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Spatial Effects in the Context of Kazakhstan's Regions

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ABSTRACT

The problem of spatial inequality in the regions of Kazakhstan has been relevant for many years and in recent years this problem has worsened due to socio-economic changes in the areas, the consequences of the COVID-19 pandemic, the negative impact of inflationary processes, increased internal migration and other factors. The purpose of this study is to analyze spatial inequality between 16 regions of Kazakhstan covering the period from 2001 to 2017. The following scientific methods were used in the study: historical method, and statistical method. During the research, a new class of spatial econometric models was developed, which are modifications of the Durbin spatial model. These models are characterized by variable coefficients with spatial lags of the dependent and independent variables. The models were evaluated based on information about Kazakhstan's regions, using the regional gross domestic product per capita as a dependent variable. The findings of the study show the advantages of the SDM model with fixed effects compared to alternative models, which is confirmed by the results of the assessment using the criteria of the Akaike Information Criterion (AIC) and Bayes (BIC). According to the SDM model, a 1% increase in gross regional product per capita in the base year leads to an increase in the growth rate of gross regional product per capita, all other things being equal. It is also worth noting that an increase in the unemployment rate by 1% contributes to an acceleration in the growth rate of the gross regional product per capita by 0.451, all other things being equal. An increase in government spending per unit in the region contributes to a decrease in the growth rate of the gross regional product per capita in the neighboring region, all other things being equal. The spatial lag coefficient indicates that changes in the indicators of the domestic regional product per capita in one region have an impact on changes in the domestic regional product per capita in the neighboring region. The results of the study indicate the need to use spatial weights when evaluating regional regression models.

KEYWORDS: Inequality, Region, Regional Economy, Regional Strategy, Economic Growth, Geographical Heterogeneity, Durbin Spatial Model, Spatial Effects, Kazakhstan

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Пространственные эффекты в контексте регионов Казахстана

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АННОТАЦИЯ

Проблема пространственного неравенства регионов Казахстана является актуальной на протяжении многих лет и в последние годы данная проблема усугубилась в связи с социально-экономическими изменениями в регионах, последствиями пандемии COVID-19, негативным влиянием инфляционных процессов, усилением внутренней миграции и других факторов. Целью данного исследования является анализ пространственного неравенства между 16 регионами Казахстана охватывающий временной период с 2001 по 2017 годы. В исследовании использовались следующие научные методы: исторический метод, статистический метод. В процессе исследования был разработан новый класс пространственно-эконометрических моделей, являющихся модификациями пространственной модели Дарбина. Данные модели характеризуются непостоянными коэффициентами при пространственных лагах зависимой и независимых переменных. Оценка моделей осуществлялась на основе сведений о казахстанских регионах, с использованием в качестве зависимой переменной темпа роста регионального внутреннего валового продукта на душу населения. Выводы исследования показывают преимущества модели SDM с фиксированными эффектами по сравнению с альтернативными моделями, что подтверждается результатами оценки с использованием критериев информационного критерия Акаике (AIC) и Байеса (BIC). Согласно оценки модели SDM, увеличение на 1% валового регионального продукта на душу населения в базовом году, приводит к увеличению темпов роста валового регионального продукта на душу населения при прочих равных условиях. Также стоит отметить, что увеличение уровня безработицы на 1% способствует ускорению темпов роста валового регионального продукта на душу населения на 0,451 при прочих равных условиях. Рост расходов государства на 1 единицу в регионе способствует к снижению темпов роста валового регионального продукта на душу населения в сопредельном регионе при прочих равных условиях. Коэффициент пространственного отставания указывает на то, что изменения в показателях внутреннего регионального продукта на душу населения в одном регионе оказывают влияние на изменения внутреннего регионального продукта на душу населения в сопредельном регионе. Результаты исследования свидетельствуют о необходимости использования пространственных весов при оценке региональных регрессионных моделей.

КЛЮЧЕВЫЕ СЛОВА: неравенство, регион, региональная экономика, региональная стратегия, экономический рост, географическая неоднородность, пространственная модель Дурбина, пространственные эффекты, Казахстан

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INTRODUCTION

Since gaining independence, Kazakhstan has undergone several major regional administrative and territorial reforms. In 1997, the Zhezkazgan region was merged with the Karaganda region, the Kokshetau region was divided between the Akmola and North Kazakhstan regions, the Semipalatinsk region became part of the East Kazakhstan region, the Turgai region became part of the Kostanay region and Taldykorgan region became part of Almaty region. The events of January 2022, the socio-economic tensions in depressed regions, and the spatial inequality of the regions served as the impetus for new administrative and territorial reforms in May 2022. Thus, Zhezkazgan and Semey were again given the status of regional centers with the formation of Ulytau and Abai regions, respectively. Konayev acquired this status for the first time, becoming the regional center of the Almaty region. Also, eight districts, the cities of Tekeli and the Taldykorgan, separated from the Almaty region, thereby forming the Zhetysu region. The new administrative-territorial units are designed to improve management efficiency, strengthen socio-economic stability, reduce regional inequality, etc. Thus, according to some indicators, the "new" regions are significantly lagging behind the national average. For example, in terms of life expectancy at birth, the Ulytau region in 2022 was an absolute outsider with an indicator of 71.44 years, and the indicator of the Abai region was 73.8 years. The average national age in this indicator was 74.44 years, the leading region was the city of Almaty with an indicator of 77.32 years. In 2022, the Ulytau region was also the "leader" in terms of the proportion of NEET youth at 12.6%, while the national average was 6.5%.

The uneven spatial development of the regions of Kazakhstan continues to be one of the main problems of the country's government. It requires the state to make significant inter-budgetary redistributions between rich and poor regions. Considering the new administrative and territorial reforms, various support mechanisms have been developed for depressed and economically weak regions. Taking into account the assessment of the effectiveness of the state's regional policy aimed at reducing regional disparities and the study of the spatial evolution of regions, this study is relevant. It contributes to a better understanding of spatial effects in the context of the regions of Kazakhstan. The study examines how the growth rate of regional GDP per capita influences the gross regional product per capita in the base year, along with factors such as government spending per capita, the unemployment rate, and investment in fixed assets at the regional level.

The scientific significance lies in the proposed modification of the Durbin spatial model, taking into account differences in growth trajectories due to regional differences that determine the individual characteristics of the dynamics of public investment in regional infrastructure and social projects; differences in unemployment rates between regions, differences in investment activity, taking into account the mutual influence of regions on each other. A quantitative assessment of the impact of the level of government spending per capita and investment in fixed assets in the region on neighboring regions has been carried out.

The study aims to analyze spatial inequality between the regions of Kazakhstan before implementing administrative and territorial reforms aimed at reducing the depression of individual regions and eliminating regional disparities.

LITERATURE REVIEW

The problem of spatial inequality is relevant in Kazakhstan and other developing and developed countries (Niembro & Sarmiento, 2021; Eva et al., 2022). The issues of spatial inequality are interdisciplinary and are closely interconnected with such scientific regions as regional economics, urban sociology, political science, urban studies, ecology, etc. (Gyuris, 2018). Much of the research on spatial inequality focuses on inequality within urban environments (Sarkar et al., 2024; Kilroy, 2009) and inequality between urban and rural regions. Spatial inequality occurs at different scales and is evident in different economic and social spheres (Turok & Visagie, 2025). Thus, in South Korea, spatial inequalities in transport, healthcare, culture, education, and economic opportunities vary significantly between urban centers and densely populated regions compared to rural and remote regions (Han, 2022). Regions with low accessibility are usually characterized by many older adults and a few non-disabled people (Lee et al., 2024). Research on spatial inequality in higher education between cities and rural regions is widespread in the scientific literature (Zahl-Thanem & Fredrik Rye, 2024). Spatial inequality in the UK is an important economic and social problem for the whole society, and a better standard of living is being recorded in London in such regions as healthcare, education, wages, etc. (Higgins et al., 2014; Overman & Xu, 2024).

The Achten and Lessmann study examines how spatial inequality affects the economic activity of existing and artificial countries using exogenous

variations in geographical characteristics (Achten & Lessmann, 2020). Instrumental variable estimates show a strong causal relationship between spatial inequality between countries and the level of economic integration with the global world, affecting regional income inequality (Ezcurra & Del Villar, 2021). In the scientific community, discussions about methods of combating spatial inequality occur at the national and regional levels (Todes & Turok, 2017).

Regional inequality is one of the important components of national disparities (Shifa & Leibbrandt, 2022). Regional differences contribute to overall inequality within a state, in a broader context regional inequality includes inequality between cities and rural regions, regions, and cities (Lu et al., 2015). Differences in the level of development of regions can contribute to increased social tension, polarization of regions, dissatisfaction with elites, and a decrease in national cohesion (Floerkemeier & Spatafora, 2021). Regional inequality and inequality in neighboring regions directly affect the growth rate of production in the regional economy (Panzera & Postiglione, 2021). Spatial inequality in the health sector shows that in France, there is a significant difference in mortality between rich metropolitan regions and regional municipalities, as in rich regions, mortality is 15.1 lower than in other regions of the country (Fayet et al., 2020). A study conducted in the United States covering the period from 1960 to 2019 shows that per capita incomes in the states vary before taxes and, thanks to transfers, it is possible to reduce spatial income inequality (Gaubert et al., 2021). Early studies on regional inequality focused on population density or income (Folmer & Oosterhaven, 1979). Studies conducted considering one indicator did not show a complete picture of the causes of spatial inequality.

Spatial inequality contributes to the uneven distribution of resources, which ultimately leads to the marginalization and deprivation of vulnerable segments of the population (Wu & Liu, 2022; Vogel & Zwiers, 2018) and undermines social cohesion and political stability (Liu et al., 2024). It is worth noting that to reduce spatial inequality between regions, it is necessary to take decisive measures on the part of the state and society (Doran, 2022; MacKinnon et al., 2024). In England, the government uses decentralization of public administration and devolution mechanisms to strengthen local government bodies and develop regional management capabilities. It was found that regions with weaker local governance experienced difficulties in obtaining funding, developing investment plans, and attracting investment. Weak local governance capacity was characterized by weak economic productivity (Newman & Hoole, 2024). The experience of Italy, France, and Germany shows that the governments of these countries have strategies to combat spatial inequality through strong governance mechanisms. The effectiveness of these strategies is linked to strong institutions and funding (Giovannini & Vampa, 2020). An empirical analysis of the long-term effects of fiscal decentralization aimed at reducing economic and social inequality in Indonesian regions demonstrates the need for effective local policies and balanced national policies to support regions, considering liberalization (Aritenang & Chandramidi, 2023). To achieve sustainable development goals and reduce inequality between and within countries, expanding access to health care and education services and reducing poverty at micro-spatial levels (Niranjan, 2020).

The SDM model has been widely applied in spatial inequality studies to analyze the relationships between regional inequality and natural resources (Ponce et al., 2023), education (Delprato et al., 2024), health (Zhang et al., 2020), economic growth (Khotiawan et al., 2023), innovation (Bürscher & Scherngell, 2023), regional income (Jadhav & Viswanathan, 2023), digital economy (Xia et al., 2024), poverty (Ifa et al., 2024).

Research devoted to spatial inequality in the regions of Kazakhstan is widely represented in domestic and foreign scientific literature. Among the available studies, one can note a study examining the inequality of regions by level of well-being (Rodríguez-Pose et al., 2024). The well-being of regions depends, among other things, on the population's poverty level, so in the study of Chulanova et al. (2024), the integrated poverty index of the regions of Kazakhstan was assessed. Socioeconomic inequality has a direct and significant impact on regional development governance in Kazakhstan and remains one of the main problems of society (Sermagambet et al., 2022; Nurlanova et al., 2023). Fayziy (2024) showed differences in inequality of opportunity on income and employment status between regions of Kazakhstan using ordinary least squares, logarithmic models, and Gini coefficients. The sectoral structure of the economy has a significant impact on the inequality of labor income in the regions of Kazakhstan; to reduce regional inequality in income, it is proposed to use taxation instruments, as well as the introduction of regional coefficients (Nurlanova et al., 2024). Using the ARIMA method, we analyzed how income inequality affects social inequality in the regions of Kazakhstan (Ismagulova & Massakova, 2024). Calculations of the specialization index (KDI) confirm the pronounced spatial differentiation of economic activity between the re-

gions of Kazakhstan. The bidirectional relationship between income inequality and economic growth shows different regional dynamics, suggesting that future research should consider regional specificities and interregional heterogeneity (Temerbulatova et al., 2024). The results of the studies show that factors such as GDP growth and migration have a positive effect on reducing income inequality and that social assistance hurts reducing inequality. Anderson and Pomfret (2004) conducted a comprehensive empirical study of spatial inequality in Central Asian countries and Kazakhstan and concluded that spatial inequality has negative consequences. Research findings highlight the importance of education in reducing regional inequality (Kireyeva et al., 2023). The differences in economic inequality are analyzed using Kazakhstan, the former Soviet Union, and the OECD as examples (Jumambayev et al., 2022).

The literature review revealed the multifaceted nature of spatial inequality due to socio-economic, political, geographic, historical, and other factors. This study contributes to a deeper understanding of the role of spatial effects in the context of the mutual influence of regions of Kazakhstan. The study is distinguished by the use of the SDM method with spatial fixed and random effects, which allows for a better understanding of the level of dependence between regions, allows for a more accurate prediction of the impact of economic changes in one region on neighboring regions and takes into account the geographical heterogeneity of Kazakhstan. Within the framework of existing studies of the development of regions of Kazakhstan, approaches based on the SDM model have not previously been used, so this study can become the basis for a more detailed analysis of future studies in the field of regional policy, sustainable development and reducing spatial inequality of regions.

RESEARCH METHODS

The study is based on regional data from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan (Bureau of National Statistics, 2024). Due to changes in the administrative and territorial structure of the country in 2018 and 2022, which included the formation of new regions (Turkestan, Abai, Zhetysu, and Ulytau regions) and the city of Shymkent, the analysis covers the period from 2003 to 2017. During this period, Kazakhstan included 14 regions and two cities of national significance – Almaty and Astana.

In our study, we use one weighting matrix, the boundary matrix. The diagonal elements of the weight matrices are zero. The wij element of the boundary matrix is one if regions with numbers i and j have a shared land border and zero if they do not have a common land border. The boundary matrix is presented in Table 1.

Table 1. Boundary matrix of regions of Kazakhstan

Region	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Akmola	0	0	0	0	0	0	1	1	0	0	0	1	1	0	1	0
Aktobe	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0
Almaty	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	1
Atyrau	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0
West Kazakhstan	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Zhambyl	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0
Karaganda	1	1	1	0	0	1	0	1	1	0	1	1	0	1	0	0
Kostanay	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0
Kyzylorda	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0
Mangistau	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
South Kazakhstan	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0
Pavlodar	1	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0
North Kazakhstan	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
East Kazakhstan	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0
Astana city	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Almaty city	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

Note: compiled by authors

Using statistics for these 15 years made it possible to consider longer-term trends and the broader context of the country's development. A regression analysis of the spatial inequality of the regions of Kazakhstan was carried out. The Durbin spatial model (SDM) is used for this purpose.

The Spatial Durbin Model (SDM) has recently become more noticeable in economic studies due to its broad method of modeling spatial relations. As initially indicated by Anselin (1988), and formerly by Beer and Riedl (2012), SDM combines a spatial lag for mutually dependent and independent variables, making it principally skillful at catching externalities and spillovers from different origins. SDM's growing approval is demonstrated in its regular use through numerous economic literature. For example, as stated before, Hu et al. (2022) discuss the application of SDM alongside two supplementary mutual spatial econometric models for studying cross-sectional data: the spatial autoregressive model (SAR) and the spatial error model (SEM). They found that although SAR is usually applied while the dependent variable displays spatial correlation through regions, SEM is more appropriate while spatial correlation exists in the independent variables (Hu et al., 2022). SDM, in contrast, prolongs these frameworks by allowing for the autocorrelation of both dependent and independent variables, consequently including both spatial lag and spatial error mechanisms in the study. This marks SDM as a robust model for investigating the complicated flow of spatial interdependencies (Hu et al., 2022). Before Anselin (1988), there was Burridge (1981) who, as referenced by Elhorst (2011), indicates the price of introducing a spatial framework with an extensive model such as the Spatial Durbin Model (SDM), which incorporates less compound models inside its arrangement. This methodology supports assessing whether SDM can shorten its nested frameworks, supplying a vigorous framework for interpreting spatial dependencies in data (Elhorst, 2011).

Pace and LeSage (2010) point out the advantages of using the spatial Durbin model (SDM). Their analysis shows that when variables exhibit spatial dependence, both in perturbations and between dependent and explanatory variables, traditional methods such as the least squares method (OLS) can lead to biases of missing variables. SDM solves this problem by integrating spatial delays of both dependent and explanatory variables into the model. Ezcurra and Rios (2015) have shown that the Durbin spatial model also solves the problem of model endogeneity.

The equation for the regression model using formula (1):

$$\ln Y_{it} = \rho W \ln Y_{ito} + \beta_1 \ln X_{1it} + \beta_2 \ln X_{2it} + \beta_3 \ln X_{3it} + \beta_5 \ln X_{5it} + \beta_6 \ln X_{6it} + \beta_7 \ln X_{7it} + \varepsilon_{it} \quad (1)$$

where:

W – the boundary matrix (reflects the influence of all other regions), the matrix elements reflect the distance between the regions.

Y_{it} – the growth rate of regional GDP per capita in region *i* in the year *t.*

Y_{ito} – the gross regional product per capita in the base year (tenge) in region *i* in year *t*;

X_{1it} – government expenditures per capita (tenge) in region *i* in year *t*;

X_{2it} – unemployment rate (in decimals) in region *i* in year *t*;

X_{3it} – investments in fixed assets (tenge) in region *i* in year *t*;

ρ – spatial lag coefficient;

ε_{it} – error term.

The number of observations amounted to 272, allowing us to cover a wide range of regional data. Based on Barro and Sala-i-Martin (2004) study of endogenous growth models, the main factors of economic growth are capital, labor, and technology. In this study, we used fixed capital investment as the capital indicator, the unemployment rate as the labor force indicator, and government expenditure as an exogenous variable. The following indicators were used for the analysis: the regional GDP per capita in the region (dependent variable), gross regional product per capita in the base year in the region, government spending per capita, unemployment rate, and investment in fixed assets (independent variables).

The specified independent variables were included in the model for the following reasons:

1. GRP per capita – it is assumed that the higher the GRP per capita, the better the general economic situation in the region, the lower the unemployment rate, and the higher the relative wages and economic growth rate.

2. Government expenditure per capita – it is assumed that government expenditure per capita has a very noticeable impact and return in the form of an increase in GRP. Using the variable government expenditure per capita, analyzing the dynamics of government investment in infrastructure, social, and other regional projects aimed at improving the population's lives is possible.

3. Unemployment rate – this variable is included based on the assumption that economically stronger regions offer better job opportunities and higher wages, attracting labor migration. Regions with low unemployment and higher wages are typically growth leaders. The unemployment rate helps

highlight disparities across regions, particularly in densely populated areas.

4. Investments in fixed capital – it is assumed that investments in fixed capital are a key condition for achieving annual growth of GRP.

Thus, the variables considered reflect important factors influencing the region's development and help to assess how various aspects can affect the region's growth and quality of life.

RESULTS AND DISCUSSION

In the initial stage of the period under review, the country underwent economic transformation and modernization, market expansion, and rising prices for exported raw materials. In 2008, Kazakhstan, like many other countries, faced the consequences of the financial and economic crisis. In 2014, there was a drop in world oil prices, which hurt the economic situation both in the regions and the country as a whole. This paper conducted a regression analysis to better understand the situation during this period.

The Durbin model (SDM) with fixed random effects was used in spatial regression analysis. Considering the component of spatial dependence, this model is an extension of traditional regression analysis since variables in one region can depend not only on their values but also on the values of the corresponding variables in neighboring regions. The SDM model can provide more accurate data on regional interactions and identify hidden dependencies that might have been overlooked when using traditional methods.

It is worth noting that when modeling macroeconomic indicators of regions, it is necessary to consider the influence of other factors in these regions and the values of these same macroeconomic indicators in other regions. If the spatial autocorrelation coefficient is significant and positive (negative), this indicates the presence of corresponding spatial effects. A positive coefficient indicates that changes occurring in one region will lead to similar changes in adjacent regions. In contrast, a negative coefficient means that changes in one region will cause opposite changes in an adjacent region (considering using the boundary matrix W). Thus, the model takes into account the mutual influence of the selected groups of regions on each other.

Table 2 shows the SDM spatial model simulation results with random effects.

Table 2. Spatial SDM model with random effects

Variable	Coefficient	Coefficients taking into account the spatial lag (W)	Spatial variable
lnY_0	0.0160	0.0593*	
	(0.0201)	(0.0319)	
lnX_1	0.00221	-0.0514*	
	(0.0218)	(0.0281)	
lnX_2	0.247**	-0.139	
	(0.0981)	(0.118)	
lnX_3	0.00131	-0.0336	
	(0.0194)	(0.0219)	
ρ			0.575***
			(0.0855)
Constant	0.300**		
	(0.138)		
Number of observations	272	272	272
R-squared	0.180	0.180	0.180
Number of ID	16	16	16
Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1			

Note: compiled by authors

The model used dependent variables ln Y_0 (logarithmic values of variables), independent variables lnX_1, lnX_2, LnX_3, and a spatial variable with a lag (W).

lnY_0: Given the spatial effects, it can be argued that a 1% increase in gross regional product per capita in the region contributes to a 0.016% increase in gross regional product per capita in the next period. The impact of government spending per capita is small if spatial interactions are not considered.

lnX_2: Unemployment rates have a more significant impact on the gross regional product per capita. Thus, an increase in the unemployment rate by 1% is accompanied by an increase in the regional GDP per capita by 0.247%. This is probably due to structural unemployment or improved labor productivity.

It should be noted that in the model, investments have a relatively weak impact on the regional GDP per capita. The spatial lag of 0.575 indicates a significant impact of the gross regional product per capita level in neighboring regions on the corresponding indicator in the region under consideration.

The analysis showed that economic factors and spatial relationships between regions influence regional GDP growth. Factors such as unemployment and GRP per capita in the base year and less significant factors such as investment and government spending significantly depend on the spatial context.

Table 3 shows the SDM spatial model simulation results with fixed effects.

Table 3. SDM model with spatial fixed effects

Variable	Coefficient	Coefficients taking into account the spatial lag (W)	Spatial variable
lnY_0	0.370***	-0.165	
	(0.105)	(0.129)	
lnX_1	-0.0271	-0.118**	
	(0.0270)	(0.0545)	
lnX_2	0.451***	-0.162	
	(0.137)	(0.155)	
lnX_3	0.0222	-0.0401	
	(0.0268)	(0.0338)	
ρ			0.570***
			(0.0782)
Number of observations	272	272	272
R-squared	0.034	0.034	0.034
Number of ID	16	16	16
Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1			

Note: compiled by authors

Comparing the estimates of the AIC and BIC criteria for different models, the paper concluded that the SDM model with fixed effects is the best of all the above.

lnY_0: The coefficient of 0.370 indicates that an increase in the gross regional product per capita by 1% in the base year is associated with an increase in the gross regional product per capita rate by 0.370 units, all other things being equal. This coefficient is statistically significant ($p < 0.05$).

lnX_2: An increase in the unemployment rate by 1% is accompanied by an increase in the gross regional product per capita growth rate by 0.451, all other things being equal. The coefficient reflecting the effect of the unemployment rate is statistically significant ($p < 0.05$).

Spatial lag of independent variables: coefficients for spatially lagging independent variables indicate the influence of adjacent regions' characteristics on a given region's dependent variable. Since the spatial lag coefficient lnX_1 is statistically significant, an increase in government spending in neighboring regions by one unit leads to a decrease of 0.118 in the GRP per capita growth rate in the observed region, all other things being equal. Also, the spatial lag coefficient for the unemployment rate is negative, which means that an increase in unemployment in neighboring regions leads to a decrease in GRP per capita in this region.

Spatial lag Y: The coefficient of spatial lag of the dependent variable, equal to 0.570, is statistically significant. This indicates that the gross regional product per capita in one region significantly depends on the gross regional product per capita in neighboring regions, which confirms the correctness of the spatial econometric model. When evaluating regional regression models, spatial weights must be considered.

Thus, identifying a positive spatial effect on the growth of GRP in regions indicates that an economically developing region contributes to the growth of adjacent regions, exerting a positive influence on them. In turn, a negative spatial effect on the growth of GRP indicates that an economically growing region attracts resources and investments, which limits the development opportunities of adjacent regions, hindering their economic growth.

During the study, the Hausman test was performed for each specification of the decision-making model, choosing a model with random effects and fixed effects. A reliable Hausman test for choosing between fixed-effect and random-effect models:

H_0: difference in coeffs, not systematic chi (9) =83.69 Prob > = chi = 0.000

According to the test results, the null hypothesis is rejected, and fixed-effect models should be used. Therefore, in the future, it is necessary to use models with fixed effects.

An extended statistical analysis was carried out during the study, revealing a correlation between quantitative variables. Scattering diagrams were constructed to visually represent the relationship between the dependent and independent variables to analyze this relationship. Figures 1,2,3,4, and 5 show graphs showing the correlation between the variables. An analysis of these diagrams showed that the linear form of the regression equation is acceptable since the points of the graphs are visually located around the assumed straight line, which indicates a possible linear relationship.

The diagram in Figure 1 shows the dependence of the regional GDP per capita growth rate in region i in year t on the regional GDP per capita growth rate in region i in year t.

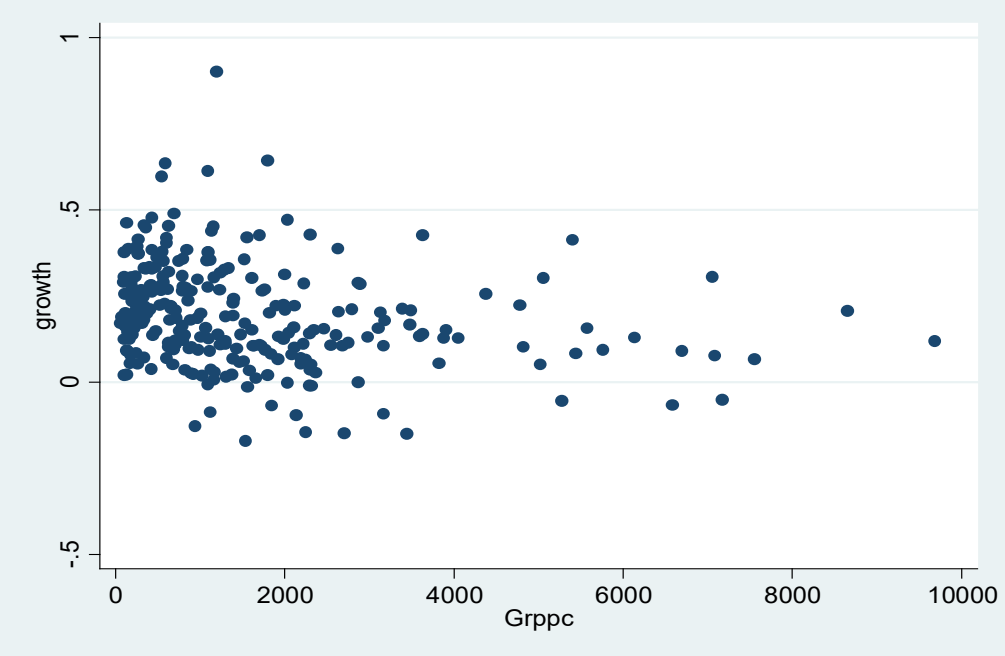

Figure 1. Scatterplot of the relationship between growth and Grppc

The scatterplot shows a negative relationship between the GRP per capita in the base year and its subsequent growth rate. This indicates that less developed regions experience faster economic growth (catch-up effect) while richer regions experience economic stabilization (declining marginal growth rate theory). High dispersion indicates different economic dynamics in poor regions. The following factors can influence the economic situation in regions: the level of government support, the presence of large mineral deposits, lack of investment, demographics, declining industrial production, etc. Developing infrastructure projects and providing tax breaks and subsidies is necessary

to stimulate growth in individual regions artificially. In the diagram, points above 0.5 indicate abnormally high growth in some regions, which may indicate that regions with a rich raw material base receive a sharp influx of investment in large projects. Points below -0.5 indicate regions with a sharp drop in GRP per capita.

Thus, according to the scatter diagram presented in Figure 2, there is negative feedback between government spending and the rate of regional GDP per capita, with an increase in spending (X), the growth rate (Y) decreases.

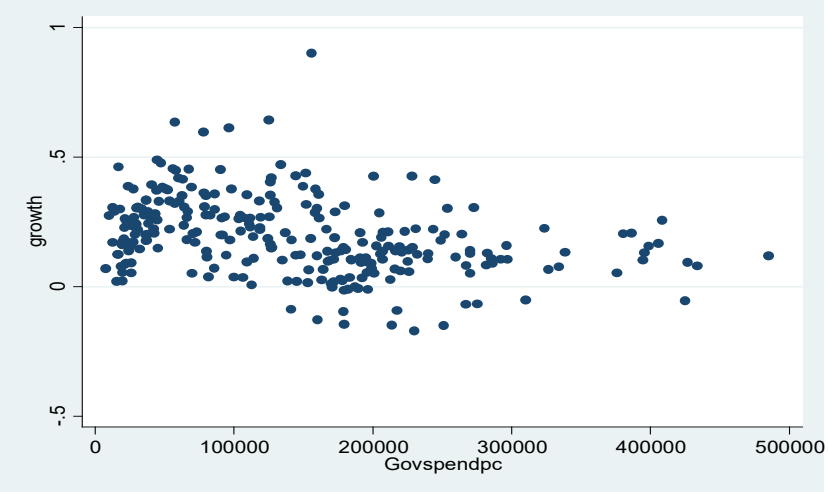

Figure 2. Scatterplot of the relationship between regional GDP growth and government expenditure per capita

High dispersion indicates strong variability in the growth rates of regional GDP. The presence of outliers in the upper part of the graph (Y> 0.5) indicates the presence of regions in Kazakhstan with specific abnormal growth of regional GDP. In general, a negative relationship may indicate that the growth of government spending does not always contribute to the growth of regional GDP. This can be explained by ineffective management and distribution of funds, and insufficient multiplier effect. Different regions of Kazakhstan have different economic structures, and accordingly, the impact on the reaction of regional GDP to changes in government spending can vary significantly. It is also necessary to consider threshold effects, probably upon reaching a certain level of government spending, additional increases in government spending do not contribute to economic growth in the regions.

Figure 3 provides an opportunity to see the dynamics and nature of changes in the indicators "growth rate of regional GDP per capita in the region" and "unemployment rate" over time.

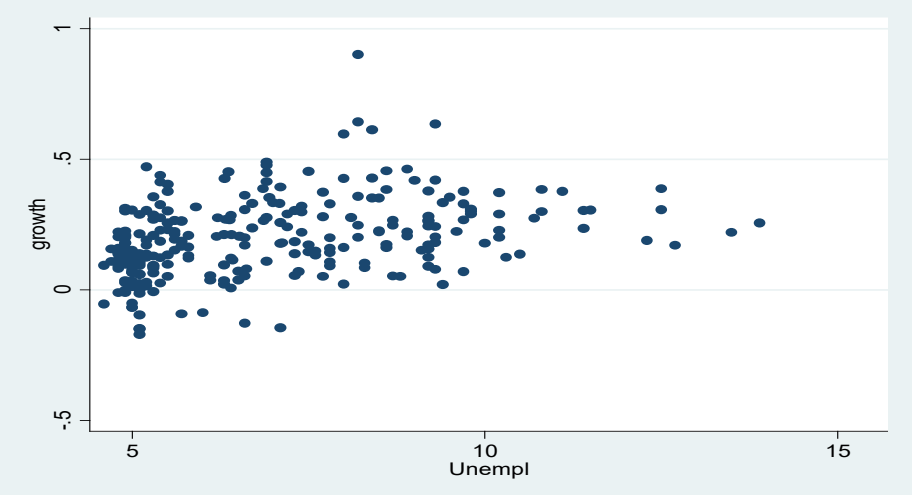

Figure 3. Scatterplot of the relationship between regional GDP growth and the unemployment rate

Thus, the scatter diagram shows the absence of a pronounced relationship between the unemployment rate and the growth rate of GRP per capita. Most regions have an unemployment rate within the 5-10% corridor. Only a few regions show an unemployment rate above 10%. There is a high level of dispersion of growth rates with a low unemployment rate. In the range of 5-7% unemployment, there is a strong variability in the GRP growth rate. This suggests that investments, the structure of the regional economy, and budget expenditures affect the growth rate more than the unemployment rate. The dots are evenly distributed among regions with an unemployment rate of more than 10%, which may indicate that in these regions, the economy is growing slowly but at the same time, has stable growth. The absence of a pronounced relationship between unemployment and GRP growth shows that unemployment is not the main factor in economic growth. For example, frictional and structural unemployment do not have a significant impact on GRP growth.

Figure 4 shows a scatter plot of the relationship between the per capita GRP growth rate and fixed capital investment.

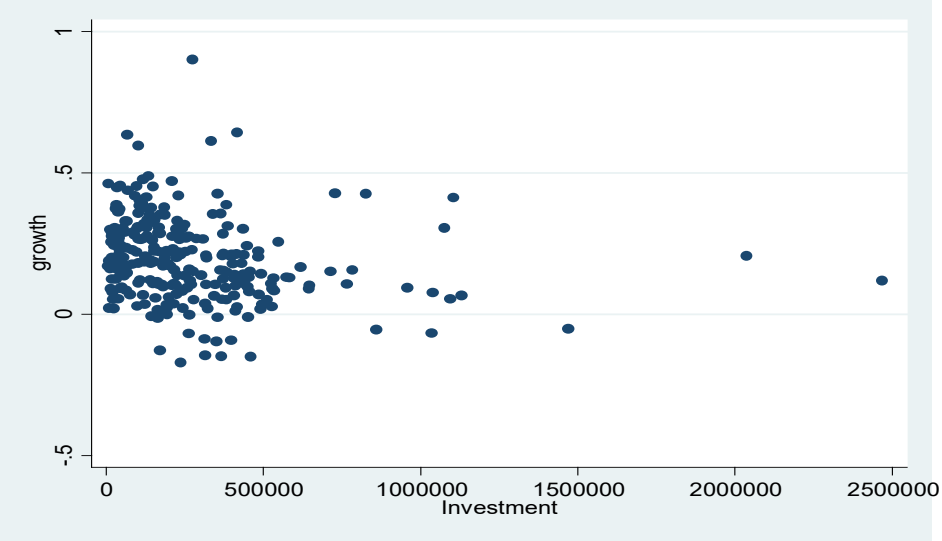

Figure 4. Scatterplot of the relationship between regional GDP growth and fixed capital investment

The data in the diagram are distributed randomly, without any clear growth or decline. In the right part of the diagram, the dots are located closer to zero GRP growth values, indicating a moderate impact on investment. The largest number of dots are located in the range of 500,000 tenge, indicating that the regions have problems attracting investment. Dots located in the range above 1,000,000 tenge correspond to a growth rate of about 0. Perhaps this fact indicates large investment projects with long-term effects that do not immediately lead to GRP growth. Regions with low investment are distinguished by significant variability in growth rates. This possibly indicates that the quality of investment and the efficiency of its use are of great importance. Fixed capital investment often has an impact on GRP with a time lag; the effect of the investment may appear in a couple of years, which explains the weak visible connection. Sensitivity to investment varies between regions; in some regions, the economy responds to an influx of investment, while in other regions, this requires additional factors in the form of entrepreneurial activity, infrastructure, and labor market development.

Figure 5 shows a scatterplot showing the relationships between all variables.

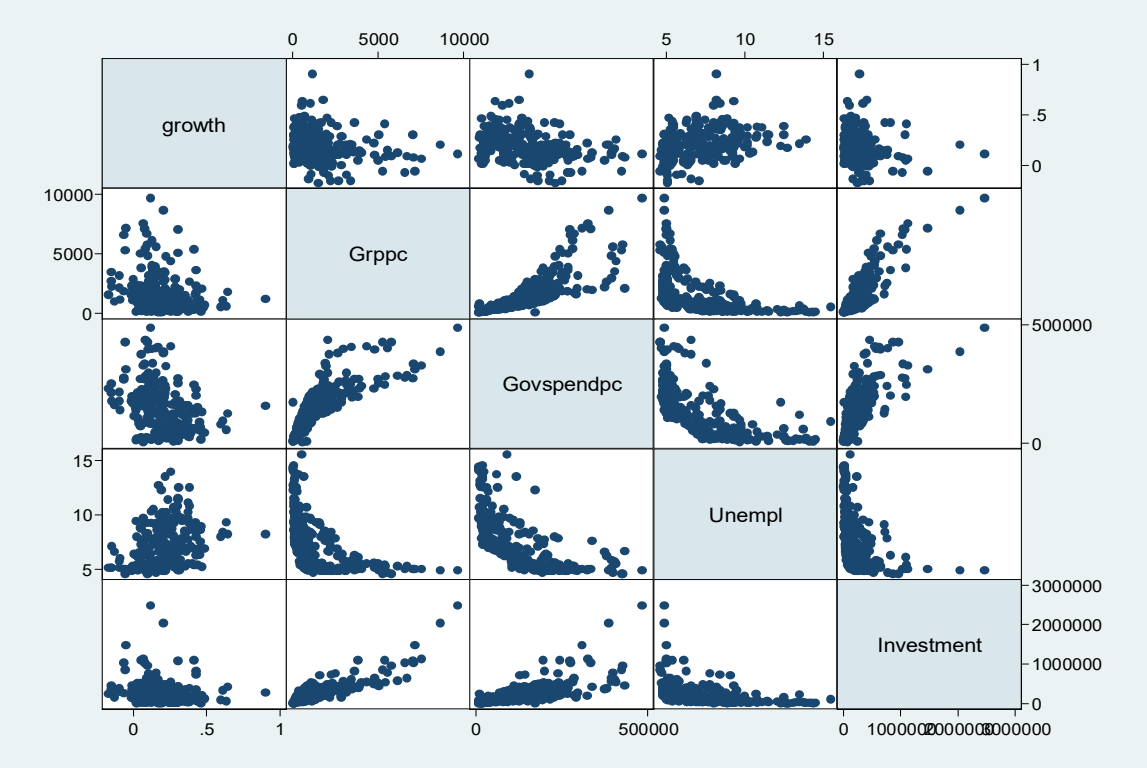

Figure 5. Scatterplots of the mutual influence of all variables on each other

Each cell contains a scatterplot between two variables. Thus, there is a negative relationship between the Grppc and Growth variables: the higher the GRP per capita in the base year, the lower its growth rate, which confirms the convergence hypothesis. The Grppc and Govspendpc variables have a clear positive relationship, which means that regions with higher GRP receive more government spending per capita. The Grppc and Investment variables show a clear positive relationship, which means that rich regions attract more investment.

The Govspendpc and Growth variables show a weak or no relationship, which means that an increase in government spending does not always lead to an increase in economic growth due to inefficient management and allocation of funds. The Govspendpc and Unempl variables show an inverse relationship, which means that in regions with high government revenues, the unemployment rate is lower (government spending is directed to social programs).

The Unempl and Growth variables show a weak or no relationship, which means that high unemployment is not always associated with a weak GRP growth rate. The Unempl and Grppc variables show a negative relationship, which means that developed regions have a low unemployment rate and, conversely, poor regions have a high unemployment rate. The Investment and Growth variables have an unclear relationship, which is explained by the long-term effect of investment. The Investment and Grppc variables have a strong positive relationship, which means that developed regions attract more investment.

Thus, it can be noted that developed regions grow more slowly, and less developed ones can show high rates of economic growth. Government spending is directed more to developed regions, the higher the GRP, the more spending, however, the impact of this spending on the growth of the GRP is not noticeable. Investments are directed more to developed regions, the higher the GRP per capita in a region, the more investment it attracts. However, there is no clear connection between investment and rapid economic growth. Unemployment is higher in less developed regions. There is a negative correlation between the level of GRP and unemployment. Note that government spending can help reduce unemployment.

CONCLUSIONS

As a result of the research, spatial econometric models were developed, which are modifications of the Durbin spatial model with variable coefficients with spatial lags of both dependent and independent

variables. The models were evaluated based on data from the Kazakhstan region, where the regional gross domestic product per capita growth rate was used as a dependent variable. A generalization of the spatial autoregression model is proposed when the regions under consideration are divided into two groups that influence each other. The weighting matrix in such a model is split into two parts, and spatial coefficients are estimated. The proposed model is used to analyze four macroeconomic indicators of Kazakhstan's regions, preliminarily divided into adjacent and non-adjacent regions. The econometric analysis revealed the asymmetry of the influence of these two groups of regions on each other. Calculations have shown spatial effects reflecting the influence of Kazakhstan's regions on each other. So, one region can directly affect a neighboring region, or changes in one region will affect changes in the neighboring region.

The scatterplots compiled confirm certain economic regularities, such as convergence, uneven distribution of investments, and the impact of government spending on unemployment. However, it is worth emphasizing that some dependencies require additional research, especially in terms of the impact of investments on economic growth in regions. This can be compensated for by future research that can supplement and clarify existing data.

The study results show the need for uniform development of Kazakhstan's regions and a reduction in the level of spatial inequality between regions. The existing socio-economic problems of the regions (Turkebayeva & Wolff, 2022; Dodonov, 2024; Brimbetova et al., 2022; Rakymzhanova & Bekbenbetova, 2024) require decisive measures from the Government of Kazakhstan to carry out a more effective regional policy. To do this, it is necessary to take into account the spatial interaction between the regions of Kazakhstan, reduce regional disparities, and take a differentiated approach to planning government spending and reducing unemployment and investment policy. Otherwise, the uneven development of the regions will contribute to increasing social discomfort, strengthening internal migration sentiments among the population, increasing the income gap between poor and prosperous regions, and strengthening environmental, infrastructural, and other problems. Foreign experience shows that regional spatial inequality is a pressing issue for many countries. To reduce the level of spatial inequality in regions, a comprehensive approach is needed, including the interaction of all state institutions, business, and civil society. Effective regional institutions are one of the key mechanisms for reducing regional inequality, while state regional policy plays an equally important role in ensuring the balanced development of regions. Also, to solve the existing problems of regional inequality, it is necessary to develop regional infrastructure, stimulate GRP, develop regional education and healthcare, attract investment, and solve environmental problems. No less important is the use of tax instruments to reduce regional disparities and income inequality between regions, which is an important strategy in the context of the economic and social development of the state. Based on this, the implementation of an effective fiscal policy can help reduce regional inequality. Therefore, Kazakhstan needs to take a balanced approach to tax reform and the adoption of a new tax code in 2025.

AUTHOR CONTRIBUTIONS

Conceptualization and theory: AKR, YB, AK and LS; research design: AKR, YB, AK and LS; data collection: AKR; analysis and interpretation: AK; writing draft preparation: YB; supervision: LS; correction of article: YB and AK; proofread and final approval of article: AKR and LS. All authors have read and agreed to the published version of the manuscript.

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