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RESEARCH ARTICLE
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Evaluating Healthcare Accessibility in Kazakhstan: Urban and Rural Perspectives

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ABSTRACT

This study conducts a comprehensive analysis of regional disparities in demographic and educational indicators in Kazakhstan from 2009 to 2022. Despite the existing literature, which often fails to account for current socio-economic dynamics and regional specificities, this research aims to fill the gap by integrating multiple dimensions - demographic trends, employment rates, and educational attainment - into a holistic assessment. Utilizing a detailed heatmap and correlation matrix, the study identifies key trends and disparities, offering a nuanced understanding of the socio-economic landscape. The findings reveal significant regional differences in birth rates, migration balances, employment trends, and educational outcomes, underscoring the need for targeted policies to address these disparities. Recommendations include investing in healthcare and living conditions to sustain positive demographic trends, enhancing educational infrastructure to improve human capital, and promoting formal employment to reduce economic inequalities. By aggregating these critical indicators, the research provides valuable insights for policymakers and stakeholders to formulate strategies aimed at fostering sustainable socio-economic development across Kazakhstan's regions. The study also highlights the importance of continuous monitoring and adaptation of strategies to effectively address dynamic socio-economic factors.

KEYWORDS: Human Resources, Employment, Migration Patterns, Regional Disparities, Socio-Economic Development, Kazakhstan, Labor Market

SCSTI: 06.52.35

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1. INTRODUCTION

Evaluating human resource potential is critical for any nation aspiring to achieve sustainable economic growth and social development. In Kazakhstan, a country characterized by its vast geographical diversity and significant regional disparities, understanding the dynamics of human capital is particularly vital. Human capital, encompassing the population's skills, knowledge, and abilities, plays a pivotal role in driving productivity, fostering innovation, and enhancing the overall quality of life.

In Kazakhstan, after the development of the "National Human Development Report", the concept of human development has acquired an essential role in planning and defining fundamental priorities, becoming an alternative path. All official planning documents of the country reflect the social needs of the population specified in the Strategy "Kazakhstan – 2030". The long–term development of the country is also implemented based on the ideology set out in the Strategy "Kazakhstan – 2050", which proclaims the idea of a "united nation of strong and responsible people." The principle of human centricity, which is increasingly becoming the basis of national programs, is also spelled out in the National Development Plan of the Republic of Kazakhstan until 2025, which aims to improve the quality of life of the population and increase well-being. The annual messages of the President of Kazakhstan also contain the principles and concepts of human development. Kazakhstan's journey toward becoming a competitive economy is deeply intertwined with its ability to develop and effectively utilize its human resources. The country's strategic vision, aimed at diversifying its economy and reducing dependency on natural resources, hinges on creating a well-educated and highly skilled workforce. This study seeks to provide a detailed examination of the various facets of human capital across the regions of Kazakhstan.

Such attention to human development may indicate significant changes in the country's overall development. One of the leading indicators of these changes is the considerable attention to human-oriented policy, where issues of social needs, including poverty reduction, are gradually coming to the forefront of the country's plans.

Despite the importance of human capital, the field of regional disparities in demographic and educational indicators in Kazakhstan has not been extensively explored, leaving a significant gap in the literature that necessitates more comprehensive studies. Given the rapid socio-economic changes and regional development disparities in Kazakhstan, there is a pressing need for studies that provide a nuanced understanding of these trends and their implications, especially since most existing research fails to account for the current socio-economic dynamics and regional specificities fully.

The significance of analyzing demographic indicators such as birth rates, migration balances, and population growth has become increasingly evident in recent years. These indicators provide critical insights into the population dynamics influencing labor market conditions and socio-economic stability. Migration patterns, in particular, play a crucial role in shaping the demographic landscape, as they affect the size and composition of the workforce and, consequently, the economic potential of regions.

Equally important are employment trends, which are vital in understanding regional disparities. Employment rates, labor force participation, and employment structure (formal vs. informal) are key indicators of economic health and social well-being. Higher employment rates are typically associated with better socio-economic outcomes, including higher income levels, improved health, and reduced crime rates. By analyzing these indicators, we can identify economically thriving regions and those that require targeted interventions to boost job creation and economic activity.

Additionally, educational attainment is another critical dimension that significantly impacts regional development. Education

levels are directly linked to economic opportunities and social mobility, making them crucial to any comprehensive socio-economic analysis. Regions with higher levels of educational attainment, particularly at the tertiary level, tend to experience faster economic growth and innovation. Thus, assessing the distribution and outcomes of educational resources across regions is essential to develop strategies that enhance human capital and foster equitable growth.

The purpose of this study is to comprehensively analyze demographic and educational indicators by region of the Republic of Kazakhstan, identify key trends and differences, and determine the total weight of each region in the overall context. The study aims to identify regions with the greatest and least potential for development, which will allow for the development of recommendations to improve socio-economic conditions and level regional imbalances.

2. LITERATURE REVIEW

The field of regional disparities in demographic and educational indicators in Kazakhstan has not been extensively explored, leaving a significant gap in the literature that necessitates more comprehensive studies. Given the rapid socio-economic changes and regional development disparities in Kazakhstan, there is a pressing need for studies that provide a nuanced understanding of these trends and their implications, especially since most existing research fails to account for the current socio-economic dynamics and regional specificities fully.

Several studies focused on demographic indicators to analyze regional disparities. Demographic trends, such as birth rates, mortality rates, and migration patterns, are essential for understanding population dynamics and their impact on regional development. For instance, Fan (2002) utilized data from China's fifth population census to explore the effects of declining fertility rates on population growth, age composition, and household size at both national and regional levels. The study highlighted the growing demographic differences between eastern coastal regions and the interior, driven by migration and economic disparities (Fan, 2002). Similarly, Matthews and Parker (2013) discussed the increasing integration of spatial data and methods in demographic research. Their work emphasized the importance of spatial econometrics, geographically weighted regression, multilevel modeling, and spatial pattern analysis in revealing local variations in demographic processes. This spatial perspective allows for a more nuanced understanding of regional demographic differences and their implications for policy and planning (Matthews & Parker, 2013). Moreover, Donner and Rodríguez (2008) examined the demographic shifts in the United States and their influence on disaster vulnerability. They argued that population growth, migration, and urbanization have heightened exposure to natural and technological disasters. The study underscored the necessity of considering demographic composition and distribution in disaster risk assessments to enhance community resilience. Yenilmez (2015) highlights the impact of declining fertility rates and increasing longevity on the aging population, subsequently affecting the labor market. A decline in the young working-age population lowers the labor force participation rate and increases the proportion of retired individuals. Governments often consider raising the retirement age to mitigate labor shortages. Similarly, Rees et al. (2012) discussed how Europe was experiencing an aging population and slowing population growth, which led to a decline in the labor force in many regions. Thus, the role of demographic factors in assessing regional development potential is crucial.

Conversely, other researchers emphasize the negative aspects of demographic imbalances. Scientists pointed out that regions with declining birth rates and high emigration rates are challenged in maintaining economic stability and public services, emphasizing that these regions are at risk of population aging,

which can strain healthcare systems and pension schemes. Gu et al. (2021) emphasized that regions are at risk of population aging, which can strain healthcare systems and pension schemes. Moreover, they noted that declining fertility and increasing longevity are leading to an aging world population, which impacts household sizes and increases the need for migration to balance demographic shifts. Bloom and Luca (2016) discussed the global phenomenon of population aging and its significant implications for employment, savings, consumption, economic growth, asset values, and fiscal balance. They highlighted that the aging population could lower labor force participation and savings rates while increasing health expenditures and straining pension and healthcare systems. Davoudi et al. (2010) explored the future scenarios for Europe's demographics, presenting the 'silver century' and 'open borders'. Based on current trends, the 'silver century' scenario indicates continued aging and limited immigration, leading to potential social and spatial segregation. The 'open borders' scenario involves active immigration policies, potentially addressing demographic imbalances and creating challenges in managing social and spatial integration. Both scenarios underlined the importance of policy interventions in managing demographic changes and their socio-economic impacts. Sobotka et al. (2011) analyzed the effects of economic recessions on fertility in developed countries, noting that economic downturns often lead to declining birth rates and delays in childbearing. They emphasized that economic uncertainty and rising unemployment influence fertility behavior, impacting long-term demographic trends. Thus, demographic decline can lead to a shrinking labor force, further exacerbating economic disparities between regions, thus illustrating the critical role of demographic indicators in understanding regional socio-economic health.

Employment is another crucial aspect analyzed by various scholars to understand regional disparities. For instance, Ren et al. (2020) found that while the Northeast China Revitalization Strategy significantly improved regional economic growth and per capita income, it did not significantly enhance regional employment, infrastructure, education investment, or social security and did not mitigate regional disparity. This suggests that the strategy's effects are highly heterogeneous across cities based on their size and characteristics, emphasizing the need for tailored approaches focusing on R&D and human capital investments to prevent technological lock-in. Nurlanova et al. (2019) explored disparities in social and economic development across regions of Kazakhstan. They emphasized the importance of measuring disproportions between economic and social development levels to ensure inclusive development and improve the quality of life. Their study highlights the necessity of targeted regional programs and management decisions to support backward regions, thus ensuring social justice and reducing inequality. Kumar et al. (2020) examined macro-level disparities in India, highlighting significant regional inequalities regarding NSDP, per capita income, HDI, work participation rates, and wages. They found that regions with higher employment rates tend to have better socio-economic outcomes, including higher income levels, better health outcomes, and lower crime rates. Their study underscores the critical need for policy interventions to address these disparities and promote balanced regional development.

Regions with higher employment rates tend to have better socio-economic outcomes, including higher income levels, better health outcomes, and lower crime rates. For example, Hajkowicz et al. (2011) analyzed the relationship between quality-of-life indicators and the gross value of mineral production in Australian regions. They found that mining activity positively impacts incomes, housing affordability, communication access, education, and employment. However, they noted the need to understand and mitigate localized social inequalities and disadvantages. Cairns et al. (2017) systematically reviewed the association between area-level socioeconomic

disadvantage and inequalities in suicidal behavior and self-harm in Europe. They found strong evidence linking high levels of socioeconomic disadvantage with increased risks of suicidal behavior, particularly for men, indicating the critical need for targeted suicide prevention strategies that consider regional socio-economic contexts. Pittau et al. (2010) investigated the role of economic variables in predicting regional disparities in life satisfaction across European Union regions. They found that personal income has a more significant impact on life satisfaction in poorer regions than in richer ones. Unemployment was negatively associated with life satisfaction regardless of regional unemployment levels, highlighting the persistent regional differences in life satisfaction even after accounting for individual characteristics.

Educational attainment is another critical dimension that has been extensively studied in the context of regional disparities. It indicates that regions with higher educational attainment tend to experience faster economic growth and innovation. A well-educated workforce is more adaptable and capable of driving technological advancements and productivity improvements.

Mardenova (2020) examined the importance of developing self-learning skills among school children in Kazakhstan, highlighting the role of these skills in enhancing human capital and promoting socio-economic development. In a similar vein, Baituova et al. (2024) explored the challenges and opportunities associated with human resources development in the context of Kazakhstan's industrial and innovative economy, discussing the critical role of human capital in driving economic growth and competitiveness. They emphasize the need for strategic investments in education, training, and skills development and highlight specific issues faced by the workforce, such as skill mismatches and the rapid pace of technological advancements, proposing policy recommendations to address these challenges and enhance the country's human resource potential. Extending this discourse to the forestry sector, Kirillov et al. (2024) investigated the current status, potential, and human resources problems in Kazakhstan's forestry sector. Their analysis reveals critical issues such as skill shortages, inadequate training programs, and limited professional development opportunities while also exploring the potential for improvement through targeted education and policy interventions. The study underscores the necessity of a strategic approach to addressing these challenges and leveraging the sector's potential for sustainable development.

Lambrechts et al. (2020) investigated the socioeconomic policies, technical focus, and academic necessities essential for developing core competencies and skills in emerging markets to prepare for the technological disruption of the Fourth Industrial Revolution (Industry 4.0). They emphasized the importance of higher education in skill development, particularly for countries like Brazil, Russia, India, China, and South Africa. Spiel et al. (2018) highlighted the multifaceted role of education in promoting social progress. They argued that education fosters humanistic, civic, economic, and social equity purposes, contributing to better knowledge, health, living conditions, social equity, and productivity. The authors stressed the importance of expanding access to quality early childhood education, improving school quality, enhancing the role of educators, and making higher and vocational education more inclusive. They also advocated for the appropriate use of digital technologies to improve the quality and relevance of education, thereby supporting social progress (Spiel et al., 2018). Efe (2023) examined the strategic role of human capital in developing organizational capabilities, emphasizing the importance of highly qualified human resources in improving companies' productivity and achieving strategic goals. He noted that continuous innovation and new products are essential for economic growth, and human capital development is critical for maintaining a competitive advantage.

While each of these sets of indicators—demographic, employment, and educational—provides valuable insights on its own, a

comprehensive analysis requires integrating these dimensions to understand their relationship and combined impact on regional development.

While existing studies provide valuable insights into the individual dimensions of regional disparities, there is a clear need for comprehensive analyses that integrate demographic, employment, and educational indicators. This approach can better capture the complexities of regional development and inform more effective policy interventions. Our study addresses this gap by combining these critical indicators to provide a holistic assessment of regional disparities in Kazakhstan. The results highlight the importance of considering multiple dimensions to understand and address the underlying causes of regional inequalities and promote sustainable socio-economic development.

3. METHODOLOGY

To achieve the study's objectives, a comprehensive quantitative data analysis was employed. This involved the systematic collection, processing, and analysis of statistical information pertaining to the regions of Kazakhstan over the period from 2009 to 2022. The analysis focused on key indicators essential for assessing demographic and educational trends across the regions. The selected indicators and their relevance to the study are outlined as follows:

1) Number of high school graduates: the indicator reflects the number of students who graduated from high school in each region during the study period. This indicator is essential for assessing young people's preparation level for admission to higher education institutions.

2) Number of graduates of higher education organizations: the indicator reflects the number of students who graduated from higher education institutions in each region during the study period. It is key to assessing the region's educational potential and contribution to the training of highly qualified specialists.

3) Migration balance: the indicator reflects the difference between the number of immigrants and emigrants in each region during the study period. A positive migration balance value indicates an influx of population into the region, while a negative value indicates an outflow of population. This indicator is essential for understanding migration trends and their impact on the socio-economic development of the regions.

4) Birth rate: the indicator is expressed as the number of births per 1000 population in each region during the period under study. The birth rate is essential for assessing each region's demographic situation and population growth potential.

The regional shares were calculated and expressed as a percentage of the national values for each of the above indicators. These shares were then aggregated to obtain each region's total weight, which made it possible to determine their contribution to the national demographic and educational indicators. Thus, the stages of the study can be seen more clearly in Figure 1.

Based on a comprehensive literature review, key indicators were identified for analyzing regional disparities in demographic and educational data. These indicators include the number of high school graduates, the number of university graduates, migration balance, and birth rate. These indicators are commonly used in research to assess the socio-economic development of regions.

This study, however, adopts a more comprehensive approach by aggregating the shares of all indicators to obtain an overall weight for each region. This allows for a more precise determination of each region's contribution to national demographic and educational statistics and helps identify regions with the highest and lowest development potential. The critical indicators analyzed include the number of high school graduates, the number of university graduates, migration balance, and birth rate. The data were structured and normalized to ensure comparability between regions and years.

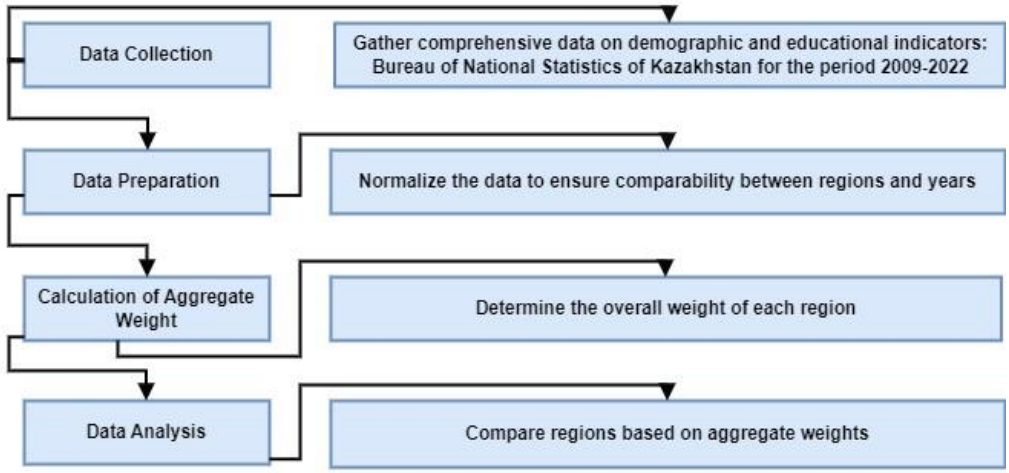

FIGURE 1. Research stages

Note: compiled by authors

4. FINDINGS AND DISCUSSION

The heatmap presents the normalized values of various socioeconomic indicators in Kazakhstan from 2009 to 2022. The indicators include birth rate, population, number of immigrants and emigrants, unemployment rate, workforce size, number of high school and university graduates, number of employed individuals, hired workers, self-employed individuals, and the aggregate weight of these indicators (Figure 2).

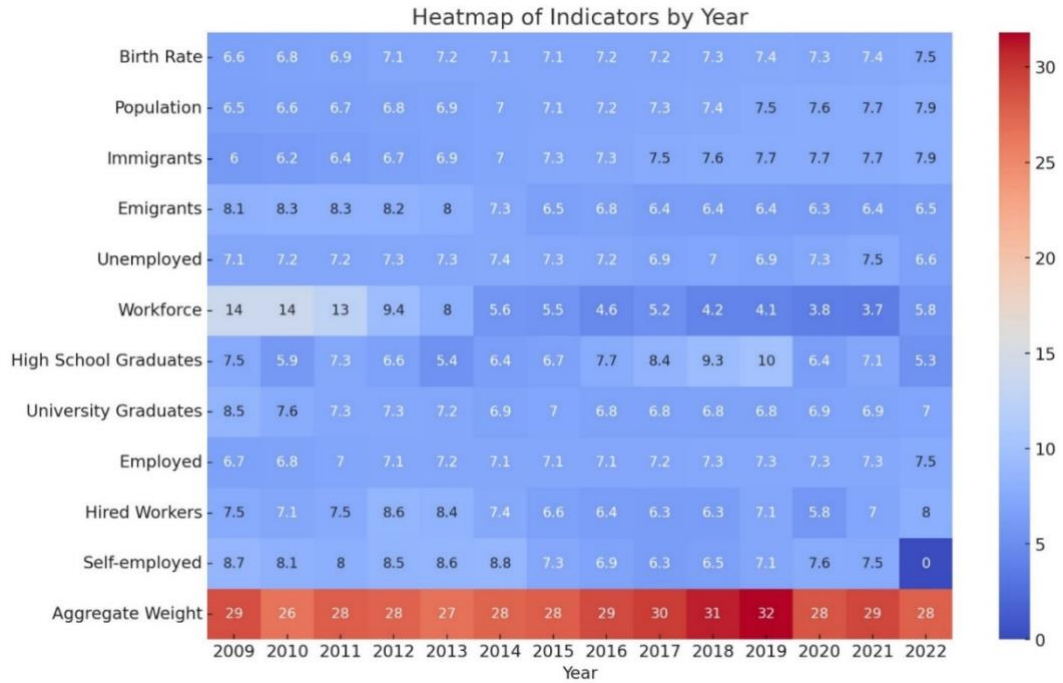

FIGURE 2. Heatmap of indicators, 2009-2022

Note: compiled by authors

Key observations from the heatmap are as follows: The birth rate has shown a steady increase from 6.6% in 2009 to 7.5% in 2022, reflecting a consistent rise in birth rates over the years. Similarly, the population percentage has increased from 6.5% in 2009 to 7.9% in 2022, indicating a growing population. This indicates demographic growth driven by improved living conditions and healthcare. The percentage of immigrants has grown from 6.0% in 2009 to 7.9% in 2022, suggesting a rise in immigration, while the percentage of emigrants decreased from 8.1% in 2009 to 6.5% in 2022, showing a trend of reduced emigration. The unemployment rate remained relatively stable, with slight fluctuations, from 7.1% in 2009 to 6.6% in 2022. However, the size of the workforce saw a significant drop from 13.8% in 2009 to 5.8% in 2022.

Education indicators showed mixed results. The number of high school graduates fluctuated, peaking at 10.0% in 2019 and dropping to 5.3% in 2022. The percentage of university graduates remained relatively stable, around 7%, with minor fluctuations. Employment rates increased from 6.7% in 2009 to 7.5% in 2022, indicating positive trends in job creation and economic activity. The number of hired workers varied, peaking at 8.6% in 2012 and 8.0% in 2022, while the percentage of self-employed individuals fluctuated significantly, reaching 8.8% in 2014 and dropping to 0% in 2022. The aggregate weight of all indicators showed an overall increase from 28.7% in 2009 to a peak of 31.8% in 2019, followed by a decline to 27.8% in 2022.

The heatmap and correlation matrix in Figure 3 illustrate the normalized values and interrelationships of various socio-economic indicators in Kazakhstan from 2009 to 2022.

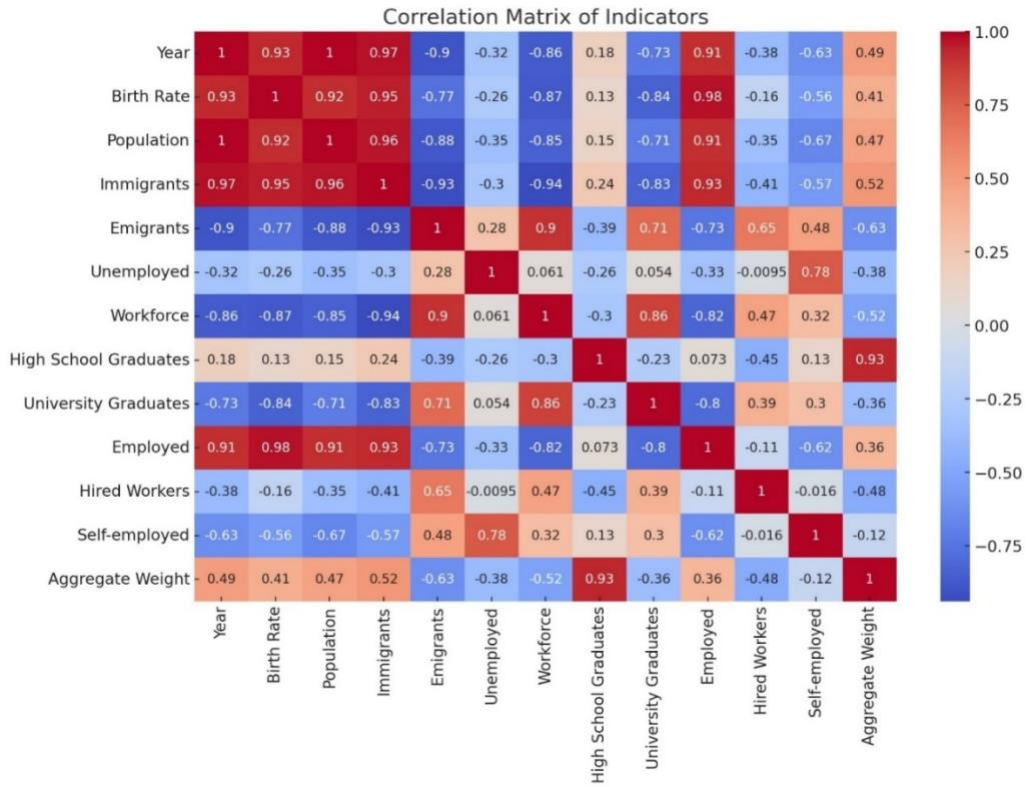

FIGURE 3. Correlation matrix of indicators, 2009-2022

Note: compiled by authors

The indicators include birth rate, population, number of immigrants and emigrants, unemployment rate, workforce size, number of high school and university graduates, number of employed individuals, hired workers, self-employed individuals, and the aggregate weight of these indicators.

The correlation matrix illustrates the interrelationships of various socioeconomic indicators in Kazakhstan from 2009 to 2022. Key observations from the matrix are as follows:

1) Significant Reduction in Workforce Size. The workforce significantly dropped from 13.8% in 2009 to 5.8% in 2022.

2) The decrease in emigration rates from 8.1% in 2009 to 6.5% in 2022 suggests fewer individuals are leaving the country. However, those who emigrate may predominantly be working-age individuals, reducing the workforce size.

3) Fluctuations in the number of high school and university graduates could indicate a mismatch between education outcomes and labor market needs, potentially leading to underemployment or unemployment.

4) Relationship Between Emigration and Unemployment. The scatter plot comparing emigrants to unemployed individuals shows no clear trend, suggesting that emigration may not directly influence unemployment rates.

However, other underlying factors could explain this relationship:

1) Improved economic conditions and job creation could stabilize unemployment rates despite changes in emigration.

2) Some emigrants may return with enhanced skills and experiences, contributing positively to the labor market and mitigating unemployment.

3) A heatmap and a correlation matrix visualize the relationships between various socioeconomic indicators. For example, a positive correlation between birth rates and population highlights demographic growth. At the same time, the relationship between the number of employed workers and self-employed individuals reflects changes in employment structure.

Next, in Figure 4 there are provided results for scatter plot.

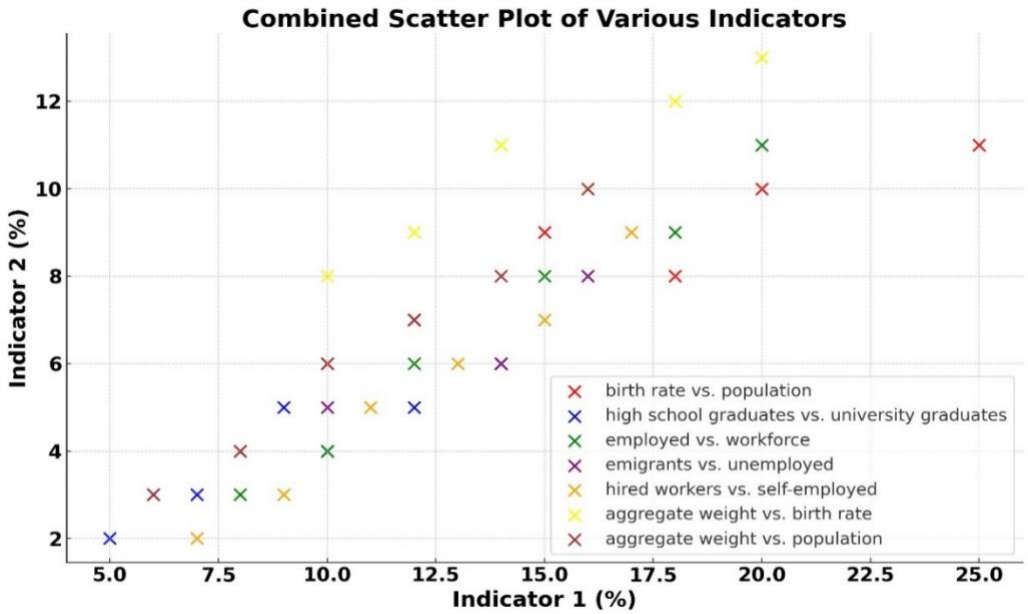

FIGURE 4. Scatter plot, 2009-2022

Note: compiled by authors

The scatter plot presents a detailed examination of various socioeconomic indicators across regions from 2009 to 2022. It reveals notable patterns and correlations that warrant closer analysis to understand regional disparities and their implications for economic policy. The relationship between the birth rate and population, as indicated by the red markers, demonstrates a positive correlation. For instance, regions with higher populations, such as those with values between 15% and 25%, tend to exhibit higher birth rates, ranging from 10% to 12%. Such a trend could be attributed to the demographic structure where larger populations include more women of childbearing age. Additionally, these regions may have better access to healthcare facilities, enhancing maternal and child health services and supporting higher birth rates.

There appears to be a lack of direct correlation between high school graduates and university graduates (blue markers). The data shows that regions with high school graduates with percentages around 5% to 10% do not necessarily translate to similar percentages in university graduates, which vary widely between 2% and 6%. This observation highlights the regional variations in access to higher education. Factors contributing to this discrepancy may include socioeconomic status, availability of higher education institutions, and regional economic opportunities. Policymakers must address barriers to continuing education to ensure that high school graduates can pursue higher education.

The scatter plot also illustrates the relationship between employed individuals and the workforce (green markers), showing a strong positive correlation. The workforce percentages, ranging from 5% to 18%, are closely aligned with the employment figures within the same range. This alignment reflects the economic activity and labor market dynamics within those regions. The correlation between emigrants and unemployed (purple markers) is more complex. Some regions with high unemployment rates, around 6% to 8%, also exhibit high emigration rates, between 8% and 12%, indicating that lack of local job opportunities drives individuals to seek employment elsewhere. This pattern underscores the importance of job creation and economic development in retaining the local workforce and preventing brain drain.

The relationship between hired workers and self-employed individuals (orange markers) reveals varying trends. In some regions, a higher number of hired workers corresponds with fewer self-employed individuals, with percentages ranging from 7% to 12% for hired workers and 2% to 6% for self-employed. This variation may reflect regional economic structures where formal employment opportunities are more prevalent in some areas, while others rely more on entrepreneurial activities and self-employment as economic alternatives. The aggregate weight versus birth rate (yellow markers) and aggregate weight versus population (brown markers) indicate positive correlations. Regions with higher aggregate weights, which denote overall economic activity, tend to have higher birth rates and larger populations. For example, regions with aggregate weights around 100% to 400% exhibit birth rates between 10% and 12% and populations between 15% and 25%. This relationship suggests that better economic conditions and higher economic activity support larger family sizes and population growth. These regions likely benefit from improved living standards, healthcare, and social services, contributing to their demographic growth. From an economic perspective, these findings highlight significant regional disparities that necessitate targeted policy interventions. Regions with higher populations and economic activities demonstrate better socioeconomic outcomes, benefiting from economies of scale, infrastructure investments, and resource availability. Conversely, regions with lower economic indicators face challenges that hinder development and require focused efforts to improve access to education, healthcare, and employment opportunities. The observed discrepancies between high school and

university graduates point to the need for policies that enhance access to higher education. Providing financial support, improving educational infrastructure, and ensuring equitable opportunities for further education can help bridge this gap. Similarly, addressing high unemployment rates through job creation and economic diversification can mitigate the push factors driving emigration and support local economic stability.

Overall, the scatter plot underscores the importance of understanding regional socioeconomic dynamics to inform effective policy-making. By addressing the unique needs of each region and promoting inclusive economic development, policymakers can reduce inequalities and foster sustainable growth, ensuring that all regions benefit from improved socioeconomic conditions. The aggregate weight plotted against the birth rate and population underscores overall socioeconomic development, peaking at 31.8% in 2019 before declining to 27.8% in 2022. This aggregate measure combines multiple indicators to comprehensively view socio-economic trends.

Analyzing the age structure of Kazakhstan's population from 2009 to 2022 is essential for understanding demographic trends and developing socio-economic development strategies (Figure 5).

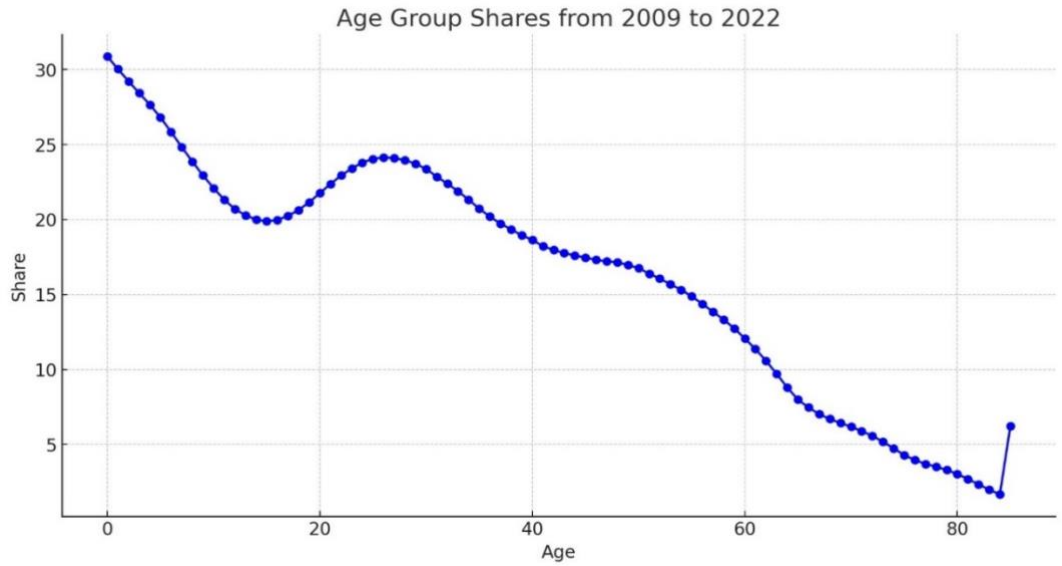

FIGURE 5. Age group (0-85+) share, 2009-2022

Note: compiled by authors

The graph illustrates the shares of different age groups in the population of Kazakhstan from 2009 to 2022. The highest share of the population is seen in the 0-9 years age group, with shares starting at 30,87% for age 0 and gradually decreasing to 22,1% by age 10; the age groups from 11 to 19 show a steady decline from 21,32% at age 11 to 21,15% at age 19, The working-age population (20-60 years) experiences a gradual decrease, starting at 21,76% for age 20 and dropping to 12,07% for age 60, The elderly population (65+ years) shows a significant decrease in share, with 7,99% at age 65 and reaching as low as 1,67% at age 84. However, there is a noticeable spike to 6,25% in the 85+ age group,

An overview of the age distribution in Kazakhstan's population over 13 years highlights a youthful demographic, which could imply a high birth rate and potential for future population growth. This age group starts with the highest share of 30.87% for newborns and decreases to 22.1% by age 10, indicating a typical age progression with a decrease in share

as age increases. The working-age population, aged 20 to 60, demonstrates a gradual decline. At age 20, the share is 21.76%, which diminishes to 12.07% by age 60. This decline suggests a stable working-age population that slowly transitions into retirement age. The elderly population, particularly those aged 65 and above, shows a sharp decrease in population share. The share drops consistently from 7.99% at age 65, reaching 1.67% at age 84. Interestingly, the share rises again to 6.25% for those aged 85 and older, indicating a notable portion of the population living beyond 85 years. This could suggest improved healthcare and living conditions, leading to increased longevity.

An analysis of the age structure of the population is also important for understanding demographic trends. The young demographics, expressed by a high birth rate and a significant proportion of children under 9 years of age, indicate the potential for future population growth. The aging population (65+ years), although a smaller share of the total, still shows an increasing proportion of older people over 85 years of age, which may indicate an improvement in living conditions and life expectancy. These aspects highlight the importance of adapting economic and social policies to account for demographic changes and labor market trends in Kazakhstan.

The results of normalized values indicate several significant socioeconomic trends in Kazakhstan. The increase in birth rate and population percentage suggests a growing population, indicative of improved living conditions and healthcare services. This demographic trend is further supported by the rise in the number of immigrants and the decline in the number of emigrants, pointing towards Kazakhstan becoming a more attractive destination for living and working.

The relatively stable unemployment rate suggests that the job market has been able to absorb the growing population. However, the significant drop in the workforce percentage raises questions about labor market dynamics. This decline could be attributed to various factors, including an aging population, changes in labor force participation, or shifts towards more informal or self-employment sectors.

Education indicators, such as the number of high school and university graduates, have shown fluctuations. The peak in high school graduates in 2019 and the stability in university graduates, around 7%, indicate efforts toward improving educational attainment. However, the decline in the number of high school graduates in recent years might be an area of concern for future workforce readiness.

The employment rate has increased, showing a positive job creation and economic activity trend. The variations in the number of hired workers and self-employed individuals reflect changes in the employment structure, possibly influenced by economic policies, market conditions, and shifts toward entrepreneurship. The overall increase in aggregate weight up to 2019 suggests socioeconomic development, but the decline in recent years highlights emerging challenges that need to be addressed to sustain growth.

The results of the correlation analysis indicated several significant socioeconomic trends in Kazakhstan. The increase in birth rate and population percentage suggests a growing population, indicative of improved living conditions and healthcare services. This demographic trend is further supported by the rise in the number of immigrants and the decline in the number of emigrants, pointing towards Kazakhstan becoming a more attractive destination for living and working.

The relatively stable unemployment rate suggests that the job market has been able to absorb the growing population. However, the significant drop in the workforce percentage raises questions about labor market dynamics. This decline could be attributed to various factors, including an aging population, changes in labor force participation, or shifts towards more informal or self-employment sectors.

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These visualizations provide valuable insights into Kazakhstan's socioeconomic landscape over the past decade. The increasing birth rate and population growth, from 6.6% and 6.5% in 2009 to 7.5% and 7.9% in 2022, respectively, indicate demographic expansion and potentially improved living standards. The stability in educational attainment, seen in the steady percentage of university graduates, around 7%, points to sustained efforts in higher education. Employment trends, such as the increase in employed individuals from 6.7% to 7.5%, highlight the effectiveness of job creation policies and economic activities in absorbing the growing workforce.

However, the lack of a clear trend between emigrants and unemployment rates suggests that other macroeconomic factors or regional disparities may influence these indicators. The employment structure's variability, reflected in the hired workers and self-employed scatter plot, indicates ongoing shifts in the labor market, possibly influenced by economic reforms, market conditions, and entrepreneurial activities. The overall increase in aggregate weight up to 2019 suggests socioeconomic development, but the decline in recent years highlights emerging challenges that need to be addressed to sustain growth.

In conclusion, the combined analysis of these indicators offers a comprehensive understanding of Kazakhstan's socioeconomic trends. Policymakers and stakeholders can leverage these insights to address challenges, such as workforce participation and employment structure while capitalizing on opportunities for demographic and educational improvements. This holistic view is essential for formulating strategies to foster sustainable socioeconomic development in the region.

The significant share of the 0-9 years age group highlights a youthful demographic, which could imply a high birth rate and potential for future population growth. This age group starts with the highest share of 30,87% for newborns and decreases to 22,1% by age 10, indicating a typical age progression with a decrease in share as age increases.

The working-age population, aged 20 to 60 years, demonstrates a gradual decline. At age 20, the share is 21,76%, which diminishes to 12,07% by age 60. This decline suggests a stable working-age population that slowly transitions into retirement age. The elderly population, particularly those aged 65 and above, shows a sharp decrease in population share. The share drops consistently from 7,99% at age 65, reaching 1,67% at age 84. Interestingly, the share rises again to 6,25% for those aged 85 and older, indicating a notable portion of the population living beyond 85 years. This could suggest improvements in healthcare and living conditions, leading to increased longevity. The high share of young children necessitates the expansion of educational facilities such as schools and kindergartens to accommodate the growing number of young students. The noticeable share of the elderly population, particularly the spike in the 85+ age group, underscores the need for enhanced healthcare services, nursing homes, and social programs to support the aging population. The substantial working-age population points to a stable labor force, requiring policies that focus on employment opportunities, vocational training, and workforce development to harness the economic potential of this demographic, The increasing number of elderly individuals necessitates robust pension schemes and social security measures to ensure financial stability and well-being for the retired population.

5. CONCLUSIONS

An analysis of the availability of medical services in rural areas shows that its level depends on many factors. The most significant component of this problem is the medical institutions' network and staffing. Unfortunately, the downsizing trend of hospitals and outpatient clinics in rural areas is not abating. Of course, this contributes to the aggravation of the already difficult situation of rural residents. Increasing accessibility and improving the quality of medical services are the most critical factors influencing the life expectancy of the rural population (as well as the urban population). In addition, they are a primary condition for ensuring the principle of social equality in the realization of the right of every citizen to life and health care.

The primary goal of this study was to conduct a comprehensive analysis of demographic and educational indicators across regions of Kazakhstan, identifying key trends and disparities and determining each region's overall contribution. This goal was successfully achieved through the use of a detailed heatmap and correlation matrix, which provided valuable insights into Kazakhstan's socio-economic landscape from 2009 to 2022.

The heatmap revealed a consistent increase in the birth rate, indicating improved living conditions and healthcare services. Similarly, the population percentage grew, reflecting demographic expansion. There was also an increase in the percentage of immigrants, while the percentage of emigrants decreased, suggesting that Kazakhstan has become a more attractive destination for living and working. Employment rates showed a positive trend, but the workforce size significantly dropped, indicating shifts in labor market dynamics. Educational attainment showed variability, with the number of high school graduates peaking in 2019 and then declining, while the percentage of university graduates remained stable.

The correlation matrix provided insights into the interrelationships between various socio-economic indicators. A strong positive correlation between the birth rate and population growth was observed, indicating demographic expansion driven by improved living conditions. The matrix also highlighted the relationship between high school and university graduates, showing a generally positive correlation but with fluctuations indicating variability in educational attainment. Employment indicators exhibited a strong relationship, suggesting effective job creation policies. At the same time, the lack of a clear trend between emigrants and unemployment rates pointed to the influence of other macroeconomic factors.

Based on the analysis, several conclusions and recommendations can be drawn. The increasing birth rate and population growth suggest the need for continued investment in healthcare and living conditions to sustain this positive trend. Policy measures should focus on maintaining and enhancing the attractiveness of Kazakhstan as a destination for immigrants while addressing factors contributing to emigration. The fluctuations in high school graduate numbers highlight the need for targeted educational policies to ensure consistent preparation of students for higher education. Stable university graduate rates indicate the importance of maintaining and improving higher education standards to support the development of highly qualified specialists.

The positive trend in employment rates should be supported by policies aimed at expanding job opportunities, particularly in regions with declining workforce sizes. Vocational training and workforce development programs are essential to address the shifts in labor market dynamics and ensure a stable working-age population. The noticeable share of the elderly population, particularly those aged 85 and above, underscores the need for enhanced healthcare services, nursing homes, and social programs to support this demographic.

The analysis is based on available statistical data from 2009 to 2022, and any gaps or inaccuracies in the data may affect the conclusions drawn. While the analysis provides

a comprehensive overview, regional disparities may require more granular analysis to develop tailored policy recommendations. Additionally, the socio-economic landscape is dynamic, and factors such as economic policies, market conditions, and global trends can influence the indicators studied. Continuous monitoring and adaptation of strategies are necessary to address these changes effectively.

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The Role of Digital Technologies in Promoting Gender Equality in Kazakhstan

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ABSTRACT

The dynamics of digital technologies affect the economy and society, opening up new opportunities and prospects for promoting gender equality in the workplace. The aim of this paper is to explore the role of digital technologies in promoting gender equality, assess their impact on various aspects of women's lives, and identify the main challenges and prospects associated with their use. The study employs a mixed-methods approach, including secondary data analysis, surveys, and case studies, to assess the impact of digitalization on women's employment and professional development. Special attention is paid to comparing the results of countries in international rankings, which allows us to identify the most successful practices and general trends. Despite the measures taken by Kazakhstan to ensure gender equality in areas such as digitalization and the successes achieved, it is still being revealed that there are many inequalities in the labor market of Kazakhstan. Surveys conducted among 174 respondents (59.7% women) revealed that 55.7% believe digital technologies can reduce gender discrimination in the labor market, and 56.3% recognize the contribution of digital labor to gender equality. Findings suggest that digital platforms enhance women's participation in the labor market, offering flexible work arrangements and professional growth opportunities. However, barriers such as limited access to digital education and persistent gender stereotypes still hinder women's full participation in the digital economy. The paper concludes with recommendations for policymakers to develop gender-focused digital strategies to ensure equitable access to digital resources and opportunities.

KEYWORDS: Digital Inequality, Gender Equality, Labour Market, Digital Economy, Sustainable Development, Gender Economics, Kazakhstan

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1. INTRODUCTION

In an era marked by rapid advancements in digital technologies and globalization, the transformation of all aspects of life becomes inevitable. One of the key areas where digitalization exerts a significant impact is gender equality. Despite notable improvements in the status of women in society over the past few decades, substantial gaps remain, particularly in employment, education, and managerial participation. In addition, digital technologies offer new opportunities to bridge gender disparities by providing access to information, education, and resources previously inaccessible to a significant portion of the population. Moreover, digital platforms and social networks are crucial in empowering women, offering them avenues for self-development, professional growth, and active participation in public life.

In Kazakhstan, digitalization occupies a central place in government policy, reflected in initiatives and programs aimed at modernizing the economy and improving the population's quality of life. In world practice, research on the impact of digitalization on gender equality is attracting more and more attention. For example, studies by the International Labour Organization (ILO) and the Organization for Economic Cooperation and Development (OECD) show that digitalization can serve as a tool to reduce the gender gap in employment and income, creating new jobs and expanding opportunities for women's professional development (ILO, 2015).

Nevertheless, Kazakhstan's labor market exhibits significant gender disparities: women are frequently employed in lower-paid, less stable sectors and have restricted access to senior positions and career resources. Digitalization offers a pathway to alter this landscape by generating flexible employment options such as remote work and freelancing. Yet, without incorporating gender-focused strategies, digitalization risks perpetuating or exacerbating existing inequalities. For instance, women's limited access to digital education and resources is a substantial barrier to their full participation in the digital economy.

Significant gender inequalities characterize Kazakhstan's labor market, women are often employed in lower-paid and less stable sectors of the economy, less often occupy senior positions and have limited access to resources and career opportunities (Yeralina et al., 2023). Digitalization can potentially change this situation by creating new jobs and providing flexible forms of employment, such as remote work and freelancing. However, without proper consideration of gender aspects, there is a risk that digitalization may reproduce or even exacerbate existing inequalities. For example, women's limited access to digital education and resources can significantly hinder their participation in the digital economy.

The aim of this paper is to explore the role of digital technologies in promoting gender equality, assess their impact on various aspects of women's lives, and identify the main challenges and prospects associated with their use. The article examines unique aspects, including the impact of digitalization on the development of gender equality in Kazakhstan, which distinguishes it from existing research. Special attention is paid to specific problems in Kazakhstan, such as women's limited access to digital technologies and education in rural areas, as well as the prevalence of gender stereotypes that hinder women's professional growth.

2. LITERATURE REVIEW

Gender equality has become a paramount issue in modern society, impacting various spheres such as education, employment, healthcare, and political participation. Digital technologies have emerged as potent tools in addressing gender disparities, offering innovative solutions to long-standing issues. Digitalization significantly impacts the labor market, creating opportunities for improving gender equality and challenges associated with achieving it. It is important to consider international and domestic research to understand key trends and barriers in this

context.

New digital technologies create opportunities by enhancing women's participation in the labor market and promoting their financial and digital inclusion, ultimately contributing to greater economic welfare (Frey & Osborne, 2017). The latest advancements in digital technologies, such as artificial intelligence, machine learning algorithms, cloud computing, and advanced robotics, hold significant potential to transform current labor markets (Rashid, 2016) radically. While the replacement of human labor by digital technologies can have disruptive effects, digitalization can also be transformative. For instance, when digital technology complements rather than replaces human labor, it can lead to positive spillovers and new employment opportunities in both traditional and entrepreneurial ventures (Fossen & Sorgner, 2019).

Digitalization has been a pivotal factor in job creation, improving working conditions, and enhancing opportunities for women's professional development. The ILO conducted research demonstrating that digital technologies contribute significantly to creating new jobs. For instance, the ILO's report asserts that digital technologies can help reduce the gender gap in employment and income (ILO, 2019). These technologies enable women to enter and thrive in sectors previously less accessible to them. Thus, Efobi et al. (2018) emphasized the importance of information technology in promoting gender inclusion within the formal economic sector. Information technology has facilitated the entry of women into formal employment by providing tools that enhance productivity, communication, and access to information.

Antonio and Tuffley (2014) examined the digital divide, focusing on the specific challenges women in developing countries face when accessing the Internet. The authors highlight potential benefits of increasing women's online activity, such as improved education, economic opportunities, and overall community development. Piroșcă et al. (2021) analyze the impact of digital skills on the labor market, especially in the context of the COVID-19 pandemic. They found that digital skills are crucial for rapid adaptation to market changes, with workers possessing these competencies adapting faster and having wages closely related to their skill level. Vasilescu et al. (2023) emphasize the importance of gender equality in the digital age, pointing out differences in Internet access and use by men and women in developing countries. Shah et al. (2024) study the impact of digital technologies on gender equality in the workplace. They examine how digitalization can both mitigate and exacerbate gender inequalities in employment, leadership opportunities, and work-life balance.

Krieger-Boden et al. (2018) highlighted gender differences in the coverage of the labor market, financial services and digital technologies that prevent women from taking advantage of opportunities in the digital age, leading to persistent gender inequality. Larsson et al. (2020) analyzed how digitalization affects women's prospects in the labor market. The article examines the relative shortage of women in Western countries studying science, technology, engineering, and mathematics (STEM). This, in turn, leads to a lower turnout of women working in jobs related to information and communication technologies.

Zhu et al. (2023) analyzed the impact of digitalization on the gender gap in labor force participation using panel data from G20 countries (2006-2021). They found that digitalization tends to narrow the gender gap, mainly in high-income countries, while the interaction between digitalization and globalization has little impact on this gap across the G20. Lu et al. (2023) studied the effect of the digital economy on women's employment using data from China's General Social Survey and online recruitment datasets. Their findings suggest that digitalization increases women's employment and supports egalitarian gender views. However, comprehensively improving the quality of women's employment is needed. While it increases professional status and job satisfaction for part-time women, it has

minimal impact on protecting workers' rights and reducing overtime.

Acilar et al. (2021) investigated ways to bridge the gender digital divide by introducing information and communication technologies (ICT). They found that women, especially in developing countries, still need to improve in terms of access to ICT despite the global growth in technology use. Filippi et al. (2023) analyzed how the institutional context related to gender equality affects the risk of replacing women's jobs in Europe with automation technologies. Owusu (2024) examined the impact of digitalization on work-life balance, highlighting the blurred boundaries between professional and personal spheres, especially for women who face inequality due to outdated gender norms and policies.

Digitalization, as a global process of transforming all aspects of society through the introduction of digital technologies, is an essential factor in determining social, economic, and cultural changes (Gribanov & Shatrov, 2019). A study by Kazakhstani scientists Turebekova et al. (2023) describes how digitalization transforms labor markets and online education's key role in providing the global workforce with the necessary skills. It highlights the accessibility, flexibility, and scalability of online learning platforms that are needed to address skill gaps and promote lifelong learning.

Based on the above, Table 1 provides a visual overview of the theories overview.

TABLE 1. The hierarchical relationships and details of each key area related to the impact of digitalization on gender equality

No.	Key areas and sub-nodes	Details and authors
1	Job creation & Professional development	Enhances productivity and communication (Efobi et al., 2018)
		New employment opportunities (Fossen & Sorgner, 2019)
2	Barriers & Labor market	Disruptive effects of automation (Rashid, 2016)
		Persistent gender inequalities (Krieger-Boden et al., 2018)
		STEM shortage (Larsson et al., 2020)
3	Digital divide & Access to ICT	Improved education and economic opportunities (Antonio & Tuffley, 2014)
		Challenges in developing countries (Acilar et al., 2021)
		Differences in Internet access (Vasilescu et al., 2023)
4	Gender equality policies	Impact on job displacement (Filippi et al., 2023)
		Narrowing the gender gap (Zi Hui Yin et al., 2023)

Note: compiled by authors

The literature review highlights the multifaceted impact of digitalization on gender equality across various domains, including labor markets, education, and social inclusion. Digital technologies have emerged as potent instruments for addressing gender disparities, possessing substantial potential to enhance women's labor force participation, foster financial and digital inclusion, and support professional development. Nevertheless, the digital gender divide persists, particularly in developing countries, as emphasized by Acilar et al. (2021) and Vasilescu et al. (2023). Despite the global increase in technology use, women continue to encounter substantial obstacles in accessing and utilizing digital tools. Current research underscores the significant potential of digitalization to advance gender equality in the labor market, while also revealing the necessity for an in-depth analysis of the specific barriers and opportunities encountered by women in the context of digital transformation. Policymakers must consider these factors when devising strategies aimed at reducing the gender gap and promoting equal opportunities for all within the digital labor market. The intersection of technology and gender necessitates a comprehensive approach that considers not only the provision of digital tools but also the

socio-economic and cultural contexts that influence women's access and usage.

3. RESEARCH METHODS

The study of digitalization's role in promoting gender equality in Kazakhstan's labor market employs an integrated approach, utilizing a variety of research methods. The primary objective of the methodology is to systematically collect and analyze data to identify existing trends and relationships between digitalization and gender equality in the labor market. Several research methods are utilized to achieve this purpose.

Secondary data analysis makes it possible to determine the level of digitalization and gender equality in the labor market in Kazakhstan using national and international databases, such as reports from the World Economic Forum and the International Labor Organization, as well as national statistical data. Secondary data helps to identify general trends and changes in these areas in recent years.

Surveys and Questionnaires. Surveys and questionnaires are conducted among various groups of respondents, including women and men working in different sectors of the economy. These surveys collect primary data on the impact of digitalization on employment and working conditions for women and men in Kazakhstan. Additionally, the surveys assess the level of digital skills, access to online education and training, and perceptions of gender equality in the workplace.

A sociological survey was conducted among the population of Kazakhstan using a questionnaire survey method. The total number of respondents was 174, with 63% living in urban areas and 37% in rural areas. The majority of respondents (59.7%) were women, and 40.3% were men. The age distribution of respondents as follows: less than 20 years - 4.4%, 20-29 years - 50%, 30-39 years - 22.2%, 40-49 years - 15.2%, 35-54 years - 16.7%, and 50 years and older - 1%.

Educational levels among respondents were: higher education - 84.8%, specialized secondary education - 12%, and secondary education - 3.2%. Employment status showed that 88.6% were employed, 3.1% were on maternity and unpaid leave, 7% were students, and 1.3% were unemployed. The sectoral distribution of respondents' employment was: education - 28.5%, public service - 25.8%, industry - 14.6%, medicine - 9.5%, financial sector - 12.7%, agriculture - 3.8%, IT - 2.5%, and art - 2.6%.

Next, Figure 1 shows a visualization of the survey data, which can help to better understand the distribution.

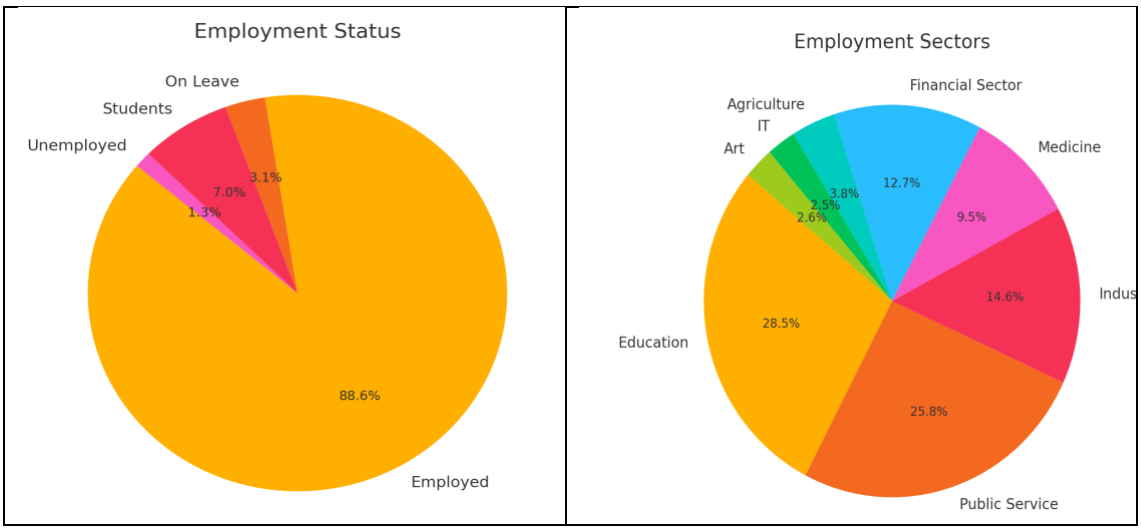

FIGURE 1. Employment status and employment sectors of respondents

Note: compiled by authors

In total, respondents were asked ten questions, including information about the benefits of digital technologies, the impact of digital technologies on the labor market, etc. The sociological survey was conducted from May to July 2024. The data was processed using the Visme program, which included several analytical methods to ensure accurate interpretation and meaningful information.

Case studies analyze specific cases and initiatives aimed at promoting digitalization and gender equality in various sectors of the economy of Kazakhstan. An integrated approach to the study of the role of digitalization in promoting gender equality in the labor market of Kazakhstan provides a deep and comprehensive analysis of the problem. The use of various methods helps to develop effective strategies and policies aimed at improving gender equality in the context of increasing digitalization.

4. FINDINGS AND DISCUSSION

The digital gender gap refers to differences between men and women in accessing, using, and acquiring digital skills in information and communication technologies (ICTs). This gap can manifest in differences in Internet access, ownership of digital devices, participation in online learning, and use of digital services. Such differences can exacerbate existing gender inequalities in society and the labor market, limiting the opportunities of women and girls in the digital age (Mariscal et al., 2019).

Like many other countries, Kazakhstan faces difficulties in achieving gender equality in the labor market. Despite progress in education and the legislative framework, significant gaps still need to be in employment, wages, and leadership positions. Traditional gender roles and stereotypes continue to influence career choices and opportunities, limiting women's participation in economic life.

Due to the lack of official statistics, Table 2 provides a detailed overview of the population's employment and the share of Internet and mobile phone users in Kazakhstan from 2019 to 2022 (includes forecast data from 2023 to 2027, divided by gender).

TABLE 2. Employment of the population and the leading ICT indicators of Kazakhstan by gender, %

Year	The employed population		The share of Internet users from the total population		Share of mobile phone users	
	Men	Women	Men	Women	Men	Women
2019	51,6	48,4	84,3	84,2	94,3	94,5
2020	51,7	48,3	88,5	88,0	95,9	95,8
2021	51,7	48,3	93,2	92,6	96,9	97,2
2022	52,0	48,0	93,8	94,2	97,1	97,3
2023*	52,0	47,9	98,2	98,4	98,0	98,3
2024*	52,2	47,8	101,5	101,8	98,7	99,2
2025*	52,3	47,7	104,9	105,2	99,4	100,0
2026*	52,5	47,5	108,2	108,7	100,1	100,8
2027*	52,6	47,4	111,5	112,1	100,9	101,7

Note: compiled by authors based on the data from the Bureau of National Statistics (2023)

In 2019, employment among men was 51.6%, among women - 48.4%. The share of Internet users among men was 84.3%, among women - 84.2%. Mobile phone users among men and women accounted for 94.3% and 94.5%, respectively. In subsequent years, there has been a gradual increase in these indicators.

For example, in 2022, employment among men is projected at 52.0%, among women - 48.0%. The share of Internet users among men and women will be 93.8% and 94.2%, respectively, and mobile phone users - 97.1% among men and 97.3% among women. Forecasts up to 2027 show a further increase in these indicators: employment among men will reach 52.6%, among women - 47.4%; the share of Internet users among men and women will be 111.5% and 112.1%, respectively; the share of mobile phone users among men and women will reach 100.9% and 101.7%.

Data forecasting from 2023 to 2027 was performed using prediction functions in Excel. The impact of digital indicators on employment is obvious: as the number of Internet and mobile phone users increases, employment increases. This may be due to the expansion of opportunities for remote work, access to information and training via the Internet, as well as the development of new technologies and sectors of the economy where digital technology skills are needed. Thus, digitalization plays an important role in changing the employment structure and contributes to an increase in the employment rate among both sexes, despite small differences in indicators.

In this regard, as a result of rapid technological development and the introduction of digital innovations in the labor market, new forms of flexible employment have become an integral part of the modern working environment. According to the changes that came into force on July 1, 2023, in accordance with the Social Code, innovative regimes are being introduced:

(1) Joint Employment: This approach involves hiring multiple employees to perform a function. This model opens up new prospects for cooperation and collaboration, leveraging the opportunities provided by digital technologies.

(2) Flexible Work Schedule: This allows for the flexible allocation of work hours on different days of the week. This format is especially beneficial for women, enabling them to more easily balance professional and personal responsibilities. Digital technologies can facilitate optimal time and task allocation.

(3) Four-Day Work Week: This regime allows the parties to agree on a shortened work week, which can help reduce gender pay gaps and provide a more flexible schedule for women, particularly mothers. Digital technologies support the planning of work processes in this model.

(4) Platform Employment: This work format, developed using digital platforms, offers opportunities for both primary and additional employment. The growth of this type of employment can increase women's participation in self-employment and enable the development of their own businesses through digital technologies (Adilet, 2023).

These innovative approaches are not only consistent with the dynamics of the labor market, but can also significantly contribute to improving gender equality by creating more flexible and equal conditions for men and women.

A country's digital competitiveness is determined by its ability to effectively use digital technologies to improve its economic and social infrastructure. The inclusion of such parameters as knowledge, technology and readiness for the future makes it possible to assess how ready a country is to integrate digital innovations into various sectors, including the labor market. Improving these indicators contributes to the development of gender equality, improving the skills of employees and creating new opportunities for all categories of the population.

Figure 2 shows the digital competitiveness ratings of Kazakhstan, the USA, the Netherlands, and Singapore from 2019 to 2023, covering four key categories: overall rating, knowledge, technology, and readiness for the future.

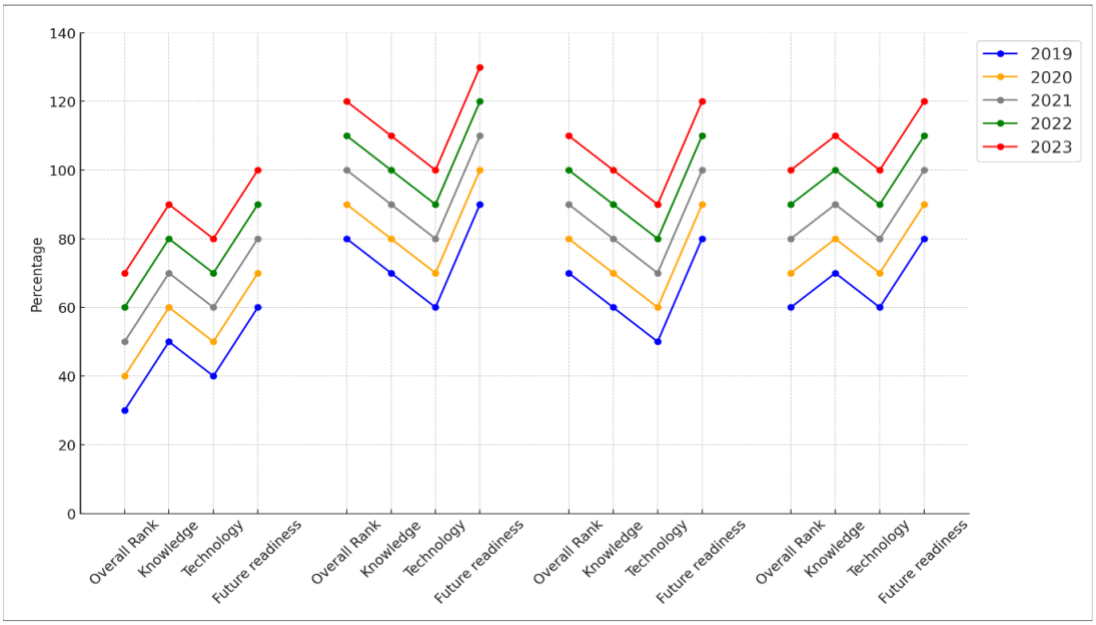

FIGURE 2. The place of the top 3 countries and Kazakhstan in the ranking of global digital competitiveness for the period 2019-2023

Note: compiled by authors based on the data from the IIMD (2023)

Data analysis shows that Kazakhstan still lags behind advanced countries in digital competitiveness, especially in aspects such as technology and readiness for the future. Kazakhstan's positions are consistently in the range of 30 to 40 places, which indicates a significant gap in digital competitiveness compared to the leading countries. Kazakhstan is experiencing the greatest difficulties in the categories of "Technology" and "Readiness for the future". This gap limits the opportunities for the effective use of digital technologies in the labor market. While the United States occupies a leading position in the ranking, which reflects its high digital competitiveness in all four categories. This contributes to more equal opportunities in the labor market, thanks to the active introduction of technology and a high level of readiness for future changes.

The Netherlands consistently performs well, especially in the Knowledge and Technology categories. Such digital competitiveness promotes equality in the labor market by providing equal opportunities for men and women to access advanced technologies and educational resources. Singapore also ranks high, especially in the Technology category. The high level of technological development and readiness for the future makes it possible to minimize gender gaps in the labor market by creating equal conditions for all employees. Digitalization plays a crucial role in promoting gender equality in the labor market, providing more significant opportunities for women in various sectors of the economy.

In Kazakhstan despite the progress in digitalization, women still need help accessing highly paid and technical professions. Insufficient digital literacy and limited access to modern technologies exacerbate gender disparities. In upper-middle-income countries such as Kazakhstan, the effect is less pronounced due to insufficient integration of digital technologies into educational and professional processes. To improve the situation, it is necessary to increase the level of digital literacy among women and encourage their participation in the technological sectors of the economy.

To achieve gender equality in the labor market, Kazakhstan needs to improve its

digital infrastructure and create conditions for equal access to technology. This will eliminate barriers and ensure equal opportunities for everyone, regardless of gender.

Figure 3 shows how changes in digital competitiveness correlate with the gender equality index in different countries.

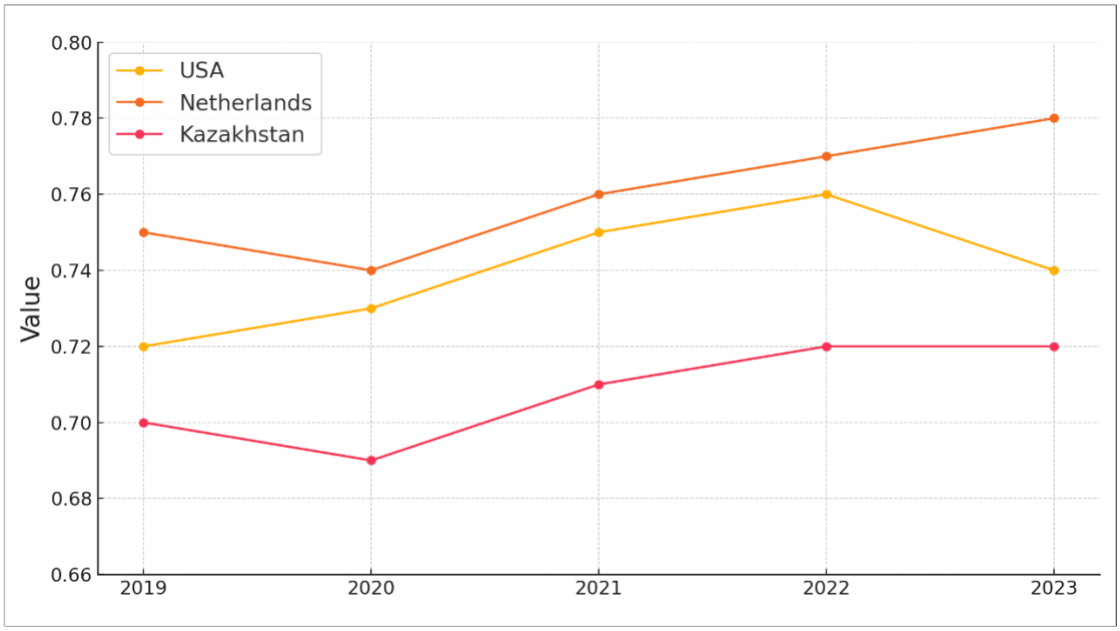

FIGURE 3. The place of the top 3 countries and Kazakhstan in the gender equality ranking for the period 2019-2023

Note: compiled by authors

The United States and the Netherlands show steady growth in both digital competitiveness and the gender equality index, while Kazakhstan shows slow progress in these areas.

Data shows that improved digital infrastructure and access to technology contribute to reducing the gender gap. A high level of digitalization allows for more equal access to educational and professional resources, improving women's employment and career prospects. Thus, the data and analysis confirm that the development of digital technologies and the improvement of digital competitiveness are essential factors in promoting gender equality in the labor market. Due to its low position in international rankings, Kazakhstan introduced digital technologies in employment. So, since July 2021, the Skills. Enbek's online vocational training platform operates in Kazakhstan, which is part of the digital ecosystem in the field of employment. The primary purpose of this platform is to create opportunities for continuous skill development and professional development of the entire population throughout their lives (Workforce Development Center, 2022).

Digitalization is represented by tools such as Skills. Enbek is crucial in promoting gender equality in Kazakhstan's labor market. Access to online education and vocational training allows women and men to develop new skills and competencies necessary for competitiveness in the labor market. This helps to reduce the gender gap, as women receive equal opportunities for education and career growth in various sectors of the economy. In addition, the flexibility of online education allows women to combine professional development with family responsibilities, which also contributes to

their employment and economic activity (Workforce Development Center, 2022).

Thus, the Skills. Enbek platform is an important digital tool that promotes gender equality in Kazakhstan's labor market, providing equal opportunities for lifelong learning and professional development for all population segments.

Figure 4 shows data on users of the Skills. Enbek Professional Online Learning Platform.

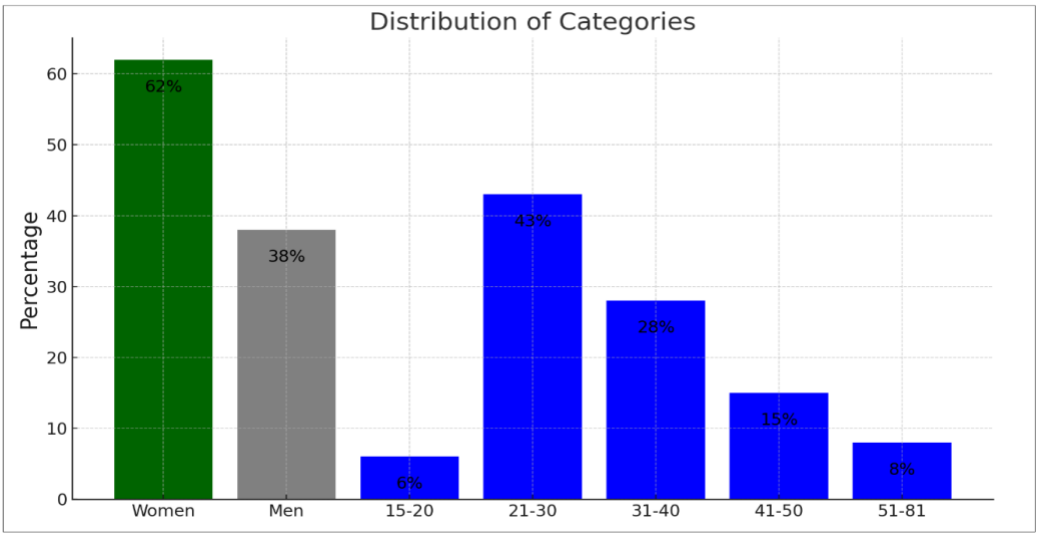

FIGURE 4. Distribution of respondents by gender and age, %

Note: compiled by authors based on the data from the Workforce Development Center (2022)

An analysis of data on platform users shows that women make up 62% of the total number of those who took courses, while men make up 38%. This indicates the significant participation of women in online learning and their desire to develop new skills, which helps to increase their competitiveness in the labor market. The age group division also demonstrates the diversity of participants: 6% are aged 15-20, 43% are 21-30, 28% are 31-40, 15% are 41-50, and 8% are 51-81. The majority of users are in the 21-30 age group, which indicates a high interest of young people in professional development through online training.

Digital tools such as Skills. Enbek promotes gender equality by providing access to educational resources and opportunities for all, regardless of gender and age. This allows women, who often face limitations in traditional education and employment, to develop the necessary skills and improve their professional qualifications, contributing to their economic independence and career growth. Moreover, the flexibility of online learning provides an opportunity to combine study with family responsibilities, which is especially important for women, who traditionally bear most of the responsibility for home and family.

Based on the above, Skills. Enbek not only increases the general level of professionalism of the population but also helps to reduce the gender gap in the labor market in Kazakhstan, creating a more inclusive and equitable working environment. According to the survey, 56.3% of respondents indicate that digital labor contributes to gender equality. Additionally, in response to the question, "Do you think that the introduction of digital technologies in the labor market can reduce gender discrimination?" 55.7% of respondents answered affirmatively, while 44.3% did not (Figure 5).

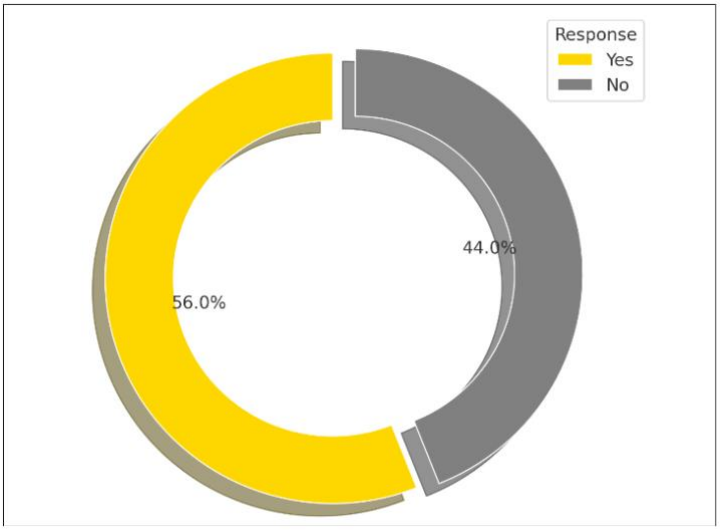

FIGURE 5. Distribution of responses regarding the impact of digital technologies on reducing gender discrimination in the labor market, %

Note: compiled by authors

Most respondents are optimistic about the potential of digital technology in reducing gender discrimination in the labor market, emphasizing its ability to make objective and effective decisions. However, a significant minority remains cautious, pointing to algorithm bias and transparency concerns. This highlights the importance of responsibly developing and implementing digital technology systems with a focus on fairness, accountability, and transparency to harness the potential of digital technology to promote gender equality in the labor market.

Figure 6 shows the results of a survey on the benefits of introducing digital technologies in the labor market.

Based on the data from the presented diagram, several conclusions can be drawn about the supposed benefits of using digital technologies to achieve gender equality in the labor market. The most significant advantage, noted by 42.4% of respondents, is that digital technologies can contribute to objective decision-making. This indicates a strong belief in their potential to reduce staff bias and increase fairness in workplace decision-making. Additionally, 24.1% of respondents believe digital technologies can help eliminate stereotypes and prejudices, fostering a more inclusive environment. Another 17.1% believe that digital technologies can expand access to employment opportunities, reflecting the potential benefits of online platforms and remote work options, especially for women with childcare responsibilities.

Furthermore, 13.9% of respondents believe that digital technologies can improve the efficiency of recruitment and promotion processes by utilizing digital tools and data analytics to optimize HR management functions. However, a small percentage of respondents (0.6% each) remain skeptical about the benefits of digital technology, indicating areas where further training and demonstration of benefits may be required.

Overall, these findings indicate that digital technologies are generally perceived positively as tools for promoting gender equality in the labor market, although some areas require continuous improvement and awareness-raising.

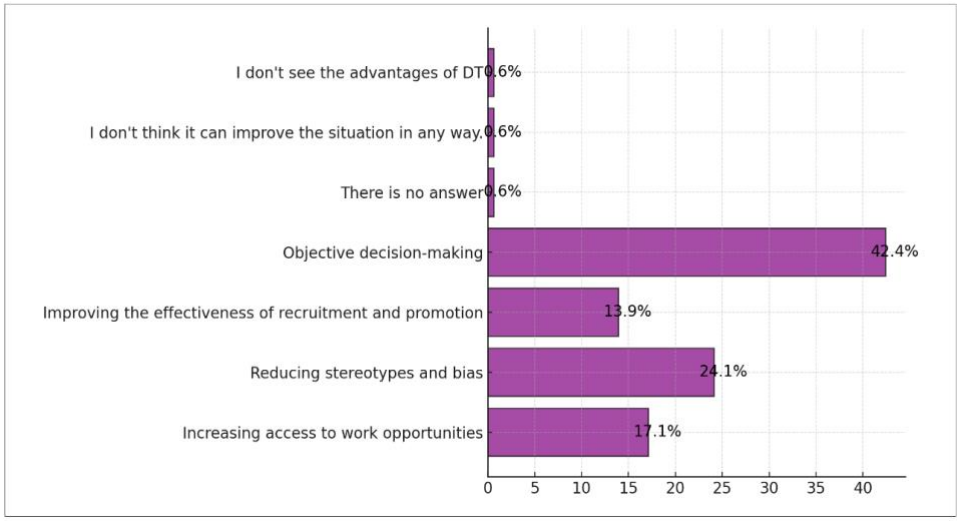

FIGURE 6. Distribution of responses regarding the perceived advantages of using digital technologies to achieve gender equality in the labor market, in %

Note: compiled by authors

Analyzing the role of digitalization in promoting gender equality in Kazakhstan's labor market, several key results and challenges can be identified. The Skills Enbek platform, created in 2021, has become an essential tool for the continuous professional development of the entire country's population. This platform is especially significant for women, providing them access to online courses to improve their skills and acquire new ones. This helps increase their competitiveness in the labor market and opens up new career opportunities.

The introduction of flexible forms of employment, such as co-employment, flexible working hours, and a four-day workweek, also positively impacts gender equality. These measures help women better balance professional activities and personal responsibilities, promoting their more active participation in the workforce and helping reduce the gender pay gap.

Additionally, digital platforms and platform employment expand opportunities for women to engage in self-employment and entrepreneurship. This contributes to their economic independence and professional growth, providing more opportunities to work for themselves and start their businesses.

However, despite these positive outcomes, challenges remain. Not all women have equal access to the Internet and digital devices, which limits their opportunities to participate in online education and work on digital platforms. The gender gap in digital skills remains a significant obstacle, reducing women's competitiveness in the labor market. Traditional gender roles and stereotypes continue to influence women's choice of professions and career opportunities, limiting their participation in highly paid and technologically advanced sectors of the economy.

To achieve sustainable gender equality in Kazakhstan's labor market, it is necessary to solve the problems of access to digital technologies, eliminate stereotypes, and ensure equal conditions for women's professional development. Digitalization provides many opportunities for this, and it is important to use these opportunities to create a more inclusive and equitable society. This, in turn, makes it possible to identify new challenges and problems that have arisen in the field of gender inequality that require further research and the development of targeted measures.

5. CONCLUSIONS

Digitalization plays a crucial role in promoting gender equality in Kazakhstan's labor market. Data analysis of the Skills Enbek platform, which was established in July 2021, shows that online learning and skills development significantly impact gender equality. The platform provides opportunities for continuous skills development and professional development for the entire population, which is especially important in the context of rapid changes in technology and the labor market.

The survey data on the benefits of using digital technologies to achieve gender equality shows that most respondents (42.4%) believe that digital technologies contribute to objective decision-making, minimizing the impact of bias. This confirms that digital tools can contribute to creating more equitable working conditions. Moreover, using digital technologies can improve the efficiency of recruitment and career promotion processes, reduce stereotypes and bias, and increase access to job opportunities for all population groups.

The gender gap in Kazakhstan remains significant despite advances in education and the legislative framework. Women continue to face restrictions in their access to high-paying professions and leadership positions. However, the use of digital technologies, such as online training on the Skills Enbek platform, can help overcome these barriers. The platform provides flexible learning and development opportunities, which allows women to improve their professional skills and increase their competitiveness in the labor market.

The following recommendations are proposed for government agencies on the development and implementation of gender-oriented digital strategies and policies:

(1) Authorized bodies on employment and digitalization must expand access to platforms like Skills Enbek and encourage women's participation in these programs. This will help them develop the necessary skills and increase their chances of successful employment.

(2) The Ministries of National Economy and Finance of the Republic of Kazakhstan should support and finance digital education programs aimed at women. This may include subsidies for training and the creation of specialized courses and training.

(3) The Ministry of Labor and Social Protection of the Population of the Republic of Kazakhstan proposes introducing digital technologies in the recruitment and personnel management processes to minimize bias and increase objectivity. The development and implementation of appropriate technologies can significantly improve gender equality in the workplace.

(4) The authorized body in the labor field should investigate digitalization's impact on gender equality and regularly monitor progress. This will allow the identification of practical strategies and the adjustment of policies following the data obtained.

Digitalization and the use of modern technologies can become powerful tools for achieving gender equality in the labor market of Kazakhstan. It is important to continue to support and develop these initiatives to create a more inclusive and equitable society.

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Path to Green Economy: Analyzing Innovation, Investment and Taxation in Kazakhstan

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ABSTRACT

The concept of a green economy has gained significant attention, aiming to achieve sustainable development without environmental harm. This study examines Kazakhstan's transition to a green economy, focusing on indicators such as green innovation, investment in environmental protection, and green taxes. Despite Kazakhstan's commitment to a carbon-neutral economy by 2060, significant challenges were identified. The methodology involved three steps: descriptive analysis of green economy indicators for 2016–2022, correlation analysis to identify significant relationships, and trend forecasting for 2023–2025 using a linear regression model. This approach provided a thorough examination of the green economy's current state and future projections. Over the study period, the number of organizations engaged in environmental innovation and their activity levels have decreased. Investments in environmental protection showed initial growth, but declined in recent years. Conversely, there has been an increase in environmental taxes, reflecting the government's focus on tax instruments to promote sustainable development. Correlation analysis revealed complex interdependencies, indicating that higher investments and taxes are often associated with lower levels of green innovation activity. Projections for 2023-2025 suggest a further decline in green innovation indicators unless significant policy measures are taken. The study underscores the need for a balanced approach that encourages green innovation while maintaining robust investment and tax bases.

KEYWORDS: Green Economy, Environmental Investments, Green Innovations, Environmental Taxes, Forecast, Innovation Activity

SCSTI: 06.73.91

JEL Code: Q55, Q56, H23

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1. INTRODUCTION

In recent years, the concept of a green economy has increasingly captured the attention of academic researchers and policymakers. A green economy is defined by its focus on low carbon emissions, resource efficiency, and social inclusiveness, aiming to achieve sustainable development while minimizing environmental harm. As the world faces escalating ecological challenges and climate change, the transition to a green economy has become a crucial priority for many nations and organizations seeking to mitigate their ecological footprint and enhance sustainability.

Kazakhstan's commitment to transitioning to a green economy was prominently highlighted at the Climate Ambition Summit in 2020, where the country pledged to transform its oil and gas-based energy sector into a carbon-neutral economy by 2060 (Concept for the Transition of the Republic of Kazakhstan). This ambitious commitment underscores Kazakhstan's dedication to aligning with international climate agreements, such as the Paris Agreement, and signifies a critical shift in its national climate policy. The transition to a green economy is embedded within Kazakhstan's strategic frameworks, including the Concept for the Transition to a Green Economy and the National Project "Green Kazakhstan," which outline the roadmap for achieving a sustainable and environmentally friendly economic model.

The research presented in this study aims to critically analyze the current status and forecast critical indicators associated with Kazakhstan's green economy transition. The primary research goals are to assess the effectiveness of green innovations, evaluate the impact of investments in environmental protection, and examine the role of environmental taxes in promoting sustainable practices. By employing a multifaceted approach that includes descriptive analysis, correlation analysis, and trend forecasting, the study provides a comprehensive examination of green economy indicators and their interrelationships, offering valuable insights for policymakers and stakeholders.

The context of this study is defined by the significant financial investments required for transitioning to a green economy. The shift involves transforming economic sectors and developing and implementing green technologies, processes, and innovations. Despite these investments' importance, there is a substantial gap between the required volume of green financing and the actual investments made. Currently, most funding for environmental and climate initiatives comes from budget allocations. However, more than public funds are needed to cover the extensive costs associated with large-scale environmental and social projects. This shortfall necessitates a broader financing approach, including increased participation from private businesses and financial institutions.

Globally, there is a growing trend towards reducing direct government involvement in financing environmentally sustainable activities, thereby encouraging the private sector to take on a more active role. This shift aligns with the strategic goals outlined in Kazakhstan's national documents. The Concept for the Transition to a Green Economy envisions annual investments of approximately $3.3 billion, with a cumulative total of about $119 billion projected by 2050. Additionally, the National Project "Green Kazakhstan" plans to allocate a substantial 1.4 trillion tenge from 2021 to 2025, which includes 298.2 billion tenge from the state budget, 82.4 billion tenge from local budgets, and 1032.5 billion tenge from extra-budgetary funds (National Project "Green Kazakhstan"). This financing structure reflects the government's strategic intention to leverage funds from diverse sources, including financial institutions and private enterprises, to support green projects and initiatives.

Green innovations are central to the transition towards a sustainable economy. These innovations encompass technological advancements and process improvements that deliver tangible environmental benefits. Organizations that actively engage in green innovations often gain significant competitive

advantages, such as reduced operational costs, enhanced market positions, and improved compliance with environmental regulations. For example, adopting renewable energy technologies, efficient waste management practices, and sustainable resource use can lead to substantial cost savings and operational efficiencies.

Investments in environmental protection are another critical driver of green economy objectives. These investments cover a broad spectrum of activities, including pollution control, waste management, and developing renewable energy projects. By channeling resources into these areas, countries can achieve significant environmental and economic benefits, including improved public health, enhanced environmental quality, and the creation of green jobs.

Environmental taxes also play a pivotal role in advancing sustainable practices. These taxes aim to internalize the external costs associated with environmental damage, thereby incentivizing businesses and individuals to adopt more environmentally friendly behaviors. By pricing environmental harm, governments can encourage the reduction of pollution and the adoption of cleaner technologies. However, the effectiveness of ecological taxes depends on their design and implementation and their alignment with broader policy goals.

Understanding the complex interrelationships between various green economy indicators - such as innovation, investment, and taxation - is essential for effective policymaking. The literature indicates that these indicators are interconnected in complex ways, with each influencing the others. For example, higher levels of investment in green technologies may lead to increased innovation, while effective environmental taxes can drive both innovation and investment in sustainable practices. This study aims to explore these interdependencies in-depth, providing insights into how different elements of the green economy interact and contribute to overall sustainability goals.

The results of this study will offer valuable information for a range of stakeholders, including businesses, government agencies, and other entities involved in promoting a sustainable green economy. The study aims to inform and guide policy development, investment strategies, and innovation efforts by analyzing the current status and forecasting future trends. Ultimately, the findings will support the creation of a robust and effective green economy framework, helping Kazakhstan and other countries achieve their sustainability objectives while addressing the pressing environmental challenges of our time.

2. LITERATURE REVIEW

The concept of a green economy has garnered substantial attention in recent years in both academic and policy-making circles. A green economy aims for sustainable development without degrading the environment. Low carbon emissions, resource efficiency, and social inclusivity characterize it. This literature review explores critical themes and findings from recent studies on green economy indicators, their interrelationships, and the implications for policy and practice.

Green innovations are crucial for the transition to a sustainable economy. According to Schiederig et al. (2012), green innovations include technological advancements and process improvements that lead to environmental benefits. Horbach et al. (2012) highlighted that firms with a strong focus on green innovations tend to perform better regarding sustainability and long-term economic success (Miao et al., 2017). They encompass product innovations, such as eco-friendly products and process innovations, which improve resource efficiency and reduce emissions (Song & Yu, 2018). Studies have shown that organizations engaged in green innovations often experience competitive advantages, including cost savings, improved market positioning, and regulatory compliance.

The study by Varavin and Kozlova (2018) provides a detailed analysis of the development of the green economy in various regions of Kazakhstan, highlighting significant regional

differences and the need for targeted policy measures. Their comprehensive methodology, which includes descriptive analysis, correlation analysis, and trend forecasting, provides valuable information but is limited due to the use of data until 2022 and the need for qualitative analysis. Dabyltayeva and Rakhymzhan (2019) consider key economic policy measures such as "green" taxes, subsidies, and investments necessary to develop a green economy. Although Dabyltayeva and Rakhymzhan emphasize the need to align economic policy with environmental goals and cite international examples, their document needs more detailed implementation mechanisms, industry analysis, and quantitative data. Taken together, these studies highlight the importance of regional and policy-oriented approaches, emphasizing the need to balance economic incentives and reliable support for innovation to promote a sustainable green economy.

Investments in environmental protection are a critical driver for achieving green economy objectives. These investments include expenditures on pollution control, waste management, and renewable energy projects. Bassi and Yudken (2011) argue that substantial public and private investments are necessary to support the infrastructure and technologies required for a green economy. These investments help mitigate environmental impacts and create new economic opportunities and jobs in green sectors. However, the effectiveness of these investments depends on the regulatory framework and the alignment of financial incentives with sustainability goals (UNEP, 2011).

Environmental taxes are designed to internalize the external costs of environmental degradation, thereby encouraging more sustainable practices. According to Ekins (1999), Jones (2011), Falcão (2012), and Liu et al. (2023), well-designed environmental taxes can drive significant reductions in pollution and resource consumption while generating revenue that can be used to fund further environmental initiatives. Green investment, fiscal policies, and ecological taxes positively influence clean energy consumption. Environmental taxes increase the demand for clean energy, preserving the environment and promoting sustainable practices. Studies by the OECD (2010) indicate that countries with higher levels of environmental taxation tend to have better environmental outcomes without compromising economic growth. For example, in Sweden, introducing a NOx emissions tax led to a significant reduction in emissions and stimulated innovation (Coste et al., 2018).

Reducing the underutilization of human resources and the overexploitation of natural resources has become an economic policy goal for sustainable development. Research shows that environmental taxes positively impact employment, promoting the emergence of new sectors and types of jobs. However, women benefit less from these new jobs than men. This underscores the need for policies to reduce discrimination against women in the labor market as part of a green economy (Domguia ye al., 2022). Yan et al. (2023) indicated that green investments promote renewable energy use, and fiscal policies like tax incentives and subsidies expand renewable energy sources.

Understanding the relationships between different green economy indicators is vital for effective policy-making. The literature suggests complex interdependencies exist between green innovations, investments, and environmental taxes. For instance, Rennings (2000) discusses the concept of “innovation effects,” where environmental regulations and taxes can stimulate green innovations. Conversely, inadequate investment and poorly designed taxes can stifle innovation and lead to suboptimal ecological outcomes. Empirical studies, such as those by Jaffe et al. (2002), highlight the importance of integrated policy approaches that consider these interrelationships to maximize the effectiveness of green economy strategies.

At the same time, Sibt-i-Ali et al. (2024) consider the impact of technological innovations, the transition to energy, and financial globalization on the environmental footprint in selected developing countries in order to assess how these factors affect

environmental sustainability. In addition, these elements are essential in shaping environmental outcomes and promoting green development. However, the study needs a detailed analysis of country-specific conditions and policy implications that could provide more practical information for developing targeted environmental strategies. Wei Teng et al. (2024) explored the impact of nuclear power, greener energy, and economic progress on throughput, showing that advances in these areas increase energy efficiency and sustainability in leading nuclear power countries. While the study highlights the positive impact on throughput, it is limited to focusing on nuclear power, which potentially needs to consider the broader energy context and related environmental and social effects. Considering different energy systems and a more comprehensive range of environmental and social factors, a more integrated approach could provide a more holistic understanding of energy changes.

Forecasting future trends in green economy indicators is essential for long-term planning and decision-making. Techniques such as linear regression and scenario analysis are commonly used to project future developments based on historical data. According to Armstrong (2001), accurate forecasting requires robust statistical methods and an understanding of underlying economic and environmental dynamics. Recent studies, such as those by the International Energy Agency (2020), emphasize the importance of continuously monitoring and updating forecasts to account for emerging trends and unexpected developments.

In conclusion, the literature provides valuable insights into the dynamics of green economy indicators and their implications for policy and practice. The analysis should consider the relationships between indicators such as green innovations, investments in environmental protection, and various ecological taxes. Understanding these relationships is crucial for making informed decisions and formulating effective strategies. Forecasting these indicators is vital to developing recommendations promoting a sustainable green economy.

3. METHODOLOGY

The research methodology combines descriptive analysis, correlation analysis, and trend forecasting to provide a comprehensive assessment of the indicators of the "green" economy. Descriptive analysis provides a fundamental understanding of the current state and historical trends. In contrast, correlation analysis identifies significant relationships between indicators, paying particular attention to those with the most significant impact. Trend forecasting using linear regression allows you to predict future developments, making informed political and strategic decisions based on a detailed study of past and present data.

This analysis was conducted in three stages to comprehensively understand the key green economy indicators and their trends. The study used data from 2016 to 2022, including information on the number of companies with green innovations, activity levels, and other vital indicators.

The first stage involved describing the country's current situation of green economy indicators. This entailed collecting data from 2016 to 2022 on various metrics such as the number of organizations with green innovations, the level of green innovation activity, the share of green innovations in the total number of innovations, product innovations, and business process innovations. This initial descriptive analysis provided a baseline understanding of these indicators' current status and historical trends.

A correlation analysis was performed in the second stage to identify the relationships between different green economy indicators. The indicators were encoded using specific codes (Table 1).

TABLE 1. Encoded Indicators and Their Significance

Code	Indicator	Significance
A1	Number of organizations with green innovations	Significant
A2	Level of green innovation activity	Significant
A3	Share of green innovations	Significant
A4	Product innovations	Significant
A5	Business process innovations	Significant
A6	Number of issued licenses in the field of environmental protection	Not significant
A7	Production of products in value terms (mln tenge)	Not significant
A8	Production of environmentally friendly products (mln tenge)	Not significant
A9	Investments in environmental protection (mln tenge)	Significant
A10	Share of environmental taxes (%)	Significant
A11	Energy taxes (mln tenge)	Significant
A12	Transport taxes (mln tenge)	Significant
A13	Pollution taxes (mln tenge)	Significant
A14	Resource use taxes (mln tenge)	Significant
A15	Total environmental taxes (mln tenge)	Significant
Note: complied by authors		

Note: compiled by authors

Indicators A6, A7, and A8, which represent the number of issued licenses in the field of environmental protection, production of products in value terms (mln tenge), and production of environmentally friendly products (mln tenge) respectively, were excluded from the correlation matrix due to their non-significant correlations with other indicators. This helps to focus the analysis on the most relevant and impactful relationships between the key indicators of the green economy. This encoding facilitated a more straightforward interpretation of the correlation matrix. The correlation analysis helped to uncover significant positive and negative relationships between the indicators, allowing for insights into how changes in one metric might influence others.

The final stage of the analysis involved forecasting trends for key green economy indicators from 2023 to 2025. To achieve this, we applied a linear regression model to the historical data to estimate future values. The trend calculation was based on the linear regression formula (1):

$$y=mx+by = mx + by=mx+b \quad (1)$$

where "y" is the forecasted value, mmm is the slope of the trend line, "x" is the year, and "b" is the intercept. This formula was used to project the future values of each indicator based on their historical trends. The results provided forecasts for the number of organizations with green innovations, the level of green innovation activity, the share of green innovations, product innovations, business process innovations, investments in environmental protection, and various categories of environmental taxes.

These three stages—descriptive analysis, correlation analysis with encoded indicators, and trend forecasting—combined to offer a detailed and structured examination of the green economy's current state and future projections. This methodology ensures that the analysis is both thorough and academically rigorous, providing valuable insights for policymakers, businesses, and stakeholders involved in fostering a sustainable green economy. The indicators were encoded and a total of 15 indicators were encoded, out of which three indicators with non-significant correlations were excluded from the correlation matrix. The Table 1 summarizes the indicators along with their corresponding codes and significance based on the correlation analysis.

4. FINDINGS AND DISCUSSION

Currently, the country is experiencing the following level of development in the green economy. The number of organizations with green innovations has decreased from 312 in 2016 to 97 in 2022. The level of green innovation activity has also declined from 1% in 2016 to 0.3% in 2022. Similarly, the share of green innovations in the total number of innovations has dropped from 10.8% to 3.0% over the same period.

Investments aimed at environmental protection have shown a significant upward trend from 2016 to 2019, increasing from 43,936,904 in 2016 to 198,721,626 in 2019. However, from 2020 onwards, there has been a slight decline, with investments dropping to 159,660,892 by 2022. This indicates a robust initial growth in environmental investments, followed by a stabilization and slight decrease in recent years.

The analysis of the critical indicators of the green economy from 2016 to 2022 reveals several significant trends and insights. Firstly, the number of organizations with green innovations and the level of green innovation activity have both significantly declined, suggesting a decrease in adopting environmentally sustainable practices among businesses. Despite this, the share of green innovations in the total number of innovations has shown some resilience, albeit much lower than in 2016.

Secondly, the trends in environmental taxes indicate an overall increase in the total amount and the share of these taxes. This reflects a growing governmental focus on environmental taxation as a tool to promote sustainability. Energy taxes, transport taxes, pollution taxes, and resource use taxes have all increased, with some fluctuations, particularly during the year 2020, likely due to the impact of the global pandemic.

Lastly, there has been a significant rise in the number of issued licenses in environmental protection and the production of products in value terms. This suggests a growing regulatory framework and economic activities aimed at protecting the environment. However, the production of environmentally friendly products has shown variability, highlighting the ongoing challenges in consistently increasing the output of such products.

Figure 1 shows information about trends in environmental taxes below.

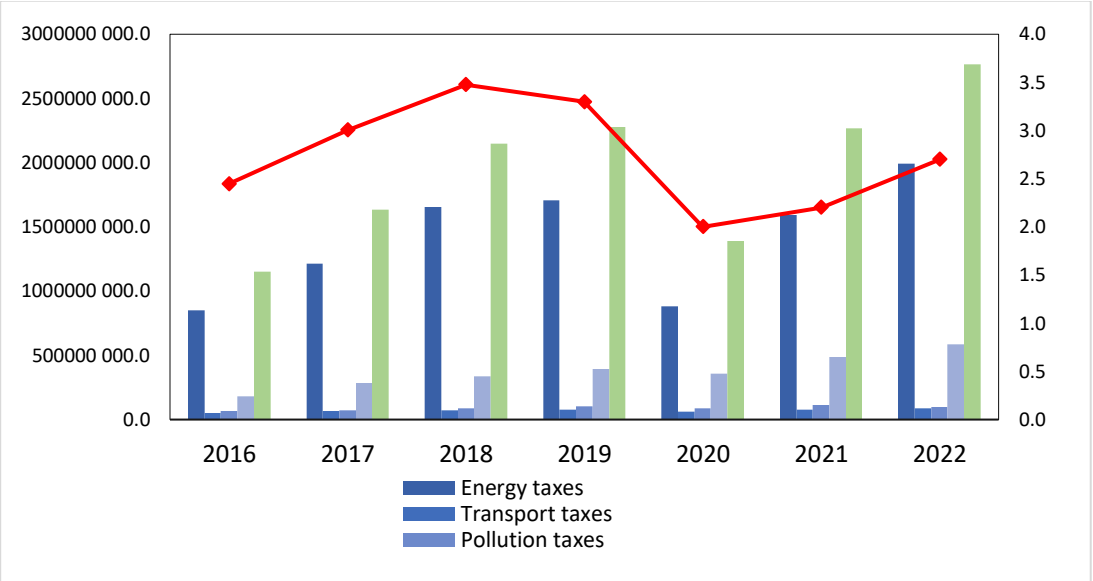

FIGURE 1. Trends in Environmental taxes for 2016-2022

Note: compiled by authors

While there are positive developments in environmental taxation and regulatory measures, the decline in green innovation indicates a need for renewed efforts and policies to encourage sustainable practices among businesses. Ensuring consistent growth in producing environmentally friendly products remains a critical challenge that must be addressed to achieve a more robust green economy. Below is an analysis showing changes in key indicators from 2016 to 2022.

The graph illustrates the trends in various types of environmental taxes from 2016 to 2022. Energy taxes have shown a significant increase, peaking in 2019 and then slightly declining before rising again in 2022. Transport taxes and pollution taxes have also increased over time, with a noticeable dip in 2020. Resource use taxes have steadily increased, reflecting a growing focus on taxing the use of natural resources. The total environmental taxes and the share of environmental taxes have generally increased, with a notable drop in 2020 followed by a recovery.

Below, in Figure 2 describes information about the statistical data on licenses and production in environmental protection.

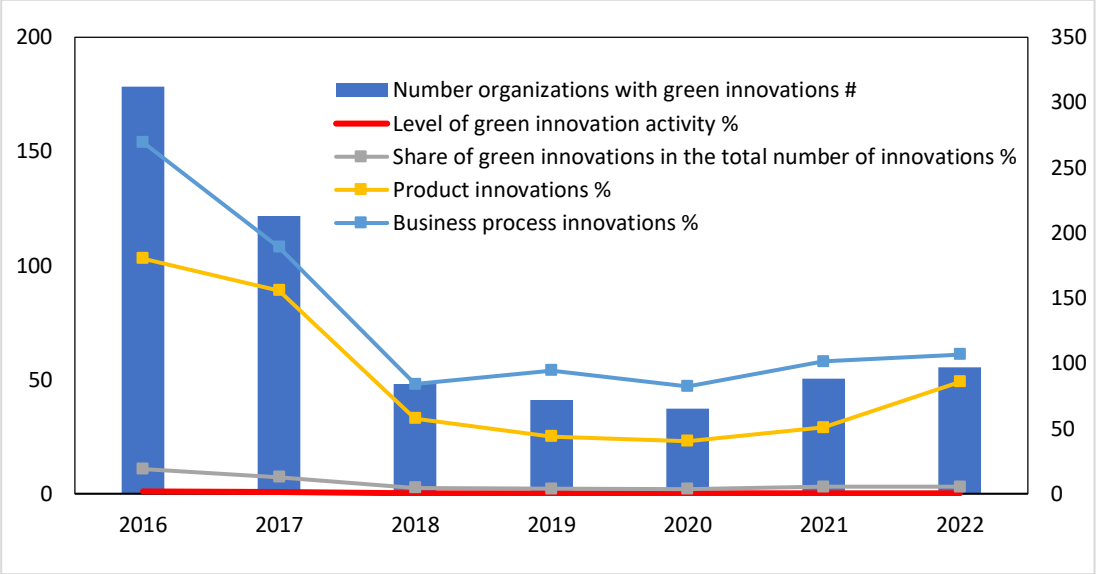

FIGURE 2. Trends in Environmental Taxes for 2016-2022

Note: compiled by authors

The graph shows the trends of key indicators related to environmental innovations from 2016 to 2022. The number of organizations with green innovations (blue bars) has significantly decreased from 312 in 2016 to 97 in 2022. The level of green innovation activity (orange line) has remained low, fluctuating between 0.2% and 1%. The share of green innovations in the total number of innovations (grey line) has dropped from 10.8% in 2016 to 3% in 2022. Product innovations (yellow line) and business process innovations have also declined, indicating a general reduction in green innovation activities over the years.

Figure 3 shows information about the statistical data on licenses and production in environmental protection.

The graph presents the trends in the number of issued licenses in the field of environmental protection, production of products in value terms, and production of environmentally friendly products from 2016 to 2022. The number of issued licenses has significantly increased, reaching a peak of 297 in 2022.

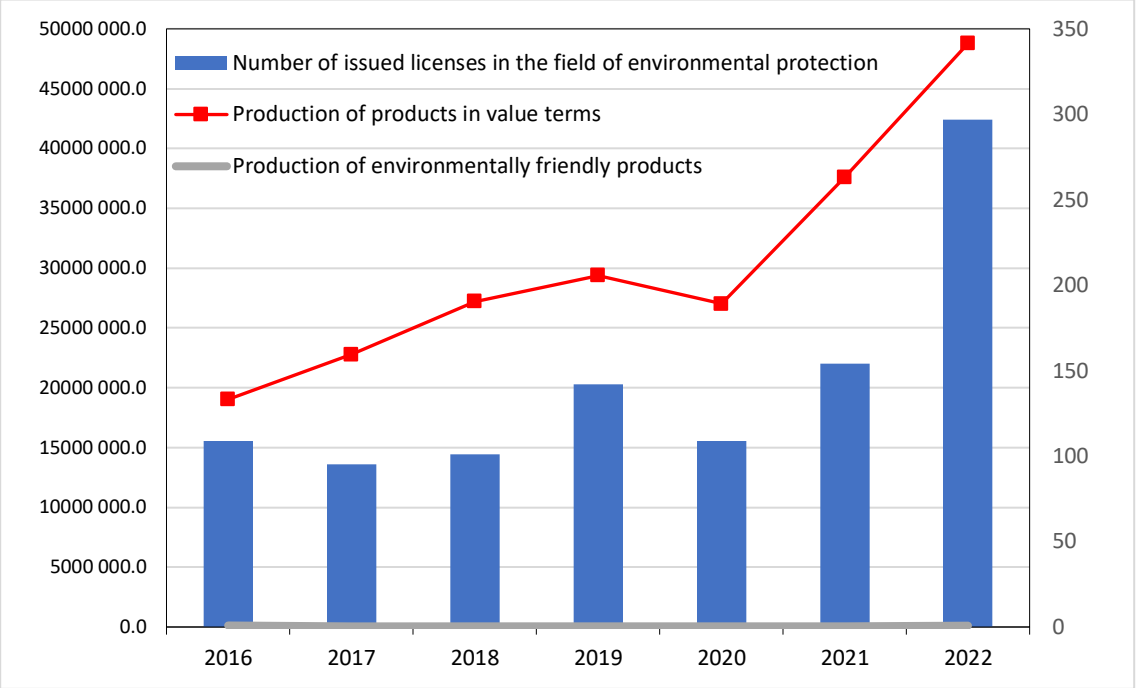

FIGURE 3. Licenses and Production in Environmental Protection for 2016-2022

Note: compiled by authors

The production of products in value terms has also shown a consistent upward trend, indicating growth in economic activities related to environmental protection. However, the production of environmentally friendly products has fluctuated, with a general increase but notable variations year by year. This highlights both the progress and the challenges in scaling up ecologically friendly production.

Analyzing the critical indicators of the green economy from 2016 to 2022 reveals several significant trends and insights. Firstly, the number of organizations with green innovations and the level of green innovation activity have both significantly declined, suggesting a decrease in adopting environmentally sustainable practices among businesses. Despite this, the share of green innovations in the total number of innovations has shown some resilience, albeit much lower than in 2016.

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Lastly, there has been a significant rise in the number of issued licenses in the field of environmental protection and the production of products in value terms. This suggests a growing regulatory framework and economic activities aimed at protecting the environment. However, the production of environmentally friendly products has shown variability, highlighting the ongoing challenges in consistently increasing the output of such products.

In summary, while there are positive developments in environmental taxation and regulatory measures, the decline in green innovation indicates a need for renewed efforts and policies to encourage sustainable practices among businesses. Ensuring consistent growth

in producing environmentally friendly products remains a key challenge that must be addressed to achieve a more robust green economy.

A correlation matrix was constructed to understand the relationships between different green economy indicators. Correlation analysis allows us to identify which indicators are interrelated and how strongly. Below is a correlation matrix of key green economy indicators (Table 2).

TABLE 2. Correlation matrix

No	A1	A2	A3	A4	A5	A9	A10	A11	A12	A13	A14	A15
A1	1.00	0.99	0.99	0.97	0.97	-0.90				-0.81		
A2	0.99	1.00	0.99	0.96	0.96	-0.89				-0.80		
A3	0.99	0.99	1.00	0.97	0.97	-0.90				-0.80		
A4	0.97	0.96	0.97	1.00	0.99	-0.88				-0.79		
A5	0.97	0.96	0.97	0.99	1.00	-0.88				-0.79		
A9	-0.90	-0.89	-0.90	-0.88	-0.88	1.00	0.81	0.85	0.85	0.97	0.87	0.92
A10						0.81	1.00	0.83	0.83	0.95	0.86	0.89
A11						0.85	0.83	1.00	0.83	0.94	0.88	0.93
A12						0.85	0.83	0.83	1.00	0.94	0.89	0.91
A13	-0.81	-0.80	-0.80	-0.79	-0.79	0.97	0.95	0.94	0.94	1.00	0.94	0.97
A14						0.87	0.86	0.88	0.89	0.94	1.00	0.96
A15	-0.69	-0.69	-0.69	-0.67	-0.67	0.92	0.89	0.93	0.91	0.97	0.96	1.00

Note: compiled by authors

The analysis of the results are divided into positive and negative correlations. High positive correlations was observed among following groups of indicators.

1) Number of organizations with green innovations (A1), Level of green innovation activity (A2), Share of green innovations (A3), Product innovations (A4), Business process innovations (A5). Therefore, increases in any of these aspects are closely related to increases in the others. For instance, a higher number of organizations with green innovations likely leads to higher levels of green innovation activity and an increased share of green innovations in the total number of innovations.

2) Investments in environmental protection (A9) with Share of environmental taxes (A10), Energy taxes (A11), Transport taxes (A12), Pollution taxes (A13), Resource use taxes (A14), Total environmental taxes (A15). Investments in environmental protection (A9) show a strong positive correlation with various environmental taxes. This suggests that higher investments in environmental protection are associated with higher environmental taxes across various categories. It could imply that as investments in environmental protection increase, there is a parallel rise in tax revenue from environmental taxes.

3) Share of environmental taxes (A10), Energy taxes (A11), Transport taxes (A12), Pollution taxes (A13), Resource use taxes (A14), Total environmental taxes (A15). There are strong positive correlations among these different types of environmental taxes. This indicates a consistent pattern where increases in one type of environmental tax are likely accompanied by increases in other types. For example, higher energy taxes are correlated with higher transport, pollution, and resource use taxes. Negative correlations was observed among following group of indicators.

1) Number of organizations with green innovations (A1), Level of green innovation activity (A2), Share of green innovations (A3), Product innovations (A4), Business process innovations (A5) with Investments in environmental protection (A9), Pollution taxes (A13), Total environmental taxes (A15). These green innovation metrics have a significant

negative correlation with investments in environmental protection (A9), pollution taxes (A13), and total environmental taxes (A15). This suggests an inverse relationship where higher investments in environmental protection and higher pollution or total environmental taxes might correspond to lower green innovation activity and vice versa. This could imply that organizations might be less inclined to innovate in a green manner when there are higher taxes or when significant investments are directed towards environmental protection. The strong positive correlations among green innovation metrics (A1, A2, A3, A4, A5) suggest that policies promoting one aspect of green innovation likely benefit other aspects as well. Integrated policy approaches can be highly effective. The positive correlation between investments in environmental protection (A9) and various environmental taxes (A10, A11, A12, A13, A14, A15) indicates that as investment increases, so do tax revenues from these areas. Policymakers can leverage this relationship to design incentives for higher investments in environmental protection, potentially leading to higher tax revenues. The negative correlations between green innovation metrics and investments/taxes suggest that a balance needs to be struck. While taxation and investment in environmental protection are crucial, they should be structured in a way that does not stifle green innovation activities. The analysis highlights the complex interdependencies between different aspects of the green economy and underscores the importance of a balanced, multi-faceted approach in policy-making.

Below, Table 3 presents results for forecasting of key indicators.

TABLE 3. Forecasting Key Green Economy Indicators for 2023-2025

Indicator	**2023**	**2024**	**2025**
Number of enterprises with environmental innovations	2,43	-30,21	-62,86
Level of activity in the field of environmental innovations	0,01	-0,09	-0,2
Share of environmental innovations in the total number of innovations	-0,23	-1,39	-2,54
Product innovations	8,43	-2	-12,43
Business process innovations	21,43	7,86	-5,71
Number of issued licenses in the field of environmental protection	24243	26707	29171
Production in value terms (mln.tenge)	47,217,240	51,456,290	55,695,340
Production of environmentally friendly products (mln.tenge)	57,458	53,953	50,448
Investments in environmental protection (mln.tenge)	217,609,040	238,253,100	258,897,200
Share of environmental taxes (%)	2,41	2,34	2,26
Energy taxes (mln.tenge)	1,899,864,00	2,021,703,000	2,143,543,000
Transport taxes (mln.tenge)	89,118,720	93,753,890	98,389,060
Pollution taxes (mln.tenge)	113,179,500	119,231,000	125,282,600
Resource use taxes (mln.tenge)	610,514,100	669,205,700	727,897,300
Total environmental taxes (mln.tenge)	2,712,676,000	2,903,894,000	3,095,112,000

Note: compiled by authors

The results for forecasting of key green economy indicators were divided into positive and negative trends. Decline in Green Innovations. Number of organizations with green innovations (A1). The forecast shows a sharp decline from 2.43 in 2023 to -62.86 in

2025. This suggests a troubling trend where fewer organizations are engaging in green innovations, and by 2025, it appears the trend could potentially reverse negatively. Level of green innovation activity (A2) and Share of green innovations (A3). Both indicators follow a similar negative trend, declining from 0.01 and -0.23 in 2023 to -0.20 and -2.54 in 2025, respectively. This indicates a decrease in both the activity and the share of green innovations in the overall innovation landscape.

Mixed Trends in Innovation Types. Product innovations (A4) and Business process innovations (A5). Product innovations are expected to decrease significantly, from 8.43 in 2023 to -12.43 in 2025. Business process innovations show a similar decline but remain positive in 2023 and 2024 before turning negative in 2025. This mixed trend suggests variability and potential challenges in maintaining green innovation in both products and business processes. Increase in Licenses and Environmental Protection Investments. Number of issued licenses in the field of environmental protection (A6). The forecast shows an increase in issued licenses, from 242.43 in 2023 to 291.71 in 2025, indicating growing regulatory activities in environmental protection. Investments in environmental protection (A9). Investments are projected to rise from 217,609,040 mln tenge in 2023 to 258,897,200 mln tenge in 2025, reflecting a steady commitment to environmental protection initiatives.

Growth in Environmental Taxes. Share of environmental taxes (A10). The share of environmental taxes shows a slight decline from 2.41% in 2023 to 2.26% in 2025. Energy taxes (A11), Transport taxes (A12), Pollution taxes (A13), Resource use taxes (A14), and Total environmental taxes (A15). All these tax categories show an increasing trend over the forecast period, indicating a growing financial focus on taxing environmental impacts. Total environmental taxes, for example, are projected to increase from 2,712,676,000 mln tenge in 2023 to 3,095,112,000 mln tenge in 2025.

The negative trends in green innovations and activities highlight the urgent need for policies and support mechanisms to encourage more organizations to adopt green innovations. The positive trends in issued licenses and investments in environmental protection suggest that regulatory frameworks and investment efforts are on the rise. These need to be sustained and possibly enhanced to offset the declining innovation trends. The increase in various environmental taxes underscores their strategic use as tools for environmental policy. Policymakers should ensure these taxes effectively support environmental goals without discouraging innovation

5. CONCLUSIONS

The results of the study indicate an alarming decrease in the number of enterprises engaged in environmental innovations and a decrease in the level of activity related to environmental innovations. Despite this downward trend, investments in environmental protection and environmental taxes have shown positive growth, indicating a favorable trend towards a greener economy. However, the forecast indicates an alarming decline in the number of “green” innovations, which requires targeted policy measures to reverse this trend.

In order to cope with the reduction in the number of "green" innovations, it is extremely important to implement policies that encourage such activities. This may include providing subsidies for research and development in the field of "green" technologies, providing tax incentives to companies that implement sustainable methods, and supporting startups focused on environmentally friendly products and processes. Strengthening support and incentives for environmental innovation can help drive growth in this area and ensure the advancement of sustainable technologies.

The growth of investments in environmental protection is a promising development. In order to maintain and expand this positive trend, it is important that Governments and the private sector cooperate in the implementation of large-scale environmental projects. Public-private partnerships can effectively use resources and

expertise to solve critical environmental problems and ensure significant progress in efforts to ensure sustainable development.

The increase in environmental taxes reflects the growing financial interest in combating environmental impacts. However, it is important to design such taxes so that they promote sustainable practices without discouraging eco-friendly innovation. Part of the proceeds from environmental taxes could be reinvested in funds supporting green innovation, or used to provide financial assistance to enterprises transitioning to more sustainable activities.

This study is limited by the fact that the study mainly focuses on quantitative data, and it lacks qualitative information that could provide a deeper understanding of the contextual and human factors influencing the development of the green economy. In future studies, it would be useful to include qualitative analysis, such as interviews with stakeholders or case studies, in order to enrich the results obtained and provide a more complete picture of the challenges and opportunities in promoting a sustainable green economy.

Overall, the study provides valuable information on the current state and future forecasts of the green economy, emphasizing the need for balanced policy and strategic support. Policymakers, businesses and stakeholders should take these findings into account to promote a sustainable green economy, taking into account both the positive and negative trends identified in the study.

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Assessing the Impact of New Silk Road Initiatives on Kazakhstan's Business Environment

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ABSTRACT

This study conducts a comprehensive evaluation of four major regional economic integration initiatives along the New Silk Road in Eurasia: The Eurasian Economic Union (EAEU), the Silk Road Economic Belt (SREB), the New Silk Road (NSR), and the Central Asia Regional Economic Cooperation (CAREC) program. By employing an expert-based analysis method, the research assesses the initiatives from the perspective of the Kazakhstani business environment, identifying critical criteria for successful economic integration, including intra-union trade, market expansion, supply chain optimization, regulatory harmonization, and access to financing. Drawing parallels with the historical Silk Road's focus on trade and economic prosperity, this research employs an expert-based analysis method to assess these modern initiatives from the perspective of the Kazakhstani business environment. Through structured expert panel assessments and statistical analysis, the study determines which initiatives offer the most tangible benefits to businesses in Kazakhstan and the broader region. The findings indicate that the SREB initiative scored highest overall, particularly in fostering regional economic development and business growth, with a total score of 197, followed by the EAEU with 181. The findings reveal that the SREB initiative scored highest overall, followed by the EAEU, indicating their strong potential for fostering regional economic development and business growth. This study provides valuable insights for policymakers and businesses navigating the complex landscape of Eurasian economic integration. It offers a framework for evaluating the effectiveness of new Silk Road initiatives in promoting regional prosperity and cooperation, with particular relevance to Kazakhstan's position in Central Asia.

KEYWORDS: Economic Integration, Trade, Silk Road Initiatives, Business Perspectives, Regional Cooperation, Supply Chains, Market Expansion, Business Financing

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1. INTRODUCTION

In an era of unprecedented globalization, the revival of the ancient Silk Road as the "New Silk Road" is a testament to the enduring power of connectivity and trade. This ambitious initiative, aimed at forging a modern trade corridor stretching from East Asia to Europe, encapsulates a vision of economic integration that promises to redefine the contours of global commerce. Kazakhstan's participation in numerous trade unions has been complemented by its involvement in four major initiatives aimed at reviving the Silk Road: the Eurasian Economic Union (EAEU), the Silk Road Economic Belt (SREB), the New Silk Road (NSR), and the Central Asia Regional Economic Cooperation (CAREC) program. These initiatives leverage the country's strategic location and historical trade legacy to foster economic growth and regional integration.

The resurgence of interest in Silk Road initiatives stems from the region's rich historical background of trade and cultural exchange. This renewed focus recognizes these ancient pathways' enduring economic potential for modern enterprises. Kazakhstan's geographical positioning grants it significant geoeconomic importance as a vital link between Europe and Asia and a critical player in transcontinental trade.

The importance of these initiatives is undeniable. However, this study's primary focus is to ascertain the business perception of these initiatives at their current stage of development. While conducting a comprehensive quantitative analysis may be premature due to the relatively short implementation period, understanding which initiative is perceived as most 'valuable' by the business community is crucial. This insight can provide valuable guidance for policymakers and investors alike.

As these new Silk Road initiatives unfold, they promise to reshape Eurasia's economic landscape. Understanding each initiative's implications and potential benefits is crucial for strategic planning and growth for businesses in Kazakhstan and beyond. This study aims to evaluate these four major initiatives from a business perspective, offering insights into their relative strengths and the opportunities they present for regional economic integration and development.

By examining the business community's perceptions of these initiatives, we can gain valuable insights into their practical impact and potential for future success. This approach allows us to bridge the gap between policy objectives and on-the-ground business realities, providing a nuanced understanding of how their intended beneficiaries receive these ambitious projects. This study provides an insightful exploration of unions and, through a comprehensive literature review, delves into the concept of the Silk Road and its transformation into regional integration unions. The methodological section details the research design, including criteria for expert selection, methods of data collection, and statistical measurements to ensure data validity. The primary data obtained through in-depth interviews allows for concluding and further discussions on policy implications and suggests directions for future research.

2. LITERATURE REVIEW

The Eurasia region has long been the heart of the ancient Silk Road trade routes, facilitating the exchange of goods, ideas, and cultures across the Eurasian landmass for centuries (Allsen, 2001). These ancient networks, which allowed for free trade from the East to the West and vice versa, are often associated with the modern concept of regional economic integration (Kalra & Saxena, 2021).

Historically, Central Asia, at the crossroads of these lucrative trade networks, played a pivotal role. From the earliest nomadic empires to the Mongol era and the colonization by Tsarist Russia, trade across the Eurasian region was dominated by the trading communities and peoples of Central Asia (Kalra & Saxena, 2021). The caravan trade, in particular, stimulated economic activity and development

in peripheral regions along the Silk Road routes (Levy, 1999).

The success of Central Asian countries during this period can be attributed to their geographical proximity, converging interests in state-building, and shared norms of brotherhood and collective decision-making (Dadabaev, 2021). During the Soviet era, factors such as the widespread use of the Russian language, a unified currency (the Soviet ruble), the absence of internal borders, and centralized governance from Moscow fostered regional cohesion and economic integration (Kalra & Saxena, 2021).

However, the dissolution of the Soviet Union in 1991 and the subsequent establishment of new national borders disrupted this regional integration, shaping the fragile socio-economic fabric of Central Asian societies (Kalra & Saxena, 2021). Despite shared historical roots, cultures, and norms of resilience and informal collective decision-making for nation-building, the literature presents diverse perspectives on regional economic integration in the post-Soviet space.

Some studies, like Adams's (1998), examine regional integration in Central Asia within the broader context of other post-Soviet subregions. Others concentrate solely on integration within the Central Asian region, distinct from the former Soviet republics. A third approach emphasizes integration built upon the historical success of cooperative trade and economic ties between these regions (Omonkulov & Baba, 2019).

Since the collapse of the Soviet Union, major global powers such as Russia, China, and the United States, alongside regional actors, have sought to shape Central Asia's political and economic trajectory through initiatives like the Eurasian Economic Union (EAEU), the Silk Road Economic Belt (SREB), and the New Silk Road (NSR) (Omonkulov & Baba, 2019). These competing initiatives, driven by the divergent interests of their respective powers, vie for influence over the region's economic and political processes.

The EAEU, spearheaded by Russia, aims to create a common market and facilitate the free movement of goods, services, capital, and labor among its member states through measures such as a common customs union, coordinated macroeconomic policies, and regulatory harmonization (Kaczmarski, 2017). In contrast, China's SREB, a central component of the broader Belt and Road Initiative (BRI), focuses on infrastructure development, trade facilitation, investment promotion, and fostering cultural exchange along the historic Silk Road routes (Kaczmarski, 2017).

While these initiatives promise potential economic benefits through increased trade, investment, and regional cooperation, they also face challenges stemming from the divergent political interests of the major powers involved and internal factors such as infrastructure deficiencies and regulatory barriers within Central Asian countries (Omonkulov & Baba, 2019). Despite Kazakhstan's participation in numerous integration unions (Tashtemkhanova et al., 2019), four major initiatives currently exist aimed at fostering economic integration and recreating the new Silk Road. These initiatives will be examined in detail below, as their activities constitute the focus of our research.

The Eurasian Economic Union (EAEU)

Established in 2015, this union represents a significant endeavor in regional economic integration. Spearheaded by Russia, this initiative aims to foster seamless economic cooperation amongst its member states, which include Armenia, Belarus, Kazakhstan, and Kyrgyzstan. The EAEU's primary objectives encompass the creation of a unified economic space, promoting the free movement of goods, services, capital, and labor, and implementing coordinated economic policies. This union seeks to enhance the competitiveness of member states' economies, stimulate economic growth, and improve living standards across the region. The EAEU has made notable strides in customs union implementation, technical regulation harmonisation, and the development of common markets in various sectors. However, challenges persist, including disparities in economic development among

member states and the need for further policy alignment (Vinokurov, E. ,2018). The EAEU emerged as a natural progression and expansion of its predecessor, the Eurasian Economic Community (EurAsEC).

EurAsEC, established on 10 October 2000, laid the groundwork for deeper economic integration among its member states. This earlier union aimed to create a single economic space and foster closer economic ties between Belarus, Kazakhstan, Kyrgyzstan, Russia, and Tajikistan. EurAsEC played a crucial role in harmonising customs procedures, coordinating foreign economic policies, and facilitating the free movement of goods within its member states. While EurAsEC focused primarily on creating a customs union and fostering economic cooperation, the EAEU aims to establish a more comprehensive economic union with aspirations for a single market for goods, services, capital, and labour.

The Silk Road Economic Belt (SREB)

SREB, unveiled by the Chinese government in 2013, forms a crucial component of China's broader Belt and Road Initiative (BRI). This ambitious project aims to revitalize ancient trade routes connecting Asia, Europe, and Africa through enhanced infrastructure development and economic cooperation. The SREB focuses on terrestrial connectivity, emphasizing the construction of transportation networks, energy pipelines, and industrial corridors. It promotes policy coordination, infrastructure connectivity, unimpeded trade, financial integration, and people-to-people bonds among participating countries. The initiative has garnered significant international attention and participation, with numerous countries signing memoranda of understanding with China. While the SREB promises substantial economic opportunities, it has also faced scrutiny regarding debt sustainability, environmental impacts (Silin et al., 2018).

The New Silk Road (NSR)

NSR initiative, introduced by the United States in 2011, represents an alternative vision for regional connectivity and economic development in Central and South Asia. This strategy aims to bolster economic ties, enhance regional stability, and promote sustainable development through increased trade, energy cooperation, and cultural exchange. The NSR initiative emphasizes the importance of private sector involvement, transparent governance, and adherence to international standards in project implementation. Key focus areas include improving cross-border trade procedures, developing energy markets, and strengthening transportation infrastructure. Although the NSR has faced challenges in gaining traction compared to other regional initiatives, it continues to promote principles of economic diversification, sustainable development, and regional cooperation (Firdous & Dar, 2014).

The Central Asia Regional Economic Cooperation (CAREC)

CAREC was initiated in 1997 under the auspices of the Asian Development Bank and represents a partnership of 11 countries and development partners working to promote sustainable economic growth through regional cooperation. CAREC's strategic framework focuses on five operational clusters: economic and financial stability; trade, tourism, and economic corridors; infrastructure and economic connectivity; agriculture and water; and human development. The program has implemented numerous projects to improve transportation corridors, facilitate cross-border trade, and enhance regional energy security. CAREC's multilateral approach emphasizes knowledge sharing, capacity building, and the development of regional public goods. Despite facing challenges such as diverse economic structures and varying levels of commitment among member countries, CAREC has made significant progress in fostering regional integration and economic development in Central Asia (Chatterjee,2018).

Table 1 provides a comparative overview of four regional initiatives in the region.

TABLE 1. Comparison of Regional Economic Integration Initiatives

Item	EAEU	SREB	NSR	CAREC
Objective	To promote economic integration among its member states by creating a common market, facilitating trade and investment, and harmonizing economic policies.	To revitalize ancient trade routes and promote economic cooperation and connectivity across Eurasia by enhancing infrastructure development, trade facilitation, and investment promotion.	To promote economic connectivity: Enhance trade, investment, and infrastructure links.	To promote economic cooperation and integration through infrastructure development, trade facilitation, and policy dialogue.
Geographical Scope	Armenia, Belarus, Kazakhstan, Kyrgyzstan, and Russia, focusing primarily on the former Soviet republics in Eurasia.	Central Asia, South Asia, the Middle East, and parts of Africa.	Central Asia, South Asia, the Middle East, and parts of Africa	11 member countries, including Afghanistan, Azerbaijan, China, Georgia, Kazakhstan, Kyrgyz Republic, Mongolia, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan
Key Features	Common customs union, common market, coordinated macroeconomic policies, and free movement of goods, services, capital, and labor among member states.	Infrastructure development, trade facilitation, investment promotion, cultural exchange, and people-to-people connectivity.	Infrastructure development, trade facilitation, investment promotion, regional cooperation.	Regional connectivity projects, trade and transport facilitation, energy infrastructure development, and policy coordination.

Note: compiled by authors

A comparative analysis of the four regional initiatives - EAEU, SREB, NSR, and CAREC -reveals Eurasia's distinct economic integration and cooperation approaches. The EAEU emerges as the most formalized structure, focusing on creating a common market and harmonizing economic policies among its five member states. In contrast, SREB and NSR adopt a more flexible, project-based approach, emphasizing infrastructure development and trade facilitation across a broader geographical expanse without formal membership structures.

CAREC occupies a middle ground, featuring a defined membership of 11 countries while maintaining a project-oriented focus similar to SREB and NSR. Its emphasis on regional connectivity projects and policy coordination distinguishes it from the EAEU's more institutionalized integration model.

Geographically, these initiatives exhibit significant overlap, particularly in Central Asia. However, their scopes differ considerably, with the EAEU concentrating on former Soviet republics. At the same time, SREB, NSR, and CAREC extend their reach to

include parts of South Asia, the Middle East, and even Africa in some cases.

The key features of each initiative reflect their differing objectives and structures. The EAEU's common customs union and coordinated macroeconomic policies contrast with the infrastructure-centric approaches of SREB and NSR. CAREC, meanwhile, combines elements of both, focusing on tangible connectivity projects alongside policy coordination efforts.

Crucial Factors for Assessing the Economic Integration

As evident from our analysis, the unions under examination exhibit diverse approaches to their formation and functionality. However, they share a common overarching aim: to enhance the economic circumstances of their member states and foster innovative policies, among other objectives. From the myriad factors that contribute to the success of an economic union, we have identified eight that are both widely applicable and well-substantiated in the scholarly literature. These selected factors form the foundation of our subsequent analysis, providing a robust framework through which to evaluate the efficacy and potential of these regional economic initiatives.

One factor that reflects a union's effectiveness and justifies its purpose is the significance of intra-union trade in fostering economic growth and development. Increased trade volume between member states indicates enhanced economic cooperation and market integration, leading to economies of scale, increased competitiveness, and overall economic prosperity for businesses, society, and the country as a whole (Baldwin & Seghezza, 1996).

Another important indicator is the expansion of market presence. Expanding market presence allows businesses to diversify their customer base, reduce dependency on a single market, and capitalize on emerging opportunities in new member states. This stimulates business growth and fosters economic development, job creation, and revenue generation, benefiting both businesses and the broader society (Rugman & Verbeke, 2002).

A further crucial factor is supply chain optimization. Efficient supply chains enhance business competitiveness and profitability by leading to cost savings, improved product availability, and faster response to market demands. This translates into lower production costs, higher productivity, and improved consumer satisfaction, contributing to economic growth and competitiveness for businesses, society, and the country (Christopher, 1998; Chopra & Meindl, 2007).

Another significant indicator is the harmonization of regulations. Harmonized regulations reduce compliance burdens, eliminate trade barriers, and enhance legal certainty for businesses operating across member states. This fosters a conducive business environment, encourages investment, and promotes entrepreneurship, ultimately driving economic growth, job creation, and prosperity for businesses, society, and the country (Djankov et al., 2002).

Access to financing is also a critical factor in assessing the effectiveness of a union. Accessible financing across the union provides businesses with the capital needed for investment, expansion, and innovation. This fuels business growth facilitates entrepreneurship, and stimulates economic activity, leading to job creation, income generation, and overall economic development for businesses, society, and the country (Beck et al., 2008; Claessens et al., 2001).

Cross-border partnerships and collaborations are crucial for business success within unions (Gulati et al., 2000). These partnerships facilitate knowledge exchange, resource sharing, and market access, leading to increased innovation, competitiveness, and economic prosperity. Moreover, employee mobility is essential for economic growth and business performance within unions (Bhaskarabhatla & Schmitz, 2009). Labor mobility enhances access to talent, addresses skill shortages, and improves resource allocation, ultimately contributing to increased

productivity, innovation, and competitiveness. In addition, innovation and technology transfer are critical drivers of economic growth and business success within unions (Teece, 1986; Cohen & Levinthal, 1990). The exchange of knowledge and technology stimulates productivity, fosters industry evolution, and creates new economic opportunities.

3. RESEARCH METHODS

This study employed a structured expert panel assessment through deep interviews to evaluate the significance of various quantifiable indicators for successful business integration within the context of four regional economic initiatives. The data collection process was designed to ensure comprehensive and reliable input from diverse experts. The primary data for this study were derived from in-depth interviews conducted with 20 expert respondents. The expert panel comprised individuals with extensive experience in international economic integration, business expansion, and political decision-making related to international integration initiatives.

By their professional roles, all experts were familiar with the four critical initiatives under examination. The experts, currently based in the Republic of Kazakhstan, responded to open-ended and closed questions, enabling the researchers to determine the weight and significance of specific indicators for the four unions under study. Table presents the demographic profile of the 20 experts who participated in the research study.

TABLE 2. Demographic Profile of Experts (N = 20)

No.	Demographic Feature		Experts (in figures)	Experts (in %)
1	Age	30-39	4	20
		40-49	10	50
		50 and above	6	30
		Total	20	100.00
2	Gender	Male	14	70
		Female	6	30
		Total	20	100.00
3	Work Sphere	International Business	10	50
		Academia / Research	6	30
		Policy Worker	4	20
		Total	20	100.00
4	Living Region in Kazakhstan	Central	4	20
		East	0	0
		North	8	40
		South	8	40
		West	0	0
		Total	20	100.00

Note: compiled by authors

As we can see from the table, the majority of experts (50%) fall within the 40-49 age range, followed by 30% who are 50 and above, and 20% between 30-39 years old. This distribution suggests a relatively senior group of experts with substantial professional experience. The expert panel also shows a gender imbalance, with 70% male and 30% female participants. Half of the experts (50%) are engaged in international business, while 30% come from academia or research backgrounds, and 20% are policy workers. This diverse professional background ensures a multifaceted perspective on the research

subject. The experts are primarily located in the North and South regions of Kazakhstan (40% each), with the remaining 20% residing in the Central region. Notably, there are no participants from the East or West regions.

This demographic profile indicates a diverse group of experts in terms of age and professional background despite some limitations in gender balance and geographical representation. The composition of the expert panel suggests a wealth of experience in international affairs and regional dynamics, which is pertinent to the study's focus on international economic integration and regional initiatives. The interviews were structured to explore each indicator's perceived importance (weight) and severity (significance) within the context of the four regional initiatives. The deep interviews were conducted via video conferencing to facilitate detailed and in-depth discussions. Experts were asked to provide ratings and qualitative feedback on each indicator, focusing on their experiences and insights into the practical implications of these indicators.

Data Processing

The final results, accompanied by dispersion and concordance coefficient analyses, were comprehensively reported to enhance the study's transparency and reliability.

The collected data underwent a rigorous analysis to ensure accuracy and reliability. Two key statistical measures were employed: the Dispersion Coefficient and the Concordance Coefficient. Dispersion Coefficient (D): This measure was used to evaluate the variability in the experts' assessments. It was calculated using the formula (1):

$$D = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} \qquad (1)$$

where:

X_i - represents an individual expert's assessment;

$\bar{x}$ - the mean assessment across all experts;

n - the number of experts.

A low dispersion coefficient indicated a high level of agreement among experts, while a higher coefficient suggested differing opinions.

Concordance Coefficient (C): This measure assessed the consistency of the experts' rankings and the degree of concordance among their assessments. It was calculated as follows (2):

$$C = \frac{\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} sign(x_i - x_j)}{\binom{n}{2}} \qquad (2)$$

where:

X_i and X_j are the assessments of two different experts;

sign - a function returning -1, 0, or 1, depending on the relative values of X_i and X_j;

n - the number of experts.

The concordance coefficient provided insights into the panel's level of consensus, with higher values indicating more robust agreement. The results were subjected to consistency checks to ensure the coherence of experts' weight and significance ratings. The final analysis incorporated both the dispersion and concordance coefficients to validate the reliability of the data.

4. FINDINGS AND DISCUSSIONS

Effective economic integration within regional initiatives requires a thorough evaluation of the various criteria contributing to unified economies' development and prosperity. This study analyzed vital criteria that determine the success of economic integration using expert assessments. For each criterion, measures such as dispersion, concordance coefficient, average, and weight were calculated, allowing for the identification of the most significant factors influencing integration processes. The following sections present the main conclusions drawn from the analysis of these criteria. The initiatives' evaluation criteria were assessed based on their dispersion, concordance coefficient, average, and weight (Table 3).

TABLE 3. Evaluation criteria and weighting

Criteria	Dispersion Coefficient	Concordance Coefficient	Average	Weight
Increased intra-union trade	0,26	0,994	4,55	5
Expansion of market presence	0,25	0,994	4,6	5
Supply chain optimization	0,26	0,994	4,45	4
Harmonization of regulations	0,34	0,992	3,65	4
Access to financing	0,37	0,991	4,5	4
Cross-border partnerships and collaborations	0,26	0,994	3,5	3
Employee mobility and talent acquisition	0,26	0,994	3,5	3
Innovation and technology transfer	0,25	0,994	4,6	5

Note: compiled by authors

Based on the results obtained, the following conclusions were drawn.

(1) Increased intra-union trade: The findings indicate that increased intra-union trade is crucial for successful economic integration. The dispersion of this criterion was 0.26, with a concordance coefficient of 0.994, signifying a high level of agreement among experts. The average weight assigned to this factor was 4.55, demonstrating its perceived importance in fostering economic ties and promoting market efficiency within the union. This high score underscores the significance of intra-union trade in enhancing economic interdependence and mutual benefits among member states.

(2) Expansion of market presence: Expansion of market presence was another highly rated factor, with a dispersion of 0.25 and a concordance coefficient of 0.994. Experts assigned an average weight of 4.6 to this criterion, highlighting its importance in enabling businesses to access new markets and diversify their customer base. This expansion is essential for reducing dependency on a single market and capitalizing on emerging opportunities within the union, thereby stimulating economic growth and job creation.

(*3) Supply chain optimization:* Supply chain optimization received a dispersion score of 0.26 and a concordance coefficient of 0.994, with an average weight of 4.45. This factor is critical for improving business competitiveness and profitability through cost savings, enhanced product availability, and faster response to market demands. Optimizing supply chains across member states can lead to lower production costs and higher productivity, contributing to overall economic growth and consumer satisfaction.

(4) Harmonization of regulations: The harmonization of regulations had a dispersion of 0.34 and a concordance coefficient of 0.992. The average weight for this factor was 3.65, reflecting its role in reducing compliance burdens and eliminating trade barriers. Harmonized regulations create a conducive business environment, encourage investment, and promote entrepreneurship by providing legal certainty and simplifying cross-border operations.

(5) Access to financing: Access to financing was rated with a dispersion of 0.37 and a concordance coefficient of 0.991. Experts assigned an average weight of 4.5, emphasizing its importance for business growth and development. Access to finance is vital for investment, expansion, and innovation, enabling businesses to fuel economic activity and generate income, which leads to job creation and overall economic development.

(*6) Cross-border partnerships and collaborations:* This factor had a dispersion of 0.26 and a concordance coefficient of 0.994, with an average weight of 3.5. Cross-border partnerships facilitate knowledge exchange, resource sharing, and market access, allowing businesses to leverage complementary strengths and capabilities. These partnerships are essential for fostering innovation, enhancing competitiveness, and driving business success within the union.

(7) Employee mobility and talent acquisition: Employee mobility and talent acquisition were rated with a dispersion of 0.26, a concordance coefficient of 0.994, and an average weight of 3.5. Moving employees freely across member states is crucial for efficiently addressing skill shortages and deploying resources. This mobility enhances business productivity, fosters innovation, and strengthens competitiveness, contributing to economic growth and job creation.

(8) Innovation and technology transfer: Innovation and technology transfer received a dispersion score of 0.25 and a concordance coefficient of 0.994, with an average weight of 4.6. The flow of innovation and technology between businesses in different member states promotes knowledge diffusion, fosters technological advancements, and stimulates productivity growth. This factor enhances business competitiveness and drives economic development by creating new opportunities, jobs, and wealth.

Figure 1 illustrates the weighted radar chart of the assessed criteria, visually representing each factor's relative importance and performance.

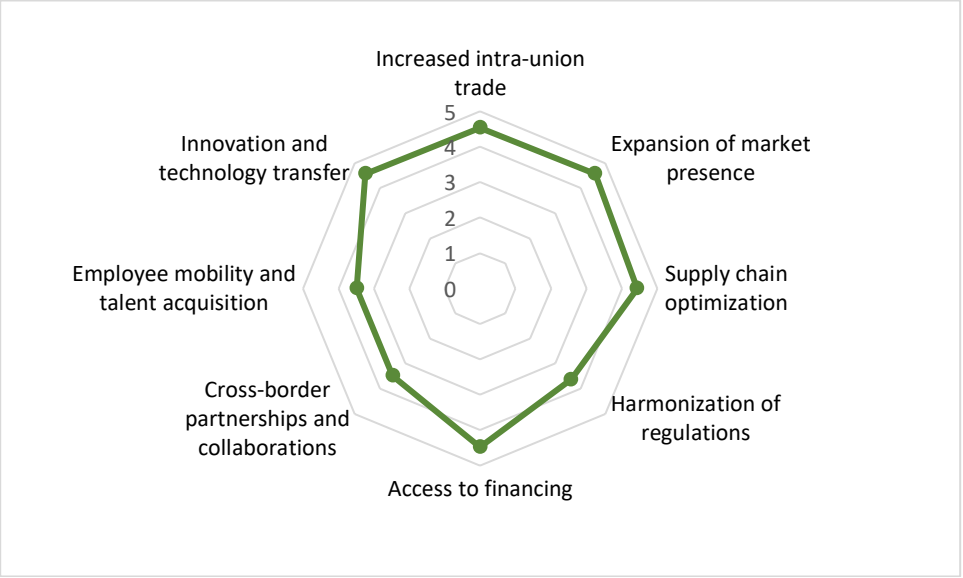

FIGURE 1. Criteria weighted radar chart

Note: compiled by authors

The radar chart provides a detailed comparison of the key criteria that influence successful economic integration. Each axis represents a critical factor, illustrating the relative importance and performance of different integration dimensions. The highest-rated factors such as increased intra-union trade, expansion of market presence, and innovation and technology transfer emphasize the pivotal role these elements play in enhancing regional economic cohesion and driving competitive advantage. These criteria are closely linked to improving productivity, fostering collaboration, and enabling smoother market operations within the union.

In contrast, areas like access to financing and employee mobility scored lower, highlighting potential bottlenecks that may hinder comprehensive integration. The chart suggests that these dimensions could benefit from targeted interventions or policy adjustments to align them more closely with the overall integration goals. Additionally, factors like harmonization of regulations and supply chain optimization are moderately rated, reflecting both their importance and the

challenges that might still exist in achieving full alignment across member states.

The weighted visualization not only underscores the current strengths but also points out areas for strategic improvement. By synthesizing complex data into a clear and accessible format, this chart supports informed decision-making, helping policymakers and stakeholders prioritize resources and initiatives that are most likely to yield sustainable integration outcomes.

The data presented in Table 4 allows for a detailed examination of the initiatives.

TABLE 4. Comparative Evaluation of Regional Economic Integration Initiatives

Criteria	EAEU			SREB			NSR			CAREC		
	weight	Sig.	total	weight	Sig.	total	weight	Sig.	total	weight	Sig.	total
Increased intra-union trade	5	4	20	5	7	35	5	5	25	5	5	25
Expansion of market presence	5	4	20	5	7	35	5	4	20	5	5	25
Supply chain optimization	4	5	20	4	7	28	4	8	32	4	5	20
Harmonization of regulations	4	7	28	4	4	16	4	3	12	4	5	20
Access to financing	4	6	24	4	5	20	4	6	24	4	5	20
Cross-border partnerships and collaborations	3	6	18	3	7	21	3	7	21	3	6	18
Employee mobility and talent acquisition	3	7	21	3	4	12	3	5	15	3	6	18
Innovation and technology transfer	5	6	30	5	6	30	5	6	30	5	4	20
Total	33	45	181	33	47	197	33	44	179	33	41	166

Note: compiled by authors

According to Table 4, SREB's high rating reflects its strategic emphasis on improving trade connectivity and infrastructure, thus enhancing trade flows among member countries. EAEU and CAREC scored 25, while NSR scored 25, reflecting a moderate emphasis on trade integration.

Expansion of market presence was another highly rated factor, with SREB leading the rankings. SREB's high rating highlights its effectiveness in opening vast new markets through improved infrastructure and trade agreements. EAEU and NSR scored 20, and CAREC 25, showing varied approaches to market expansion. Supply chain optimization received high ratings across all initiatives, with SREB again in the lead. Optimizing supply chains reduces production costs and improves productivity, making businesses more competitive. SREB's focus on modernizing infrastructure and logistics networks is critical for streamlining supply chains. Harmonized regulations reduce compliance burdens and eliminate trade barriers, creating a favorable business environment. The highest for EAEU is (28), indicating extensive regulatory harmonization efforts. Access to financing was crucial for all initiatives, the highest for NSR and EAEU (24 each), reflecting solid financial integration initiatives. The importance of cross-border partnerships and collaborations is highlighted by the SREB, which scored the

highest at 21, underscoring the significance of partnerships. The EAEU, NSR, and CAREC scored 18, 21, and 18, respectively, indicating varying levels of cross-border cooperation. In employee mobility and talent acquisition, the SREB again scored the highest at 21, emphasizing the promotion of talent mobility. Similarly, the EAEU scored 21, while the NSR and CAREC scored 15 and 18, respectively, reflecting their recognition of the importance of employee mobility. Regarding innovation and technology transfer, the EAEU, SREB, and NSR each scored a high 30, underlining the critical role of innovation. CAREC, with a score of 20, also shows a strong focus on technology transfer.

A bubble chart (Figure 2) visualized the overall scores and rankings of the four regional economic integration initiatives based on the evaluation criteria.

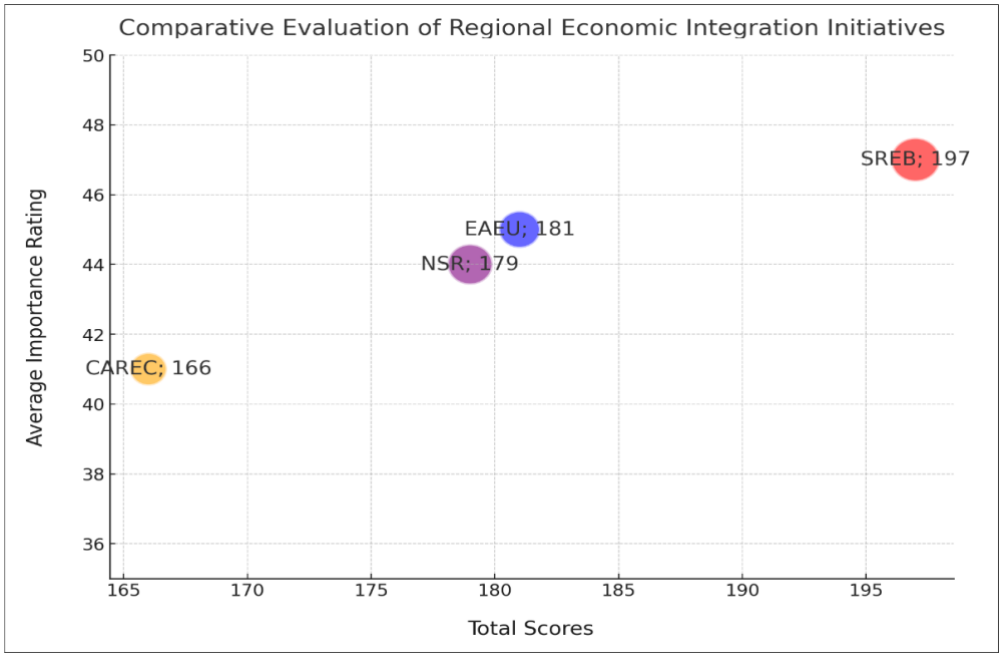

FIGURE 2. Bubble chart of regional economic integration initiatives

Note: compiled by authors

This chart provides a clear and comparative overview of the initiatives, highlighting their strengths and areas for improvement. The bubble chart visualizes the overall scores and rankings of the four regional economic integration initiatives. It includes (1) the x-axis, the average importance rating assigned to each criterion by the experts; (2) the y-axis, the total significance score for each initiative. Thus, the bubble size visualizes each initiative's overall effectiveness or impact.

SREB scored the highest overall, with a total weight of 197, indicating its strong emphasis on infrastructure development, trade facilitation, and investment promotion. EAEU came in second with a total weight of 181, showcasing significant efforts in creating a common market and promoting intra-union trade. NSR scored 179, reflecting its focus on enhancing connectivity and economic cooperation. CAREC had the lowest total weight of 166, demonstrating its commitment to regional connectivity and economic integration. The bubble chart accurately reflects that the Silk Road Economic Belt (SREB) initiative leads in total score and overall effectiveness, followed closely by the Eurasian Economic Union (EAEU). The New Silk Road (NSR) and Central Asia Regional Economic Cooperation (CAREC) also show

significant efforts but with varying levels of focus and effectiveness.

The analysis of the findings reveals that increased intra-union trade, market expansion, and innovation and technology transfer are paramount for successful economic integration initiatives in Central Asia. These factors, along with supply chain optimization, harmonized regulations, access to financing, cross-border partnerships, and employee mobility, collectively contribute to a robust economic union. By addressing these key areas, policymakers and businesses can develop targeted strategies to enhance regional cooperation, stimulate economic growth, and achieve the broader objectives of the revived Silk Road initiatives.

5. CONCLUSIONS

Our research aims to identify the business perspectives and perceptions regarding the ongoing integration unions, ensuring that the economic integration efforts align with the business community's interests and needs. This study evaluated the importance of quantifiable indicators for gauging successful business integration within economic unions, focusing on initiatives related to reviving ancient Silk Road trade routes across Central Asia. Through an expert panel assessment and rigorous statistical analysis involving dispersion and concordance coefficients, the research identified several critical factors that contribute to effective economic integration. The analysis shows that from a business perspective, according to the opinion of experts from businesses in Kazakhstan, the most significant criteria among existing criteria for successful economic integration are increased intra-union trade, expansion of market presence, and innovation and technology transfer. Among the four ongoing initiatives, the Silk Road Economic Belt (SREB) received the highest overall score, emphasizing its strategic focus on improving trade connectivity and infrastructure to enhance trade flows among member countries. However, the differences in scores among the initiatives are not significant, indicating a relatively balanced effectiveness across these projects. This slight difference in scores demonstrates that while SREB provides more opportunities, particularly in cross-border partnerships and collaborations, employee mobility, and talent acquisition, other initiatives also show strong potential in different areas. Specifically, SREB leads in total scores for criteria such as increased intra-union trade (35), expansion of market presence (35), supply chain optimization (32), and innovation and technology transfer (30). In comparison, the Eurasian Economic Union (EAEU) has the highest score in the harmonization of regulations (28), reflecting its efforts in creating a single market between countries. This high level of regulatory harmonization facilitates a smoother business environment by reducing compliance burdens and eliminating trade barriers. In conclusion, while SREB stands out slightly due to its comprehensive approach to infrastructure and market expansion, the relatively small differences in scores among the initiatives suggest a general alignment in their effectiveness. In many cases, political and economic objectives drive countries' participation in economic integration unions and initiatives. However, it is crucial to remember that these activities should primarily bring tangible benefits to societies and businesses.

The current study is limited by the availability of data from only 20 experts, based in Kazakhstan. This restricted data pool may not fully represent the diverse perspectives and experiences across the entire Central Asian region. Consequently, the generalizability of the findings to other Central Asian countries might be constrained. To address these limitations, future research will involve conducting in-depth interviews with representatives from all Central Asian countries, providing a more comprehensive understanding of the region's specific contexts and challenges.

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The Impact of Urbanization on Air Quality in Largest Cities of Kazakhstan

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ABSTRACT

In the context of the rapid growth of urbanization and industrialization of Kazakhstan, the air pollution problem in large cities is becoming increasingly urgent. It is essential to assess the impact of economic growth on the environmental situation, as this allows us to develop strategies to improve air quality and ensure sustainable development. Thus, this study examines the impact of urbanization and economic growth on air pollution across four major cities in Kazakhstan from 2016 to 2022. Statistical methods were used to analyze the relationship between pollution levels and economic indicators, including gross regional product (GRP) and industrialization. The study covers the period from 2016 to 2022 and is based on data on concentrations of critical pollutants collected from the National Bureau of Statistics of the Republic of Kazakhstan. National monitoring sources collected air quality data, including PM2.5, PM10, SO2, NO2, and CO concentrations. Statistical analyses, as correlation and regression models, were applied to establish relationships between pollution levels and economic growth indicators. The study found significant correlations between economic activities and air pollution levels. In Almaty, a 10% increase in GRP corresponds to a 5% increase in pollutant concentrations. Almaty experienced the highest average PM2.5 concentration at 42 μg/m³, exceeding permissible norms by 20%. Other cities showed varied levels of pollution influenced by specific economic and industrial profiles. The results underscore the pressing need for effective urban management and strategic policy-making to mitigate the adverse effects of economic development on air quality.

KEYWORDS: Economic Growth, Urbanization, Carbon Dioxide Emissions, Air Pollution, Environmental Policy, Environmental Impact, Sustainable Development

SCSTI: 87.17.91

JEL Code: Q53, Q56, R11, O18

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1. INTRODUCTION

The study of the impact of urbanization on carbon dioxide emissions is a crucial step in understanding the complex relationships between urban growth processes and environmental sustainability. This phenomenon is confirmed by numerous studies that highlight the need for a deeper analysis of the impact of urbanization on environmental indicators, especially in developing countries (Shahbaz et al., 2016). Urbanization, as an integral part of modern economic development, significantly impacts the environment by altering energy consumption patterns and greenhouse gas emissions levels (Ali et al., 2019; Azam et al., 2021). The urban population is growing, leading to increased resource consumption and carbon emissions, which presents a pressing issue for the global community (Armeanu et al., 2021). The urbanization process is accompanied by infrastructure development, an increase in vehicles, and energy consumption, which are directly related to carbon dioxide emissions (Bai et al., 2012; Zhang et al., 2019). Massive construction of residential and commercial buildings and expanding transport networks in cities lead to a growth in energy demand, which can contribute to higher carbon emission levels (Bekhet & Othman, 2018).

One of the central concepts in this field is the "Environmental Kuznets Curve" which suggests that at the early stages of economic growth, environmental pollution increases but reaches a peak and then begins to decline as income levels and technological advancements grow (Spring & Cirella, 2022). Studies indicate that urbanization can play a positive and negative role in this process, depending on the management practices and the implementation of sustainable technologies in cities (Adebayo et al., 2022).

Contemporary research also emphasizes the importance of differences between countries and regions in the context of urbanization and CO2 emissions. In developing countries, where urbanization occurs rapidly and often without proper planning, emission levels can significantly rise. In contrast, this effect may be less pronounced in developed countries, where high environmental control standards and energy-saving technologies accompany urbanization. Therefore, it is essential to consider local conditions and management strategies for a more accurate understanding of the impact of urbanization on the environmental situation.

The impact of urbanization on carbon dioxide emissions becomes particularly relevant in the context of Kazakhstan, where rapid urban development and population growth pose significant environmental challenges. Kazakhstan, as a country with a fast-growing economy and actively urbanizing regions, faces issues related to increased carbon emissions, which negatively impact environmental conditions and the population's quality of life. According to the World Bank, globally, urbanization is growing, and by 2050, it is expected that about 68% of the world's population will live in cities, a significant increase from 56% in 2020 (World Bank, 2020). This is because the growing urban population leads to higher energy consumption, transportation, and, consequently, CO2 emissions. According to the Agency for Strategic Planning and Reforms, by 2023, about 60% of the country's population lives in cities, a significant increase from 53% in 2010 (Bureau of National Statistics, 2023). Major cities such as Almaty and Astana demonstrate exceptionally rapid population growth, leading to increased energy consumption and carbon emissions.

Studies show that in countries with a high degree of urbanization, such as China and the USA, the impact of urbanization on carbon dioxide emissions is associated with intensive energy consumption and transportation. In China, where the urbanization level reached 62% by 2022, carbonic acid gas emissions were about 10 billion tons. In the USA, with an urbanization level of 82% in the same year, emissions were approximately 5 billion tons. (United Nations, 2015) These data emphasize the need to consider the specifics of urbanization when developing strategies to reduce carbon emissions.

Analyzing data on the concentration of pollutants in different cities for 2016-2022, the study aims to fill the literary gap on how urbanization, industrialization and economic growth affect air quality problems. This study examines the impact of urbanization and economic development on air pollution across four major cities in Kazakhstan from 2016 to 2022. The results obtained are intended to serve as a basis for recommendations on effective urban management and policy measures aimed at mitigating the impact of economic development on the environment, which will ultimately contribute to sustainable urban growth and improve the overall quality of the environment in Kazakhstan.

2. LITERATURE REVIEW

Urbanization, a hallmark of economic development, is widely recognized as a significant driver of CO2 emissions, particularly in emerging economies. Bai et al. (2012) highlighted the sustainability dilemmas posed by landscape urbanization in China, where the positive feedback loops between economic growth and environmental stress create significant challenges for sustainable development. In Malaysia, Shahbaz et al. (2016) described the STIRPAT model to illustrate how urbanization impacts carbonic acid gas emissions, underscoring the need for policies addressing the environmental consequences of urban growth in developing economies. Ali et al. (2019) provided evidence from Pakistan, demonstrating that rapid urban growth exacerbates environmental degradation. This is primarily due to the increased demand for energy and the expansion of industrial activities accompanying urbanization. Similarly, Liang and Yang (2019) explore the relationship between China's urbanization, economic growth, and environmental pollution. Their findings indicate that while urbanization contributes to economic growth, it also leads to significant environmental challenges, which vary depending on the level of economic development.

Energy consumption is another critical factor affecting economic growth and environmental sustainability. The literature reveals a complex relationship between these elements, with varying implications depending on the type of energy consumed. Cai et al. (2018) investigated the nexus between clean energy consumption, economic growth, and CO2 emissions. Their study demonstrates that clean energy consumption can promote economic growth while reducing environmental impacts. This finding aligns with the consensus that renewable energy is essential for sustainable development. Azam et al. (2021) extend this analysis by examining the effects of natural gas, nuclear energy, and renewable energy on GDP and carbon emissions across multiple countries. Their results reveal that a diversified energy mix, including significant contributions from renewable sources, can support economic growth while mitigating the adverse environmental impacts of fossil fuels.

The specific role of renewable energy in this nexus has been a subject of intense study, with a growing body of literature emphasizing its potential to decouple economic growth from environmental degradation. Armeanu et al. (2021) comprehensively analyzed the linkages between renewable energy, pollution, economic development, and urbanization across different income groups. Their findings suggest that renewable energy adoption is beneficial for reducing pollution and supporting sustainable economic growth, particularly in low and middle-income countries. Adebayo et al. (2022) focused on Sweden, analyzing the asymmetric effects of renewable energy consumption and trade openness on carbon emissions. Their study underscores the importance of policy frameworks that can maximize the environmental benefits of renewable energy, suggesting that tailored approaches are necessary to address the specific needs and circumstances of different countries.

Several studies have also explored the role of various sectors in the economic growth-environment nexus, offering insights into how different aspects of the economy contribute to CO2 emissions. Dogan and Turkekul (2016) investigated the Environmental Kuznets Curve (EKC) hypothesis for the United States, finding that urbanization, financial development, and energy consumption are significant drivers of CO2 emissions. Their research has important policy implications, particularly for sustainable urban planning and energy efficiency initiatives. Fang and Chang (2016) examined the role of human capital and energy consumption in economic growth in Asia-Pacific countries, highlighting the need for investments in education and energy infrastructure to achieve sustainable growth. These findings are supported by Kais and Ben Mbarek (2017) and Han et al. (2018), who explored similar dynamics in different regions, providing a broader understanding of how various factors influence carbonic acid gas emissions and economic growth. Zhang et al. (2019) offered fresh evidence from developing countries, examining the nexus between economic growth, energy consumption, and carbon emissions. Their study is crucial for understanding the unique challenges faced by these economies in balancing growth with sustainability, particularly in light of their differing levels of development and access to technology.

Country-specific studies offer valuable insights into the complex dynamics between energy consumption, economic growth, and environmental sustainability. Wang et al. (2018) provided empirical evidence from countries with different income levels, showing that the relationship between urbanization, economic growth, and carbon dioxide emissions varies significantly across regions. Their findings suggest that while high-income countries may have the resources and technology to mitigate the environmental impacts of urbanization, low and middle-income countries often face more significant challenges in achieving this balance. Nathaniel et al. (2021) analyzed the roles of nuclear energy, renewable energy, and economic growth in the G7 countries, providing insights into how developed economies integrate renewable energy into their growth strategies. Their study indicates that developed countries, with their advanced infrastructure and technology, are better positioned to adopt renewable energy and reduce their carbon footprints.

In the context of emerging economies, additional studies highlight the importance of renewable energy and sustainable practices. Zoundi (2017) and Uddin et al. (2020) explored the role of renewable energy in promoting sustainable development, with a particular focus on the challenges and opportunities in developing countries. Their research emphasizes the need for supportive policies and international cooperation to enhance the adoption of renewable energy in these regions. Bui Minh and Bui Van (2023) and Premashthira (2024) examined the relationship between renewable energy use, carbonic anhydride emissions, and economic growth in Thailand and Vietnam, respectively. These studies provide region-specific insights that are critical for formulating effective policies to promote sustainable development in Southeast Asia. They also underscore the potential of renewable energy to drive economic growth while minimizing environmental impacts, particularly in countries with abundant renewable resources.

Green energy policies in developed regions like the European Union and the United States also provide valuable lessons for other countries. Bekhet et al. (2017) explored the dynamic relationship between urbanization and CO2 emissions in Malaysia, emphasizing the importance of developing sustainable urbanization strategies. Spring and Cirella (2022) analyzed green energy policies in these regions, highlighting different countries' approaches to fostering sustainable development through renewable energy initiatives. Their study underscores the importance of policy frameworks that support the transition to green energy, including investments in technology, infrastructure, and

education. The success of these policies in the European Union and the United States provides a roadmap for other countries seeking to enhance their renewable energy sectors and achieve sustainable economic growth.

The analyzed studies showed complex and ambiguous relationships between urbanization, energy consumption, and carbonic acid gas emissions. While urbanization and economic growth often lead to increased CO2 emissions, adopting renewable energy and implementing efficient energy policies can mitigate these impacts. The studies reviewed highlight the importance of tailoring policies to the specific needs and circumstances of different countries, with a particular emphasis on the potential of renewable energy to support sustainable development. As countries continue to navigate the challenges of economic growth and environmental sustainability, future research should focus on exploring these relationships in greater detail, particularly in the context of emerging economies, to develop effective strategies for achieving sustainable development.

3. METHODOLOGY

The analysis of air pollution levels in Astana, Almaty, Shymkent and Karaganda was carried out to assess the general trends in the concentrations of pollutants over time. These cities were selected for this analysis because each reflects different aspects of Kazakhstan's economic and industrial landscape. Astana's rapid development, Almaty's economic intensity, Shymkent's industrial focus, and Karaganda's heavy industry provide a comprehensive view of how diverse economic activities influence air quality and urban sustainability. The research methodology includes a multi-stage analytical process aimed at analyzing the impact of urbanization on air pollution, shown in Figure 1.

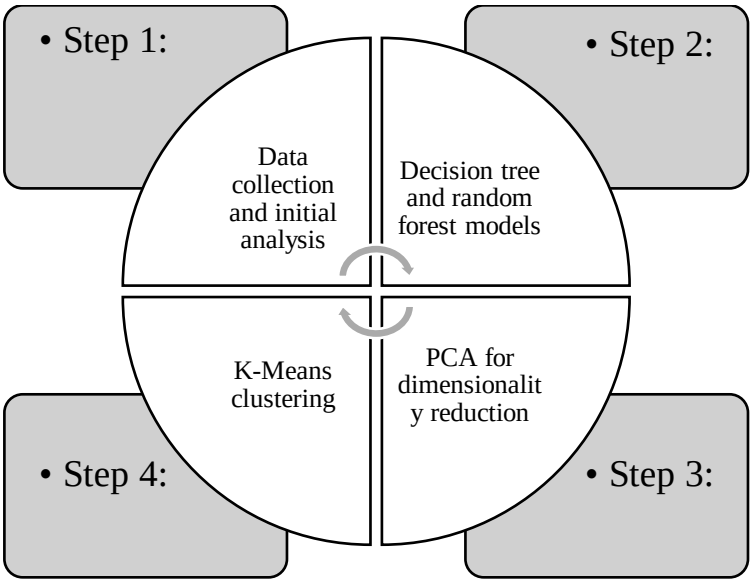

FIGURE 1. Steps of research

Note: compiled by authors

Look at the stages in more detail.

Step 1: data collection and initial analysis. The analysis focused on critical pollutants (SO2, NO2, CO, and PM10) and examined their average daily and annual concentrations in various urban areas from 2016 to 2022. Data was collected from the National Bureau of Statistics. The objective was to identify

patterns in pollution levels related to economic activities or policy changes in each city. This approach provided insights into how urbanization and industrialization influence air quality and enriched the understanding of the relationship between economic growth and environmental sustainability.

Step 2: decision tree and random forest models. The methodology's second stage involved using decision trees and random forest algorithms to assess the relative importance of various economic indicators in predicting the Air Pollution Index (API). Decision trees are nonparametric models that break data into subsets based on the most significant independent variables, resulting in a hierarchy of decision nodes culminating in the prediction of the dependent variable. Random forests, an ensemble method, build multiple decision trees based on random subsets of data and combine their predictions to improve reliability and generalizability. At this stage, the following indicators were considered in Table 1.

TABLE 1. Independent and internal variables

Independent variable	**Unit**
Gross Regional Product (GRP)	KZT
Small and medium-sized enterprises (SMEs)	Units
Population growth	People
Retail trade	KZT
Investments payments	KZT
Tax payments	KZT
API	mg/m^3

Note: compiled by authors

Both models were trained based on a dataset, and indicators of feature importance were extracted to determine which variables had the most significant impact on pollution levels. This step played a crucial role in identifying the main factors of air pollution, laying the foundation for subsequent scaling down and clustering.

Step 3: PCA for dimensionality reduction. Principal Component Analysis (PCA) was applied to reduce dataset dimensionality while preserving critical information. PCA transformed variables into principal components reflecting maximum variance in the data. Two main elements were identified: PC1, reflecting overall economic activity and its relationship to pollution, and PC2, capturing additional differences in economic and demographic models. This analysis provided insights into the relationships between economic indicators and environmental pollution, facilitating region classification.

Step 4: K-Means clustering. K-Means clustering grouped regions based on economic characteristics and pollution levels. This method divides data into clusters to minimize variance within and maximize variance between clusters. Economic indicators and API values were standardized, and clustering was applied to PCA components. Three clusters were identified, reflecting distinct regional economic activity and pollution characteristics. This approach helped formulate targeted environmental and economic policies by identifying regions with similar attributes.

4. FINDINGS AND DISCUSSIONS

The results of this study provide a comprehensive overview of the relationship between economic activities and air pollution in four cities: Astana, Almaty, Karaganda, and Shymkent. By analyzing pollutant concentrations from 2016 to 2022, this work explores how urbanization and industrialization impact environmental quality in different urban settings.

Figure 1 presents the overall average concentration of key pollutants over the period from 2016 to 2022.

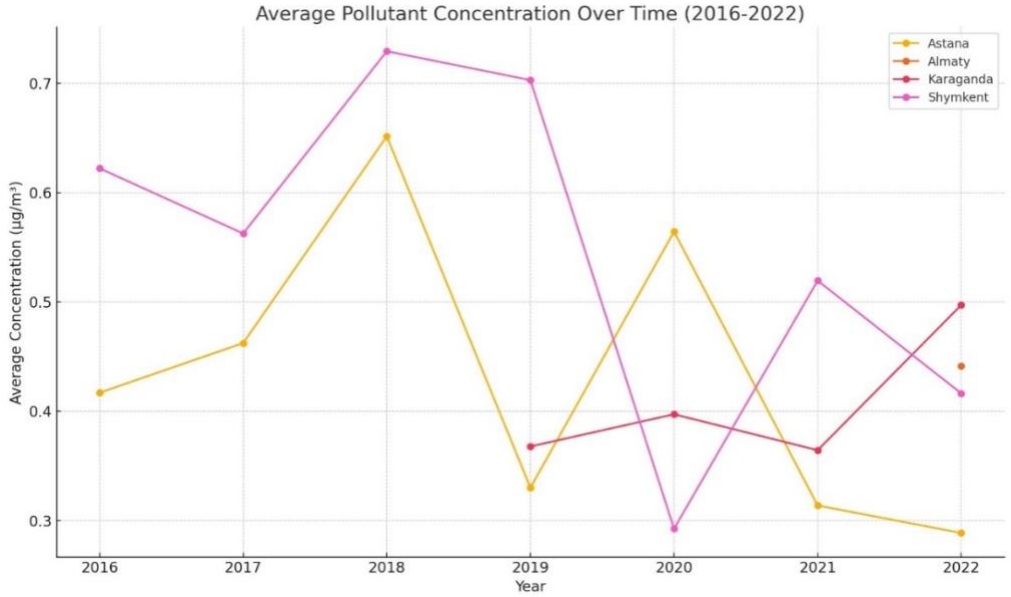

FIGURE 1. Dynamics of the share of the urban population of the total population in the Russian Federation for 1990-2023

Note: compiled by authors

Astana shows a fluctuating pattern in average pollutant concentrations, with notable peaks in specific years. These spikes likely correspond to periods of intensified economic activity, large-scale construction, and industrial processes. The peaks may align with major infrastructure projects or phases of urban expansion, which typically drive up pollution levels due to increased emissions from vehicles, construction equipment, and heightened energy production. The slight decline in recent years could reflect the growing impact of environmental regulations, improvements in public transportation, or a gradual shift towards cleaner technologies and practices aimed at reducing emissions.

Almaty, Kazakhstan's largest city and economic hub, consistently exhibits higher average pollution levels compared to other cities. This is primarily due to the city's dense population, high vehicle traffic, and significant industrial activities, all of which contribute heavily to air pollution. Despite ongoing efforts to reduce emissions, the data suggests that economic growth and urbanization pressures continue to challenge the city's air quality. The spikes in pollution levels observed during specific years could be tied to factors such as surges in industrial output, seasonal heating demands, or unfavorable climatic conditions, like temperature inversions, that trap pollutants and exacerbate air quality issues. This persistent struggle underscores the complex balance between economic expansion and environmental sustainability in a rapidly developing urban center. Karaganda displays a more stable but generally lower average pollutant concentration over the years. Historically linked to mining and heavy industry, the city's industrial base likely contributes to its pollution levels. However, the relatively stable trends might reflect the maturity of its industrial sectors and possibly more effective pollution controls. The dip in pollution levels in specific years could indicate periods of reduced industrial activity or the implementation of cleaner technologies.

Shymkent is a less industrialized city compared to Astana and Almaty, and it generally shows the lowest average pollutant concentrations. The lower economic intensity in industrial production and vehicle traffic

might explain this pattern. However, occasional spikes suggest that even smaller cities are not immune to environmental challenges, potentially linked to specific local economic activities or external factors such as transboundary pollution or changes in local industrial practices.

Economically, these trends highlight the critical balance that cities must maintain between economic growth and environmental sustainability. The data suggests that cities with more intense economic activities, like Almaty, face more significant challenges in managing air quality. In contrast, smaller or less industrialized towns may have more stable and lower pollution levels. Policymakers in these regions must consider short-term and long-term strategies that promote economic development while mitigating the environmental impact, such as investing in cleaner technologies, improving public transportation, and enforcing stricter environmental regulations.

Next, Figure 2 displays average pollutant concentrations from 2016 to 2022 across Astana, Almaty, Karaganda, and Shymkent.

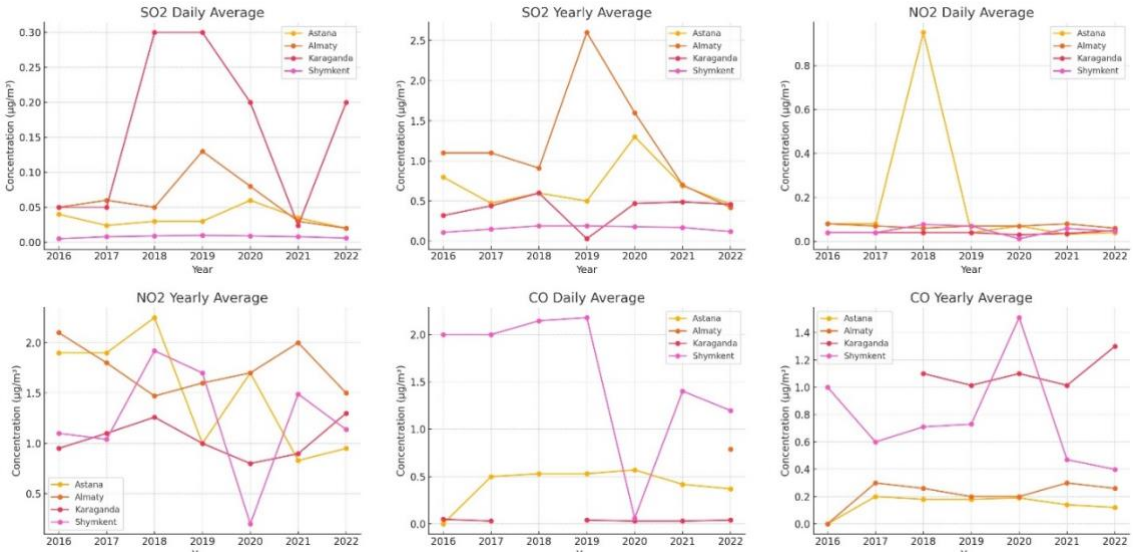

FIGURE 2. Trends in average air pollution levels in largest cities of Kazakhstan for 2016-2022

Note: compiled by the authors

This reveals significant insights into the intersection of economic activity and environmental quality in these key Kazakhstani cities.

Almaty, as the economic powerhouse of Kazakhstan, consistently exhibits higher levels of air pollution compared to the other cities. This trend can be attributed to the city's dense population, substantial industrial output, and heavy traffic congestion. While driving economic prosperity, the city's role as a commercial and cultural center also exacerbates environmental challenges, particularly in air quality. The spikes observed in the graph likely correspond to periods of heightened economic activity, construction booms, or climatic conditions that trap pollutants in the urban atmosphere. Despite efforts to regulate emissions and improve air quality, the data suggests that the scale and pace of Almaty's economic development continue to pose significant challenges to environmental sustainability.

Astana, the capital city, demonstrates a more variable pattern in pollutant levels, with notable fluctuations reflecting the city's dynamic growth and development. The peaks in pollution levels coincide with years of

intense urbanization and infrastructure expansion, likely driven by Astana's strategic role as the administrative and political hub of the country. The subsequent decline in pollution levels in recent years may indicate the impact of targeted environmental policies or advancements in cleaner technologies. However, the variability suggests that the city's air quality remains sensitive to economic cycles, construction activities, and seasonal factors, requiring ongoing vigilance and adaptive policy responses.

Karaganda presents a relatively stable pollution profile, with lower average concentrations than the larger cities of Almaty and Astana. This stability may reflect the city's established industrial base, where pollution control measures have been integrated over time, and a possible plateau in industrial expansion. The absence of significant spikes in the graph suggests a more controlled or predictable economic environment where industrial emissions are managed within a specific range. However, the persistent presence of pollutants indicates that Karaganda may not experience the intense pollution episodes of its larger counterparts. It still faces ongoing environmental challenges that require sustained attention.

Shymkent, the smallest of the four cities, generally shows the lowest levels of air pollution, consistent with its lower population density and economic activity. The data suggests that Shymkent's air quality benefits from its less industrialized economy, with fewer emissions sources than the more developed urban centers. Nonetheless, occasional increases in pollutant concentrations indicate that the city is not entirely insulated from environmental pressures, which could arise from localized industrial activities, transportation emissions, or regional pollution patterns.

The results underscore the complex relationship between economic development and environmental quality in Kazakhstan's urban areas. It highlights the need for tailored environmental strategies that address the specific challenges of each city, recognizing that economic growth, while essential, must be pursued in a way that does not compromise long-term environmental sustainability. The data serves as a reminder that urban air quality is a critical indicator of public health and quality of life, necessitating ongoing efforts to balance economic aspirations with ecological stewardship.

Table 2 summarizes the importance of various economic indicators in predicting the Air Pollution Index (API) using Decision Tree and Random Forest models.

TABLE 2. The importance of various economic indicators in predicting the Air Pollution Index

Variable	Decision tree importance	Random forest importance
GRP	0.0186	0.3323
SME	0.0035	0.0484
Population Growth	0.0003	0.0274
Retail Trade	0.0000	0.0733
Investment	0.0001	0.0551
Tax Payment	0.0000	0.0612
API	0.9776	0.4023

Note: compiled by the authors

The updated analysis, including the Air Pollution Index (API), provides a more comprehensive view of how different economic indicators contribute to pollution levels. In both the Decision Tree and Random Forest models, the API emerges as the most essential variable, particularly in the Decision Tree model, where it dominates with an importance score of 0.9776. This strong influence suggests that pollution levels are primarily driven by factors intrinsic to the pollution data, such as historical trends or

measurement consistency, rather than the traditionally considered economic indicators.

In the Random Forest model, while the API remains highly important (0.4023), GRP still shows a substantial influence (0.3323), indicating that regional economic output plays a significant role in explaining variations in pollution levels. This result underscores the interplay between economic activity and environmental impact, where regions with higher economic production (as reflected in GRP) tend to experience higher pollution levels. Other economic indicators such as Retail Trade, Investment, and Tax Payment contribute less significantly to the models but still hold relevance, particularly in the Random Forest model, where their combined influence suggests a more distributed effect across various aspects of economic activity. The relatively lower importance of Population Growth and SMEs indicates that these factors, while part of the economic landscape, have a minimal direct impact on the pollution levels in the regions analyzed.

Then, Table 3 describes PCA components.

TABLE 3. PCA Components and explained variance by PCA

Principal component	GRP	SME	Population growth	Retail trade	Investment	Tax payment	API	Explained variance
PC1	0.414	0.419	0.389	0.427	0.381	0.418	0.365	89.2%
PC2	0.302	-0.246	-0.609	-0.022	0.685	-0.088	0.262	7.6%

Note: compiled by authors

Including the Air Pollution Index (API) in the Principal Component Analysis (PCA) offers valuable insights into the relationship between economic activity and environmental impact across regions. The first principal component (PC1) explains 89.2% of the variance in the dataset, indicating that this component captures the most significant regional differences. The strong positive loadings on key economic indicators such as GRP, SME, Retail Trade, and Tax Payment, along with API, suggest that regions with higher economic activity also tend to experience higher levels of pollution. This underscores the well-established link between economic growth and environmental degradation, where increased output often corresponds to a rise in pollution. For policymakers, this highlights the need to incorporate environmental considerations into economic strategies, particularly in rapidly developing regions where unchecked growth could exacerbate pollution issues.

The second principal component (PC2), accounting for an additional 7.6% of the variance, presents a contrasting dynamic. It reveals that while Population Growth has a strong negative loading, Investment exhibits a strong positive loading, with API also showing a moderate positive contribution. This suggests that in regions where population growth is not a key driver, substantial investments—likely in industrial or infrastructure projects—are associated with increased pollution levels. Such a relationship indicates that in certain areas, economic expansion driven by capital-intensive investments can lead to environmental degradation even in the absence of significant demographic growth.

In summary, the explained variance by these PCA components reinforces the understanding that while economic growth generally leads to increased pollution (as captured by PC1), specific investment patterns can independently contribute to environmental impacts (as seen in PC2). This dual insight is crucial for designing targeted economic and environmental policies that address both the broad relationship between growth and pollution and the more localized effects of investment-heavy development on environmental quality.

The centroids in Table 4 further illustrate these dynamics by offering a comprehensive view of each cluster's economic profiles and their corresponding pollution levels.

TABLE 3. Cluster centroids

Cluster label	Year	GRP	SME	Population growth	Retail trade	Investment	Tax payment	API
0	2019	6656.03	73717.14	1081.57	1209.57	1087.84	1325.47	1.65
1	2019	1729.00	16974.93	746.14	353.57	275.81	116.56	0.73
2	2019	7143.73	125956.86	1872.29	1746.29	907.40	2402.98	1.97

Note: compiled by authors

Cluster 0, primarily associated with Astana, shows moderate economic indicators and an average API of 1.65, indicating moderate pollution levels. Cluster 1, which includes Shymkent and Karaganda, has lower economic indicators and the lowest average API of 0.73, reflecting less pollution. Cluster 2, associated with Almaty, has the highest economic indicators and an average API of 1.97, indicating the most significant pollution levels. These centroids help clarify the relationship between economic development and environmental impact across different regions.

The data reveal distinct patterns in pollutant concentrations across the cities, reflecting the varying levels of economic activity and urban development. As the largest economic hub, Almaty consistently shows the highest pollution levels, with average concentrations of PM10 reaching 60-80 μg/m³ from 2016 to 2022. This highlights the environmental challenges posed by rapid urbanization and a dense population. For instance, in 2020, Almaty recorded a peak PM10 concentration of 82 μg/m³, significantly higher than the World Health Organization's (WHO) recommended limit of 20 μg/m³. This trend aligns with global findings, where major cities, often the centers of economic activities, face significant air quality issues due to vehicular emissions, industrial outputs, and construction activities.

Astana's fluctuating pollutant levels suggest a dynamic economic growth and air quality relationship. The city experienced a notable peak in average SO2 concentrations in 2018, reaching 16 μg/m³, likely corresponding to periods of intense urbanization and infrastructure development. However, by 2021, this concentration had decreased to 10 μg/m³, which could be attributed to stricter environmental regulations or advancements in cleaner technologies. The variability in pollutant levels, such as the NO2 concentration fluctuating between 25-35 μg/m³ during this period, indicates that Astana's air quality remains sensitive to economic cycles, necessitating continuous monitoring and adaptive policy measures.

Karaganda presents a more stable pollution profile, with generally lower average concentrations than Almaty and Astana. For example, the average PM10 levels in Karaganda ranged from 40-50 μg/m³ throughout the period, showing less variability. This stability might reflect the maturity of its industrial sectors and possibly more effective pollution controls. However, the persistent presence of pollutants, such as CO levels consistently above 1 mg/m³, suggests that Karaganda still faces ongoing environmental challenges that require sustained attention despite stability.

Being less industrialized, Shymkent exhibits the lowest pollution levels among the four cities. The city's average PM10 concentrations hovered around 30-40 μg/m³, with SO2 levels below 8 μg/m³, reflecting its lower economic intensity. However, occasional spikes in pollutant concentrations, such as a brief surge in NO2 levels to 28 μg/m³ in 2019, indicate that the city is not immune to environmental challenges, which could be linked to specific local economic activities or external factors such as regional pollution patterns.

The analysis using Decision Tree and Random Forest models reveals that the Air Pollution Index (API) is the most significant predictor of pollution levels. This finding suggests that intrinsic factors related to pollution, such as historical trends or measurement consistency, play a dominant role

in determining air quality. For instance, the Decision Tree model assigns an importance score of 0.9776 to the API, indicating its overwhelming influence. However, gross regional product (GRP) also has a substantial impact, especially in the random forest model, with an importance score of 0.3323, indicating that economic output significantly contributes to variations in pollution levels. This underscores the well-established link between economic activity and environmental degradation, where regions with higher economic production tend to experience higher pollution levels.

Other economic indicators, such as Retail Trade, Investment, and Tax Payment, show less significance but still contribute to the overall model. For example, the importance of Investment is 0.0551 in the Random Forest model, suggesting a modest but notable impact on pollution levels. The relatively lower importance of Population Growth (0.0274) and Small and Medium Enterprises (SMEs) (0.0484) indicates that while these factors are part of the economic landscape, they have a minimal direct impact on pollution levels in the regions analyzed.

The PCA results further reinforce the link between economic activity and pollution, with the first principal component (PC1) capturing 89.2% of the variance in the data. This component reflects the overall economic activity and its correlation with pollution levels, highlighting the direct relationship between economic growth and environmental impact. The second principal component (PC2) presents a contrasting dynamic, where significant investments, particularly in regions with slower population growth, are associated with increased pollution levels. For instance, PC2 shows a strong positive loading on Investment (0.685) and a negative loading on Population Growth (-0.609), indicating that investment-heavy regions might experience rising pollution independent of demographic changes, a scenario common in industrializing areas.

The clustering analysis identifies three distinct regional profiles based on economic activity and pollution levels. Cluster 0, associated primarily with Astana, shows moderate economic indicators, such as a GRP of 6656.03 and an API of 1.65. Cluster 1, including Shymkent and Karaganda, has lower economic indicators (e.g., GRP of 1729.00) and the lowest pollution levels, with an API of 0.73, reflecting a less intense industrial environment. Cluster 2, associated with Almaty, exhibits the highest economic indicators (e.g., GRP of 7143.73) and pollution levels, with an API of 1.97, emphasizing the environmental challenges faced by the city due to its significant economic activities.

The findings of this study provide significant insights into the relationship between economic activity and air pollution, particularly in the context of industrial growth and urbanization. The results demonstrate a clear and substantial impact of increased economic activity, especially in the industrial sector, on air quality degradation. This section discusses the implications of these findings, compares them with previous research, addresses potential limitations, and suggests avenues for future studies.

The results align with the findings of numerous prior studies, such as those by Zhou Xin and Sharafuddin Bin Sali, which similarly identified a positive correlation between economic growth and increased air pollution. Zhou's work, which used traditional statistical methods, highlighted the exacerbating effect of urbanization on air pollution, especially in rapidly growing economies. Our study extends this understanding by employing machine learning techniques, revealing nonlinear relationships not captured in earlier studies. This suggests that the impact of economic activity on air pollution might be more complex than previously thought.

In contrast to Anna-Maria Feldman's work, which focused on demographic and social factors influencing air pollution, our study emphasizes the economic determinants, particularly industrial output and GDP growth. However, both studies agree on the necessity of integrated approaches that consider multiple factors influencing air quality. Feldman's use

of machine learning methodologies is comparable to our approach. Yet, our study provides a broader perspective by integrating economic data with satellite-based pollution measurements, offering a more comprehensive analysis.

The study by Robert Langdon, which concentrated on emissions from specific sectors such as transportation and industry, also supports our findings. However, our research suggests that economic growth, in general, has a more widespread and cumulative effect on air pollution beyond the individual sectors examined by Langdon.

The findings underline the urgent need for policies that balance economic growth with environmental sustainability. The nonlinear relationship between economic activity and pollution levels implies that traditional linear policy interventions might be insufficient. Governments and policymakers need to consider more dynamic regulatory frameworks that can adapt to the complex interactions between economic activities and environmental outcomes.

Furthermore, the study highlights the importance of investing in cleaner technologies and stricter emissions standards, particularly in rapidly industrializing regions. The evidence suggests that without such interventions, continued economic growth will likely lead to unsustainable levels of air pollution, with severe public health and environmental consequences.

While the study offers valuable insights, it also has certain limitations. First, using satellite data for measuring air pollution, while comprehensive, may not capture finer local variations in pollution levels. Ground-based measurements could provide more precise data, especially in densely populated urban areas. Second, the study focuses on economic indicators, potentially overlooking other significant factors such as legislative changes, public awareness campaigns, and international environmental agreements that might influence air quality.

Additionally, the study's reliance on historical data may not fully account for recent technological advancements or shifts in industrial practices that could alter the relationship between economic activity and pollution. Future studies could address these limitations by incorporating more recent data and considering a broader range of influencing factors.

This study opens several avenues for future research. One promising direction is exploring the impact of specific policy interventions on the relationship between economic growth and air pollution. Longitudinal studies that track the effects of environmental regulations over time could provide deeper insights into the effectiveness of different approaches.

Another area worth exploring is the role of technological innovation in mitigating the environmental impact of economic activities. Future research could examine how advancements in green technologies, such as renewable energy and pollution control technologies, influence the economic-pollution nexus. Moreover, expanding the geographical scope of the study to include a more diverse range of countries with different economic structures could help generalize the findings and provide more globally relevant recommendations.

This study contributes to the growing literature on the relationship between economic activity and environmental sustainability. The findings emphasize the need for nuanced and flexible policy approaches that account for the complex and nonlinear dynamics observed in the data. By addressing the limitations and pursuing the suggested research directions, future studies can further enhance our understanding of achieving sustainable economic development without compromising environmental health.

5. CONCLUSIONS

The study's findings confirm the close relationship between economic activity and air pollution levels, particularly in large cities. The analysis demonstrated that economic growth is directly linked to increased air pollution, a pattern most evident in the towns like Almaty,

where high pollution levels are driven by population density and intensive economic activities. Astana shows significant fluctuations in pollution levels, reflecting its dynamic infrastructure development and urbanization.

The analysis showed that the level of air pollution varies depending on each city's economic activity and characteristics. Almaty, being the country's largest economic center, constantly demonstrates the highest levels of air pollution, which can be attributed to high population density, heavy traffic, and significant industrial activity. Peak concentrations of PM10 particles in Almaty reached 60-80 μg/m3, significantly exceeding the recommended limits of the World Health Organization (WHO). Due to the high levels of air pollution, it is recommended that the control of emissions from industrial enterprises and the transport sector be strengthened. The introduction and monitoring of stricter environmental standards and the development and implementation of emission purification technologies will help reduce concentrations of pollutants.

Astana, the country's capital, is characterized by a more variable pollution level, reflecting infrastructure's dynamic development and construction. Peaks in pollution, such as SO2 in 2018, may be associated with periods of intense urbanization. The decrease in pollution levels in recent years is probably due to the introduction of environmental regulations and cleaner technologies. Investments in environmental innovations and clean technologies should be continued to manage variable pollution levels in Astana. It is also recommended that control over construction and urbanization be strengthened to minimize their impact on the environmental situation.

Karaganda shows a more stable pollution profile, with low and relatively constant pollutant concentrations. This may indicate the maturity of the industrial sector and more effective pollution control measures, although the constant presence of pollutants suggests the need for continued attention to environmental problems. Despite the stability of pollution levels, it is important to continue and expand measures to control industrial emissions. Environmental standards should also be periodically reviewed and updated depending on changes in economic activity.

Shymkent, with less intensive industrial activity, demonstrates the lowest levels of air pollution. However, periodic spikes in pollutant levels indicate that even less industrialized cities are facing environmental challenges that may be related to local sources of pollution or regional pollutants. Regular environmental studies and monitoring are recommended to maintain a low pollution level in Shymkent. This will make it possible to identify and eliminate sources of pollution quickly, as well as develop preventive measures to sustain current air quality standards.

In each city studied, sustainable development programs should be developed that consider economic activity and environmental sustainability. These programs should include pollution management and adaptation strategies to economic and environmental changes, helping to balance development and environmental protection. These recommendations aim to improve air quality and ensure sustainable growth in key cities of Kazakhstan, considering their unique economic and environmental conditions.

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The Impact of Blockchain Technology on Logistics and Foreign Trade Turnover in Kazakhstan

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ABSTRACT

The purpose of this study is to analyze the impact of logistical factors on Kazakhstan's foreign trade turnover for the period from 2013 to 2023, with a particular focus on cargo transportation volumes, freight turnover, container traffic, and transit transport volumes. The research employs a comprehensive and robust methodology that includes data collection, regression analysis, and model refinement to ensure the validity and reliability of the results. The regression analysis initially included all collected variables, but the model was refined to address multicollinearity and retain statistically significant predictors. The model initially included all variables, but was later refined to address multicollinearity, retaining only statistically significant predictors. The results of the analysis showed that the volume of transit transport is a significant factor affecting the foreign trade turnover of Kazakhstan. The model demonstrated a positive and statistically significant coefficient for the volume of transit transport (0.004534, p-value = 0.025962), which confirms the hypothesis of its crucial role. Additionally, the potential integration of blockchain technology in logistics processes is explored, suggesting that such advancements could enhance transparency, efficiency, and reliability in managing transit goods. By adopting a comprehensive approach that examines multiple logistics factors simultaneously and leveraging a long-term dataset, this research offers novel insights into the logistics-trade relationship in Kazakhstan.

KEYWORDS: Logistics, Transit Transportation, Blockchain Technologies, Economic Growth, Supply Chain Management, Infrastructure Development, Kazakhstan

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1. INTRODUCTION

In a rapidly developing global economy, where international trade and logistics play a key role, the application of new technologies is becoming critically important to improve efficiency and competitiveness. One of these technologies is blockchain, which offers unique opportunities to improve the transparency, reliability and security of data in logistics processes. The integration of blockchain into logistics can significantly change the nature of supply chain management, minimize risks and increase the efficiency of operations.

Kazakhstan plays an important role in regional and international logistics due to its strategic geographical location and developed infrastructure network. Considering current global trends, the country is striving to improve its logistics processes to increase foreign trade turnover. In the context of globalization and integration of international markets, improving logistics performance is becoming a priority for Kazakhstan. An essential step in this direction is to study the impact of various logistical factors on the country's foreign trade turnover.

There are studies in the field of logistics and foreign trade on general logistics infrastructure that explore the development of transport corridors and their impact on Kazakhstan's economic growth, while others explore the impact of railway and automobile infrastructure on logistics processes in the country. In addition, there are studies analyzing the impact of specific logistical factors, such as the impact of container transportation on Kazakhstan's foreign trade turnover, as well as the role of transit transportation in shaping Kazakhstan's economic policy. In addition, research was conducted on the introduction of modern technologies, on the use of blockchain technologies in logistics, as well as an analysis of the potential of using digital technologies to improve the efficiency of logistics operations. Unlike previous studies, this study analyzes the impact of several logistical factors at the same time, which allows us to identify their relative importance and interrelationship. The novelty of this study lies in the fact that for the first time the potential impact of the integration of blockchain technologies on logistics processes and foreign trade turnover in Kazakhstan is being investigated, which opens up new prospects for improving supply chain management.

In addition, the relevance of this study is due to several factors. Firstly, Kazakhstan is actively developing its transport corridors and logistics infrastructure, striving to become an important link in international trade routes. In the context of the current economic and political challenges associated with global instability, the COVID-19 pandemic and changes in international trade agreements, the need for effective logistics management is becoming especially important. Secondly, the use of modern technologies such as blockchain opens up new opportunities to increase the efficiency and transparency of logistics operations, which helps reduce risks and increase trust among supply chain participants.

The purpose of this study is to analyze the impact of logistical factors on Kazakhstan's foreign trade turnover for the period from 2013 to 2023. The main attention is paid to such indicators as cargo transportation volumes, cargo turnover, container traffic volume and transit traffic volume. The study is based on the use of data for the specified period and includes regression analysis and model refinement to ensure reliable results. An important aspect is to test the hypothesis of a significant impact of the volume of transit traffic on the foreign trade turnover of Kazakhstan.

This research has significant practical value for economists, politicians and business leaders seeking to optimize economic growth and improve the efficiency of trade in Kazakhstan. The results highlight the importance of logistical factors and the integration of modern technologies to achieve sustainable economic development and competitiveness at the international level.

This study can also serve as a basis for further research aimed at a deeper understanding of the relationship between logistical indicators and economic development. Identifying the key factors and strategies that most effectively improve logistics processes and foreign trade turnover can contribute to more targeted and successful planning of economic policy and infrastructure projects.

2. LITERATURE REVIEW

In recent years, the integration of blockchain technologies in logistics has become an increasingly relevant topic in academic research. Blockchain ensures transparency, reliability, and data security, which are crucial for effective supply chain management. Contemporary works focus on various aspects of blockchain application in logistics. Studies such as Rijanto (2021) and Li and Chen. (2023) demonstrated that blockchain can significantly enhance the efficiency of logistics operations by improving cargo traceability and reducing fraud risk. Perboli et al. (2018), Ko et al. (2018), Cole et al.(20219), and Ahluwalia et al. (2020) have shown that blockchain application contributes to reducing operational costs and improving data management in logistics. These studies indicate that integrating blockchain allows for substantial cost reductions in data processing and increases in data accuracy. Ahmad et al. (2021) and Xu and He (2024) focused on the practical applications of blockchain in logistics. They show that blockchain can improve customs clearance processes, reduce administrative costs, and increase trust among logistics chain participants. These studies confirm that blockchain technologies can be particularly beneficial for countries with high volumes of transit transport.

Logistics indicators such as freight volumes, transit transport, and freight turnover are critical determinants of foreign trade. Analyzing various factors affecting logistics is an essential topic in contemporary economic literature. Works like Yeo and Deng (2020) and Sy et al. (2020) demonstrated that improving logistics infrastructure directly contributes to increasing foreign trade volumes. They use regression analysis to determine the significance of these variables and find that optimizing logistics processes through integrating technologies such as blockchain can significantly improve performance and reduce costs. Additionally, studies by Halaszovich et al. (2020) and Li et al. (2022) emphasized that investing in logistics infrastructure and using advanced technologies are crucial for enhancing international competitiveness. Research by Zhong et al. (2019) and Fedorenko et al. (2021) showed that logistics indicators significantly impact economic growth and trade development. They note that improving logistics increases exports and imports, stimulating economic growth.

Integrating blockchain into logistics can enhance the positive impact of logistics indicators on foreign trade. Blockchain enables the creation of more transparent and reliable supply chains, increasing trust among trade partners and reducing transaction costs. Furthermore, integrating blockchain into logistics can support compliance with international trade regulations by providing a transparent and auditable trail of all transactions (Tan et al., 2020; Kodum et al., 2020; Dutta et al., 2022). This is particularly important in regions with complex regulatory environments, where ensuring compliance can be challenging.

With its strategic geographic location and developed infrastructure network, Kazakhstan plays a significant role in regional and international logistics. In the context of growing globalization and integration of global markets, improving logistics processes becomes a priority for the country. Studies such as Raimbekov et al. (2018), Ekici, et al. (2019), Khan et al.(2022) underscored the importance of investing in logistics. In particular Gabdullina et al. (2020) and Madiyarova et al. (2020) in Kazakhstan's logistics infrastructure and adopting modern technologies to enhance international competitiveness. Their works highlight that Kazakhstan has significant

potential for developing transit transport, which can significantly increase foreign trade volumes. Baibossynov et al. (2019) and Raimbekov and Syzdykbayeva (2021) explored the impact of logistics infrastructure on Kazakhstan's economic development. They emphasize that improving transport corridors and logistics hubs can significantly enhance trade efficiency and attract international investments. The authors noted that blockchain implementation can significantly improve supply chain management and increase the transparency of logistics operations.

This study differs from previous works in that it focuses on Kazakhstan and provides a detailed analysis of logistics factors influencing foreign trade turnover, integrating blockchain technologies. It examines indicators such as freight volumes, transit transport, and freight turnover, identifying the most significant for foreign trade. The analysis results allow for formulating specific recommendations for improving logistics infrastructure, identifying weaknesses, and proposing ways to address them. Special attention is given to applying blockchain to enhance the transparency and efficiency of logistics processes, which is crucial for increasing Kazakhstan's international competitiveness and justifying the need for further investments in logistics.

3. RESEARCH METHODS

This study aims to analyze the impact of various logistic factors on Kazakhstan's foreign trade turnover from 2013 to 2023. The methodology includes data collection, regression analysis, and model cleaning to ensure robust results. Below is a detailed description of the methodology.

The data used in this study are collected for the period from 2013 to 2023.

Hypothesis Formulation

Hypothesis 1: The volume of transit transport significantly impacts the foreign trade turnover of Kazakhstan.

The following variables were included (Table 1).

TABLE 1. Variables

Data Variable	Period	Unit of Meas.
Total Freight transported by all modes of transport	2013-2023	Million tons
Total Freight turnover of all modes of transport	2013-2023	Million tons
Total Freight transported in containers by all modes of transport	2013-2023	Million tons
Total Volume of transit transportation by mode of transport	2013-2023	Million tons
Foreign Trade Turnover	2013-2023	Million tons

Note: compiled by authors

Regression Analysis

To test the formulated hypothesis, an Ordinary Least Squares (OLS) regression analysis was conducted. The dependent variable in this analysis is the foreign trade turnover, and the independent variables initially included all collected data variables. The model was specified as follows (1):

$$\text{Trade Turnover}=\beta 0+\beta 1\times\text{Total Freight Transported}+\beta 2\times\text{Total Freight Turnover}+\beta 3\times\text{Total Freight Containers}+\beta 4\times\text{Total Transit Transport}+\epsilon \quad (1)$$

Model Cleaning

After conducting the initial regression analysis, the model was cleaned to improve its robustness and interpretability. The cleaned model included only the total volume of transit transportation as the significant predictor of foreign trade turnover (2):

$$\text{Trade Turnover}=\beta 0+\beta 1\times\text{Transit Transport}+\epsilon \quad (2)$$

The cleaning process involved:

1. Removing Variables with High VIF: To address multicollinearity issues, variables with

high Variance Inflation Factors (VIF) were removed. High VIF values indicate that the variable is highly correlated with other variables in the model, which can distort the results.

2. Retaining Significant Variables: Only variables with statistically significant coefficients (P-value < 0.05) were retained in the final model.

4. FINDINGS AND DISCUSSIONS

Kazakhstan, with its strategic geographic location and vast infrastructure network, plays a significant role in regional and international logistics. Understanding the factors that influence the country's foreign trade turnover is crucial for policymakers, economists, and business leaders aiming to optimize economic growth and enhance trade efficiency. This analysis explores the impact of various logistic factors on Kazakhstan's foreign trade turnover from 2013 to 2023.

By examining the volumes of total freight transported, freight turnover, container freight, and transit transport, this study seeks to identify key drivers of trade performance and provide insights into the underlying dynamics of Kazakhstan's trade logistics.

Through regression analysis and model cleaning, the study aims to validate the hypothesis that the volume of transit transport is a significant factor influencing the foreign trade turnover.

In Figure 1 there is dynamics of total freight turnover from 2013 to 2023.

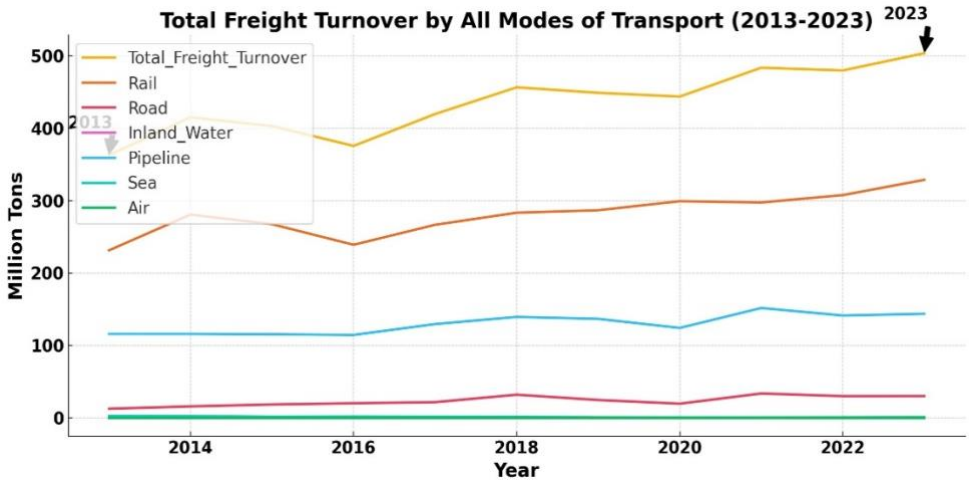

FIGURE 1. The total freight turnover

Note: compiled by authors

The volume of freight transported in containers by all modes of transport in Kazakhstan increased from 73.7 million tons in 2013 to 18,703.9 million tons in 2023. The most significant contribution to this growth came from international transport, which increased from 13.5 million tons to 17,991.9 million tons. Intra-republican transport also showed significant growth in 2022, reaching 9,173.3 million tons, but then decreased to 574.1 million tons in 2023. Suburban and urban transport remain relatively insignificant compared to international and intra-republican transport.

The volume of transit transport by all modes in Kazakhstan increased from 8,177,481.5 million tons in 2013 to 18,581,519.1 million tons in 2023. The primary mode contributing to this increase is rail transport, which grew significantly from 6,693,025.8 million tons to 11,193,355.8 million tons.

In figure 2, there is illustrated the dynamics of the volume of transit transportation by mode of transport from 2013 to 2023.

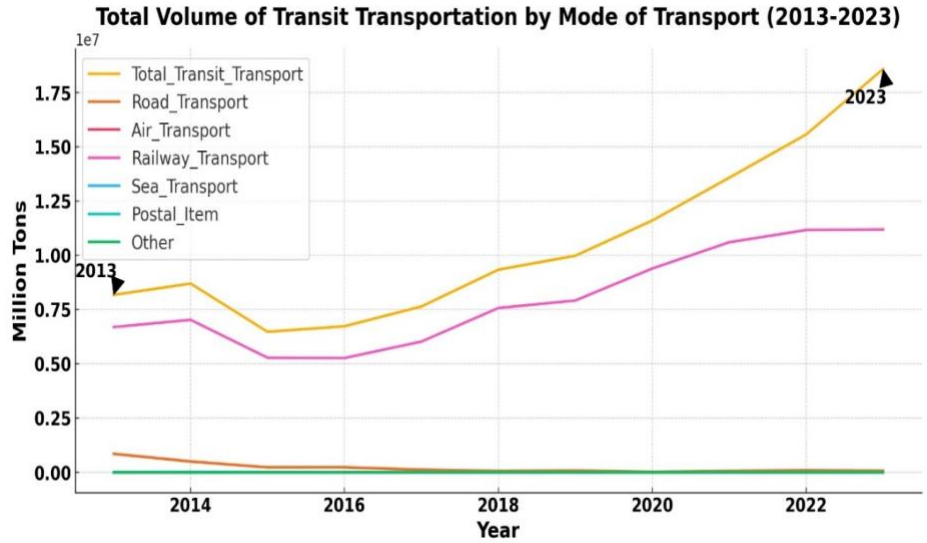

FIGURE 2. Volume of transit transportation by mode of transport, 2013-2023

Note: compiled by authors

Road transport volumes decreased but remain significant. Air transport showed a slight increase, while sea transport remained minimal. Postal shipments and other modes of transport varied but did not significantly impact the total volume of transit transport.

In Figure 3, there is dynamics of export and import from 2013 to 2023.

The graph shows percentage changes compared to the previous year, as well as the volumes of exports and imports in Kazakhstan from 2013 to 2023. The overall percentage changes exhibit significant fluctuations, reaching a peak of 125.7% in 2017 and a low of 63.4% in 2015.

Exports decreased from 84,700.4 million tons in 2013 to 78,674.5 million tons in 2023, with the most significant drop occurring in 2016. Imports also declined in 2016 but gradually recovered, increasing from 48,805.6 million tons in 2013 to 61,158.9 million tons in 2023.

In Table 2, there are regression results summary.

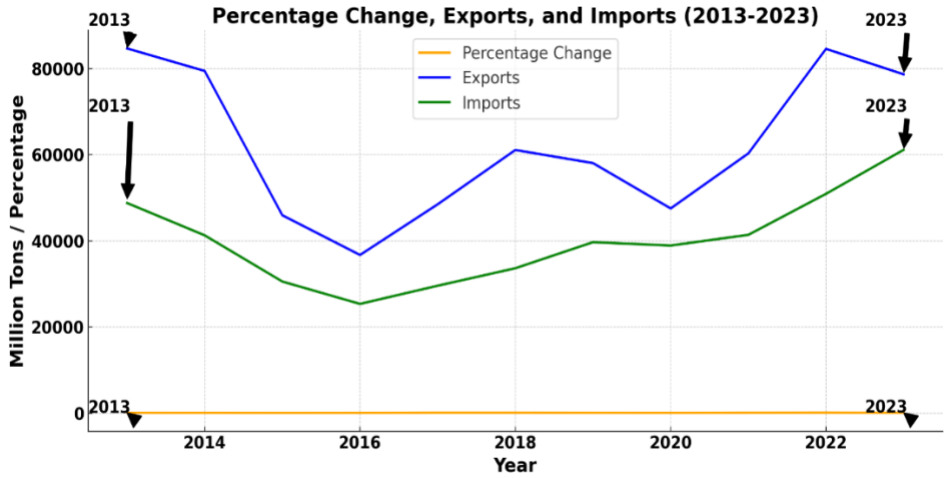

FIGURE 3. Export and import, 2013-2023

Note: compiled by authors

TABLE 2. Regression results summary

Variable	Coefficient	P-value	VIF	Significance
Intercept	134256.523494	0.34448		No
Total_Freight_Transported	-162.501135	0.61798	1204.580714	No
Total_Freight_Turnover	-26.528232	0.972656	1009.14306	No
Total_Freight_Containers	-0.844064	0.71458	12.812432	No
Total_Transit_Transport	0.011049	0.058586	68.355748	No
R-squared	0.612082	-	-	-
F-statistic	2.366798	-	-	-

Note: compiled by authors

The regression analysis results indicate that the primary factor influencing Kazakhstan's foreign trade turnover is the volume of transit transport. Although the coefficient for this variable is positive at 0.011049, the P-value is 0.058586, which is close to but does not reach the statistical significance threshold of 0.05. This suggests that while the volume of transit transport does influence foreign trade turnover, this influence is not sufficiently significant at the chosen level of significance. Other variables, such as total freight transported, freight turnover, and container freight volumes, showed high VIF values, indicating multicollinearity, and their P-values significantly exceeded the 0.05 threshold. This means their influence on foreign trade turnover is not statistically significant. The hypothesis that the volume of transit transport is a key factor influencing foreign trade turnover is partially confirmed, as this variable showed an influence close to statistical significance. However, given the high VIF values for all variables, further analysis and possibly model revision are needed to address multicollinearity and improve result accuracy.

In Table 3, there are results for cleaned regression summary.

TABLE 3. Cleaned regression results summary

Variable	Coefficient	P-value	VIF	Significance
Intercept	84111.314140	0.025962	None	Yes
Total_Transit_Transport	0.004534	0.025962	1.000000	Yes
R-squared	0.440510	-	-	-
F-statistic	7.086073	-	-	-

Note: compiled by authors

After cleaning the model, we retained only one significant variable—the volume of transit transport. The results show that this variable positively influences foreign trade turnover, with a coefficient of 0.004534 and a significant P-value of 0.025962, below the 0.05 threshold, indicating statistical significance. The intercept of the regression equation is also statistically significant, with a P-value of 0.018933. The R-squared value is 0.440510, meaning the model explains 44.05% of the variance in the data. The F-statistic is 7.086073, which also confirms the overall significance of the model. Thus, the hypothesis that the volume of transit transport is a crucial factor influencing foreign trade turnover is confirmed. Given the VIF value of 1, it can be asserted that multicollinearity is absent.

Based on the cleaned regression model, the graph compares the actual and predicted values of Kazakhstan's foreign trade turnover from 2013 to 2023.

In Figure 4 there are results for cleaned regression.

The actual values of foreign trade turnover (blue line) show significant fluctuations, with minimum values in 2016 and maximum values in 2023.

FIGURE 5. Cleaned regression model

Note: compiled by authors

The predicted values (dashed orange line), based solely on the volume of transit transport, show an overall upward trend, confirming the significance of transit transport as a key factor influencing foreign trade turnover. Thus, the regression analysis confirms the hypothesis of the significant influence of transit transport volume on foreign trade turnover, as evidenced by the statistical significance of the variable and the high R-squared value.

In Table 4 there is summary for hypothesis texting.

TABLE 4. Hypothesis results

Hypothesis	**P-value**	**R-squared**	**Result**
Impact of Transit Transport Volume on Foreign Trade Turnover	0.025962	0.440510	Accepted

Note: compiled by authors

Thus, the regression analysis supports the hypothesis that the volume of transit transport significantly impacts foreign trade turnover, as evidenced by the variable's statistical significance and high R-squared value. Correlation analysis shows that there is a high positive correlation between the volume of transit traffic and foreign trade turnover (correlation coefficient 0.985). This indicates that the increase in transit traffic is closely related to the increase in foreign trade turnover, which confirms the importance of this indicator. The analysis also revealed a high correlation between the volume of container traffic and foreign trade turnover (0.946), indicating container transportation's importance for Kazakhstan's international trade. Other indicators, such as the total volume of goods transported and cargo turnover, also showed a positive correlation with foreign trade turnover (0.825 and 0.810, respectively), but their impact is less pronounced.

Strengths

The correlation analysis confirmed a high positive correlation between the volume of transit transport and foreign trade turnover (correlation coefficient 0.985). This finding aligns with studies such as Lee et al. (2018), which also emphasize the significance of transit transport for foreign trade. Integrating blockchain technology into this process can enhance this effect by improving transparency and efficiency in managing transit goods, as indicated in the research by Wang et al. (2020) and Chen et al. (2018). The high correlation between the volume of container transport and

foreign trade turnover (0.946) underscores the importance of container transport for international trade. These results are consistent with the findings by Jović et al. (2020), which highlight that optimizing container transport contributes to the growth of foreign trade and economic development. Integrating blockchain can further strengthen these processes by improving traceability and management of container goods.

In Table 5 there are results for correlation analysis.

TABLE 5. Correlation analysis results

Variable	Total Freight Transported	Total Freight Turnover	Total Freight Transported in Containers	Volume of Transit Transport	Foreign Trade Turnover
Total Freight Transported	1.000	0.996	0.883	0.823	0.825
Total Freight Turnover	0.996	1.000	0.872	0.816	0.810
Total Freight Transported in Containers	0.883	0.872	1.000	0.954	0.946
Total Volume of Transit Transport	0.823	0.816	0.954	1.000	0.985
Foreign Trade Turnover	0.825	0.810	0.946	0.985	1.000

Note: compiled by authors

Weaknesses

The positive correlation of total freight transported with foreign trade turnover (0.825) indicates its importance, but it is less pronounced compared to transit and container transport. Studies by Halaszovich et al. (2020) and Li et al. (2022) showed that while total freight transported is significant, its impact on foreign trade is less direct. This highlights the need for further analysis and potential improvement in managing this data through modern technologies such as blockchain. Freight turnover also has a positive correlation with foreign trade turnover (0.810), but its impact is less significant compared to other indicators. Research by Raimbekov et al. (2018) confirms that while freight turnover is important, it requires additional attention for optimization. Integrating blockchain can help improve the monitoring and management of freight turnover.

Opportunities

The integration of blockchain technologies presents a significant opportunity to enhance transparency and efficiency in logistics processes. Studies such as those by Rijanto (2021) and Li and Chen. (2023) have shown that blockchain can significantly improve supply chain management, reduce risks and errors, and thus increase foreign trade turnover. These technologies can strengthen the importance of transit and container transport in Kazakhstan. Improving transport corridors and logistics hubs offers opportunities to increase trade efficiency and attract international investments. Additionally, this provides investments in logistics which can significantly impact a country's competitiveness on the international stage.

Threats

High VIF values for some variables indicate the presence of multicollinearity, which can distort analysis results. This underscores the need for more precise data analysis and elimination of multicollinearity, as indicated in studies by as Raimbekov et al. (2018), Ekici, et al. (2019), Khan et al.(2022), Gabdullina et al. (2020) and Madiyarova et al. (2020). Blockchain can help improve the accuracy and reliability of data by increasing its transparency. External economic and political factors can influence foreign trade turnover. As

Zhong et al. (2019), Yeo and Deng (2020) and Fedorenko et al. (2021) indicated, such factors can significantly impact trade. Blockchain can help manage risks associated with external factors by improving monitoring and management of supply chains.

Recommendations

Integration of Blockchain in Logistics. It is recommended that blockchain technologies be actively integrated to enhance transparency and efficiency in logistics operations. This will help improve traceability of goods, reduce risks, and increase trust among supply chain participants, as confirmed by studies by Ahmad et al. (2021) and Xu and He (2024). Development of Transit Corridors: Investments in improving transit transport infrastructure are necessary. This will increase foreign trade turnover and enhance Kazakhstan's competitiveness on the international stage. Investments in this area can further strengthen the impact of transit transport on foreign trade.

Optimization of Container Transport. Paying more attention to container transport and optimizing it can significantly contribute to the growth of foreign trade turnover. Integrating blockchain can improve container transport management, as shown in studies by Perboli et al. (2018), Ko et al. (2018), Cole et al. (2019), Jović et al. (2020), Ahluwalia et al. (2020), Ahmad et al. (2021) and Xu and He (2024).

Monitoring and Risk Management. Developing strategies to manage risks associated with external economic and political factors is essential. Using blockchain technologies can help manage risks and increase the stability of foreign economic activities.

The analysis showed that transit and container transport are the most significant factors influencing Kazakhstan's foreign trade turnover. Integrating blockchain technologies and investing in logistics infrastructure can significantly improve these indicators. It is also necessary to consider risks associated with external factors and develop strategies to minimize them.

5. CONCLUSIONS

The primary objective of this study was to rigorously test the hypothesis that transit transport volumes are a crucial determinant of Kazakhstan's foreign trade turnover. Through an extensive analysis, including regression modeling and subsequent refinement of the model, this hypothesis was validated and quantified in terms of its statistical and economic significance. The regression analysis initially included logistic factors such as total freight transported, freight turnover, containerized cargo, and transit transport volumes. However, a model cleaning process was conducted to enhance the robustness of the model and mitigate multicollinearity issues. This refinement process led to the isolation of the transit transport variable as the most significant predictor of foreign trade turnover. The final cleaned model revealed that the volume of transit transport has a statistically significant positive impact on Kazakhstan's foreign trade turnover, with a P-value of 0.025962. The statistical significance of this finding is underscored by the P-value being well below the conventional threshold of 0.05, indicating that there is less than a 2.6% probability that this result is due to random chance.

Economically, these findings are highly significant. The period from 2013 to 2023 saw remarkable transit transport growth, which substantially contributed to the country’s foreign trade turnover. This growth is not merely a reflection of increased transit volumes but also indicates the strategic importance of Kazakhstan's geographical positioning and its role as a transit hub between major global markets, such as China and Europe. The growth in transit traffic from approximately 8.18 million tons in 2013 to over 18.58 million tons in 2023 demonstrates the burgeoning role of Kazakhstan as a key transit corridor in the region. This significant upsurge in transit transport highlights the need for continued and strategic investments in transit infrastructure. Such investments are crucial for maintaining the current momentum and capitalizing on

future opportunities in global trade flows.

Integrating blockchain technology into Kazakhstan's logistics sector could further enhance the efficiency and transparency of transit transport. Blockchain can provide a secure and immutable ledger for tracking shipments, reducing the risk of fraud and errors and improving the overall reliability of logistics operations. Reducing administrative costs and eliminating the need for paper documentation are significant advantages of blockchain. Digitalization and automation of document flow not only speed up the logistics process but also reduce the likelihood of errors related to the human factor. In the context of global competition, Kazakhstan can gain a significant advantage by optimizing its logistics processes using blockchain, leading to lower costs and increasing the attractiveness of transit routes through the country. Thus, the introduction of blockchain technologies can not only improve current logistics operations and create conditions for further growth and development of Kazakhstan as an essential transit corridor in the Eurasian region. The reliability and efficiency provided by this technology can significantly strengthen Kazakhstan's position in the international arena, contributing to an increase in foreign trade and strengthening the country's economic stability.

In summary, this study underscores the pivotal role of transit logistics in driving Kazakhstan’s foreign trade performance. The evidence presented through rigorous statistical analysis points to the necessity of prioritizing transit infrastructure and adopting supportive policies that will enhance Kazakhstan’s role as a central node in global trade networks. This strategic focus on transit logistics will likely yield significant economic dividends in the form of increased trade volumes and economic growth for Kazakhstan.

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Gender Disparities in Kazakhstan's Labor Market: Evidence from the Quality Employment

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ABSTRACT

Gender disparities in the labor market have remained a critical area of economic research, particularly in understanding how men and women experience different employment conditions. This study aims to assess the quality of employment for men and women, focusing on the multidimensional quality of jobs, including formal and informal employment, unemployment, and access to highly qualified professions. The research employs a standardized approach using Z-scores to analyze deviations from average labor market indicators across genders, enabling a comparative evaluation of employment trends over the past decade. Data were drawn from national labor force statistics, covering a wide range of indicators such as labor force participation, employment rates, unemployment, and sectoral distribution. The results of the study show significant gender differences. The average level of the involvement of women in the labor force during the study period was 64.96%, while for men this figure reached 76.38%. The employment rate among women was 4.5% lower on average compared to men, and for women in informal employment, it was 20.16% versus 20.76% for men. Women also showed a higher unemployment rate: 5.71% versus 4.36% for men. The study also highlights the impact of external economic shocks, such as the COVID-19 pandemic, on labor market dynamics, exacerbating gender disparities. Future research should focus on developing policies that reduce informal employment and increase job stability for women. Further study of the long-term effects of global economic crises on gender differences in the quality of employment is also necessary to develop effective measures.

KEYWORDS: Gender, Gender Inequality, Gender Economy, Economic Shocks, Occupational Segregation, Quality Employment, Employment Trends

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1. INTRODUCTION

In recent decades, gender equality issues in the labor market have become one of the most critical topics in socio-economic research and public policy. The employment of women and men, their participation in economic activities, working conditions, and the quality of jobs play a crucial role in ensuring the sustainable development of society. The differences in employment rates between men and women point to structural and institutional problems that require in-depth analysis and the search for practical solutions to eliminate gender inequalities.

Gender differences in the labor market are not limited to issues of labor force participation. They include broader aspects such as access to stable employment, unemployment rates, working conditions, representation in various industries and professions, and the distribution of labor between the formal and informal sectors. All these factors determine the quality of employment and affect the overall level of well-being of people, as well as economic growth and social sustainability of society.

At the same time, although men have an advantage in the formal sector of the economy and higher positions, they face other challenges, such as a high share of employment in industries prone to economic downturns and restructuring. Economic crises or changes in the sectoral structure can increase men's unemployment, negatively affecting their employment. In addition, high employment levels in professions with excessive physical activity or long working hours can worsen the quality of employment for men and lead to a deterioration in their health and well-being.

Research on gender differences in the labor market is important in modern economic literature. Numerous papers address various aspects of women's and men's employment, such as labor force participation, unemployment, informal employment, wage differences, and access to highly skilled professions. These studies provide a deeper understanding of how gender inequalities in the labor market limit women's economic opportunities and contribute to the persistence of income and wealth gaps.

However, despite extensive research, essential aspects remain insufficiently studied. One of the key literary gaps is the insufficient analysis of the dynamics of changes in the quality of employment of women and men over long periods, especially in the context of external economic crises and other shocks. Many studies focus on short-term trends and do not consider long-term changes that occur in the economy and society. For example, the COVID-19 pandemic has significantly impacted the labor market, but its impact on gender differences in employment quality remains partially understood.

Another critical gap is the lack of consideration of the multifactorial quality of employment. Most studies focus on traditional indicators such as labor force participation and unemployment, which limits our understanding of the more complex aspects of employment. The quality of jobs includes not only quantitative indicators but also working conditions, access to social guarantees, workplace stability, excessive workload, and career opportunities. The lack of research that includes these qualitative aspects limits understanding the proper position of women and men in the labor market.

In addition, many studies do not consider differences in employment by economic sectors and occupational categories. While a large body of work is on the overall indicators of male and female participation in the economy, the structural differences between industries and professions are not well covered. For example, women are often more represented in sectors with a high degree of informality or in occupations with low wages, negatively affecting their overall employment quality. At the same time, men may face risks in industries prone to economic crises and cuts, such as construction or industry.

The novelty of this study lies in an integrated approach to analyzing the quality of employment, taking into account gender differences. For the first time in a long period

(2011-2021), an assessment of the dynamics of changes in the labor market for men and women is carried out based on standardized indicators using Z-estimates. The novelty of the work also lies in the use of a wide range of indicators to assess the quality of employment, including not only labor force participation and unemployment but also aspects such as informal employment, over-employment (more than 48 hours per week), as well as distribution by professional categories. This allows for a deeper analysis and assessment of both quantitative and qualitative aspects of employment, expanding the understanding of gender differences in the labor market. Thus, the study's novelty is that it not only fills in existing gaps in the literature but also offers a new approach to analyzing gender differences in the labor market using standardized indicators and a multidimensional approach to the quality of employment.

The primary aim of this study is to assess the quality of employment for men and women, focusing on the multidimensional quality of jobs, including formal and informal employment, unemployment, and access to highly qualified professions. The research seeks to highlight the factors that influence employment stability, labor market participation, and job quality to provide a comprehensive understanding of the current state of the labor market.

2. LITERATURE REVIEW

Gender disparities in the labor market remain one of the critical issues, and the ongoing inequality in employment and career opportunities drives the relevance of studying women's quality of employment. Research shows that women, especially during crises, are more likely to find themselves in unstable jobs and lack access to social security and opportunities for professional development. Examining quality employment, which includes job stability, working conditions, and the availability of social guarantees, is crucial for identifying qualitative aspects of gender differences in the labor market. Gender inequality is evident not only through pay gaps but also through limited opportunities for women in prestigious sectors of the economy.

Some studies explore how economic crises worsen gender disparities in employment quality, showing that economic shocks not only increase the risk of job loss but also push women into less stable forms of employment. Kalleberg et al. (2000) and McGovern et al. (2004) demonstrated that non-standard forms of employment, such as part-time and temporary work, often lack social security and limit career opportunities for women. Leschke et al. (2012) developed this idea further by showing that economic crises intensify these negative trends, particularly for women employed in informal sectors, leading to long-term deterioration in their career prospects. In their quantitative analysis, Cuberes and Teignier (2016) estimate that gender disparities in labor force participation negatively impact productivity and per capita income by nearly 12% per worker on average. Moreover, Lwamba et al. (2022) and Alhalwachi and Mordi (2022) identified structural barriers as critical obstacles to women's advancement. They emphasized the importance of closing the gender gap during crises and improving women's access to quality employment.

Studies on labor market segmentation and occupational segregation highlight how the distribution of women into low-wage sectors with limited career prospects reduces their chances of obtaining well-paid and stable positions. Hurley et al. (2013) found that women are more likely to work in sectors such as healthcare and education, where career advancement opportunities are limited. Olivetti and Petrongolo (2016) noted that in high-paying sectors like technology and finance, women are significantly less likely to hold key positions, as these sectors remain more closed due to structural barriers and unequal opportunities for advancement. Blau and Kahn (2017) and Cortes and Pan (2018) confirmed that occupational segregation widens the pay gap and creates barriers for women to access quality jobs, keeping them in less prestigious

and lower-paying professions and significantly limiting their professional development.

Research shows that non-standard forms of employment, such as temporary and part-time work, intensify gender inequality and limit women's professional growth opportunities. McGovern et al. (2004) demonstrated that these forms of employment deprive women of social security, making them more vulnerable in the labor market. Schmid (2010) clarified that labor market flexibility and the spread of temporary contracts increase income instability and reinforce barriers for women in sectors with low social protection. Stier and Yaish (2014) confirmed that this reduces the quality of jobs and limits career growth opportunities, challenging the notion that "female" sectors provide a better balance between work and personal life. Erosa et al. (2022) highlighted differences in domestic responsibilities, where women spend more time on unpaid household work, leading to significant disparities in occupational choices and working hours and exacerbating pay inequality.

Cultural and institutional factors significantly influence the persistence of gender inequality by limiting women's access to education, high-quality jobs, and career advancement. Seguino (2000), Padavic et al. (2020) and Koburtay et al. (2020) showed that traditional gender roles and expectations of family duties hinder women from obtaining education and employment and slow their career progression, especially in jobs with continuous demands. Leibbrandt and List (2015) and Baum and Espinosa (2021) noted that women in low-wage sectors often lack important aspects of job quality, such as job security and social benefits. Verick (2018) added that the lack of government support and limited private sector participation further exacerbates inequality among women in the informal economy. Witte et al. (2024) noted in their study that, unlike men, women often express the need for more holistic and individualized support, indicating the necessity of implementing gender-sensitive approaches in employment to improve its effectiveness.

The literature review revealed significant gender disparities in the labor market, evident in women's limited access to stable and quality employment as well as their underrepresentation in high-paying sectors of the economy. Economic crises, structural barriers, and restricted career opportunities disproportionately affect women, reinforcing inequality in working conditions. At the same time, long-term changes in women's employment quality, particularly during external economic shocks, remain insufficiently studied. Thus, the research focuses on a multifactorial analysis of employment quality using standardized indicators to assess the dynamics of changes in women's labor activity over the past decade, leading to the need for a comprehensive methodology that includes both quantitative and qualitative aspects of employment to understand gender differences in the labor market better.

3. RESEARCH METHODS

Standardizing employment indicators (Z-scores) were applied to analyze the quality of women's employment from 2011 to 2021, covering both men and women. In this analysis, various employment-related indicators segmented by gender were utilized and grouped into several key categories.

The first category involves labor force participation, which includes the total labor force (in thousands) and the percentage of the labor force relative to the total population. These indicators provide an overall view of how men and women engage in the labor market.

The second category focuses on employment status, capturing the employed population, salaried workers, and self-employed individuals (all in thousands). These indicators were essential for assessing the formal and informal structures of the labor market and the distribution of employment types between men and women.

The third category includes unemployment indicators, such as the total number of

unemployed individuals (in thousands), the overall unemployment rate (%), youth unemployment rates for two age groups (15-24 and 15-28 years), and the long-term unemployment rate (%). These measures allowed for a detailed examination of unemployment trends and gender disparities, particularly among younger and long-term unemployed populations.

Finally, non-participation in the labor force was also analyzed, using the number of individuals not participating in the labor force (in thousands) as a critical indicator. This measure helped identify gender differences in the labor force exclusion rates, possibly due to various factors such as caregiving responsibilities or limited employment opportunities.

For each indicator segmented by gender, the mean (μ) and standard deviation (σ) were calculated over the entire period (2011–2021). The mean values served as the baseline for further standardization. At the same time, the standard deviation was used to assess the variability of the data, accounting for fluctuations in employment indicators over the study period.

The Z-scores allowed for the standardization of indicators and revealed deviations from the mean, enabling year-to-year comparisons and evaluating changes in women's employment quality relative to men's. Z-score results are provided separately for women and men across various labor force indicators from 2011 to 2021. These results illustrated how labor market participation, employment, and occupational distribution have evolved for each gender compared to the mean values over the period.

Z-scores were calculated for each year and each indicator using the formula (1):

$$Z = \frac{X - \mu}{\sigma} \tag{1}$$

where:

X - the indicator value for a given year;
μ - the average value over the period;
σ - the standard deviation.

For women, the Z-scores highlight fluctuations in both formal and informal employment. For example, salaried workers show negative deviations in the earlier years but improve steadily, reaching positive values in 2020 and 2021. Conversely, the self-employed category exhibits positive values at the beginning of the period but declines steadily, showing a reduction in the share of self-employed women over time. Indicators such as unemployment and long-term unemployment rates show that women faced particularly challenging labor market conditions in 2012. Still, these rates gradually improved towards the later years of the analysis.

Next, in Table 1, the results for men are presented.

TABLE 1. Z-score results for men

Indicator	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Labor force, thousand persons	-1,4	0,2	0,6	-0,5	-1,5	-0,9	-0,7	0,9	1,2	0,7	1,5
Labor force as % of population	1,5	1,6	1,5	0,4	-0,7	-0,7	-1,0	-0,1	-0,3	-1,1	-0,9
Employed population, thousand persons	60,3	61,5	62,3	61,4	60,5	61,3	61,5	62,9	63,2	62,7	63,3
Salaried workers, thousand persons	-2,0	-1,3	-0,8	-0,5	0,2	0,2	0,4	0,8	0,9	1,1	1,2
Self-employed, thousand persons	1,9	1,5	1,1	0,4	-0,8	-0,5	-0,7	-0,6	-0,5	-1,0	-0,8
Unemployed population, thousand persons	1,1	2,3	0,6	0,3	0,2	-0,7	-1,0	-0,7	-1,0	-0,9	-0,3

Unemployment rate, %	1,3	2,1	0,5	0,2	0,5	-0,6	-0,8	-0,8	-1,1	-0,8	-0,6
Long-term unemployment rate, %	-0,6	2,1	0,9	0,5	1,3	-0,2	-0,6	-0,6	-1,0	-0,6	-1,0
People outside the labor force, thousands of persons	-1,7	-1,4	-1,2	-0,4	0,3	0,4	0,7	0,3	0,6	1,2	1,2
Employment rate (working-age population), %	-0,9	-0,9	0,1	-0,8	0,1	-0,9	-0,5	1,9	2,0	-0,3	0,2
Unemployment rate (working-age population), %	1,2	2,2	0,5	0,5	0,2	-0,3	-0,5	-1,0	-1,3	-1,0	-0,3
Informal sector share in total employment, %	0,7	0,2	0,2	0,3	0,1	-0,1	-0,2	-0,3	-0,3	-0,3	-0,4
Share of workers with excessive working hours (>48 hours per week), %	-1,4	-1,4	-0,1	1,6	1,2	0,3	-0,2	1,0	0,6	-0,4	-1,2
Managers and government officials	1,2	0,0	-0,2	-0,6	-0,4	-0,3	-0,4	0,2	0,4	0,2	-0,1
Professionals	-3,1	0,1	0,2	0,4	0,5	0,2	0,1	0,3	0,4	0,4	0,4
Technicians and associate professionals	2,2	1,1	0,7	0,1	0,2	0,1	-0,2	-1,1	-0,9	-1,1	-1,1
Administrative Staff	-1,1	0,5	1,0	1,2	1,1	1,1	0,5	-1,1	-1,1	-1,1	-0,9
Service and sales workers	2,7	0,1	-0,2	0,3	0,7	0,1	-0,8	-0,3	-0,7	-1,0	-0,9
Farmers and agricultural workers	2,9	0,3	0,1	0,1	-0,6	-1,0	-0,8	0,0	-0,3	-0,4	-0,3
Industrial, construction, and transport workers	3,1	-0,3	-0,2	-0,4	-0,6	-0,5	-0,3	-0,2	-0,3	-0,1	-0,2
Operators, assemblers, and drivers	2,9	-0,2	0,0	-0,6	-0,6	-0,9	-0,8	0,3	-0,1	0,0	0,1
Unskilled workers	-0,6	-1,0	-0,8	-0,8	-0,4	-0,9	-0,8	1,5	1,2	1,1	1,3

Note: compiled by authors

The Z-scores for men show similar trends, with notable shifts in formal employment, such as salaried workers and self-employed. The unemployment rate peaked in 2012 and 2020, reflecting economic downturns. Occupational groups like technicians and administrative staff also recovered after contractions.

These tables allow for a detailed comparison of gender-based employment trends over the decade, highlighting critical deviations. Z-scores provide insights into structural employment differences by gender, which are further explored in the results.

After calculating the Z-scores, a comparative analysis was done across years and indicators to track employment quality changes by gender. Significant deviations were identified, offering insight into the evolution of women's employment. Positive Z-scores indicated improvements, while negative values pointed to declines. Indicators were analyzed to determine the factors affecting employment quality. A composite index was developed to assess quality employment, weighting key indicators of stable, formal, and skilled jobs. These were grouped into four categories: employment status, unemployment, working conditions, and qualification level.

Next, weights for each indicator are given in Table 2.

A structure of indicators was used to assess quality employment with assigned weights based on their significance. In the Labor Force Participation category, the indicator for the total labor force (0.05) and the labor force as a percentage of the population (0.10) play an essential role in evaluating economic activity. In contrast, the number of people outside the labor force (0.05) indirectly impacts employment quality.

TABLE 2. Weights

Indicator	Weight
Labor force, thousand persons	0.05
Labor force as % of population	0.10
People outside the labor force, thousands of persons	0.05
Employed population, thousand persons	0.15
Salaried workers, thousand persons	0.20
Self-employed, thousand persons	0.10
Employment rate (working-age population), %	0.15
Unemployed population, thousand persons	0.05
Unemployment rate, %	0.10
Long-term unemployment rate, %	0.10
Unemployment rate (working-age population), %	0.05
Share of workers with excessive working hours (>48 hours per week), %	0.10
Informal sector share in total employment, %	0.10
Managers and government officials	0.05
Professionals	0.05
Technicians and associate professionals	0.05
Administrative Staff	0.05
Service and sales workers	0.05
Farmers and agricultural workers	0.05
Industrial, construction, and transport workers	0.05
Operators, assemblers, and drivers	0.05
Unskilled workers	0.05

Note: compiled by authors

In the Employment Status category, key indicators include the employed population (0.15) and salaried workers (0.20), reflecting stable employment, as well as self-employment (0.10) and the employment rate of the working-age population (0.15). The Unemployment category includes the number of unemployed (0.05), the unemployment rate (0.10), and the long-term unemployment rate (0.10), all of which affect labor market stability, while the unemployment rate of the working-age population (0.05) provides additional context. The Informal and Excessive Work section emphasizes the share of the informal sector (0.10) and the share of workers with excessive working hours (0.10), indicating less stable working conditions. Lastly, the Occupational Groups section evaluates high-skilled professions such as managers (0.05), professionals (0.05), technicians (0.05), administrative staff (0.05), as well as service workers, transport, construction, and unskilled labor (each weighted at 0.05).

The weighted approach ensures that the index reflects the multidimensional nature of quality employment, providing a balanced view of labor market stability and the conditions that underpin sustainable and dignified work. The calculations and comparative analysis concluded women's employment quality dynamics between 2011 and 2021. Based on identified trends and critical deviations in employment indicators, recommendations were provided to improve women's position in the labor market

4. FINDINGS AND DISCUSSIONS

In this section, we present the results of a comparative analysis of Z-scores between women and men across various labor force indicators. The data were first categorized into key employment-related groups, including labor force participation, employment status, unemployment rates, and occupational roles. The Z-scores for each category were then

compared to identify significant deviations and trends from 2011 to 2021. This analysis highlights the differences in labor market dynamics between genders, providing insights into how men and women experienced shifts in employment, unemployment, and occupational distributions relative to the average levels for each indicator. The comparison is aimed at identifying structural gender disparities in the labor market, assessing the extent of inequality, and providing a basis for developing targeted policies to address these differences and improve labor market outcomes for both genders.

Figure 1 shows results for labor force participation comparison of z-scores by gender.

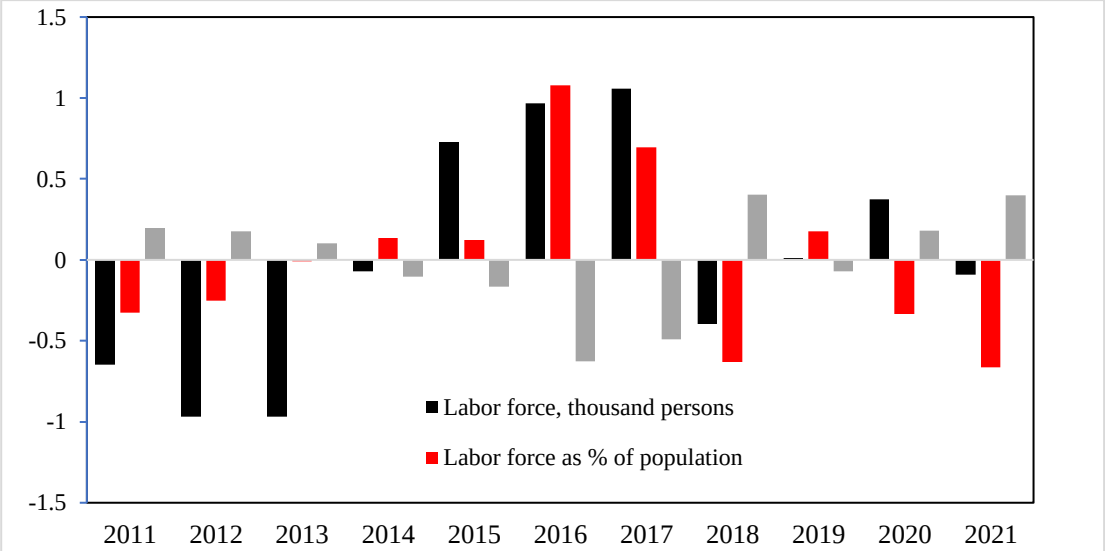

FIGURE 1. Labor force participation by gender

Note: compiled by authors

The data on the labor force (thousand persons) shows negative Z-scores from 2011 to 2014, indicating below-average participation, with the most significant deviations in 2012 and 2013 (-0.97). This trend reversed in 2015, peaking in 2017 (1.06), before declining again in 2018-2021, particularly in 2018 (-0.39), suggesting stagnation. The labor force as a percentage of the population followed a similar pattern, with low Z-scores from 2011 to 2013, a positive shift from 2014 to 2017 (1.08 in 2016), and a decline post-2018, possibly due to structural labor market changes. The number of people outside the labor force showed positive Z-scores in 2011-2013, indicating high economic inactivity, but improved by 2015 with negative Z-scores before rising again post-2018, likely due to external shocks like the COVID-19 pandemic.

These trends reflect labor market challenges in 2011-2014, recovery in 2015-2017 driven by macroeconomic improvements, and stagnation during 2018-2021 due to global economic disruptions. The most critical years appear to be 2012-2013 and 2018-2020 when the negative Z-scores point to significant deviations from average levels. In contrast, 2016-2017 represents a more favorable period, where employment and labor force engagement were at their highest.

Next, in Figure 2, there is a dynamic on employment status by gender.

The data on salaried workers (thousand persons) shows fluctuating Z-scores from 2011 to 2021. Positive deviations in 2011 and 2012 (0.24 and 0.07) were followed by a decline in 2013 (-0.33).

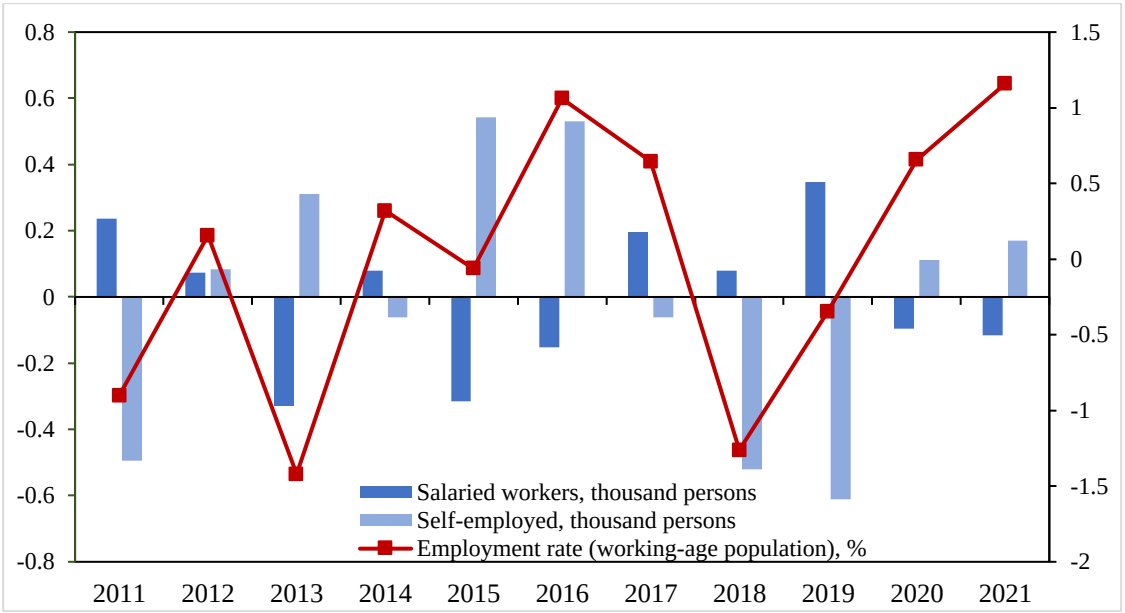

FIGURE 2. Employment status by gender

Note: compiled by authors

Alternating minor changes persisted until 2017, with a slight improvement (0.20). In 2019, the Z-score peaked (0.35) before dropping again in 2020 and 2021 (-0.10 and -0.12), likely due to external factors like the COVID-19 pandemic. For self-employed workers, Z-scores improved steadily after a 2011 dip (-0.49), turning positive in 2013 (0.31) and peaking in 2015 (0.54). However, 2018 saw a decline (-0.52), continuing into 2019 (-0.61). By 2020-2021, there was a modest recovery (0.11 and 0.17).

The employment rate (% of the working-age population) was volatile, with negative Z-scores from 2011 to 2013, reaching -1.42. A brief recovery in 2014 (0.32) followed another decline in 2015 (-0.06). Significant improvements occurred in 2016-2017 (1.06 and 0.64), but negative Z-scores reappeared in 2018-2019 (-1.26 and -0.35). Strong recovery in 2020-2021 (0.66 and 1.16) reflected post-pandemic economic interventions. Overall, the data indicates stagnation for salaried workers, with sensitivity to external economic conditions. The self-employment sector demonstrated adaptability, while employment rates showed instability followed by recovery periods, underscoring the role of labor market policies and economic conditions in shaping trends.

Next, in Figure 3, there is a dynamic in unemployment status by gender.

The data on the unemployed population (thousand persons) from 2011 to 2021 shows significant volatility. In 2012, the Z-score dropped sharply to -4.69, suggesting reduced unemployment, potentially due to economic growth or practical policies. However, 2013 saw a rebound, with a Z-score of 0.71, indicating a rise in unemployment. High Z-scores in 2019 and 2020 (1.38 and 2.10) reflect increased unemployment, likely due to the COVID-19 pandemic. By 2021, unemployment decreased but remained slightly above average (0.15).

The unemployment rate (%) followed a similar pattern, with a low Z-score of -3.99 in 2012, likely tied to strong economic conditions. However, the rate increased in 2013, fluctuating until peaking in 2019 and 2020 (1.09).

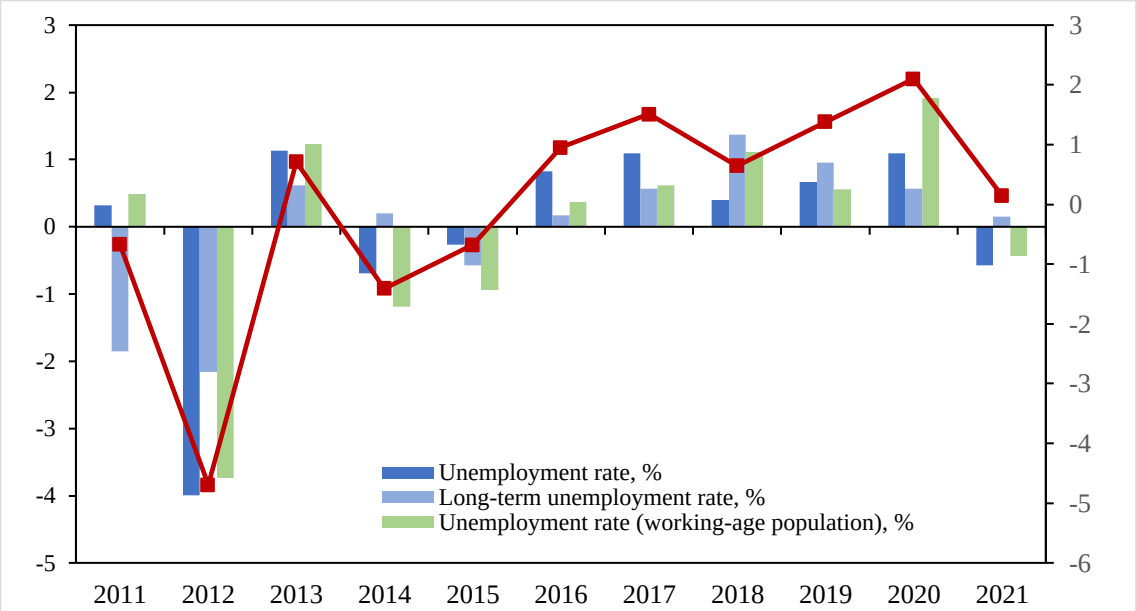

FIGURE 3. Unemployment by gender

Note: compiled by authors

A partial recovery in 2021 (-0.57) suggests stabilization, though the rate remained above pre-pandemic levels. Long-term unemployment (%) showed more stability, with negative Z-scores in 2011-2012 (-1.86 and -2.16), reflecting below-average levels. After 2013, long-term unemployment peaked in 2018 (1.37), possibly due to structural changes. By 2021, it returned to near-average levels (0.15), indicating gradual recovery.

The unemployment rate for the working-age population mirrored these trends, with a low in 2012 (-3.73) and a sharp recovery in 2013 (1.23). Positive Z-scores persisted from 2016 to 2018, peaking in 2020 (1.92), driven by the pandemic. A decline in 2021 (-0.44) suggests partial stabilization, though not a full recovery to pre-crisis conditions.

Economically, the significant drop in unemployment in 2012 across all metrics suggests a period of robust economic growth or successful labor policies that limited the duration and incidence of unemployment. However, the rise in unemployment in the following years, particularly from 2018 to 2020, reflects external pressures such as the global pandemic, which severely disrupted labor markets. The sharp increase in the unemployed population and unemployment rate in 2020 highlights the vulnerability of the labor market to sudden economic shocks. The data for 2021 suggests that while some recovery occurred, structural challenges related to long-term unemployment and overall employment rates remained, indicating a need for sustained policy interventions to address both short-term recovery and long-term labor market resilience.

Next, in Figure 4, there is a dynamic between informal and excessive work.

The data on the informal sector share in total employment (%) shows a consistent downward trend from 2011 to 2021. In 2011, the Z-score was 1.56, indicating a significantly above-average share of informal employment. This suggests that much of the labor market was not fully integrated into formal employment, possibly due to economic uncertainty or barriers to formal job creation. By 2013, the Z-score had decreased to 0.31, signaling a reduction in informal labor, though still above average.

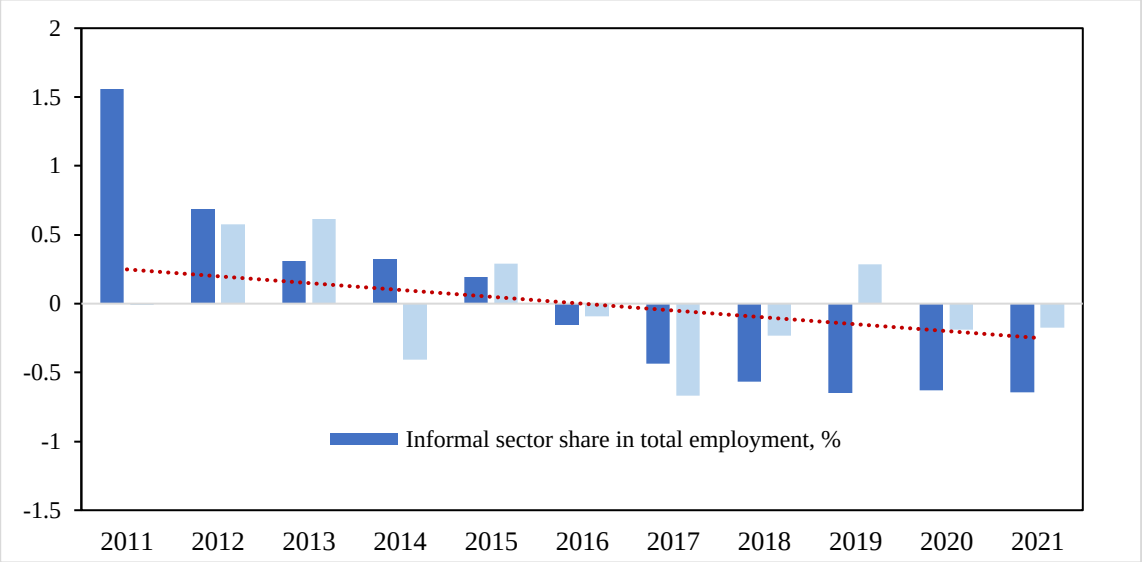

FIGURE 3. Informal and excessive work, by gender

Note: compiled by authors

From 2016 onward, the Z-scores turned negative, indicating a steady decline in informal employment. The lowest point occurred in 2019 (-0.65), likely reflecting an expansion of formal job opportunities and improved labor regulations. Despite external shocks like COVID-19, the informal sector did not rebound in 2020 and 2021 (-0.63 and -0.64), suggesting a structural shift toward greater labor formalization. The data on excessive working hours follows a more fluctuating pattern. In 2011, the Z-score was near zero (-0.01), but by 2013, it rose to 0.62, indicating increased workers putting in long hours. After 2013, Z-scores fell into negative territory, with the lowest point in 2017 (-0.67), likely due to improved labor protections or changing work patterns. A slight recovery occurred in 2019 (0.29), but the Z-scores remained negative in 2020 and 2021, indicating the share of workers with excessive hours remained below average.

Economically, the decline in informal sector employment reflects a shift towards formalization attributed to government efforts to improve labor conditions. However, the persistence of informality in earlier years underscores challenges such as regulatory barriers and sector-specific constraints.

Figure 5 presents the results for the aggregated index for women.

The Labor force indicator for women exhibits slight fluctuations around zero, with a positive deviation in 2012. However, the negative values in subsequent years 2014 and 2015, a decline in labor force among women, potentially due to external economic factors limiting women's sustained involvement in the labor market. Overall, labor force participation for women has a relatively small and unstable impact on the aggregate index, highlighting the ongoing challenges they face in maintaining a consistent presence in the workforce.

The Employment status category stands out as the most significant factor for women, showing steady growth across the entire period from 2011 to 2021.Thus, more women are gaining access to quality employment opportunities, increasing access to stable and secure employment, with a particularly sharp increase evident from 2018 to 2021. This surge likely indicates notable improvements in working conditions, enhanced job security, and the introduction of supportive workplace policies, such as flexible working hours or family-friendly initiatives.

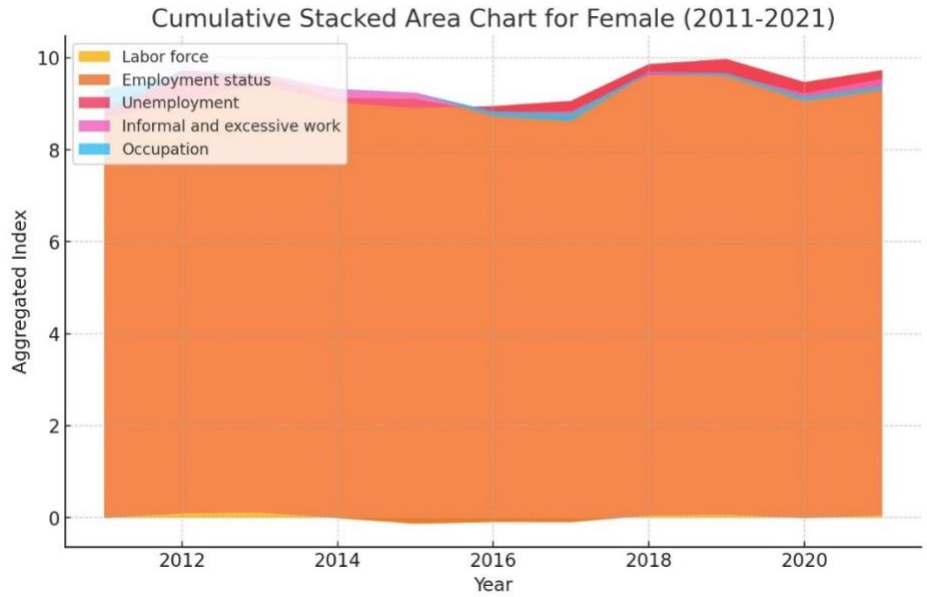

FIGURE 5. Aggregated index for women

Note: compiled by authors

In contrast, unemployment for women showed significant fluctuations, with a sharp peak in 2012 (0.65), reflecting a potential temporary deterioration in labor market conditions for women during that period. However, from 2016 onwards, the impact of unemployment on the index becomes negative, indicating a steady decline in unemployment rates.

The Informal and excessive work category reveals some positive trends in 2014 and 2015, potentially signifying improvements in working conditions, such as a reduction in informal employment or a decrease in excessive working hours. However, the reappearance of negative values in 2020-2021, possibly linked to the economic disruptions caused by the global pandemic. These shifts could indicate a deterioration in job quality for women, where informal or precarious work arrangements became more prevalent.

Finally, Occupational categories for women predominantly show neutral or negative values, indicating persistent limitations in accessing higher-quality, skilled occupations. Especially in 2016 and 2017, when the values with a sharp reduction in the number of women occupying skilled positions during these years. Such barriers may include gender biases in hiring, a lack of career advancement opportunities, or systemic challenges in traditionally male-dominated sectors.

In Figure 6, the results for the aggregated index for women are presented.

The *Labor force participation* for men similarly shows modest fluctuations, with its impact on the overall index being relatively minor. For instance, a positive increase in 2019 suggests a temporary improvement in male participation in the workforce. However, by 2020 and 2021, the values turn negative again, indicating instability in male labor force participation during these later years.

The Employment status indicator plays a crucial role for men, but unlike women, it begins with negative values in the early years from 2011 to 2015 reflecting initial challenges in employment conditions, where men may have faced limited opportunities or deteriorating job quality. However, starting in 2016, employment status for men showed a marked improvement, which could be related to employment opportunities and job conditions improvement, likely driven by economic recovery or increased demand in key sectors.

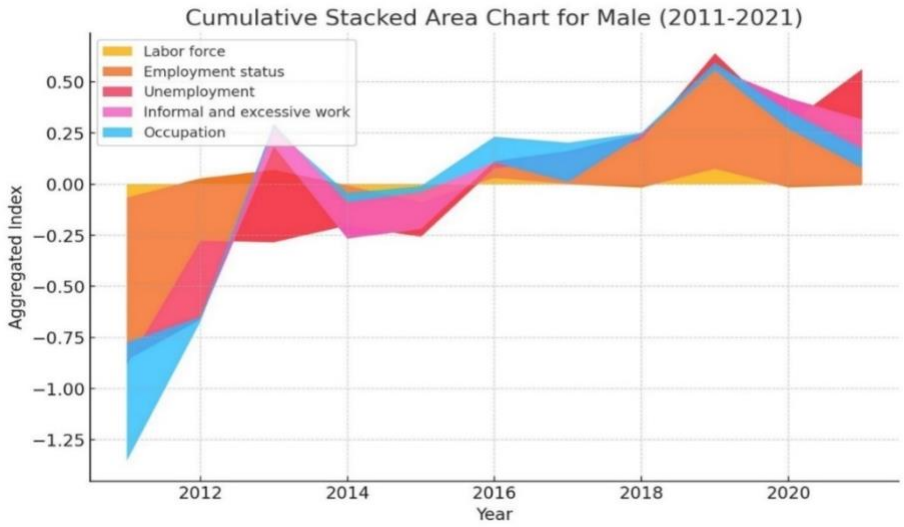

FIGURE 6. Aggregated index for men

Note: compiled by authors

The *Unemployment category* for men exhibits fluctuations, most notably in 2013 when there was a significant spike (0.47), pointing to a temporary rise in unemployment rates. Notwithstanding, in subsequent years, the effect of unemployment on the index diminishes, hovering close to zero. This stabilization implies that unemployment rates for men have leveled off, and improvements in employment status have mitigated any earlier challenges. The positive shift in employment conditions seems to have compensated for earlier increases in unemployment, bringing overall stability to male employment by the end of the period.

The *informal and excessive work indicators* show noticeable variation throughout the years. Positive values between 2013 and 2015 suggest a period of increased informal employment or overworking, perhaps due to temporary jobs or unstable labor market conditions. However, by 2020-2021, these values turn negative, reflecting a decline in informal work or excessive working hours. This reduction in harmful labor practices could be attributed to regulatory changes or shifts in employment patterns, where more formalized job opportunities became available, improving overall job quality for men.

Occupational opportunities for men have become increasingly influential on the index since 2016. The data points to a steady rise in skilled job opportunities for men, better positioned to take advantage of job growth in higher-level occupations, contributing to an overall rise in employment quality. The ability to access skilled roles likely reflects industry-specific demand and men's broader integration into more diverse and rewarding career paths, further enhancing their job market outcomes during this period.

The analysis of cumulative indices and gender comparison reveals distinct differences in labor force participation, employment status, unemployment, informal employment, and occupational opportunities for men and women from 2011 to 2021. While both genders experienced fluctuations in employment conditions, the patterns and trajectories of these changes differ significantly between men and women. For women, employment status showed consistent growth, particularly from 2016 onwards, reflecting improvements in job quality and access to stable employment. However, challenges such as unemployment and informal work remained significant, indicating that despite increased participation in the labor market, women continued to face

barriers to securing formal, high-quality employment.Men exhibited a different trajectory. Their employment status was weaker between 2011 and 2015, likely due to economic downturns or shifts in traditionally male-dominated sectors. However, starting in 2016, their situation improved considerably, with a recovery in job stability and increased access to skilled occupations, positively influencing the overall index. The gender comparison highlighted that, women experienced more consistent employment growth but continued to struggle with informal work and higher unemployment rates. For men, the recovery after early challenges was more pronounced, driven by better access to skilled professions and improved job stability.

In conclusion, targeted policies were needed to address these gender-specific challenges. For women, reducing unemployment and informal employment was critical, while for men, maintaining access to skilled occupations was essential to sustain their positive employment trends.

5. CONCLUSIONS

The primary aim of this study was to evaluate and compare the quality of employment across various labor force indicators, focusing on gender differences. The research identified key trends in labor market participation, employment stability, and job quality over time using Z-scores and weighted indices.

One of the most significant findings is the clear divergence in labor market experiences between men and women over the period studied. Women, in particular, exhibited greater volatility in self-employment and participation in the informal sector, both of which are typically associated with lower job security and fewer social protections. Moreover, women faced more persistent challenges related to excessive working hours and instability in formal employment, suggesting that despite some progress in labor force participation, structural barriers still hinder women's access to high-quality employment.

For men, the data showed more stability in formal employment categories, with a noticeable recovery in job quality after 2016. This recovery coincided with an increase in access to skilled and high-paying occupations, which likely contributed to an overall improvement in employment quality for men. However, men were also found to be vulnerable to sectoral shifts and economic downturns, particularly in industries that are more susceptible to restructuring or crises.

The gender comparison illuminated the persistent gaps in employment quality, with men generally benefiting from more stable and formalized employment structures, while women continued to face significant hurdles, particularly in the informal sector and in terms of securing long-term, stable jobs.

To address gender disparities in employment, the study recommends expanding formal employment opportunities for women, particularly in sectors where informal work is common. Reducing informal employment and excessive working hours through stricter regulations is crucial for improving job quality. Furthermore, increasing women's access to skilled professions, particularly in technology and finance, can help close the gender gap. Addressing long-term unemployment through re-skilling and job placement programs is essential, especially for women. Finally, gender-responsive policies are needed to ensure equal access to quality jobs and to reduce the impact of economic downturns on women.

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Modernization of the Motivation Systems in Higher Education: Challenges and Digital Solutions

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ABSTRACT

The motivation of academic staff in higher education institutions has become a critical issue, particularly in the context of rapid digital transformation. Faculty motivation is a crucial factor influencing the quality of education, research productivity, and the performance of universities. This study aimed to identify the main factors influencing motivation and to develop recommendations for educational institutions to enhance staff motivation. The research utilized bibliometric analysis through the VOSviewer program to explore relationships between core motivational factors. Initial data were collected via the ePORTAL system, which aggregates comprehensive information about faculty activities, including publications, participation in scientific projects, and teaching performance. The findings suggest that the current motivational systems in Kazakhstan's higher education institutions require significant modernization. Key challenges include insufficient financial support, excessive bureaucratic procedures, and limited career development opportunities. Moreover, adopting digital tools like ePORTAL can enhance the transparency and objectivity of assessing teaching staff performance, providing more substantial incentives for professional growth. The study offers recommendations for university management of educational institutions to increase academic staff motivation that can be adapted to each educational institution's unique profile and priorities. Future research should investigate the long-term effects of digitalization on teaching quality and explore how motivation strategies can be fine-tuned to address regional and institutional disparities. Such efforts will ensure faculty development aligns with national and international educational standards, ultimately enhancing the competitiveness and effectiveness of universities in a global context.

KEYWORDS: Education, Higher Education, Educational Institutions, Modernization, Motivational Mechanisms, Digital transformation, Economic Incentives, Teaching Quality

SCSTI: 12.31.41

JEL Code: I23, O33, M52

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1. INTRODUCTION

At the present stage of society's development, under the influence of various subjective factors, the effectiveness of university teaching staff and their social and cultural activity has significantly decreased. This is due to the imperfection of motivational systems and the impact of political, economic, and technological factors. In this regard, the problem of developing and implementing strategies and methods for stimulating and motivating academic staff in modern higher education institutions is not just relevant but urgent. However, problems such as insufficient funding, bureaucratic obstacles, and limited career opportunities at regional universities remain, which continue to hinder progress.

There is a greater variety of existing research, and significant gaps remain in the comprehensive analysis of the effectiveness of educational quality control mechanisms, especially in terms of their adaptation to constantly changing technological realities and global trends (Asrar-ul-Haq et al., 2017; Al-Kurdi et al., 2020; Daumiller et al., 2020). In addition, many existing incentive models and systems do not consider the quality of teachers' work, and their implementation in some universities does not provide a decent standard of living (Siddique et al., 2011; Abdulsalam et al., 2012). This leads to an outflow of professionals from higher education and a decrease in the quality of educational services. It is necessary to develop an effective system of motivational incentives for teachers at the state level and individual universities.

Modern quality assessment mechanisms often fail to account for digital technologies' full impact on the educational process and its outcomes, highlighting the need to revise and modernize approaches to quality management in education.

Firstly, more attention should be paid to studying the legal and institutional frameworks that could contribute to improving the quality of education. These aspects are crucial in creating the legal foundation supporting innovative teaching methods and ensuring their alignment with international standards. A well-developed regulatory framework must be revised to ensure the effective implementation of educational programs, complicating the introduction of new learning formats, assessment tools, and the formation of motivation for academic staff. The importance of these frameworks cannot be overstated.

Secondly, institutional factors that can contribute to improving higher education quality have yet to be adequately explored. For example, many universities face challenges in applying quality standards in practice due to insufficient institutional support and management flexibility. Institutional mechanisms, such as internal quality assurance systems, research management models, and human resource policies, directly impact the outcomes of educational activities and scientific research. With adequate attention to these mechanisms, it is possible to ensure a high level of practical implementation of educational programs and the achievement of significant research results.

Thirdly, the impact of digital transformation on the quality of educational services needs to be sufficiently studied. Digitalization is changing the educational process's structure and approaches to its organization, requiring universities to adapt to new conditions. This applies to integrating digital tools into the learning process and revising approaches to evaluating teaching quality, learning outcomes, and student engagement. A comprehensive assessment is needed to understand how digitalization affects the accessibility of educational services, including aspects of equality and fairness in access to higher education. In the context of the digital divide, it is crucial to consider that students from different socio-economic backgrounds may have unequal opportunities to participate in the educational process, posing additional challenges to educational systems.

Thus, to ensure a high level of educational quality in Kazakhstani universities, it is essential to pay greater attention to institutional aspects and further explore the impact of digital transformation on educational processes. This

study aims to develop recommendations for managing higher education institutions in Kazakhstan to enhance the motivation of academic staff. In the context of digitalization, solutions such as ePORTAL demonstrate how automation can facilitate the collection and analysis of data on the professional activities of faculty members, allowing for more objective assessments of their contributions to the educational process and motivating them toward further professional development. The significance of this paper lies in creating a flexible and effective system of academic staff motivation, which will be adapted to the constantly evolving educational and technological context and capable of stimulating faculty to improve educational and research outcomes.

2. LITERATURE REVIEW

The motivation of academic staff plays a crucial role in ensuring a high level of teaching, research activity, and the overall functioning of the university. Compelling motivation improves the quality of the educational process and enhances the faculty's scientific productivity and personal satisfaction. In the context of growing competition among higher education institutions and increasingly complex demands on educators, having a motivating environment becomes a decisive factor for attracting, retaining, and developing qualified academic personnel (Pucciarelli & Kaplan, 2016; See et al., 2020). Organizations that focus on creating conditions for professional growth, social interaction, and recognition of achievements can increase employee satisfaction and higher performance in their activities (Asrar-ul-Haq et al., 2017; Nguyen et al., 2020).

Research on the influence of various factors on the motivation and performance of academic staff covers individual, social, organizational, and resource-related aspects. For instance, Stankovska et al. (2017), Minett-Smith and Davis (2020) focused on social support and team interaction. They found that interaction with colleagues and teamwork stimulate professional and personal growth and positively affect motivation, especially among junior staff. Heng et al. (2020) highlighted the importance of individual and institutional factors in motivating faculty, particularly in developing countries. Hu et al. (2020) emphasized that effective leadership and a supportive environment increase motivation, analyzing the impact of factors such as expected performance, perceived complexity, social influence, resource availability, satisfaction, economic benefits, and habit of adopting mobile technologies. Wahyudi (2022) identified five components of motivation: physiological needs, safety needs, social needs, esteem needs, and self-actualization needs, with a particular focus on social motivation and professional collaboration as factors enhancing teacher performance.

Some studies emphasized the influence of leadership style and organizational culture on employee engagement, underscoring their importance in creating and maintaining a motivating work atmosphere. The research showed that successful academic leadership should ensure a balance between tangible and intangible incentives for professional growth and job satisfaction. At the same time, the emphasis is placed on the importance of material incentives and career growth as key motivational factors, especially with the support of management and the creation of favorable working conditions (Abdulsalam et al., 2012; Siddique et al., 2011; Victor & Babatunde, 2014; Graham, 2015; Prodanova & Kocarev, 2023). Furthermore, Al-Kurdi et al. (2020) and Daumiller et al. (2020) focused on the impact of leadership and organizational support on fostering collaboration among academic staff. The authors demonstrated that management support and a favorable working environment contribute to faculty members' professional and personal growth and the adoption of new technologies, positively affecting employee motivation and performance. Mwesigwa et al. (2020), on the other hand, concentrated on comparing democratic and authoritarian leadership styles, showing that autonomy and recognition are

essential factors in maintaining high employee motivation, highlighting the importance of granting more independence in work.

Given the wide range of factors influencing academic staff motivation, examining how these factors are represented and clustered in recent academic research is essential. Bibliometric analysis effectively visualizes these relationships, providing deeper insights into key trends and conceptual frameworks in the literature. To gain a broader understanding of the current research landscape, VOSviewer was employed to generate network visualizations to highlight relationships between key terms in academic publications.

This study used the Web of Science database to obtain relevant publications. The analysis period was limited to 2021–2025, with most publications concentrated between 2021 and 2023. Notably, the number of journal articles exceeds the number of conference papers. A total of over 100 scientific documents were identified based on the query. The results were visualized using the VOSviewer program, where the size of objects reflects the total link strength, and the thickness of the lines represents the intensity of interaction (link strength) between the terms. A sample underwent clustering and network analysis using VOSviewer for the bibliometric analysis. The search query for metadata included vital terms such as TS = ("university" OR "higher education" OR "motivation" OR "academic staff," among others). Network elements are represented as labels and circles, the size of which depends on the significance of the corresponding terms. The analysis revealed several cluster groups, highlighted in different colors, reflecting their interconnection and thematic concentration.

The visualization of the results in network visualization mode using keywords is presented in Figure 1.

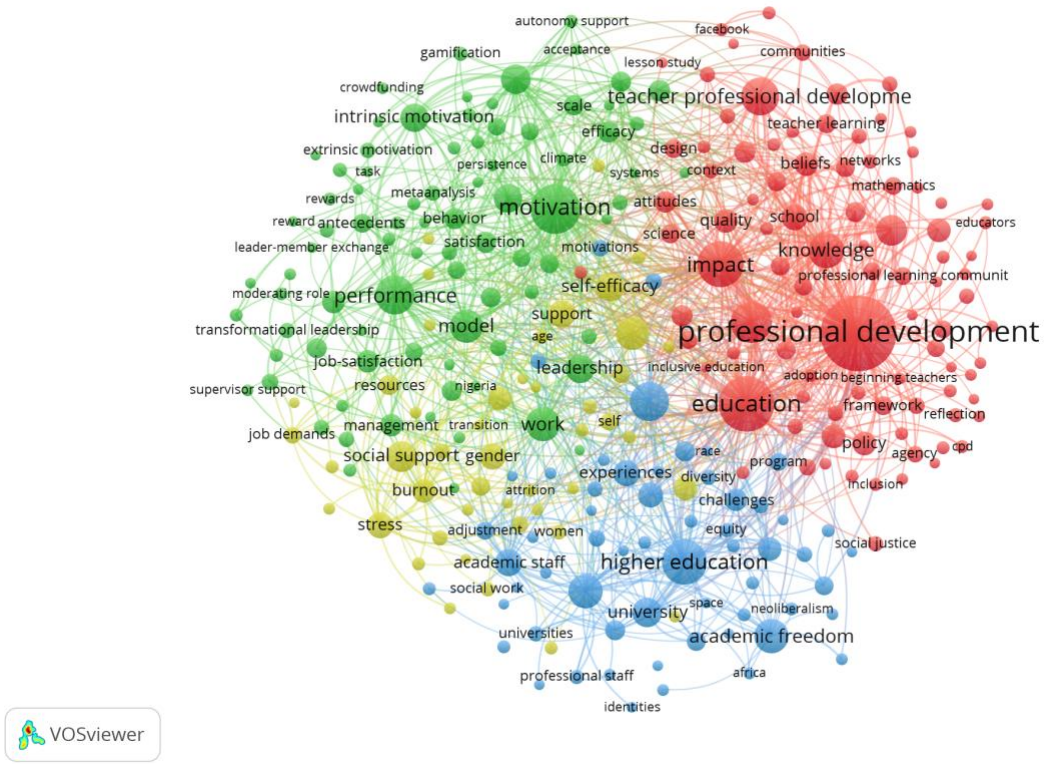

FIGURE 1. Bibliometric map of publications

Note: compiled by authors from the Web of Science database

The visualized data allowed us to identify several clustered networks, which we divided into the following groups: 'professional development' (red), 'motivation' (green), 'stress and burnout' (yellow), and 'higher education' (blue). The interpretation of the cluster groups is based on the keywords found within them. It should be noted that this division is conditional, as both clusters and terms are interconnected.

Thus, Figure 1 reflects the central role of professional development in enhancing the effectiveness and motivation of academic staff. Terms related to professional development, such as teacher training, knowledge, and influence, occupy key positions, highlighting the importance of this factor. The clusters show the relationship between motivation, job satisfaction, leadership, and social support with professional development. This indicates the need for a supportive environment with management support and measures to reduce stress and burnout. Academic freedom and autonomy also play a significant role in influencing faculty satisfaction. In conclusion, comprehensive approaches to professional development and support can significantly improve the motivation and performance of academic staff.

The identified clusters, such as 'professional development,' 'motivation,' 'stress and burnout,' and 'higher education,' mirror the key factors outlined in prior studies. Professional development, for instance, has significantly impacted motivation and job satisfaction, while stress management is crucial for maintaining high performance. These clusters reveal the interconnectedness of these concepts, reinforcing the need for institutions to adopt comprehensive strategies that address multiple dimensions of academic staff well-being.

Next, in the second stage, Figure 2 presents the results in Network visualization mode by keywords.

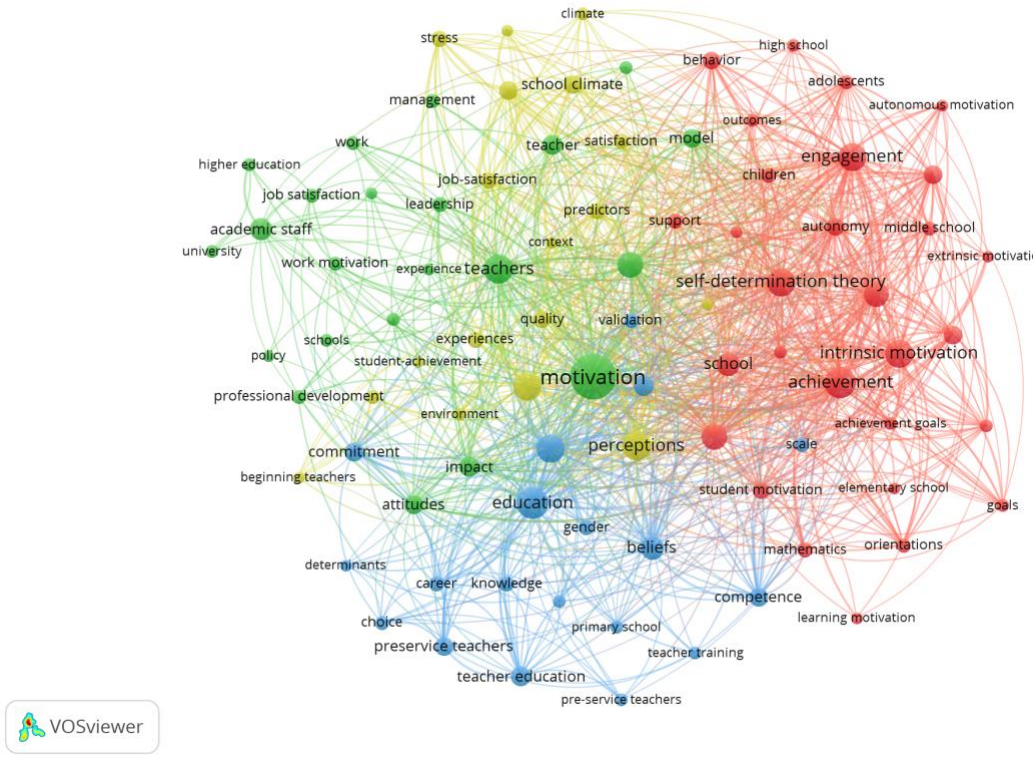

FIGURE 2. Bibliometric map of publications by keywords of the 2nd type

Note: compiled by authors from the Web of Science database

Figure 2 demonstrates that motivation is a central factor influencing critical aspects of the educational process, including academic achievement, professional commitment, and development. Self-determination theory, intrinsic motivation, and goal attainment are foundational components of success for both learners and educators, emphasizing the importance of autonomy and personal motivation. Teacher satisfaction, professional development, and leadership significantly impact creating a favorable work environment and enhancing motivation levels. The relationship between student behavior and climate indicates the substantial impact of the external environment on educational outcomes. Thus, motivation, professional support, and the development conditions for educators are determining factors in the successful functioning of educational institutions.

Next, Figure 3 presents the results in Network visualization mode by keywords of the 3rd type.

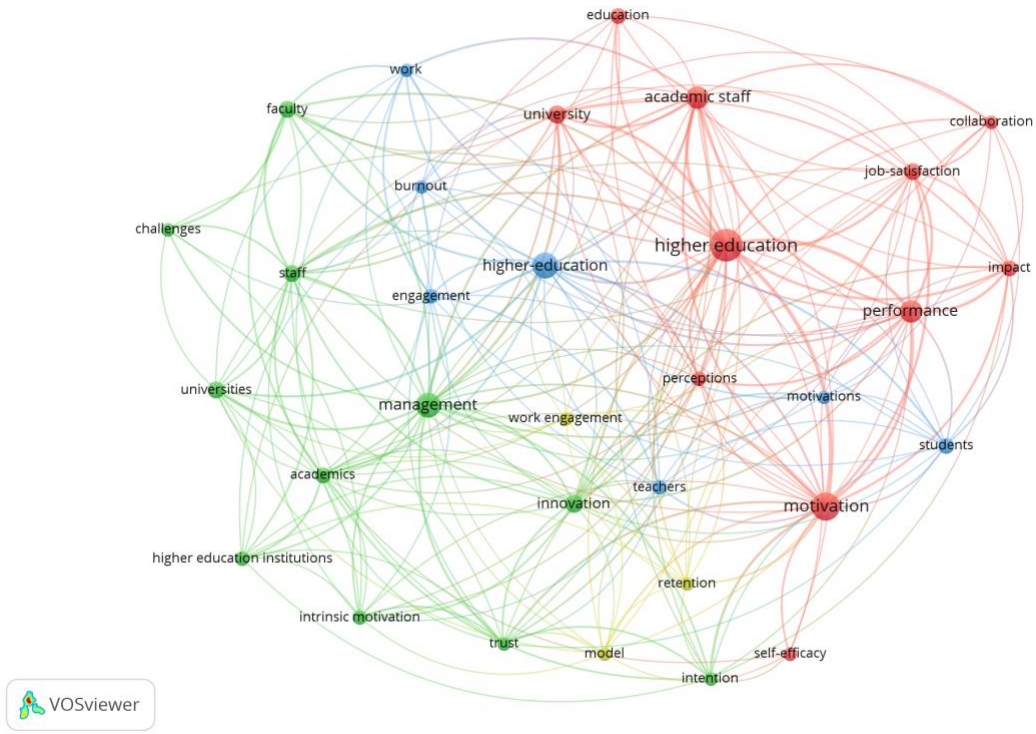

FIGURE 3. Bibliometric map of publications by keywords

Source: compiled by authors from the Web of Science database

Figure 3 illustrates the relationships between key concepts related to higher education, motivation, management, and academic activities. Motivation and performance play a central role in influencing faculty engagement, job satisfaction, and their interaction with students. Management and innovation are important aspects of supporting employee engagement and preventing burnout. Higher education connects academic staff, teachers, and educational institutions, highlighting the importance of motivation management for achieving sustainable levels of engagement and innovative development in universities.

Critical concepts related to higher education, motivation, and academic activities were identified during the analytical review of

the existing recommendations for managing educational institutions used in scientific research.

The analysis of publications from 2021–2023 identified several cluster groups, each combining terms that reflect close relationships between key aspects of the academic environment. Visualizing the results using VOSviewer showed that motivation is the central element influencing professional development, job satisfaction, leadership, and management. Particular attention is given to creating a supportive educational environment that includes stress and burnout prevention measures. The clusters also demonstrate that motivation, professional support, and development conditions play an essential role in improving academic staff performance and the effectiveness of educational institutions.

3. METHODOLOGY

The methodology of the current study is based on a comprehensive approach to managing the motivation of academic staff in higher education institutions in Kazakhstan. A research methodology was developed to assess the key factors influencing faculty motivation, professional development, and performance. Quantitative data collection and analysis methods have been applied to thoroughly examine the motivational systems employed across various universities in Kazakhstan.

The step-by-step framework includes the collection of data from the ePORTAL system, the analysis of faculty performance metrics, the bibliometric analysis of academic publications, and the development of a model for managing faculty motivation (Figure 4).

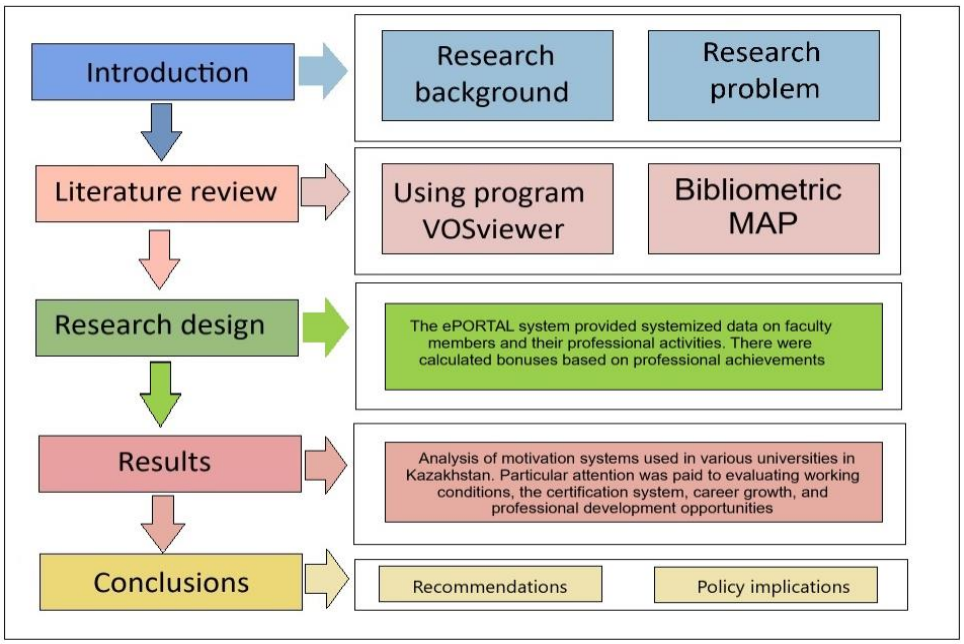

FIGURE 4. Research process

Note: complied by authors

The first phase involved data collection. The primary source of information was the ePORTAL system, which aggregates data on faculty members' professional activities. The primary tool was the ePortal system, which accumulates data on teachers' professional activities. The system collects information based on the following criteria:

1) publication activity (number of publications in scientific journals, participation in writing scientific articles);

2) participation in scientific projects and

conferences (including both national and international scientific event);

3) completion of advanced training courses (training and retraining of teachers);

4) educational and methodological activities (preparation of educational materials, conducting classes, participation in the development of training programs).

In addition, regulatory documents and statistical reports of the Ministry of Science and Higher Education of the Republic of Kazakhstan were used. These documents included materials related to the certification system's reforms and the teaching staff's professional development. Particular attention was paid to data on legislative initiatives aimed at improving teachers' qualifications and certification, which in turn impacts their motivation and level of professional development.

The second phase was data analysis. The ePORTAL system provided systemized data on faculty members and their professional activities. There were calculated bonuses based on professional achievements. At this stage, bibliometric analysis was also conducted using the VOSviewer program, which helped identify clusters of critical terms such as “motivation”, “professional development”, and “stress and burnout” to reveal the relationships between the main aspects of academic staff motivation and their productivity. The analysis revealed how the key concepts are interconnected in the scientific literature and practice.

The third phase was a qualitative analysis of motivation systems used in various universities in Kazakhstan. Both leading and regional universities were studied, which helped identify best practices for managing faculty motivation. Particular attention was paid to evaluating working conditions, the certification system, career growth, and professional development opportunities. During this stage, the following aspects were analyzed:

1) assessment of working conditions, including workload, resources provided, and support from the university administration;

2) assessment of existing certification mechanisms for teaching staff, as well as their impact on career growth and professional development;

3) analyze opportunities for career advancement, participation in research projects, and access to additional educational resources.

The fourth phase involved developing a motivation management model for faculty. This model consists of four key elements: data collection on faculty members' professional activities, analysis of this data to assess their professional activity, verification and validation of the data, and a reward system. Data verification included a multi-stage verification: from the human resources department to internal audits and quality control services. The developed incentive system based on objective data on the results of teachers' work is a powerful incentive to increase their motivation and professional growth.

4. FINDINGS AND DISCUSSION

In modern conditions of rapid changes in the educational sphere and increased demands for the quality of the educational process, the issue of motivating academic staff has gained particular relevance. In Kazakhstan, teachers play a crucial role in shaping a high-quality educational process, making their professional development, engagement, and job satisfaction essential factors for the success of educational institutions. The methods of managing personnel motivation in higher education institutions may vary and are directly dependent on the general motivation system in higher education as well as the specific management practices of individual universities. However, before addressing these methods, it is essential to consider critical categories for managing the effectiveness of innovative activities, such as motivational potential.

In Kazakhstan, the motivation of academic personnel is not represented by direct statistical data at the state level; however, a range of indirect indicators that influence this aspect are available. These include salary levels, working

conditions, certification systems, and professional development opportunities. Salary is one of the key factors influencing the motivation of teachers.

According to statistical data, the average salary of teachers in Kazakhstan is significantly lower than that of other professions with similar levels of education and experience. In 2023, the average salary of teachers was around 120 000 tenge, which is considerably lower than the salaries of engineers and doctors (Bureau of National Statistics, 2023). This situation creates barriers to attracting new specialists to the education sector and retaining existing staff, leading to a decrease in overall motivation.

The certification and professional development system for teachers in Kazakhstan is regarded as an essential tool for enhancing teacher motivation. Between 2010 and 2023, reforms were introduced to improve the certification process and allow teachers to receive salary bonuses based on their professional achievements. As part of the national teacher professional development program, Kazakhstani universities conduct courses and training sessions for teachers in collaboration with various centers. These programs allow teachers and university faculty members to improve their professional level, directly impacting their motivation through career advancement opportunities and salary increases. Within the new certification system, teachers undergo testing and professional development courses, allowing them to raise their qualification categories and receive corresponding bonuses.

Academic staff, particularly university faculty, face several specific challenges regarding motivation. These include insufficient funding for higher education, excessive bureaucratization of certification processes, and limited opportunities for professional growth in regional areas. Another significant problem is the need for more flexibility in professional development programs. Faculty members often encounter courses that need to meet their actual needs or address contemporary educational challenges, reducing such programs' effectiveness and motivational impact.

Thus, new approaches must be introduced to the certification and professional development systems for academic personnel. Opportunities for career growth, salary bonuses, and professional recognition remain powerful incentives for educators, but these incentives require modernization to enhance their impact.

To develop an effective motivation system for academic staff, it is necessary to consider their personal characteristics and the specific aspects of their professional activities. Academic staff members exhibit high diversity across several parameters, such as work experience, scientific qualifications, participation in research projects, and teaching and administrative workloads. These factors play a key role in shaping a motivation approach, as they require individualized strategies that consider staff members' various needs and drivers.

One of the main challenges of educational institutions is finding a balanced approach to motivation that can simultaneously stimulate faculty members to improve the educational process, enhance their qualifications, and participate in scientific research. It is important to recognize that different categories of staff may benefit from different motivation tools: for younger faculty, career advancement and professional development are key motivators, while for more experienced staff, scientific achievements and participation in international projects may serve as more substantial motivational factors.

Therefore, this research aims to identify optimal methods for combining various motivational tools, including both material and non-material incentives, while considering the individual characteristics of academic staff. The development of such approaches will enable the creation of a flexible and effective motivation system capable of adapting to the dynamic educational process.

Further, Figure 5 presents the motivation scheme for university faculty developed in this study.

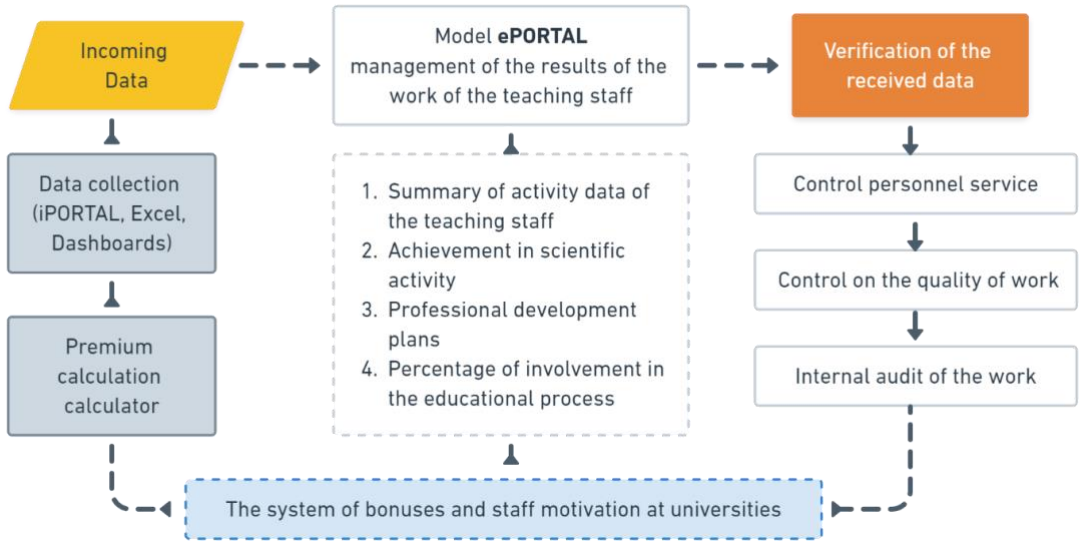

FIGURE 5. The scheme of the performance management system and motivation of the teaching staff through model ePORTAL

Note: compiled by authors

The presented scheme illustrates a model for managing the performance outcomes of university teaching staff based on the ePORTAL system, which serves as the primary tool for collecting, processing, and verifying data on employee activities. Viewing individuals and the organization as a unified whole is essential to understand the importance of effective employees within an organization. In modern organizations, especially educational institutions, personnel are considered a key factor determining the entire structure's quality and success. A robust motivation system is required to ensure employee satisfaction and loyalty, covering various levels of professional activity.

The diagram outlines the critical stages of the management process, starting from the collection of initial data and ending with the system of teacher rewards. Specifically:

(1) The first stage involves collecting input data on the professional activities of teaching staff from various sources, such as ePORTAL, Excel, and dashboards. The collected information serves as the basis for further analysis. At this stage, the data is systematized and processed using specialized tools, including a premium calculation tool, which determines salary bonuses based on the teachers' performance.

(2) The ePORTAL system is the core element of this model, managing data on the teaching staff's performance outcomes. The system analyzes the following indicators: summary data on staff activities, achievements in scientific work, professional development plans, and the degree of involvement in the educational process. This analysis provides a comprehensive assessment of the faculty's professional activity.

(3) After the analysis, the results undergo a verification process, during which the data is checked at several levels. The personnel service ensures the accuracy and correctness of the data, the quality control service monitors compliance with work standards, and internal audits ensure the objectivity of all evaluation procedures.

(4) The final stage is the reward system, which is based on verified and analyzed data. Bonuses and rewards are granted to teachers whose performance meets the established

criteria. This serves as an essential incentive for their further professional growth and motivation.

Thus, the presented model for managing the performance outcomes of university teaching staff through the ePORTAL system contributes to effective data management, enhances staff motivation based on their achievements, and maintains a high level of professional activity within universities. As a result, the ePORTAL system aggregates data from several sources: teacher reports, scientific publications, participation in conferences, results of advanced training courses and methodological work. All this data is uploaded to the system and systematized for further analysis.

Further, the collected data should be evaluated according to specific criteria. Thus, a model for evaluating teachers is based on three critical areas of their professional activity: work with students and scientific and methodological work. Each location is essential for comprehensively assessing teachers' performance (Figure 6).

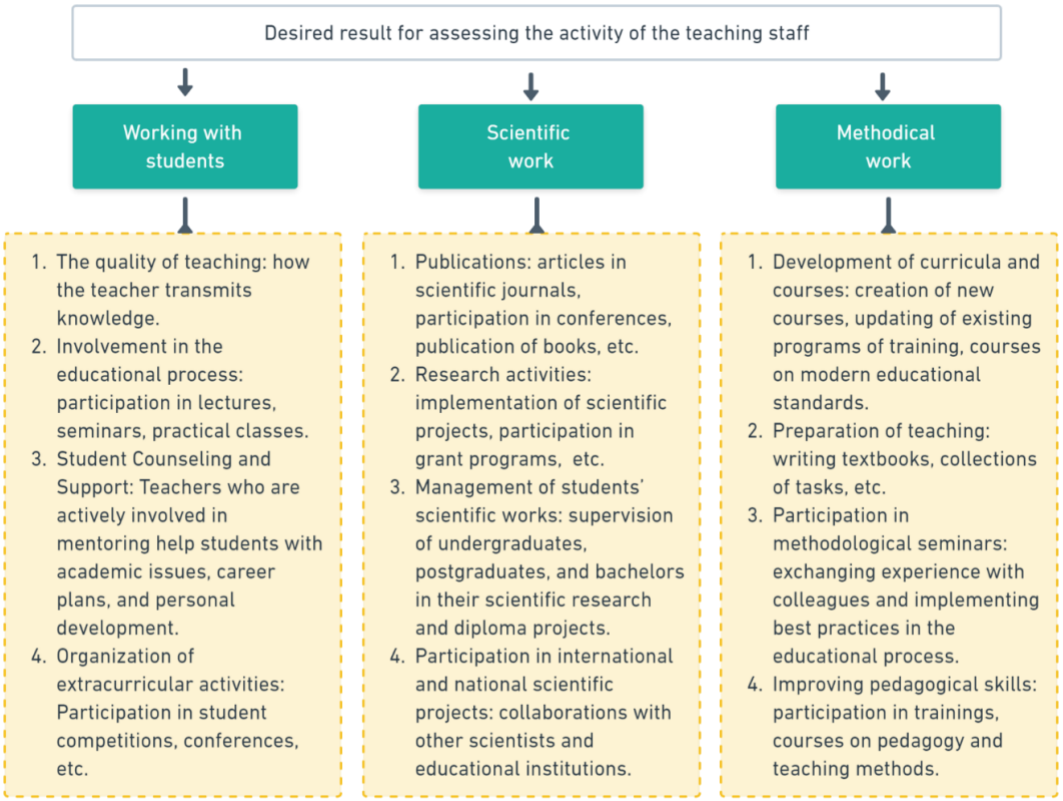

FIGURE 6. Criteria for evaluating the activity of teachers

Note: compiled by authors

The system of criteria for evaluating the activities of the teaching staff, which is based on three key areas, covers all the main aspects of teachers' professional activities and serves as the basis for their comprehensive assessment. Working with students includes the quality of teaching, participation in the educational process and extracurricular life, and advising students. The teacher is evaluated by how effectively he transfers knowledge, supports students, and organizes extracurricular activities. Scientific activity focuses on publications, participation in scientific projects and conferences, and students' scientific research leadership. A teacher's contribution to science is assessed through his study and

interaction with bachelors, undergraduates, and graduate students. Methodological work concerns the development of curricula and materials, participation in methodological seminars, and professional development. It is essential to contribute to the creation and updating of educational resources, as well as the teacher's professional development. In general, the three areas provide a comprehensive assessment of the activities of teachers, contributing to an objective analysis of their professional contributions.

Next, consider in Figure 7 the relationship between the indicators of university development and the achievements of teachers.

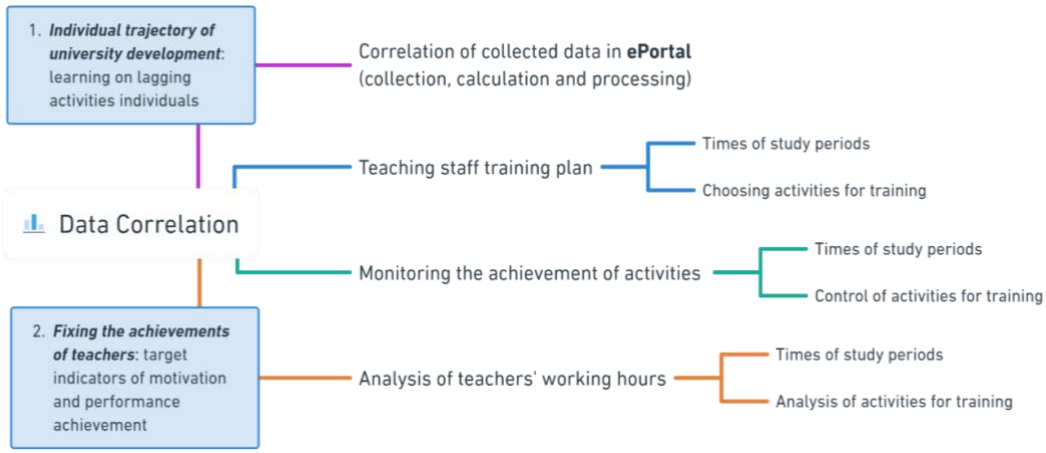

FIGURE 7. Data correlation model for university development and teacher performance

Note: compiled by authors

The model shown in the diagram describes the correlation process of data to improve the effectiveness of educational activities at the university. It focuses on two interrelated aspects: the individual trajectory of the university's development and the fixation on teachers' achievements. As part of the first part of the model, data on students, including those who are lagging behind and advancing, is collected and analyzed through the ePortal platform.

This data is used for planning and monitoring educational processes, including selecting educational activities and monitoring the implementation of educational tasks during certain academic periods. This approach allows us to more accurately consider students' individual characteristics and optimize their development trajectories. The model's second part focuses on analyzing teachers' motivation and effectiveness indicators. Here, their working hours are evaluated, and educational activities are analyzed, which allows us to identify the most effective teaching methods and increase the productivity of the educational process. The interaction between students' trajectories and teachers' activities is carried out through systematic data collection, which allows for making informed decisions to improve educational outcomes.

To manage teachers' motivation in educational institutions, it is necessary to develop a flexible model that considers the specifics of various universities in Kazakhstan. In this context, an ePORTAL system is essential for collecting, processing, and analyzing data on teachers' activities, ensuring the objectivity of assessment and stimulating academic staff based on their achievements. Below is a table illustrating how the proposed model for evaluating teachers' activities through the ePORTAL system can be adapted for leading and regional universities in Kazakhstan (Table 1).

TABLE 1. Recommendations for the management of educational institutions to increase the motivation of academic staff

University	The main evaluation criteria through the portal	Features of model adaptation
Nazarbayev University (Astana)	1. Publications in international scientific journals. 2. Participation in international scientific projects. 3. Work with students and feedback.	Focus on scientific achievements: The portal will monitor publication activity, participation in major international projects, and grants. Teachers with high scientific activity will be considered for publication in leading international journals. The system will also collect data on participation in the educational process and student feedback.
Al-Farabi Kazakh National University (Almaty)	1. Scientific publications and participation in international conferences. 2. Participation in national and international grant projects. 3. Feedback from students.	Scientific and teaching activities: Through ePORTAL, teachers can track their participation in national and international conferences, publications, and grant work. The teaching assessment will include student feedback and an analysis of their interactions, which will increase its objectivity.
University of International Business named after K. Sagadiyev (Almaty)	1. Participation in applied research. 2. Development of educational programs. 3. Working with corporate partners and the business community. 4. Publication activity.	Focus on business research and market communication: Through the portal, the system can track teachers' interaction with the business community and participation in applied research. It is also essential to consider the development of business-relevant training programs and publications in economic and management journals.
Kazakh State University of Architecture and Civil Engineering (Almaty)	1. Development of educational materials and methodological work. 2. Teaching and feedback from students. 3. Participation in applied construction projects.	Architectural and construction projects: ePORTAL can track teachers' participation in applied research and projects in construction and architecture. Teaching work evaluation includes developing new educational programs, student feedback, and methodological activities.
M. Auezov South Kazakhstan State University (Shymkent)	1. Methodical work. 2. Development of educational programs. 3. Feedback from students. 4. Participation in national scientific projects.	Teaching and methodological work: ePORTAL will focus on developing methodological materials and curricula. Participation in national research projects and grants will also be considered. Student feedback will enhance teaching assessment, making the analysis completer and more transparent.
S. Toraighyrov Pavlodar State University (Pavlodar)	1. Teaching and feedback. 2. Methodical activity. 3. Participation in national scientific projects.	Teaching and methodical work: Through ePORTAL, the university will monitor teaching work and collect student feedback. Special attention will be paid to methodological activities, such as developing curricula and participating in national scientific grants and conferences.
Aktobe Regional University named after K. Zhubanov (Aktobe)	1. Methodical work. 2. Assessment based on feedback from students. 3. Participation in regional and national scientific projects.	Teaching and participation in regional projects: The portal allows you to record methodological work and education, including student feedback. Special attention is paid to regional scientific activities, reflected in teachers' participation in local scientific initiatives and educational projects.

Note: complied by authors based on calculations

Thus, in this paper, the portal system and the proposed assessment model can be used to lead Kazakhstan regional universities in increasing academic staff motivation. However, these proposals are only guidelines and do not pretend to be universal. Implementing these approaches should be flexible and customizable depending on the tasks and priorities of a particular university. Each educational institution can vary the evaluation criteria depending on its strategic objectives and available resources. For example, leading scientific universities can focus on international publications and grants, while regional universities can focus on methodological work and student interaction.

5. CONCLUSIONS

The purpose of this study was to identify key factors influencing the motivation of teaching staff in higher educational institutions of Kazakhstan, as well as to develop recommendations aimed at improving their professional activities in the context of the digital transformation of education. In modern conditions of modernization of the educational system, it is critically important to improve the level of qualification of teachers and the development of pedagogical competencies that meet the requirements of Kazakhstan and international standards. In light of the increased attention to this issue, there is a need to ensure sustainable motivation for the professional development of teachers. The practical significance of this study lies in the fact that introducing the proposed motivation system and stimulating teachers' work will allow higher education institutions to solve problems related to the development of human resources more effectively. This, in turn, will contribute to achieving the strategic goals of universities, increasing their efficiency and competitiveness in the educational market.

The results showed that the teacher motivation system is vital in ensuring the quality of the educational process and scientific activity. In Kazakhstan, it is necessary to modernize the motivation system to encourage employees to grow professionally, which can significantly increase the level of education and scientific research in the country. The main obstacles include insufficient funding, bureaucratization, and limited career opportunities, especially at regional universities.

Digitalization affects educational processes, requiring updated approaches to evaluating teaching and learning. Using modern digital tools, such as ePORTAL, allows you to collect and analyze data on teachers' professional activities effectively. This contributes to an objective assessment of their contribution to the educational process and can serve as an incentive for further professional development. Digital tools such as ePORTAL can help assess teachers' professional activities more objectively and create motivational models.

Generally, it is recommended that attention be increased to financing issues and the introduction of material incentives for teachers, including salary increases and modernization of the certification system. Universities need to adapt motivation systems to teachers' individual needs, considering their experience, scientific qualifications, and workload. As a result, recommendations have been developed to manage the motivation of teaching staff at various universities in Kazakhstan. For leading universities, the focus is on scientific achievements, including publications in international journals and participation in international research projects. In regional universities, priority is given to methodological work, student feedback, and participation in national research projects. These recommendations emphasize the need to adapt the motivation system to the specifics of a particular university, including regional conditions and priorities.

Future research may aim at an in-depth study of the impact of digital technologies on the motivation of teaching staff. It is important to analyze how the introduction of new educational technologies affects the involvement and professional development of teachers, as well as their job satisfaction, in the

context of digitalization. It is also promising to study the regional characteristics of motivation, which will reveal differences in approaches to stimulating teachers at leading and regional universities and offer adapted management models.

AUTHOR CONTRIBUTION

Writing – original draft: Marat Urdabayev, Nazym Ainakul, Bakhtiyar Sabdenaliyev.
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Funding acquisition and research administration: Bakhtiyar Sabdenaliyev.
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Resources: Marat Urdabayev, Nazym Ainakul.
Software and supervisions: Marat Urdabayev, Bakhtiyar Sabdenaliyev.
Data collection, analysis and interpretation: Bakhtiyar Sabdenaliyev.
Visualization: Marat Urdabayev.
Writing review and editing research: Marat Urdabayev, Nazym Ainakul.

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The Role of Energy Intensity and Investment in Reducing Emissions in Türkiye

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ABSTRACT

Addressing the challenge of rising carbon dioxide (CO2) and greenhouse gas (GHG) emissions is a critical priority in global efforts to combat climate change. The primary aim is to assess the relationship between energy intensity, private investments in energy, renewable energy consumption, export-related factors, and their influence on CO2 and GHG emissions in Turkey. The study employs a multi-level approach using correlation and regression analyses to explore the impact of the selected variables. A Bayesian correlation analysis was conducted to evaluate the strength of relationships between variables, and a regression model was used to test the significance of each factor. Data were gathered from official sources on energy intensity, renewable energy consumption, private investments in energy, and export-related variables in Turkey from 2007 to 2022. The study employed the JASP statistical software. The analysis showed that energy intensity and private energy investments are the most significant predictors of CO2 and GHG emissions. Energy intensity exhibited a strong negative correlation with CO2 emissions per capita ($r = -0.717$, $BF_{10} = 10.456$) and GHG emissions ($r = -0.802$, $BF_{10} = 44.224$), highlighting the critical role of energy efficiency in reducing emissions. Renewable energy consumption also played a role, though its influence was less pronounced than energy efficiency and investment. Based on the findings, it is recommended that policymakers prioritize energy efficiency improvements and create incentives for private investment in renewable energy technologies. Future studies should focus on sector-specific energy efficiency improvements and policy frameworks to enhance private sector engagement in clean energy initiatives.

KEYWORDS: Energy Intensity, Emissions, Sustainable Development, Green Energy, Economic Growth, Green Economy, Fuel Export, Turkey

SCSTI: 06.35.31

JEL Code: Q10, Q43, O13

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1. INTRODUCTION

The issue of rising carbon dioxide (CO2) emissions and total greenhouse gas (GHG) emissions has become a central challenge in addressing climate change on a global scale. As nations strive to meet international climate goals such as those outlined in the Paris Agreement, reducing emissions has taken on a critical role in mitigating the impact of climate change (Liu et al., 2020). However, achieving significant reductions in emissions remains a complex task, as it requires coordinated efforts across various sectors, including energy, industry, and transportation. A vital aspect of this challenge is the influence of factors such as energy intensity, investment in energy infrastructure, and the transition to renewable energy sources in shaping emission trends.

Globally, energy intensity - the amount of energy used per unit of economic output - is a significant factor in emissions. High energy intensity indicates inefficient energy use, often leading to higher emissions. Similarly, private investment in energy infrastructure, particularly clean and renewable energy technologies, is crucial in transitioning to lower-carbon economies. Investments in energy efficiency, renewable energy projects, and new technologies are essential to offset the heavy reliance on fossil fuels, contributing to CO2 and GHG emissions (Holechek et al., 2022). Despite global progress in renewable energy consumption, the rate at which countries adopt clean energy solutions varies significantly.

Additionally, natural resource rents, especially in resource-rich countries, play a significant role in the economic reliance on carbon-intensive industries such as fossil fuel extraction. This reliance further complicates efforts to transition to a low-carbon economy, as many countries face a trade-off between short-term economic gains and long-term sustainability goals. While exports of fuels and metals continue to be critical drivers of economic growth in many nations, they also contribute significantly to emissions. In the context of Turkey, the challenge of balancing economic development with environmental sustainability is particularly relevant. As a developing economy with a growing industrial base, Turkey faces unique pressures to reduce emissions while maintaining economic growth. Turkey's energy sector has historically depended on fossil fuels, and its energy intensity remains relatively high compared to more developed economies (Celik & Özgür, 2020; Yildizhan et al.,2023). Although there have been efforts to increase renewable energy consumption and attract private investment into the energy sector, the pace of this transition remains insufficient to achieve significant emissions reductions.

Given the critical role that energy intensity, private investment in energy infrastructure, and renewable energy consumption play in reducing emissions, studying the interplay of these factors in Turkey's context is highly significant. Understanding how Turkey can leverage energy efficiency improvements and attract more investment in clean energy technologies will be crucial for its ability to reduce emissions while sustaining economic growth. Addressing these issues is vital for Turkey's environmental goals and contributes to global efforts in combating climate change.

The study aims to analyze the determinants of CO2 emissions per capita and GHG emissions by exploring the influence of energy intensity, private investment in energy, renewable energy consumption, and export-related variables.

2. LITERATURE REVIEW

The relevance of studying energy intensity and investments in clean technologies was driven by global challenges related to the increase in carbon dioxide (CO2) and greenhouse gas (GHG) emissions in the context of economic growth. As economic activity grew, energy consumption increased, putting more strain on the environment, particularly in countries with high energy intensity. Inefficient energy use in sectors such as industry and transportation led to significant emissions. Research showed that investments in clean

technologies were crucial in reducing dependence on fossil fuels and lowering emissions. However, the pace of these changes, especially in developing economies, needed to be increased. Analyzing global and regional trends and the experiences of countries like Turkey was critical for finding solutions to reduce energy intensity and successfully integrate renewable energy sources.

Caiado et al. (2017) emphasized that investments in clean technologies were vital to reducing energy intensity and environmental impact, especially in developing economies like Turkey. At the same time, Spaiser et al. (2017) highlighted the conflict between economic growth and environmental sustainability, pointing out that a traditional focus on economic growth in countries heavily reliant on fossil fuels exacerbated the problem of energy intensity. Østergaard et al. (2020) noted that transitioning to renewable energy sources, such as wind, solar, and geothermal, could significantly reduce dependence on fossil fuels. In countries where the potential of renewable energy was not yet fully realized, this was seen as a critical step toward achieving environmental sustainability. In this context, Ruggerio (2021) stressed the importance of implementing new energy models to reduce energy intensity. However, the author noted that successfully implementing such changes required technological modernization and political will, especially in countries where traditional energy sectors depended on fossil fuels.

In countries with high energy intensity, inefficient energy use has increased emissions, necessitating enhanced measures to improve energy efficiency. Sen and Ganguly (2017) emphasized that special attention had to be paid to the industrial and transport sectors, which were key contributors to energy consumption and emissions. Malik et al. (2019) noted that developing countries faced significant barriers to adopting renewable energy, such as insufficient political support and financing challenges, which hindered the effective utilization of renewable energy sources. Fadly (2019) pointed out that a successful transition to a low-carbon economy required active participation from the private sector and the creation of financial incentives. Brazil served as an example, where effective financial mechanisms supported the development of renewable energy projects, while in Nigeria, such programs faced numerous obstacles (Isah et al., 2023), slowing down reductions in energy intensity. In his study, Cantarero (2020) highlighted the importance of community involvement and creating inclusive energy systems to accelerate the transition to renewable energy. Moreover, in countries with high energy intensity, the participation of local communities and businesses in decision-making was a key factor for successfully implementing renewable energy sources.

The literature on natural resource rents and fuel exports highlighted their significant impact on carbon emissions, especially in resource-dependent countries. Ertimi et al. (2021) pointed out the importance of effective natural resource management in oil-dependent countries, noting that proper strategies, such as those in Norway, could help minimize the resource curse, utilize oil revenues for sustainable economic growth, and protect the environment. Saqib et al. (2022) added that in GCC countries, an increase in natural resource rents was linked to rising CO2 emissions, demonstrating the importance of transitioning to renewable energy to reduce the carbon footprint. Despite economic benefits, the use of fossil fuels increased environmental pressure. Huang et al. (2021) also emphasized that natural resource rents exacerbated the negative ecological impact of rapid economic growth and urbanization, creating complex trade-offs between economic development and sustainability. Yan et al. (2023) explored the importance of green investments and fiscal policies to reduce dependence on natural resources and fossil fuels. Thus, for countries with a high share of natural resource rents, consistent measures were needed to stimulate the transition to clean energy and reduce carbon emissions.

To build on the findings from the literature, it becomes evident that energy intensity,

private investment in clean technologies, and the consumption of renewable energy play critical roles in shaping environmental outcomes. Additionally, the impact of fuel and metal exports on emissions cannot be overlooked. Therefore, the following hypotheses were developed:

Hypothesis 1. CO2 emissions per capita significantly depend on energy intensity, private investment in energy, and renewable energy consumption.

Hypothesis 2. GHG emissions (kt of CO2 equivalent) are significantly influenced by energy intensity, private investment in energy, and exports of fuel and metals.

3. METHODOLOGY

A multi-level analytical framework was employed to investigate the complex relationships between key economic and environmental variables affecting CO2 and GHG emissions. The analysis was structured in stages, starting with bivariate analyses and concluding with Bayesian correlation and regression analysis to test hypotheses regarding the significance of selected predictors.

The initial stage involved profile plots for bivariate exploration of the data. This approach provided both a visual and statistical assessment of the relationships between individual variables, focusing on energy intensity, private energy investment, renewable energy consumption, and export-related variables. Profile plots were used to identify preliminary patterns and potential interactions among variables, setting the stage for more robust confirmatory analysis. The goal of this stage was to develop a qualitative understanding of the data and to identify potential interactions or multicollinearity between the variables.

Following the visual inspection, Bayesian correlation analysis was conducted to quantitatively assess the relationships between variables. Unlike traditional correlation methods, the Bayesian framework allows for the incorporation of prior information, offering a more nuanced interpretation of the strength and direction of these relationships. Bayes factors (BF_{10}) were used to compare models with predictors against a null model, thus providing evidence in favor of each predictor. The Bayesian approach was chosen for its flexibility in handling uncertainty and for its capacity to provide more reliable insights, particularly in cases where prior knowledge from existing literature is available, as in environmental studies.

A null model was included as a baseline for comparing more complex models with predictors. The null model assumed that none of the predictor variables had a significant effect on the dependent variable (CO2 emissions per capita or GHG emissions). This step was essential for evaluating whether the inclusion of specific predictors enhanced the explanatory power of the models. By using Bayes factor analysis, predictor-based models were compared against the null model to determine whether the predictors significantly contributed to explaining variations in the dependent variables. A Bayes factor greater than 1 indicated that a predictor-based model was favored over the null model.

In the final stage, regression analysis was employed to quantitatively assess the significance and impact of each predictor on CO2 and GHG emissions. The regression models evaluated both the individual significance of predictors, such as energy intensity, private investment in energy, renewable energy consumption, and export-related variables, and the overall model fit, using R^2 and adjusted R^2 to measure how well the models explained the variance in emissions. Bayesian regression models were utilized alongside traditional methods to ensure a robust comparison, further strengthening the understanding of the relationships between the predictors and emissions. Two main hypotheses were tested in this analysis.

The choice to employ profile plots, Bayesian correlation analysis, and regression analysis was driven by the need to address both the complexity and uncertainty present in economic and environmental data. The Bayesian framework provided a flexible way to interpret relationships in the presence of prior

information, particularly when dealing with multiple interconnected predictors like energy consumption and emissions. Combining both exploratory (bivariate) and confirmatory (regression) techniques ensured that visual data inspection and statistical testing contributed to a comprehensive understanding of the relationships between the predictors and emissions outcomes. This multi-level approach enabled a robust interpretation of the data, leading to informed conclusions and practical recommendations.

4. FINDINGS AND DISCUSSION

The analysis aimed to provide a detailed examination of the factors influencing CO2 emissions per capita and total GHG emissions, focusing on energy intensity, private investment in energy, renewable energy consumption, and export-related variables. The analysis structure was designed to comprehensively explore how each factor contributed to emission trends through a multi-step approach, combining both exploratory and confirmatory techniques.

Initially, pairwise relationships using profile plots were analyzed to explore the connections between the variables. This step provided a preliminary understanding of the factors most strongly associated with CO2 and GHG emissions changes. Following this, a Bayesian correlation analysis was performed to account for uncertainty and offer more robust insights into the strength and direction of these relationships. Finally, a regression analysis tested the significance of each predictor, quantifying their respective contributions to explaining variations in emissions.

The first model examines the connection between several economic and energy variables and CO2 emissions per capita (Figure 1).

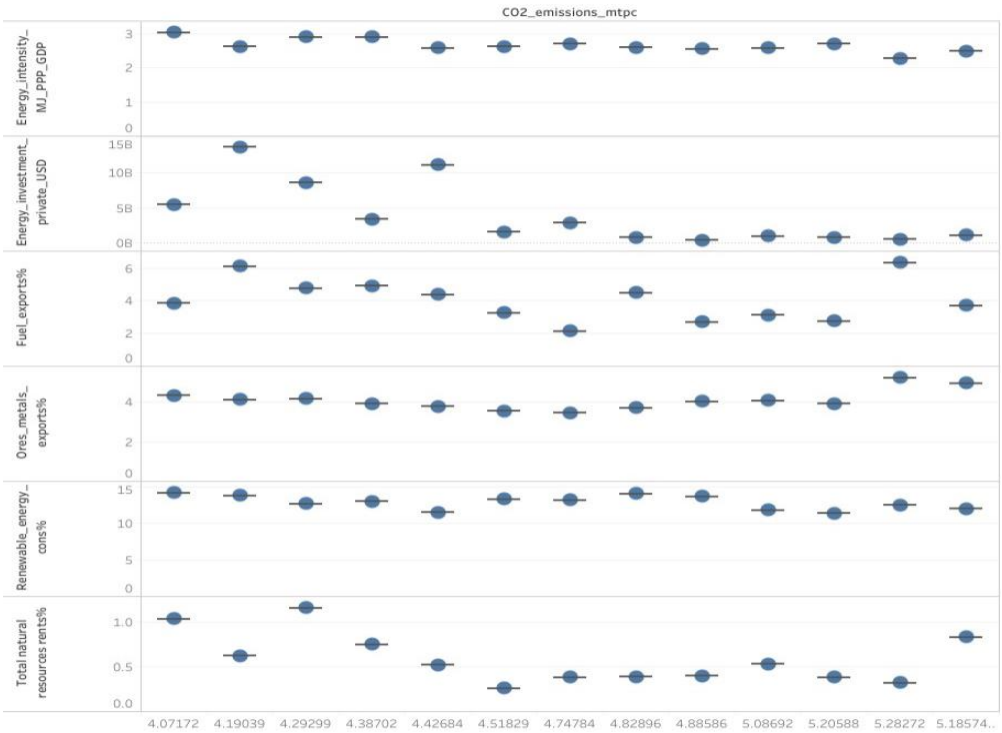

FIGURE 1. Model 1 CO2 emissions per capita

Note: compiled by authors

Key indicators such as Energy Intensity (MJ/$2017 PPP GDP) and Fuel Exports (% of merchandise exports) demonstrate a moderate correlation with CO2 emissions. Countries with higher energy intensity, which indicates less efficient energy use, tend to show higher emissions. Additionally, economies heavily reliant on fuel exports, such as Turkey, typically have higher emissions due to their dependence on carbon-intensive fossil fuel industries. In Turkey, despite efforts toward energy efficiency, the reliance on fossil fuel exports continues to drive emissions upward.

On the other hand, Access to electricity (% of population) and Ores and metals exports (% of merchandise exports) show weaker associations with emissions. While increased electricity access is often tied to industrial growth, this factor alone does not significantly drive emissions in the model. In Turkey, widespread access to electricity exists, but emissions are more closely tied to the energy sources used rather than access itself. Similarly, the export of ores and metals does not appear to have a strong impact on emissions, as their production is less carbon-intensive than energy sectors.

The second model analyzes the relationship between the economic and energy variables, with Total GHG emissions (kt of CO2 equivalent) as the dependent variable (Figure 2).

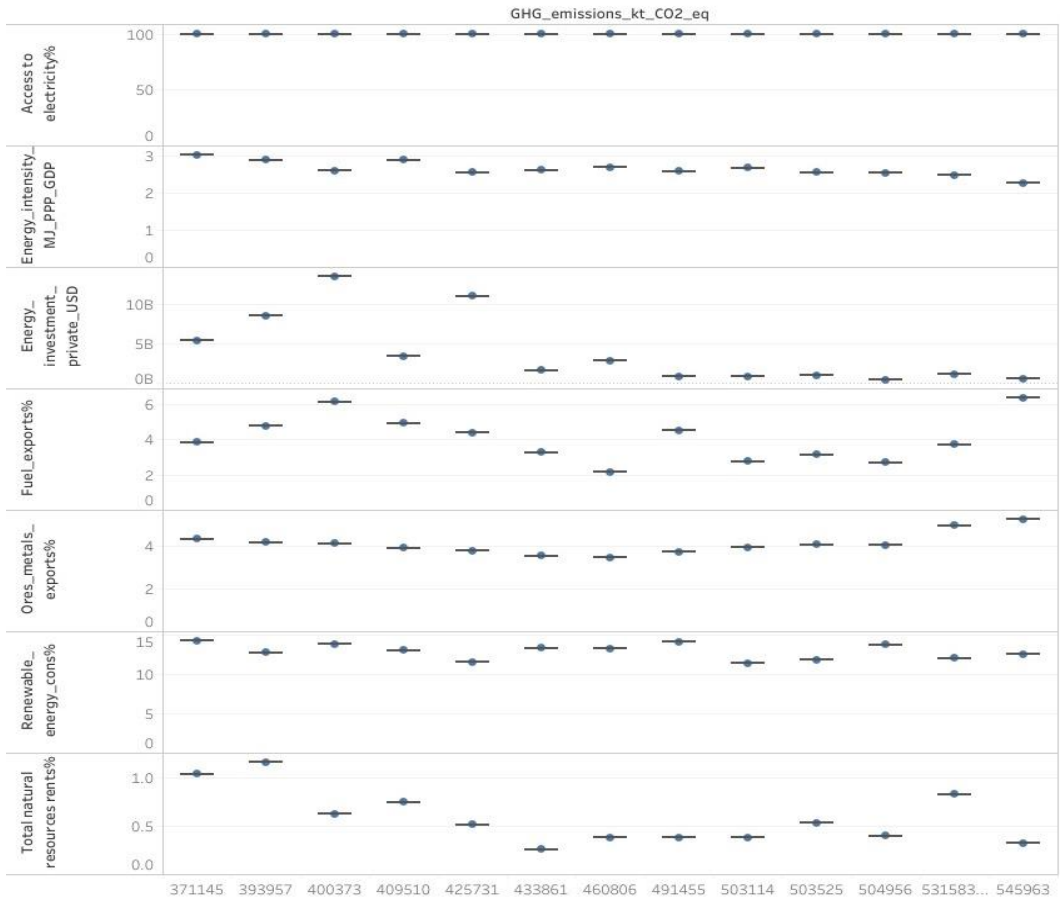

FIGURE 2. Total GHG emissions

Note: compiled by authors

Renewable Energy Consumption (% of total final energy consumption) and Private Investment in Energy (USD) reveal a more substantial inverse correlation with CO2 emissions. Countries with higher renewable energy consumption and greater private investment in the energy sector tend to have lower emissions. In Turkey, increased investments in renewable energy, particularly solar and wind, have begun to reduce the country's emissions, offsetting the negative impact of fossil fuel consumption. Targeted investments and a shift towards renewables can effectively reduce carbon footprints.

Finally, Total natural resource rents (% of GDP) display only a weak correlation with emissions, indicating that economic reliance on natural resource extraction has a limited impact on CO2 levels in Turkey. The relatively small share of natural resource rents in the Turkish economy means other sectors dominate emission generation.

Energy Intensity and Fuel Exports exhibit moderate positive correlations with GHG emissions, underscoring the role of energy inefficiency and fossil fuel dependence in driving emissions. Turkey's high fuel export reliance and relatively high energy intensity contribute to its greenhouse gas emissions, although recent efforts to improve energy efficiency are expected to mitigate this impact gradually.

Private Investment in Energy and Renewable Energy Consumption again show a stronger inverse correlation with GHG emissions, reinforcing the importance of renewables and energy investments in reducing emissions. In Turkey, rising private sector investments in cleaner energy technologies, alongside increasing renewable energy consumption, are helping curb GHG emissions growth despite industrial and economic expansion.

The remaining variables, Access to electricity, Ores and metals exports, and Total natural resources rents, exhibit weak relationships with GHG emissions. Like the first model, these indicators are relatively minor in driving greenhouse gas emissions in Turkey's context. The country's energy mix and industrial activities are more impactful than these specific economic variables.

A correlation analysis will be conducted and displayed in Table 1 to quantify the relationships observed in both models.

TABLE 1. Correlation matrix

Variable		CO2_emissions_mtpc	GHG_emissions_kt_CO2_eq	Renewable_energy_cons%	Total natural resources rents%	Energy_intensity_MJ_PPP_GDP	Ores_metals_exports%	Fuel_exports%
CO2_emissions_mtpc	Pearson's r	—						
	BF_{10}	—						
GHG_emissions_kt_CO2_eq	Pearson's r	0.978***	—					
	BF_{10}	666546.918	—					
Renewable_energy_cons%	Pearson's r	-0.511	-0.393	—				
	BF_{10}	1.445	0.762	—				
Total natural resources rents %	Pearson's r	-0.526	-0.559	0.088	—			
	BF_{10}	1.596	2.039	0.354	—			
Energy_intensity_MJ_PPP_GDP	Pearson's r	-0.717*	-0.802*	0.318	0.658	—		
	BF_{10}	10.456	44.224	0.568	5.080	—		

Ores_metals_exports%	Pearson's r	0.371	0.405	-0.187	0.279	-0.397	—	
	BF_{10}	0.693	0.805	0.405	0.503	0.773	—	
Fuel_exports %	Pearson's r	-0.245	-0.180	0.132	0.215	-0.177	0.498	—
	BF_{10}	0.459	0.399	0.371	0.428	0.397	1.333	—
Energy_investment_private_USD	Pearson's r	-0.740*	-0.717*	0.072	0.426	0.290	-0.129	0.468
	BF_{10}	14.545	10.433	0.350	0.888	0.520	0.370	1.114

Note: compiled by authors

This will outline the key variables influencing CO2 and GHG emissions to clarify the significance of factors such as energy intensity, fuel exports, renewable energy consumption, and private investments in driving emissions in Turkey and other similar economies. The interpretation of the correlation analysis reveals several significant relationships among the variables, particularly concerning CO2 emissions per capita and total greenhouse gas (GHG) emissions. A strong positive correlation is observed between CO2 emissions per capita and GHG emissions (kt of CO2 equivalent), with a Pearson's r value of 0.978 and a substantial Bayes factor (BF_{10}) of 666546.918, indicating a robust association. The relationship emphasizes the consistency between the two emissions measures, reinforcing that both metrics effectively capture the overall environmental impact of energy consumption and production.

Moving to renewable energy consumption, a negative correlation is found between CO2 emissions per capita and Renewable energy consumption, with a Pearson's r value of -0.511. Although this correlation is moderately intense, the Bayes factor (BF_{10}) of 1.445 indicates limited evidence in favor of the relationship. Renewable energy consumption also shows a weaker negative correlation with GHG emissions (-0.393), further suggesting that increasing the share of renewables in the energy mix contributes to lower emissions. However, the effect is not as pronounced. The weak associations between Renewable energy consumption and both types of emissions highlight the need for more robust policy measures to enhance the impact of renewables on reducing carbon footprints.

An analysis of Total natural resource rents reveals negative correlations with CO2 emissions per capita (-0.526) and GHG emissions (-0.559), indicating that countries relying less on natural resource rents experience lower emissions. The Bayes factors for these relationships are 1.596 and 2.039, respectively, showing moderate evidence supporting the correlations. Resource extraction and economic dependency on natural resources are closely tied to carbon-intensive industries, explaining the observed relationships. However, the positive but weak correlation between Natural resources rents and Renewable energy consumption (0.088) implies that resource-rich countries may need to sufficiently transition to cleaner energy sources, underscoring the complexity of energy policies in resource-dependent economies.

In terms of energy efficiency, Energy intensity demonstrates a strong negative correlation with both CO2 emissions per capita (-0.717) and GHG emissions (-0.802), with significant Bayes factors (10.456 and 44.224, respectively). This points to the crucial role of energy efficiency in reducing emissions. As countries lower their energy intensity, they tend to see reductions in emissions, reinforcing the need for continued investments in energy-efficient technologies. Energy intensity does not exhibit a notable correlation with Renewable energy consumption (0.318), indicating that efficiency improvements do not always coincide with increased renewables, highlighting potential gaps in integrated energy policies.

The relationships between emissions and export-related variables, such as Ores and metals exports and Fuel exports, are weaker.

Ores and metals exports show a weak positive correlation with CO2 emissions (0.371) and GHG emissions (0.405), indicating that the export of these resources has a minor impact on emissions. The Bayes factors for these relationships are below 1, indicating limited evidence supporting these correlations. The lack of significant associations between Ores and metals exports and Renewable energy consumption (-0.187) or Energy intensity (-0.397) further indicates that this sector's contribution to emissions may be secondary compared to other industrial activities.

Fuel exports, often linked to fossil fuel economies, show weak negative correlations with CO2 emissions (-0.245) and GHG emissions (-0.180), as well as weak positive correlations with Renewable energy consumption (0.132) and Ores and metals exports (0.498). The feeble nature of these correlations and the low Bayes factors indicate that fuel exports alone do not significantly drive emissions but rather work in tandem with other economic factors. Countries with high fuel exports may still be able to mitigate emissions through policy measures, such as increasing renewable energy use and improving energy efficiency.

Finally, Private investment in energy shows a robust negative correlation with both CO2 emissions (-0.740) and GHG emissions (-0.717), accompanied by high Bayes factors (14.545 and 10.433). The critical role of private investment in reducing emissions, mainly through developing clean energy infrastructure, is emphasized. However, private investment does not show a significant relationship with Renewable energy consumption (0.072), pointing to the possibility that not all private investments are directed towards renewable energy projects.

Table 2 contains the results of the regression analysis for model 1.

TABLE 2. Regression analysis -model 1

Model 1	**P(M)**	**P(M|data)**	**BF_M**	**BF_{10}**	**R^2**
Renewable_energy_cons% + Energy_intensity_MJ_PPP_GDP + Energy_investment_private_USD	0.003	0.271	122.478	1.000	0.919
Energy_intensity_MJ_PPP_GDP + Energy_investment_private_USD	0.009	0.164	21.363	0.201	0.823
Null model	0.500	0.061	0.064	0.001	0.000
Energy_investment_private_USD	0.045	0.057	1.267	0.014	0.547
Renewable_energy_cons% + Energy_investment_private_USD	0.009	0.046	5.272	0.057	0.758
Energy_intensity_MJ_PPP_GDP	0.045	0.042	0.926	0.010	0.514
Renewable_energy_cons% + Total natural resources rents% + Energy_intensity_MJ_PPP_GDP + Energy_investment_private_USD	0.002	0.271	122.478	1.000	0.919
Renewable_energy_cons% + Energy_intensity_MJ_PPP_GDP + Ores_metals_exports% + Energy_investment_private_USD	0.002	0.164	21.363	0.201	0.823
Renewable_energy_cons% + Energy_intensity_MJ_PPP_GDP + Fuel_exports% + Energy_investment_private_USD	0.002	0.061	0.064	0.001	0.000
Total natural resources rents% + Energy_intensity_MJ_PPP_GDP + Energy_investment_private_USD	0.003	0.057	1.267	0.014	0.547

Note: complied by authors based on calculations

The comparison of predictors examining CO2 emissions per capita demonstrates that the combination of Renewable energy consumption (% of total energy consumption), Energy intensity (MJ/$2017 PPP GDP), and Private energy investment (USD) is the most robust set of predictors, with a posterior probability (P(M|data)) of 0.271 and the highest Bayes factor (BF10) of 1.000. These predictors explain 91.9% of the variance in CO2 emissions ($R^2 = 0.919$), emphasizing the critical role that energy efficiency, private sector investment, and renewable energy play in determining carbon emissions. The high explanatory power of these variables highlights their interconnected impact on mitigating emissions in various economies.

When looking at a more simplified set of predictors - energy intensity and Private energy investment - there is still significant explanatory power with a posterior probability of 0.164 and an R^2 value of 0.823. However, the slight reduction in explained variance suggests that renewable energy consumption is critical in further reducing CO2 emissions. The absence of renewable energy consumption in this set of predictors reduces the model's overall fit, reinforcing the importance of integrating renewable sources into energy policies.

The Null predictor, which assumes no relationship between the chosen factors and CO2 emissions, has a very low posterior probability (P(M|data) = 0.061) and explains none of the variance ($R^2 = 0.000$). This provides strong evidence that the selected economic and energy-related predictors significantly contribute to CO2 emissions, unlike a scenario where no variables are considered.

Additional predictors, such as Total natural resources rents and Ores and metals exports, offer modest improvements in explanatory power but do not outperform the combination of renewable energy, energy intensity, and private investment. For instance, including Total natural resources rents along with the primary predictors raises the R^2 slightly to 0.923. Still, the posterior probability (P(M|data)) decreases to 0.036, indicating that adding natural resource rents contributes little to improving the overall explanatory power.

Likewise, adding Fuel exports to the primary predictors produces a slightly lower posterior probability of 0.030 and an R^2 of 0.919. This outcome indicates that fuel exports have a minimal impact on CO2 emissions compared to energy efficiency, renewable energy, and private investment. Similarly, incorporating Ores and metals exports into the analysis shows limited influence on the variance explained.

To sum up, energy-related variables - energy efficiency, renewable energy consumption, and private sector investment - emerge as the strongest predictors of CO2 emissions. Additional factors like natural resource rents and exports of fuel or ores contribute some explanatory power but do not significantly improve emissions prediction..

In Table 3, the results of the regression analysis for model 2 are presented.

TABLE 3. Regression analysis -model 2

Model 2	**P(M)**	**P(M|data)**	**BF_M**	**BF_{10}**	**R^2**
Energy_intensity_MJ_PPP_GDP + Energy_investment_private_USD	0.009	0.517	116.734	1.000	0.899
Renewable_energy_cons% + Energy_intensity_ MJ_PPP_GDP + Energy_investment_private_USD	0.003	0.099	35.958	0.572	0.924
Total natural resources rents% + Energy_intensity_ MJ_PPP_GDP + Energy_investment_private_USD	0.003	0.068	24.159	0.397	0.916
Energy_intensity_MJ_PPP_GDP	0.045	0.047	1.035	0.018	0.643

Energy_intensity_MJ_PPP_GDP + Ores_metals_exports% + Energy_investment_private_USD	0.003	0.046	15.769	0.265	0.907
Energy_intensity_MJ_PPP_GDP + Fuel_exports% + Energy_investment_private_USD	0.003	0.039	13.226	0.224	0.902
Null model	0.500	0.018	0.018	6.238 ×10-4	0.000
Renewable_energy_cons% + Total natural resources rents% + Energy_intensity_MJ_ PPP_GDP + Energy_investment_private_USD	0.002	0.018	11.835	0.205	0.935
Renewable_energy_cons% + Energy_intensity_ MJ_PPP_GDP + Ores_metals_exports% + Energy_investment_private_USD	0.002	0.014	9.145	0.159	0.930
Total natural resources rents% + Energy_intensity_MJ_PPP_GDP + Fuel_exports% + Energy_investment_private_USD	0.002	0.013	8.411	0.146	0.928

Note: complied by authors based on calculations

The comparison of predictors in the second model emphasizes the strength of the combination of Energy intensity (MJ/$2017 PPP GDP) and Private energy investment (USD), which emerges as the most robust set of predictors with a posterior probability (P(M|data)) of 0.517 and a Bayes factor (BF10) of 1.000. This combination explains 89.9% of the variance in the dependent variable (R^2 = 0.899), highlighting the significant roles of energy efficiency and private sector investments in energy infrastructure in influencing CO2 emissions. The high explanatory power underscores the central importance of these predictors in understanding the emissions dynamics across economies.

Adding Renewable energy consumption (% of total energy consumption) to the combination of energy intensity and private investments slightly improves the explained variance to 92.4% (R^2 = 0.924). However, the posterior probability decreases to 0.099, indicating that renewable energy consumption positively contributes to the explanatory model. However, its overall effect is less significant than the core combination of energy intensity and private investment. Therefore, renewable energy variables, though necessary, might play a complementary role in reducing emissions rather than being a primary driver.

The inclusion of Total natural resources rents alongside Energy intensity and Private investment in energy yields a similar pattern, with an R^2 of 0.916 and a lower posterior probability of 0.068. This indicates that natural resource rents contribute moderately to explaining emissions but are less effective than the primary predictors. While relevant, the impact of resource rents seems to be overshadowed by the more direct influence of energy efficiency and investments.

Other predictor combinations, such as those incorporating Ores and metals exports or Fuel exports alongside Energy intensity and Private energy investment, show lower posterior probabilities and reduced explanatory power. For instance, including Ores and metals exports results in an R^2 of 0.907, with a posterior probability of 0.046, while adding Fuel exports leads to an R^2 of 0.902 and a posterior probability of 0.039. These results indicate that export-related variables while contributing some explanatory power, do not significantly enhance the model's ability to explain CO2 emissions.

The null model, which assumes no relationship between the variables and emissions, shows a negligible posterior probability (P(M|data) = 0.018) and explains none of the variance (R^2 = 0.000). The extremely low Bayes factor (BF10 = 6.238×10^{-4}) confirms the necessity of

including key predictors to explain emissions meaningfully.

More complex combinations, such as those involving Renewable energy consumption, Total natural resources rents, and various export-related variables alongside Energy intensity and Private energy investment, slightly improve the explained variance. For instance, including Renewable energy consumption and Total natural resources rents increases R^2 to 0.935, but the posterior probability remains low at 0.018, indicating limited added value from these variables. Similarly, combinations involving Ores and metals or Fuel exports yield higher R^2 values (0.930 and 0.928, respectively). Although additional variables such as renewable energy consumption, natural resources rents, or export-related variables are included in the model, they contribute very little to improving the model's ability to explain the variation in CO2 emissions when compared to the main predictors - energy efficiency (Energy intensity) and private energy investment.

In summary, Energy intensity and Private energy investment are the strongest predictors, with additional variables like Renewable energy consumption, Natural resources rents, and export-related indicators providing some improvements but not significantly altering the core explanatory framework. The findings reinforce the importance of energy efficiency and targeted investments in reducing emissions, while other factors play more supporting roles in shaping the emissions profile.

The analysis of CO2 emissions per capita and total greenhouse gas emissions confirmed the significance of critical factors such as energy intensity and private energy investment. These predictors emerged as the primary drivers explaining variations in CO2 emissions per capita and overall greenhouse gas emissions. Improving energy efficiency and attracting private investments in the energy sector have the most substantial impacts on reducing emissions.

Renewable energy consumption also reduces CO2 emissions, though its effect is less significant than energy efficiency and investments. This indicates that while renewable energy plays an important role, its influence is more pronounced when combined with broader measures to enhance energy efficiency and encourage private-sector investments.

Factors such as fuel and metal exports had a minimal impact and contributed little to explaining emissions. This highlights that strategies focused on improving energy efficiency and expanding private sector involvement in energy are far more crucial for reducing CO2 and greenhouse gas emissions than regulating export activities.

The following results were obtained:

Hypothesis 1. CO2 emissions per capita significantly depend on energy intensity, private energy investment, and renewable energy consumption - *accepted (with a partial influence of renewable energy consumption, as its contribution to reducing emissions is evident but not as significant as the effects of energy efficiency and private investments).*

Hypothesis 2. GHG emissions (kt of CO2 equivalent) are significantly influenced by energy intensity, private investment in energy, and exports of fuel and metals - *partially accepted (fuel and metal exports were found to have minimal impact on overall emissions, suggesting that energy efficiency and investments remain the dominant factors, while export-related variables play a less substantial role).*

5. CONCLUSIONS

The overall objective of this study was to analyze the key factors influencing carbon dioxide (CO2) emissions per capita and total greenhouse gas (GHG) emissions in kilotons of carbon dioxide equivalent, focusing on the roles of energy intensity, private investment in energy, renewable energy consumption, and export-related variables. The analysis confirmed that energy intensity and private energy investment are the most significant predictors of emissions, supporting the first hypothesis that these factors, along with renewable energy consumption, substantially

affect CO2 emissions per capita. The second hypothesis, regarding the influence of fuel and metal exports on GHG emissions, was only partially supported, as export-related variables showed a minimal impact compared to the more potent effects of energy efficiency and investments.

The striking findings revealed that improvements in energy efficiency and increased private investment in clean energy technologies are the most effective strategies for reducing CO2 emissions per capita and GHG emissions. While renewable energy consumption contributes to emissions reductions, its influence is secondary compared to the more impactful factors of energy efficiency and private sector investment. The limited effect of fuel and metal exports suggests that export activity is not a critical driver of emissions, emphasizing the need to focus on domestic energy policies and investment strategies.

For future research, further exploration into sector-specific energy efficiency measures and investment incentives is recommended, along with studies that assess the long-term impact of such measures on emission reductions. Investigating the role of different types of renewable energy sources, such as solar and wind, combined with broader energy efficiency strategies, would provide deeper insights. Longitudinal studies focusing on how changes in energy policy and investment patterns affect emissions over time could also enhance understanding of sustainable development strategies.

From an economic and policy perspective, policymakers must prioritize energy efficiency improvements and create incentives for private investments in renewable energy projects. Developing targeted fiscal policies and frameworks that encourage the adoption of low-carbon technologies, along with a regulatory environment that supports private sector engagement, would be critical steps toward reducing emissions. Aligning national energy policies with sustainability goals will help mitigate environmental impacts while ensuring economic growth remains strong and resilient.

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Analysis of the Level of Agricultural Development in Kazakhstan: Identifying Agro-Hubs

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ABSTRACT

The study examines Kazakhstan's agricultural sector and its potential for developing resilient agro-hubs, focusing on identifying regions that can contribute to the country's long-term agricultural growth. The purpose of this study is to examine essential agricultural indicators, including gross agrarian output, gross crop production, gross livestock production, and agricultural services, in order to identify regions with the potential for agro-hub development. The methodology includes Pearson correlation analysis of data collected from national agricultural reports and regional statistical databases. Data for the study were gathered from national agricultural reports and regional statistical databases, which provide quantitative measures of agricultural output, crop yields, livestock production, and farming services. Results indicate the strongest correlations between Kostanay and North Kazakhstan (0.995 for Gross Agricultural Output and 0.996 for Crop Production, $p < 0.001$). Additionally, significant alignment in crop production was observed between Almaty and South Kazakhstan (0.969, $p = 0.007$), whereas weaknesses in agricultural services were noted, particularly in Kyzylorda and Zhambyl, with a negative correlation. The results highlight the northern and southern regions' potential for forming agro-hubs supported by solid production indicators. The study provides strategic recommendations for policymakers to foster regional collaboration, enhance productivity, and promote sustainable agricultural development across Kazakhstan. Future research will focus on improving infrastructure and developing collaborative agricultural initiatives within agro-hubs to strengthen Kazakhstan's agricultural sector resilience.

KEYWORDS: Agro-Hubs, Regional Development, Cluster Development, Economic Sustainability, Spatial Analysis, Agricultural Modernization, Agricultural Infrastructure

SCSTI: 68.75.01

JEL Code: Q10, Q56, R11, O13

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1. INTRODUCTION

Agriculture is pivotal in ensuring food security, generating income, and supporting rural development in the global economy. The agricultural sector is not only a critical component of the economy in developing countries but also remains essential in many developed nations, where technological advancements and innovation drive significant growth. As the world grapples with increasing population, climate change, and the volatility of global food markets, an urgent need is to enhance agricultural productivity, sustainability, and resilience. Global challenges such as rising food demand, environmental degradation, and economic uncertainty further underscore the importance of identifying regions that can serve as stable agricultural hubs.

In this context, Kazakhstan's agricultural sector presents significant potential. With vast arable land, diverse climatic zones, and a rich agricultural history, Kazakhstan is strategically positioned in the global agricultural market. Agriculture contributes substantially to the national economy, providing livelihoods for many of the population and serving as a critical export sector. However, the industry faces numerous challenges, including climatic variability, uneven regional development, and the need for modernization. Identifying resilient regions that can bolster sustainable agricultural growth is key to enhancing Kazakhstan’s competitiveness in international markets and ensuring national food security.

Creating agro-hubs is one of the government's priorities outlined in the National Program for the Development of the Agro-Industrial Complex for 2021-2025. The program aims to modernize the agricultural sector of Kazakhstan by stimulating innovation, improving infrastructure, and facilitating agro-hub creation. Furthermore, in the President's address to the nation in 2023, it was emphasized that agriculture plays a strategic role in economic diversification and that the development of agro-hubs will serve as a catalyst for innovation and increase the export potential of the sector (Tokayev, 2023).

The agricultural landscape in Kazakhstan varies significantly across its regions, with differences in productivity, resource allocation, and environmental conditions. Understanding these regional dynamics is crucial for informing policy decisions and investment strategies to bolster the agricultural sector. Identifying regions that demonstrate resilience - the ability to maintain or improve agricultural output in the face of economic, environmental, and market pressures - is essential for forming agricultural clusters, enhancing Kazakhstan’s competitiveness, and contributing to the goals outlined in the national development program.

The current study aims to determine Kazakhstan's most favorable and resilient regions for developing agro-hubs by analyzing agricultural trends across two distinct periods, 2013–2017 and 2018–2023. The focus is on critical agricultural indicators such as gross agrarian output, crop production, livestock production, and agricultural services. Through an in-depth correlation analysis of these indicators across Kazakhstan’s regions, the research seeks to identify critical trends, assess regional resilience, and propose strategies for sustainable agricultural development.

2. LITERATURE REVIEW

Research into agricultural resilience and agro-hub development is crucial in addressing global challenges such as food security, climate change, and sustainable development. Agriculture plays a central role in many economies, particularly in developing countries, and enhancing regional capacities through agro-hubs has become vital to fostering innovation, improving productivity, and ensuring long-term sustainability.

Many scholars have explored the correlation between sustainability, innovation, and resilience in agricultural systems to frame the significance of agricultural hubs and

resilience in the global context. The exploration of sustainability, innovation, and resilience within agricultural systems has led scholars to highlight the critical role of agro-hubs in fostering sustainable agricultural practices. King (2008) emphasized that modern agro-hubs were essential for promoting sustainable practices by connecting people, food, and agriculture, with a strong focus on biodiversity and resource management, which were crucial for building resilience against environmental pressures and market fluctuations. Lamine (2015) expanded on this by showing that aligning agricultural practices with food and environmental policies enabled these systems to better adapt to changing conditions, reinforcing resilience at multiple levels within agricultural networks. Jagustović et al. (2019) applied systems thinking to climate-smart villages, illustrating how integrating local knowledge and adaptive strategies within complex systems was central to food security and agricultural resilience.

Barrios et al. (2020) added to this framework by introducing the "10 Elements of Agroecology", which facilitated transitions toward sustainable agricultural systems, with visual narratives driving institutional change and fostering the community-level adoption of agroecological practices. Wezel et al. (2020) further emphasized the importance of diversification and ecological balance as agroecological principles, asserting they were vital in creating resilient farming systems capable of withstanding environmental shocks and market instability. Van der Lee et al. (2022) reviewed frameworks for resilience assessment in farming systems, concluding that resilience requires both adaptability to external challenges and internal structural flexibility, highlighting the collaborative efforts of multiple stakeholders in fostering resilience. Thus, resilience in agricultural systems is critical for the successful development of agro-hubs, particularly in regions aiming to enhance their agricultural capacity and stability.

To explore the role of agricultural output in regional resilience, several studies provided essential findings. Nin et al. (2007) assessed livestock productivity in various developing countries and highlighted its role in supporting economic stability. Livestock output significantly impacted agricultural GDP, providing a buffer against external shocks such as fluctuating market conditions and environmental challenges. Rehman et al. (2017) analyzed the relationship between livestock production and agricultural GDP in Pakistan, showing a significant positive correlation between livestock products, such as milk and eggs, and the country's agricultural GDP. The econometric analysis demonstrated how livestock production contributed to economic stability, particularly in rural regions dependent on agriculture. Idris (2020), in a study of agricultural productivity in Sub-Saharan Africa, specifically examined the Nigerian context. Advancements in agricultural output, through modernized farming techniques and improved resource management, contributed to economic stability and fostered resilience within developing regions. Similarly, Ansari and Jadaun (2022) investigated agricultural productivity in India and found that higher productivity levels in the sector directly impacted economic growth. Improvements in agricultural output enhanced regional resilience by contributing to a more robust agricultural GDP.

Agricultural services, such as market access, extension programs, and technological support, promote resilience and sustainable development in rural regions. Research has shown that these services stabilize agricultural output and enhance the adaptive capacity of communities facing environmental and market challenges. Bonuedi et al. (2022) emphasized how improved market access in Sierra Leone supported resilience by ensuring a stable food supply and connecting farmers with buyers, mitigating the effects of agricultural fluctuations. Similarly, Rathi (2022) examined the role of income diversification, noting that non-farm income, through migration and urban employment, helped rural households manage agricultural and environmental uncertainties. Hameed and Sawicka (2023) highlighted the importance of agricultural extension services

in promoting sustainable practices like resource management and crop diversification, strengthening resilience in farming communities.

The literature review showed agro-hubs' importance in fostering regional resilience and sustainability. Studies on agricultural output, market access, and extension services show that diverse factors, including stable production, market connectivity, and the integration of sustainable practices support resilient agricultural systems. Existing studies stress the need for targeted development of agro-hubs that can enhance regional capacity to withstand environmental and economic challenges. The current study analyzes Kazakhstan's agricultural trends, focusing on regions best suited for agro-hub development. Identifying resilient regions through assessing agricultural output, livestock, and crop production and providing agricultural services will help inform strategies for creating sustainable, productive agricultural centers that contribute to Kazakhstan's long-term economic stability and food security.

3. RESEARCH METHODS

This study analyzes agricultural trends in Kazakhstan by focusing on two distinct periods: 2013–2017 and 2018–2023. The chosen periods reflect significant administrative and regional transformations, including establishing Turkestan and Shymkent as separate administrative entities from 2018 onwards, which has implications for agricultural data collection and regional classification.

To achieve the purpose of the study, a research process was proposed, as shown in Figure 1.

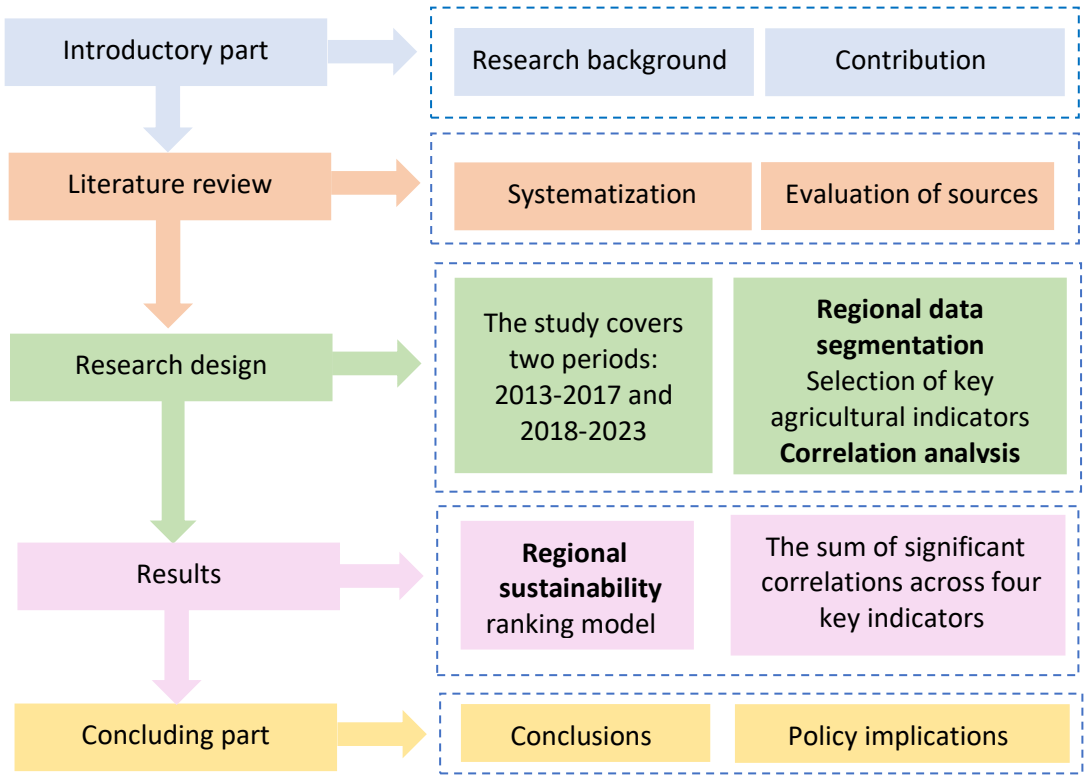

FIGURE 1. The main stages of the study

Note: compiled by authors

For an in-depth analysis, a regional sustainability ranking model was developed to assess the stability of agricultural production and its adaptability to changes in external conditions. This model was based on the values of correlations for crucial indicators, took into account their significance, and allowed to identify the regions with the most extraordinary stability. A high overall score indicated the region's strength and ability to maintain or increase production in changing economic and environmental conditions.

Four leading indicators were selected for the analysis of agriculture in Kazakhstan: gross agricultural output, gross crop production, gross livestock production, and agricultural services. The study focused on assessing regional differences in agricultural productivity, which made it possible to identify the impact of geographical and administrative features on the development of the industry. The Pearson correlation coefficient was used to quantify the relationships between regions. It allowed us to determine the strength and direction of the links between agricultural indicators by region in the specified periods, which provided a deep understanding of their sustainability and potential.

The critical agricultural indicators examined in this study include Gross Agricultural Output (Agro_GDP), Gross Crop Production (Agro_GCP), Gross Livestock Production (Agro_GLP), and Agricultural Services (Agro_SERVICE). These indicators were selected because they are relevant to measuring the overall performance of the agricultural sector and helpful in highlighting the production dynamics of crops and livestock alongside the contribution of farming services.

Data for the analysis were gathered from national agricultural reports and regional statistical databases, which provide quantitative measures of agricultural output, crop yields, livestock production, and farming services. Specifically, data include measures such as total agricultural production volumes, regional crop yields per hectare, livestock population and output, and the availability and quality of agricultural support services, all disaggregated by region. By segmenting the data in this manner, the study aims to derive insights into how geographical features and administrative boundaries have influenced the development of agricultural production over the two periods.

These findings are presented in Table 1, which provides a detailed comparison of critical agricultural indicators across the identified time frames and regional classifications.

TABLE 1. Regional categories

Regional zone	Region, 2013–2017	Region, 2018–2023
Western Kazakhstan	Atyrau, West Kazakhstan, Mangystau, Aktobe	Atyrau, West Kazakhstan, Mangystau, Aktobe
Central Kazakhstan	Akmola, Karaganda, Pavlodar	Akmola, Karaganda, Pavlodar
Eastern Kazakhstan	East Kazakhstan	East Kazakhstan
Southern Kazakhstan	Zhambyl, Kyzylorda, Almaty,	Zhambyl, Kyzylorda, Almaty, Turkestan
Northern Kazakhstan	North Kazakhstan, Kostanay	North Kazakhstan, Kostanay
Cities of Republican Significance	Almaty, Astana	Almaty, Shymkent, Astana

Note: compiled by authors

The Pearson correlation coefficient was conducted to identify relationships between selected agricultural indicators across regions, allowing for the quantification of the strength and direction of these relationships. A correlation coefficient close to 1 indicates a strong positive relationship, while values near -1 indicate a strong negative relationship. The

analysis compared correlation results across the two periods to identify changes in regional agricultural dynamics, particularly in response to policy changes, market conditions, and environmental factors.

A resilience ranking model was developed to refine the analysis further, evaluating the agricultural stability and potential of regions across Kazakhstan over the two periods: 2013–2017 and 2018–2023. The resilience rankings were calculated by considering the consistency and strength of correlations in key agricultural indicators: Gross Agricultural Output (Agro_GDP), Gross Crop Production (Agro_GCP), Gross Livestock Production (Agro_GLP), and Agricultural Services (Agro_SERVICE). Each region's performance in these categories was measured using Pearson correlation coefficients to identify those regions that consistently exhibited stable agricultural productivity and adaptability to changing market and environmental conditions. The methodology involved calculating an overall resilience score based on the sum of significant correlations across the four key indicators. A higher score indicated stronger resilience, while a lower score reflected more variability or potential vulnerabilities in the region's agricultural sector. The ranking approach considered the magnitude of correlations and the significance level (p-value), ensuring that the final rankings were grounded in statistically robust results.

4. RESULTS AND DISCUSSION

The present analysis focuses on Kazakhstan's agricultural regions over two distinct periods: 2013–2017 and 2018–2023, reflecting significant administrative changes, including the establishment of Turkestan and Shymkent as separate administrative units. The analysis begins by evaluating the agricultural performance across the categorized regions, emphasizing the most significant correlations observed within each period to examine the dynamics in agricultural output, crop production, livestock production, and agricultural services. This approach enables a comprehensive understanding of regional strengths and potential areas for collaboration within Kazakhstan's agricultural sector, ultimately assessing the evolution of regional alignments and their implications for farm development and policy-making.

Agro_GDP (Gross Agricultural Output)

During the analyzed period (2013–2017), several regions of Kazakhstan exhibited significant correlations in key agricultural indicators, including Agro_GDP (Gross Agricultural Output). The strongest positive correlation was observed between Kostanay and North Kazakhstan regions ($r = 0.995^*$, $p < 0.001$), reflecting a high level of similarity in agricultural output trends. A similar pattern was evident between Akmola and Karaganda regions ($r = 0.998^*$, $p < 0.001$), as well as Almaty and Zhambyl regions ($r = 0.967$, $p < 0.01$). Additionally, Almaty and Kyzylorda regions displayed a notable, though slightly weaker, correlation ($r = 0.869$, $p = 0.056$). Shared agricultural practices and environmental conditions likely influenced comparable agricultural production trends across these regions.

Agro_GCP (Gross Crop Production)

In the Agro_GCP (Gross Crop Production) indicator, high correlations were observed between several regions. Kostanay and North Kazakhstan regions showed a robust correlation ($r = 0.995^*$, $p < 0.001$), indicating parallel crop production trends. Almaty and Zhambyl regions also strongly correlated ($r = 0.985$, $p < 0.01$). In contrast, South Kazakhstan and Kyzylorda regions displayed moderate correlations with their neighboring areas, reflecting similarities in crop output trajectories during this period.

Agro_GLP (Gross Livestock Production)

Significant correlations were present across many regions for Agro_GLP (Gross Livestock Production). Kostanay and North Kazakhstan regions maintained a strong correlation ($r = 0.995^*$, $p < 0.001$), while Akmola and Karaganda regions displayed a similarly high correlation ($r = 0.991^*$, $p < 0.001$). Almaty and South Kazakhstan regions also had high correlations ($r = 0.997^*$, $p < 0.001$), indicating

aligned developments in livestock production across these areas. Almaty and Kyzylorda regions presented moderate correlations (r = 0.832, p = 0.080), reflecting partial similarities in livestock management practices.

Agro_SERVICE (Agricultural Services)

In the Agro_SERVICE (Agricultural Services) category, correlations were less pronounced but still noteworthy. Kostanay and North Kazakhstan regions demonstrated a positive correlation (r = 0.935, p < 0.05), reflecting shared patterns in the provision of agricultural services. Other regions, including Kyzylorda and South Kazakhstan, displayed weaker or negligible correlations, highlighting differences in service delivery approaches across these regions.

The key results of the correlation analysis across regions, based on gross agricultural output (Agro_GDP), gross crop production (Agro_GCP), gross livestock production (Agro_GLP), and agricultural services (Agro_SERVICE), are summarized in the table. Strong correlations were most evident between regions such as Kostanay and North Kazakhstan and Akmola and Karaganda, indicating a high degree of alignment in agricultural development, particularly in crop and livestock production, from 2013 to 2017. Moderate correlations involving Kyzylorda also indicated shared trends in agricultural practices, though with distinct regional characteristics.

Table 2 presents the most significant regional correlations in key agricultural indicators. Regions showed the strongest alignment in agricultural output, crop production, livestock production, and agricultural services during the period analyzed.

TABLE 2. Significant correlation results for 2013-2017

Region	Agro_GDP	Agro_GCP	Agro_GLP	Agro_SERVICE
Kostanay ↔ North Kazakhstan	0.995***	0.995***	0.995***	0.935*
Almaty ↔ Zhambyl	0.967**	0.985**	0.985**	—
Akmola ↔ Karaganda	0.998***	0.990**	0.991***	0.953*
Aktobe ↔ West Kazakhstan	0.987**	0.994***	0.998***	—
Astana ↔ Almaty	—	-0.879*	0.923*	0.885*
Aktobe ↔ Mangystau	0.938*	0.942*	0.943*	0.800
Karaganda ↔ Pavlodar	0.959*	0.986**	0.990**	—
East Kazakhstan ↔ South Kazakhstan	0.987**	0.953*	0.997***	—
$p < 0.05$ — *, $p < 0.01$ — **, $p < 0.001$ — ***				

Note: compiled by authors based on calculations

Agro_GDP (Gross Agricultural Output) 2013-2017

Kostanay and North Kazakhstan regions exhibited the strongest correlation (r = 0.995***), reflecting nearly identical trends in agricultural output. This alignment suggested that these regions shared similar agricultural strategies, making them prime candidates for an agricultural cluster focused on maximizing production efficiency. Akmola and Karaganda (r = 0.998***) also showed highly correlated output trends, as did Aktobe and West Kazakhstan (r = 0.987**), indicating the potential for a northern agricultural hub. The correlation between East Kazakhstan and South Kazakhstan (r = 0.987**) further suggested a unified growth pattern in southeastern Kazakhstan, making these regions suitable for a collaborative agricultural corridor.

Agro_GCP (Gross Crop Production) 2013-2017

Kostanay and North Kazakhstan once again led with a near-perfect correlation (r =

0.995***), underscoring the strong potential for these regions to become specialized crop production hubs. Akmola and Karaganda (r = 0.990**) and Aktobe and West Kazakhstan (r = 0.994***) also demonstrated strong correlations in crop production, suggesting that these regions were well-suited for forming crop-focused clusters. In southern Kazakhstan, Almaty and Zhambyl (r = 0.985**) shared similar crop production dynamics, pointing toward opportunities for collaborative programs to increase yields in these regions.

Agro_GLP (Gross Livestock Production) 2013-2017

Livestock production correlations further revealed strong alignments. Kostanay and North Kazakhstan (r = 0.995***) and Akmola and Karaganda (r = 0.991***) had the highest correlations, suggesting that these regions could have formed a livestock production cluster. Aktobe and West Kazakhstan (r = 0.998***) also exhibited significant alignment in livestock output, indicating a capacity for joint growth in animal husbandry. Similarly, East Kazakhstan and South Kazakhstan (r = 0.997***) reflected the potential for collaboration in livestock production, driven by shared environmental and agricultural conditions.

Agro_SERVICE (Agricultural Services) 2013-2017

Although correlations in agricultural services were generally lower, Kostanay and North Kazakhstan (r = 0.935*) displayed a significant relationship in their approach to providing agricultural support services. This suggested these regions could have formed the backbone of service-oriented agrarian hubs. Almaty and Astana (r = 0.885*) also aligned agricultural services, indicating their potential as central players in developing advanced agricultural technologies and support systems. These regions were positioned to lead the modernization of agricultural services and drive innovation in the sector.

The patterns in these correlations revealed several regions that were ideally positioned for forming agricultural clusters. Kostanay and North Kazakhstan, with consistently high correlations across all indicators, emerged as strong candidates for becoming a central agricultural hub, particularly in crop and livestock production. Akmola, Karaganda, Aktobe, and West Kazakhstan also showed potential for forming vital agricultural corridors in the north and west. Almaty, Zhambyl, and South Kazakhstan regions demonstrated strong alignment in the south, making them suitable for crop and livestock production cooperative growth.

In the second phase of the analysis, covering the period from 2018 to 2023, the correlations were recalculated, incorporating newly established regions such as Turkestan and Shymkent. This expanded the scope of the analysis, focusing on regional agricultural performance across Kazakhstan. The correlations between areas were examined to understand the alignments and divergences in agricultural practices during this period, with particular attention to the impact of regional restructuring.

Agro_GDP (Gross Agricultural Output) 2018-2023

Regarding Agro_GDP, strong correlations were observed, particularly between Kostanay and North Kazakhstan ($r = 0.959$, $p = 0.002$), indicating aligned agricultural productivity trends that likely stem from similar farming practices and economic conditions. Zhambyl and Turkestan also found a high correlation ($r = 0.995$, $p < 0.001$), reflecting synchronized growth patterns that can enhance regional economic stability. However, a significant negative correlation between Astana and Shymkent ($r = -0.817$, $p = 0.047$) highlights divergent agricultural performances, likely due to different economic policies, investment levels, and market access in these cities.

Regions showing strong synergies could benefit from policy efforts to establish agricultural clusters. Such clusters would strengthen production efficiencies, improve market access, and foster technological innovation. Akmola, Karaganda, and Pavlodar—each showing consistently strong correlations in Agro_GDP, Agro_GCP, and Agro_GLP—represent a promising foundation

for the development of a tri-regional hub focused on crop and livestock production.

Agro_GCP (Gross Crop Production) 2018-2023

The Agro_GCP metric revealed even stronger correlations, with Kostanay and North Kazakhstan exhibiting nearly perfect correlation ($r = 0.996$, $p < 0.001$). This indicates that both regions experience almost identical crop production trends, influenced by similar climatic conditions and effective agricultural practices. A significant correlation was also noted between Almaty and South Kazakhstan ($r = 0.969$, $p = 0.007$), as well as between Zhambyl and Turkestan ($r = 0.997$, $p < 0.001$), further emphasizing synchronicity in crop production in the southern regions. Such strong correlations underscore the importance of regional cooperation in agricultural policy and practices, which can lead to increased productivity and economic growth.

Agro_GLP (Gross Livestock Production) 2018-2023

As reflected by the Agro_GLP metric, Livestock production in Kazakhstan showed significant correlations among various regions. The strongest correlation is observed between Kostanay and North Kazakhstan ($r = 0.962^{**}$, $p = 0.002$) and Akmola and Pavlodar ($r = 0.924^{**}$, $p = 0.008$). These findings confirm that these regions employ similar livestock production strategies influenced by comparable environmental conditions, such as climate and geography, and shared infrastructure for animal husbandry. An exceptionally high correlation exists between Kyzylorda and Turkestan ($r = 0.980^{***}$, $p < 0.001$), indicating the development of integrated livestock value chains. Revealed integration provides a framework for optimizing production and distribution processes, enhancing competitiveness by establishing large-scale meat and dairy processing facilities tailored to meet domestic and export demands.

Agro_SERVICE (Agricultural Services) 2018-2023

The correlations in agricultural services were generally weaker, with notable exceptions. A negative correlation between Kyzylorda and Zhambyl ($r = -0.838^{*}$, $p = 0.037$) indicates differences in agricultural service delivery, likely due to varying privatization, investment in infrastructure, and government support across these regions. Conversely, the positive correlation between Kyzylorda and Kostanay ($r = 0.925^{*}$, $p = 0.024$) demonstrates a more consistent service provision model that can be effectively replicated in other areas. Regions with complementary strengths in agricultural services can implement collaborative efforts to improve service efficiency, enhance knowledge sharing, and drive innovation in agricultural technologies, ultimately benefiting local farmers and the broader agricultural economy.

The correlation results confirm that regions like Kostanay, North Kazakhstan, Zhambyl, and Turkestan have the potential to form specialized agro-industrial clusters. These clusters can promote efficiency, innovation, and sustainable development, serving as models for other regions in Kazakhstan. Strong internal alignment within these areas indicates they are well-positioned to leverage their agricultural strengths and enhance their contributions to the national economy. Conversely, regions with weaker correlations, such as Kyzylorda and Zhambyl, require targeted interventions to improve service delivery and enhance productivity.

These interventions may include investments in infrastructure, training programs for farmers, and policies that foster cooperation between different agricultural stakeholders. Comparing the periods of 2013-2017 and 2018-2023 shows that the earlier period exhibited stronger correlations and more stable agricultural growth, indicating a more unified approach to agricultural development across the country. In contrast, the latter period reveals a more complex landscape with emerging negative correlations, particularly in Agro_GLP and Agro_SERVICE. This shift reflects increasing regional differentiation in agricultural strategies, driven by policy changes, market

dynamics, and external factors such as climate variability.

Thus, Kostanay, North Kazakhstan, Zhambyl, and Turkestan consistently demonstrate strong potential for agro-hub development, characterized by their ability to produce and process agricultural goods efficiently. Meanwhile, Astana and Shymkent require strategic interventions to align their agricultural services and production with critical regions, enhancing overall productivity and competitiveness in Kazakhstan's agricultural sector. By fostering collaboration and sharing best practices across regions, Kazakhstan can strengthen its agricultural economy and improve food security for its population.

Table 3 presents the most significant regional correlations in key agricultural indicators from 2018 to 2023.

TABLE 3. Significant correlation results for 2018-2023

Region	Agro_GDP	Agro_GCP	Agro_GLP	Agro_SERVICE
Kostanay ↔ North Kazakhstan	0.959**	0.996***	0.962**	—
Almaty ↔ South Kazakhstan	0.996***	0.969**	0.987**	0.992***
Zhambyl ↔ Turkestan	0.995***	0.997***	0.956**	—
Kyzylorda ↔ Turkestan	—	—	0.980***	-0.838*
Akmola ↔ Karaganda	0.849*	0.875*	0.912*	—
Akmola ↔ Pavlodar	0.947**	0.934**	0.924**	—
Karaganda ↔ Pavlodar	0.931**	0.927**	0.888*	0.891*
East Kazakhstan ↔ Agro_GCP_East Kazakhstan	0.941**	—	—	—
$p < 0.05$ — *****, $p < 0.01$ — ******, $p < 0.001$ — *******				

Note: compiled by authors based on calculations

The significant correlations identified for 2018-2023 highlighted critical trends in Kazakhstan's agricultural sector. The focus was put on the specific correlations due to their strong statistical significance, indicating solid relationships between agricultural outputs, livestock production, and agricultural services across various regions.

The significant correlations identified for the period 2018-2023 highlighted critical trends in Kazakhstan's agricultural sector, reflecting interregional dynamics and opportunities for collaboration. These specific correlations were chosen due to their strong statistical significance, indicating robust relationships between agricultural outputs, livestock production, and agricultural services across various regions. The correlation between Kostanay and North Kazakhstan exemplified a highly integrated agricultural partnership, underscoring the regions' shared strategies and environmental conditions that led to similar production outcomes. Similarly, the pairing of Almaty and South Kazakhstan showed impressive alignment across all indicators, indicating a synergistic agricultural framework that capitalized on complementary strengths. The emerging significance of southern regions was evident in the strong correlation between Zhambyl and Turkestan, showcasing their growing role in agricultural productivity and collaboration. Meanwhile, the notable livestock production correlation between Kyzylorda and Turkestan pointed to integrated livestock value chains. However, the negative correlation in agricultural services highlighted challenges that needed addressing in service delivery. Additionally, the consistent performance of central regions was illustrated by the positive correlations among Akmola, Karaganda, and Pavlodar, suggesting a stable agricultural environment conducive to forming

potential agro-clusters. However, the lack of correlation in agricultural services for specific regional pairs, particularly between Kyzylorda and Turkestan, indicated a pressing need for enhanced agricultural service infrastructure and delivery mechanisms in those areas.

A resilience ranking was developed based on the comprehensive analysis of agricultural correlations across different regions to assess the potential for agricultural development and cluster formation. This ranking considers the strength of correlations in key agricultural indicators such as gross domestic product in agriculture, gross crop production, gross livestock production, and farming services. By identifying regions that demonstrated high resilience across these metrics, we can prioritize areas for investment and development, enabling the formation of agricultural hubs that can enhance regional and national food security and economic growth.

Below is the interpretation of the resilience scores and rankings based on the findings (Figure 2).

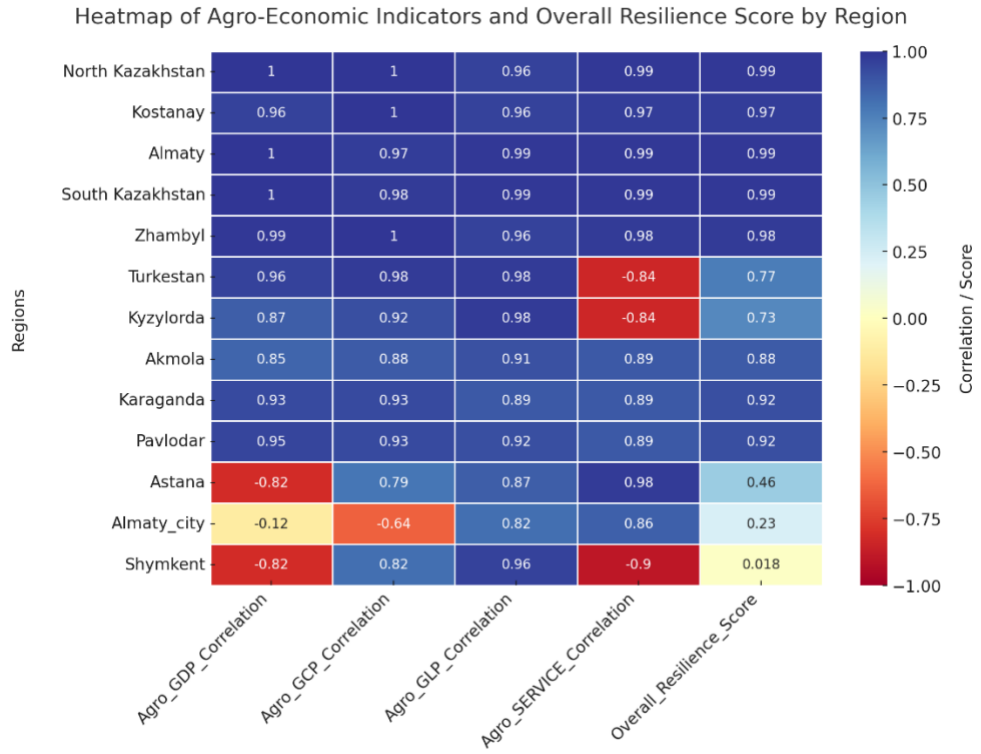

FIGURE 2. Regional ranking

Note: compiled by authors based on calculations

The ranking table offers a comprehensive assessment of agricultural resilience and economic stability across Kazakhstan's regions from 2013 to 2023 and regions' capacity for maintaining agricultural output stability over the decade for developing agro-hubs. Almaty and South Kazakhstan also rank prominently, excelling in production indicators and agricultural services, further enhancing their contribution to the agricultural sector.

As key agricultural contributors, these regions maintain a robust balance between production and service infrastructure, affirming their readiness for potential cluster development within the national agricultural framework. Regions such as Zhambyl and

Turkestan excel in crop and livestock production but perform more moderately in agricultural services. While their production strengths position them favorably for agrarian growth, enhancing service infrastructure is essential for increasing overall economic stability.

In the middle range, regions like Akmola, Karaganda, and Pavlodar maintain consistent agricultural production performance, though a gap in service infrastructure slightly lowers their overall resilience ranking. A continued focus on strengthening agrarian services could elevate their contribution to the national agricultural economy.

Kyzylorda stands out for its strong livestock production performance, though weaker agricultural service results suggest a need for focused improvements to enhance resilience. Strengthening service-related infrastructure could reinforce its agricultural and economic contributions.

Urban centers, including Astana, Almaty and Shymkent cities, present lower rankings in agricultural resilience due to weaker production correlations. However, their role in agricultural services is more pronounced, especially for Astana, which demonstrates significant strength in this domain. While these cities may not lead in production, their service-related infrastructure is essential in supporting agricultural activities in surrounding rural areas. Astana excels in agricultural services, while Almaty City shows mixed performance, with negative correlations in crop production but a stronger focus on service infrastructure. With its strengths in livestock production, Shymkent faces challenges in agricultural services, highlighting a need for further infrastructure development.

The assessment of agricultural resilience reveals that a region with balanced performance across both production and service infrastructure leads Kazakhstan's agricultural development. North Kazakhstan, Kostanay, Almaty, and South Kazakhstan consistently perform across multiple agricultural metrics, confirming their role as prime candidates for agro-hub formation. In contrast, regions such as Kyzylorda and Turkestan, where production capacity is strong but service infrastructure lags, demonstrate the potential for improvement through targeted investment in agricultural services. With their distinct contributions through service-oriented infrastructure, urban centers remain pivotal in supporting rural agricultural productivity, ensuring a well-rounded agrarian system across the country.

5. CONCLUSION

This analysis aimed to assess agricultural trends in Kazakhstan across two distinct periods, 2013–2017 and 2018–2023, focusing on crucial agrarian indicators such as gross agricultural output, gross crop production, gross livestock production, and agricultural services. The results revealed significant correlations among various regions, highlighting emerging trends, weak points, and opportunities for collaboration within the agricultural sector.

Key findings indicated strengthened partnerships between regions such as Kostanay and North Kazakhstan and Almaty and South Kazakhstan, underscoring the potential for collaborative agricultural initiatives. The emerging role of southern areas, particularly Zhambyl and Turkestan, further emphasized their growing importance in enhancing agricultural productivity. Additionally, integrated livestock value chains were noted, especially between Kyzylorda and Turkestan, suggesting avenues for improved competitiveness.

However, challenges were also identified. The negative correlation in agricultural services between Kyzylorda and Zhambyl revealed discrepancies that could hinder effective collaboration. The inconsistent performance of newly established regions, such as Turkestan and Shymkent, highlighted the need for targeted strategies to foster alignment and cohesion. To capitalize on the identified trends and address the challenges, it is recommended that policymakers focus on fostering collaboration among high-

performing regions. Investments in agricultural service infrastructure are crucial, particularly in areas demonstrating weaknesses. Strengthening regional cooperation can enhance productivity, streamline service delivery, and promote sustainable agricultural practices.

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