)$$

To assess the potential effect of management decisions, a scenario approach related to modern methods of applied economic analysis was applied. The method allows you to model changes in the level of YU with varying key factors (Table 5).

Table 5
Forecast scenario of YUR

Scenario	Change	Forecast Y (by 2029), %
Basic	The current trends ($X_1 = 63.5$; $X_2 = 60$; $X_3 = 8700$; $X_4 = 94$; $X_5 = 90$)	3.7
Educational	The growth of economic activity of young people at 3% and employment by 4% ($X_1 = 66,5$; $X_2 = 64$)	3.3
Digital	Increasing access to the Internet to 97% and the level of use of digital services to 94%	3.4
Comprehensive	Simultaneous growth of economic activity, employment and digitalization	2.9

Note: the authors' calculations are based on a panel regression model

Interpretation of forecast results:

1. The results of scenario modeling show that the YUR largely depends on the dynamics of socio-economic and digital factors. According to the baseline scenario, which assumes the continuation of current trends in the development of the economy and digital infrastructure, the projected YUR will be about 3.7%, which corresponds to the average values observed during the research period.

2. The implementation of an educational scenario involving an increase in the economic activity of young people and an increase in their employment through the development of educational programs, vocational training and incentives for youth participation in economic activities may lead to a decrease in YU to about 3.3%. This confirms the importance of human capital and professional training for the sustainable functioning of the youth segment of the labor market.

3. Under the digital scenario, which provides for further development of digital infrastructure, expansion of Internet access and wider use of digital services by the population, the projected YUR may decrease to 3.4%. This result reflects the growing role of the digital economy in creating new employment opportunities, including telecommuting, digital entrepreneurship, and the development of employment platforms.

4. The most significant decrease in YU is observed when implementing a comprehensive scenario involving the simultaneous development of economic, educational and digital factors. In this case, the projected YUR may decrease to 2.9%, which indicates the synergistic effect of the combined impact of these factors.

The results of predictive modeling confirm that a comprehensive policy aimed at developing human capital, increasing YE and expanding the digital capabilities of the economy can become an effective tool for reducing YU and increasing the sustainability of regional labor markets. The results of the research show that in order to reduce YU and increase the efficiency of regional labor markets, it is necessary to develop digital employment, support youth entrepreneurship and introduce digital educational programs. In addition, an important tool is the formation of regional employment programs that take into account the specifics of the digital transformation of the economy and the level of development of digital infrastructure in different regions.

The study is based on aggregated regional data, which limits the ability to account for individual characteristics and intra-group differences. The

model includes only official statistics. Institutional and behavioral factors (for example, employers' requirements for work experience and professional competence, the influence of age and gender factors) were not formalized by the authors in this article.

The analysis period (2020-2024) includes a period of economic instability after the pandemic, which may increase the volatility of indicators. The linear model used assumes the linear nature of the relationships, whereas in reality threshold and non-linear effects are possible. The prediction of the scenario is conditional and depends on the prerequisites for the relative stability of the external environment.

These limitations define the areas of further research, including the use of microlevel data, the expansion of the time horizon of analysis and the use of nonlinear econometric models, and once again prove the relevance of the study.

Conclusion

The results of the study confirm that the level of youth unemployment in the regions is formed under the influence of a combination of socio-economic and digital factors. The most significant impact is exerted by the level of youth employment and economic activity of the population, which confirms the conclusions of previous studies (Axelrad *et al.*, 2018; Picchio *et al.*, 2024) that the involvement of young people in labor contributes to reducing unemployment and improves the integration of young professionals into the labor market.

The results related to digitalization are of particular importance. The analysis shows that an increase in the proportion of households with Internet access and the increased use of digital services by the population contribute to reducing youth unemployment. The digital transformation of the economy is creating new employment opportunities, including telecommuting, online entrepreneurship, and freelancing. Similar conclusions are presented in the OECD (2023) and Shults (1961) studies, where the development of digital infrastructure is considered as an important factor in increasing the flexibility of the labor market and the development of human capital.

However, the impact of digitalization is uneven in different regions. In large cities such as Almaty and Astana, a high level of digital development is combined with high competition in the labor market due to the concentration of young people. In less developed regions, the potential for digital employment is limited by infrastructural barriers, which confirms the need to implement a regionally differ-

entiated policy of digitalization and human capital development.

The results show that the processes of digital transformation should be integrated into government programs to increase youth employment. The development of digital skills, support for youth entrepreneurship and the creation of new digital jobs can enhance the positive effects of economic growth and employment expansion.

Comparison with international studies shows similar trends: countries with higher levels of digitalization and developed infrastructure show lower youth unemployment (Parida & Pattayat, 2024; Majeed et al., 2023). This confirms the universality of the impact of digitalization on the labor market and underlines the need to adapt international experience to the regional peculiarities of Kazakhstan.

In general, the results of the study show that reducing youth unemployment requires an integrated approach, including economic growth, employment expansion, an increase in gross regional product and the development of digital infrastructure. Digitalization enhances the influence of traditional socio-economic factors and creates new employment opportunities for young people in regional labor markets.

From a scientific point of view, the conducted research contributes to the development of employment theory, clarifying the role of regional and structural factors in the formation of youth unemployment in a transformational economy. The use of a panel econometric model with fixed effects made it possible to take into account the spatial and tem-

poral heterogeneity of the regions and increase the explanatory power of the analysis. Promising areas for further research include the use of microdata from households and individual employment trajectories, the analysis of gender and age differences within the youth group, as well as the use of nonlinear and dynamic models that take into account the delayed effects of investment and digitalization on regional labor markets.

Author contributions

ODB: conceptualization, methodology, writing the original text;

TS: text editing, manual.

Conflict of interest

The authors declare that there is no conflict of interest.

Acknowledgments

The article is written and published within the framework of the implementation of the educational module Jean Monnet of the Erasmus+ Jean Monnet program 101176925-SOLUTION-ERASMUS-JMO-2024-HEI-TCH-RSCH «GENDER ISSUE IN MIGRATION: EUROPEAN APPROACH». Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

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Received: 19 March 2026

Accepted: 20 June 2026