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Research article

Exploring the impact of ecological dimension on municipal investment: empirical evidence from Russia

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Abstract: Investment has a crucial impact on the economic development of territories. Traditionally, scholars studied many factors influencing investment (cost of interest rate, labor productivity, GDP growth, financial firm's performance). At present, the existing body of literature demonstrates the shift of factors related to territorial investment attractiveness. Besides economic dimension, the ecological and social matters take key stages (the ESG concept and the triple bottom line concept). Our study is aimed at exploring the relationship between investment at municipal level and ecological factors, considering regional specifics and settlement patterns in Russia. We applied hierarchical (multilevel) modeling with spatial effects to accomplish a twofold goal: to estimate what share of investment variance attributed to municipal and regional scale; to distinguish between spatial error at regional level and influence of average investment in neighboring municipalities at municipal level. Our findings show that 32% total investment variance accounted for regional scale; investment is positively associated with population, production per capita and the ratio of circulating water and sequentially used water to used fresh water. The results of this paper could be useful in developing policy for attracting investment at regional and municipal levels. Given vast national territories, a variety of different regions and heterogeneous settlement patterns, our study lays an initial ground of assessing environmental impact on investment in Russia.

Keywords: investment; environmental protection; water; settlement schemes; spatial dependence; multilevel model

JEL Codes: E22, Q56, C31

Abbreviations: GRP—Gross Regional Product, ESG—environmental, social, and governance concept, HLM—Hierarchical Linear Modeling.

1. Introduction

One of the essential parts of total national income is investment in fixed assets, which is considered by scholars as a pivotal factor of economic growth, sustainable and successful territorial development (Cicea and Marinescu, 2021; Kamenju and Olweny, 2020; Sunde, 2023). Moreover, the magnitude of investment is strongly associated with a variety of different characteristics, such as labor productivity (Stundziene and Baliute, 2022); financial determinants (Ndikumana, 2000); cost of interest rate (Ababio et al., 2018). With boosting production volume and increasing anthropogenic pressure accompanied with environmental degradation, renewed approaches to investment matters arose (Okuma, 2019; Martini, 2021; Zhang et al. 2023). ESG and triple bottom line (TBL-profit, people and planet) concepts emerged to take into consideration social and environmental concerns when making decisions in business and investments. Traditionally, these concepts are being applied at microscale, but because of closely interconnected social, environmental and economic dimensions the combined impact is mixed. In our paper, we attempted to explore the impact of ecological pillar on investment in the Russian context. We narrowed the focus of our research because of the above-mentioned uncertainty of general pillars' influence and specifics of Russian space. The rest of the paper is organized as follows. Literature review embraces key factors that influence investment and reveals the major points of the ESG and TBL concepts. The materials and methods section presents data and rationale behind multilevel modelling. The results section covers empirical findings. The discussion section evaluates the meaning and importance of the obtained findings. The conclusion provides possible reasons for our findings.

2. Literature overview

2.1. Factors influence investment

The current literature that deals with the interconnectedness between investments in fixed assets at the regional level and different indicators is constantly growing. For instance, Ledyaeva (2009) explored the impact of market size, the presence of big cities and sea ports, oil and gas resources, proximity to the European market and political and legislative risks as FDI determinants in Russia. Aghasafari H. et al. (2021) study the relationship between foreign direct investment (FDI) inflows and CO_2 emissions in Middle Eastern and North African countries through constructing spatial panel simultaneous equations models while applying distance-based weight matrices. They established that the coefficient of CO_2 emissions had a positive and significant impact on FDI. Cheng et al. (2018) discover a negative and statistically significant relationship between environmental regulation and the inflows of FDI; it means that reduced environmental standards attract FDI flows. Yang et al. (2019) found that the influential effect of environmental regulation on the introduction of FDI marked regional differences: positive in the east and negative in the central and western regions of China.

Because the territory is perceived as the physical space of circulating flows of labor and capital, the spatial effects are also in the focus of studies related to investment matters. Thus, Rossia et al. (2016) explore if the spatial linkages affect Brazilian outward FDI through the third-country effect.

Authors found that spatial autocorrelation did not influence local market and investment decisions while market potential also was not an important determinant of FDI.

Liu et al. (2020) use the Spatial Durbin Model to analyze the interconnectedness between financial flexibility of firms listed on the New Third Board from 2014 to 2016 and the investment. They revealed:

1. a positive and significant relationship between firms' flexibilities and investment;
2. firms' flexibilities had a spillover effect and its increase in certain provinces led to investment reduction in other ones.

Cheng et al. (2020) apply a dynamic spatial panel model to reveal the impact of FDI on PM2.5 pollution in China. Authors use Moran's indexes to test spatial autocorrelation before constructing models. They found that the relationship between FDI and PM2.5 pollution was positive at the initial and middle stages of urban economic development, while the relationship was negative at the late stage of industrialization.

Spatial settlement schemes play a pivotal role in regional investment decision-making. Kaneko et al. (2019) conduct empirical analyses to establish the impact of urban railway investment on regional population density in the Tokyo Metropolitan Area. They reveal spatial autocorrelation for density and insignificant impact of railway investment on population density. The relationship between density concentration of different areas and investment are considered through terms of polycentricity/monocentricity in European spatial development perspective (ESDP). Thus, Pain et al. (2023) analyzes the association between urban density in terms of polycentricity/monocentricity and the topological configuration of commercial office investment. Their findings suggest that the urban extent density is closely interconnected with higher returns for real estate investors, indicating that physical density matters for returns on investment.

2.2. Triple bottom line and ESG concepts

Matters of sustainable development are becoming popular at different scales of economics due to consequences of the COVID-2019 pandemic and energy crises accompanied by economic and political instability. However, the roots of these concepts are traced back to Brundtland's report that determines sustainability as the "development that meets the needs of the present generations without compromising the ability of the future generations to meet their own needs" (Brundtland, 1987). The ESG concept, concept of triple bottom lines (profit, planet and people), was initially explored and implemented at micro level. Both concepts are based on common roots describing sustainability.

Triple bottom line (TBL) is a concept focusing on economic prosperity, environmental quality and social equity. Within theoretical frameworks of the concept, companies aim to perform not against a single, financial bottom line but against the triple bottom line (Elkington, 1998). Elkington J. highlighted three important dimensions of sustainable development: environmental quality, social equity and economic benefits.

Noguera et al. (2022) use quantitative methodology to assess how dimensions of TBL affect economic development in OECD countries. They found that social dimension had a positive impact on economic development of the country while environmental dimension negatively affected economic development, so the influence of economic dimension is mixed.

Andersson et al. (2022) deal with another research question that is how economic, social and environmental dimensions of TBL affect each other and what positive and negative effects emerge among them in Sweden (on the sample of 400 large firms). They established that the economic dimension had a significant effect on the social dimension but not on the environmental one. Moreover, the social dimension has a significant impact on the environmental dimension.

Schweikert et al. (2018) consider TBL aspects (economic, social and environmental pillars) at a regional level in relation to road infrastructure to identify priority of investments under climate changes. They found various spatial patterns of investment prioritization. For instance, Yuba City demonstrated the highest priority investment arising from TBL prioritization because of high impacts of climate change in this region while the Southern part of Sacramento investment prioritization levels are greatly variable within the city.

The urgent need to take into account environmental, social and economic issues in investment decision-making was a response to globalization, which predetermined applying ESG concept on both micro- and meso- scales. The concept was initially used at a micro level to assess a company's investment attractiveness toward environmental, social and governance (ESG) criteria.

The ESG concept is gaining popularity across Russian regions. The last report was issued in 2022 when the National Rating Agency (NRA) released the ranking of sustainable development and integration ESG criteria in activities of Russian Federation subjects (https://www.ra-national.ru/wp-content/uploads/2022/12/ranking_esg_regions.pdf). Additionally, to environmental, social and governance dimensions, the ranking embraces indicators of economic stability in the regions. This ranking does not assess a region's ability to perform their financial obligations. An average regional ESG development is 52.8 % while the average level of G (Governance) component is 59.7% and E (Environmental) component accounts for 51.1%. The social dimension on average is 47.6 % and reduces the total ESG score that emphasizes the importance of achieving a higher level of social development.

The target goal of such rankings is to assess if the established regional environment contributes to investment attractiveness by taking into account non-financial indicators. The key drawbacks of them are as follows.

1. The regions are perceived as comparable territorial units without consideration of their industrial specifics. Given engrained production and settlement patterns, Russian economic space features significant social and economic inequalities both within regions and municipalities (Zubarevich, 2019). Moscow and Saint-Petersburg are the major outliers in Russia that have huge budgets. These regions are on the top according to social dimension, which includes life quality, the level of income, housing, access to education, health services and developed infrastructure. Thus, ESG indices demonstrated the long - established nature of social intra-regional inequality.
2. Integral ESG indexes combine different dimensions (social, ecological, governmental) while each of them covers several indicators. This methodology does not allow us to assess the impact of certain indicators. Moreover, such indexes do not reflect the controversial influence of embraced dimensions. For instance, regions with "dirty" processing industries surpass the others in pollution volumes, but workers in regions have relatively high salaries and improved social infrastructure. In our opinion, the problems of the relationship between investment and social, economic and ecological aspects are quite complicated and require preliminary empirical studies as an initial point of departure.

Summing up, the essence of the triple bottom line and ESG concept traced back to sustainability as a general idea, we could conclude that they take into consideration non-financial dimensions of firms' efficiencies because of environmental and social imbalances. In academic literature, scholars treat ecological, social and economic pillars separately, but in reality, they are interconnected and their mutual influence is mixed both at firm and regional scales. On the other hand, in the territorial context, these concepts should provide a consolidated perspective that highlights the combined vulnerability of specific geographic regions. This goal is complicated with regional contexts in Russia with its non-uniform settlement patterns.

Given that and taking into account heterogeneous population density within geographical space, industrial specialization and economic inequality both across and within regions, our study focuses on the relationship between investment and ecological aspects in the Russian regions. This study contributes to the existing body of literature devoted to investment matters by encompassing hierarchical spatial structure with highlighting spatial effects. This study takes into account the following: hierarchical scales of spatial patterns (municipality; region); spatial autocorrelation between regions; industrial regional structure; settlement schemes across regions.

3. Materials and methods

3.1. Research design

3.1.1. Multilevel model

Multilevel (hierarchical) modeling gained increasing popularity in studies devoted to investment at different spatial scales. Abdelmoula and Etienne (2010) applied multilevel models to reveal the determinants of research and development investment in firms across French regions. Multilevel models enabled Kleineick et al. (2020) to explore the effect of national and regional characteristics on multinational corporations' investment in EU countries. Kashefi-Pour et al. (2020) study how national culture influences cash flow investment at firms' level across 24 OECD countries.

The multilevel approach involves the sequential construction of several models. At the first stage, we built null model with no predictors (model 1):

Level 1 (Municipal level):

$$Y_{ij} = \beta_{0j} + r_{ij} \quad (1)$$

Level 2 (Regional level):

$$\beta_{0j} = \gamma_{00} + u_j \quad (2)$$

where Y_{ij} — dependent variable related to i-municipality (1…2262) nested in j-region (1...83); γ_{00} — general intercept; r_{ij} — level 1 residual error term; u_j — random error term.

We estimate the contribution of each spatial level to the total variance of the dependent variable, considering the residuals from null model constructions.

Gained from this step estimates that $u \sim N(0, \sigma_u^2)$ и $r \sim N(0, \sigma_r^2)$ are being taken into account when calculating intraclass *Correlation Coefficient* ICC (Garson, 2013) or *Variance Partition Coefficient*, VPC (Goldstein, 2010) that calculated as follows (equation 3):

$$ICC = \sigma_u^2 / (\sigma_u^2 + \sigma_r^2) \quad (3)$$

In fact, this coefficient shows the share of the upper level in the total variance of the indicator. If ICC value is less than 0.03 or 3%, it indicates the insignificance of the upper-level impact on the lower one and the inexpediency of further building hierarchical models (Huta, 2014). Complicating the model on the next steps, we trace changes of σ_u^2 и σ_r^2 to distinguish variance shares that are attributed to different factors.

Given the assumption that included factors enable us to explain the variance, we constructed model 2 in the next step (Equation 4–6).

Level 1 (Municipal level):

$$Y_{ij} = \beta_{0j} + \beta_{1j}X_{ij} + r_{ij} \tag{4}$$

Level 2 (Regional level):

$$\beta_{0j} = \gamma_{00} + \gamma_{01}Z_j + u_j \tag{5}$$

where X_{ij} — independent variable, characterizing i-municipality (1…2262) nested in the j-region (1.83); Z_j — independent variable, characterizing j-region (1.83); β_{1j} — regression coefficient associated with X_{ij}; γ_{01} — level 2 slope, regression coefficient associated with Z_j relative to level-2 intercept.

We used a backward elimination method according to which the model with a full set of factors is initially built, and then the insignificant (least significant) factors are subsequently excluded.

This research focused on patterns evident in the data indicating the different impacts of investments growth factors influenced by the context formed at the regional level. The hypothesis is that the nature or strength of the relationship between two one-level variables (predictor and outcome) changes as a function of a higher-level variable and allows assessing cross-level interaction (Aguinis et al., 2013; Garson, 2013; Goldstein, 2010). The Random Intercept and Fixed Slope model with Cross-Level Interaction (Model 3) is as follows (Equations 6–8):

Level 1 (lower, municipalities):

$$Y_{ij} = \beta_{0j} + \beta_{1j}X_{ij} + r_{ij} \tag{6}$$

Level 2 (upper, regions):

$$\beta_{0j} = \gamma_{00} + \gamma_{01}Z_j + u_j \tag{7}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}Z_j \tag{8}$$

3.1.2. Spatial autocorrelation

Not only hierarchy, but also spatial dependence is crucial for a better understanding the differences in regional investment (Ledyaeva, 2009). In recent studies, the authors have repeatedly underlined the crucial need to include spatial dependencies in the analysis of investment (Aghasafari et al., 2021; Rossia et al., 2016; Liu et al., 2020; Cheng et al., 2020; Yang et al., 2019)

As a rule, spatial effects are assessed in several steps. The basic technique for spatial exploratory data analysis is the global Moran's I, which measures spatial autocorrelation based on both feature locations and feature values (Moran, 1948). Concurrently, the global Moran's index is detailed as follows (Equation 9):

$$Im = \frac{N}{\sum_i \sum_k W_{ik}} \frac{\sum_i \sum_k W_{ik}\,(Y_i - \bar{Y})(Y_k - \bar{Y})}{\sum_i (Y_i - \bar{Y})^2} \tag{9}$$

where *i, k* — indexes used to label territories (*i*=1..*N*, *k*=1..*N*); *N* — the number of examined territories, units; $\bar{Y}$ — the average value of indicator; W_{ik} — the binary contiguity matrix.

Moran's index value is compared with the expected value $E(I) = -1 / (n-1)$. If the index is higher than expected, spatial autocorrelation is positive and observation results in neighboring territories are similar. Otherwise, negative autocorrelation is observed; the values of observations in neighboring territories differ. In the case when the value of Moran's index is equal to the expected one, it is considered that the values of observations in neighboring territories are randomly distributed, and the data are not spatially autocorrelated (Moran, 1948).

Estimates of local Moran's index are used to analyze spatial relationships; they allow visually observe clusters of spatially related territories:

1. High-high—the cluster within which municipalities having relatively high values of examined indicators are surrounded by areas with similarly high values of indicators. The spatial correlation is positive.
2. Low-low—the cluster in which municipalities that have low values of examined indicators are surrounded by areas with similarly low values of indicators. The spatial correlation is positive.
3. High-low—the cluster in which municipalities that have high values of examined indicators are surrounded by areas with low values of indicators. The spatial correlation is negative.
4. Low-High—the cluster within which municipalities that have low values of examined indicators are surrounded by areas with high values of indicators. The spatial correlation is negative.

For further analysis, it is essential to understand whether investment in a group of municipalities nested in a certain region can affect investment in municipalities in neighboring regions.

After the confirmation of the existence of data spatial autocorrelation, we construct the model with spatial dependence.

3.1.3. Multilevel model with spatial dependencies

Hierarchy (multilevel) spatial dependence models allow consideration of both hierarchical and spatial data structure. Spatial autocorrelation can be addressed in various ways. If the spatial dependencies are significant, we conduct calculations using HLM 8.0 that includes spatial interaction in errors. To test the hypothesis about the significance of spatial interactions, a zero model does not include predictors but includes a spatial component (Model 4). The hierarchy (multi-level) spatial dependence model is compared with the hierarchy linear model using a special comparison test (Raudenbush et al., 2011).

Then, we include factors related to municipal level to partition spatial effects at municipal and regional scale (Model 5).

On the last step, we compare The Random Intercept and Fixed Slope model with Cross-Level Interaction (Model 3) with a model including spatial error (Model 6) which calculated as follows:

Level 1 (lower, municipalities):

$$Y_{ij} = \beta_{0j} + \beta_{1j}X_{ij} + r_{ij} \quad (10)$$

Level 2 (upper, regions):

$$\beta_{0j} = \gamma_{00} + \gamma_{01}Z_j + b_0 \quad (11)$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11} Z_j \quad (12)$$

Spatial Dependence:

$$b_0 = \lambda W b_0 + u_0 \quad (13)$$

where λ — a spatial correlation parameter; W — the binary contiguity matrix between regions at level 2.

If $\lambda = 0$, then it will be an HLM model with Cross-Level Interaction without spatial dependence. We compare models using the likelihood ratio test and residual variance component. We applied GeoDA (Center for Spatial Data Science, The University of Chicago) and HLM software (Scientific Software International Inc.) to conduct calculations.

3.2. Data

Our study embraces data extracted from 2262 municipalities nested in 83 Russian regions in 2019. The data for closed cities, as well as for some small areas, are absent to ensure confidentiality of primary statistical data received from organizations under the provisions of the Russian Federal State Statistics Service (https://www.gks.ru/dbscripts/munst/). Thus, the study covers 96% of Russian municipalities.

The natural logarithm of investment volume in fixed assets (excluding budgetary funds) per capita is a dependent variable, the explanatory variables are at two levels and presented in table 1.

We include several control variables: population, share of the urban population and production volume per capita at municipal level, population density, agriculture, forestry and fishing fraction in GRP, the share of extractive industries in GRP as characteristics of economic structure on a regional level.

Within our study, we explored the influence of environmental factors on investment. These statistics are not available at a municipal scale; therefore, we included environmental factors at the regional level with an emphasis on studying their cross-level interactions.

Our paper also concerns the relationship between spatial structure and investment in fixed assets. Scholars use a variety of indicators to measure population concentration (Krasnoselskaya and Timiryanova, 2022b). In this study, we use polycentricity/monocentricity indicators to assess spatial structure. The Slope 4 was chosen as a measure of polycentricity that is calculated as the rank-size distribution of the 2^{nd},3^{rd}, and 4^{th} largest municipalities in the region to estimate the slope of the regression line, and then calculated the average of these three scores (Burger and Meijers, 2012). The higher Slope 4 is the monocentric region and vice versa.

Table 1. Description of variables.

Variable	Definition	Level*	Mean	Standard deviation	Min	Max
Dependent variable:						
Y_{ij}	The natural log of average investment volume in fixed assets (excluding budgetary funds) per capita	1	2.81	1.78	−0.69	9.68
Independent variables:						
X_{ij}^1	The natural log of production per capita **	1	−0.27	0.54	−0.69	4.18
X_{ij}^2	The natural log of the volume of investment in fixed capital (excluding budgetary funds) per capita of neighboring municipalities	1	2.85	1.31	−0.66	8.72
Population structure						
X_{ij}^3	The natural log of population	1	3.34	1.01	0.18	9.44
X_{ij}^4	The natural log of share of the urban population	1	2.48	2.29	−0.69	4.91
Z_j^1	Population density (2017–2019)	2	133.57	678.36	0.1	4925.9
Z_j^2	The modulus of Slope 4	2	1.39	0.53	0.27	2.9
Economy structure						
Z_j^3	Agriculture, forestry and fishing fraction in GRP	2	7.91	6.03	0.1	27.3
Z_j^4	The share of extractive industries in GRP	2	11.77	18.87	0	79.2
Ecology						
Z_j^5	The ratio of pollutant emissions into atmosphere from stationary sources to GRP	2	0.21	0.21	0	1.59
Z_j^6	The share of atmospheric pollutants captured and neutralized in total output of pollutants	2	55.29	26.76	0	99.2
Z_j^7	The ratio of the usage of fresh water to GRP	2	0.82	1.18	0.05	8.48
Z_j^8	The ratio of circulating water and sequentially used water to used fresh water	2	4.82	6.45	0	32.61
Z_j^9	The ratio of wastewater discharge into surface water bodies to GRP	2	0.17	0.13	0	0.7
Z_j^{10}	The ratio of environmental protection expenditure to GRP	2	8.46	5.46	0.78	44.21

Note: * 1 — municipal level, 2 — regional level, ** data came from big, medium and state-owned companies.

Source: Federal state statistics service (https://www.gks.ru/dbscripts/munst/), the Unified Interdepartmental Statistical Information System (https://www.fedstat.ru/).

In our study, we raise the question of spatial interactions. First, we assess the weighted volume of neighboring municipalities' investment through a contiguity matrix, which takes into account the municipalities of first-order. Thus, we explore the interconnectedness between municipalities and their neighbors. Second, within the HLM model with spatial dependence, we assess spatial effects at the regional level using an adjacency binary contiguity matrix (W), which takes into consideration the adjacency of first-order territories. The adjacency matrix is suitable for the following assumptions: the Sakhalin region is considered as adjacent to the Primorsk, Khabarovsk, and Kamchatka territories despite the water barrier; the Kaliningrad region is considered as adjacent to the city of St. Petersburg and the Smolensk region. The latter assumption is controversial, but it enables us to include the Kaliningrad region in the study and consider the entire territory of the country as a whole, taking into account sea traffic and between these territories. We made similar assumptions when creating the adjacency binary contiguity matrix at the municipal level, calculated global Moran's I, local Moran's I and assessed weighted average volume of investment in neighboring municipalities.

4. Results

The analysis shows that variance of investment in fixed assets is largely determined by regional specifics. According to Model 1, calculations show that 32% of variance is attributed to region (1.05/(1.05+2.24)). The inclusion of explanatory variables and the subsequent assessment of cross-level interaction allowed us to reduce the unexplained part of this variance to 10% (Table 2).

Table 2. Description of variables.

Variable	HLM			HLM with Spatial Dependence		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant, γ_{00}	2.88***	1.38***	2.03***	2.83***	2.04***	2.04***
X_{ij}^1, γ_{10}		1.85***	2.13***		1 .84***	2.13***
$X_{ij}^1 * Z_{ij}^4$, γ_{11}			−0.01***		0 .12***	−0.01***
X_{ij}^2, γ_{20}		0.13***	0.13***			0.13***
Population structure						
X_{ij}^3, γ_{30}		0.28***	0.2***		0.27***	0.21***
$X_{ij}^3 * Z_{ij}^2$, γ_{31}			0.06*			0.06**
$X_{ij}^3 * Z_{ij}^8$, γ_{32}			−0.008***			−0.008**
X_{ij}^4, γ_{40}		−0.006			−0.004	
Z_j^1, γ_{01}		−0.0004**	−0.0006***			−0.0006***
Z_j^2, γ_{02}		0.32**				
Economy structure						
Z_j^3, γ_{03}		0.009				
Z_j^4, γ_{04}		0.0001				
Ecology						
Z_j^5, γ_{05}		0.34				

Continued on next page

Variable	HLM			HLM with Spatial Dependence		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Z_j^6, γ_{06}		0.0006				
Z_j^7, γ_{07}		−0.12**	−0.11***			−0.11**
Z_j^8, γ_{08}		0.03***	0.05***			0.05***
Z_j^9, γ_{09}		−0.296				
Z_j^{10}, γ_{010}		0.008				
Spatial error, λ				0.67	0.45	0.22
Regular HLM vs. HLM with spatial dependence model comparison test				$\chi 2 = 23.7$ p-value = <0.001	$\chi^2 = 6.35$ p-value = 0.011	$\chi^2 = 0.8$ p-value = >.500
Random effects						
σ^2	1.05	0.19	0.15	0.67	0.20	0.15
τ^2	2.24	1.32	1.31	2.24	1.32	1.31
ICC	0.32	0.13	0.10	0.23	0.13	0.10
Estimation of model quality						
Log likelihood	−4223.7	−3581.1	−3566.7	−4211.6	−3590.5	−3566.3
Deviance	8447.4	7162.2	7133.4	8423.2	7181	7132.6

Note: *** indicates p< 0.01, ** indicates p< 0.05, * indicates p< 0.1.

Model 2 demonstrates that not all factors enrolled within the hypothesis are statistically significant. The population, production per capita and investment in neighboring municipalities have a positive considerable influence on investment. Among ecological factors - the ratio of circulating water and sequentially used water to used fresh water have a positive impact on investment while the relationship between usage of fresh water and investment is negative. Densely-populated and polycentric regions feature relatively low values of investment in fixed assets.

Variable Slope 4 (Z_j^2) showed its insignificance after excluding insignificant factors from the model; its significance in Model 3 is underlined. By sequentially excluding factors, we tested their possible indirect effect on the dependent variable through exploring the cross-level interaction for independent variable and municipal level factors in the context of the possible influence of the regional level factors (Figure.1).

The inclusion of cross-level interaction in Model 3 improved its quality in comparison with Models 1 and 2.

In general, population has a positive effect on investment in Model 2. In Model 3, we consider the coefficient for the population as a function of regional dimension. The high value of population remains its positive impact on investment that is higher for monocentric regions.

Figure 1a demonstrates that the line reflecting the relationship between population and investment in monocentric regions is higher than in polycentric ones with the same population size.

Higher ratio of circulating water and sequentially used water to used fresh water with the same level of population size also determine the high investment. Figure 1b demonstrates that the line reflecting the relationship between population and investment in regions which use more circulating water is higher than in others with the same population size. However, the slope regression shows that the gap for more populated areas is shrinking.

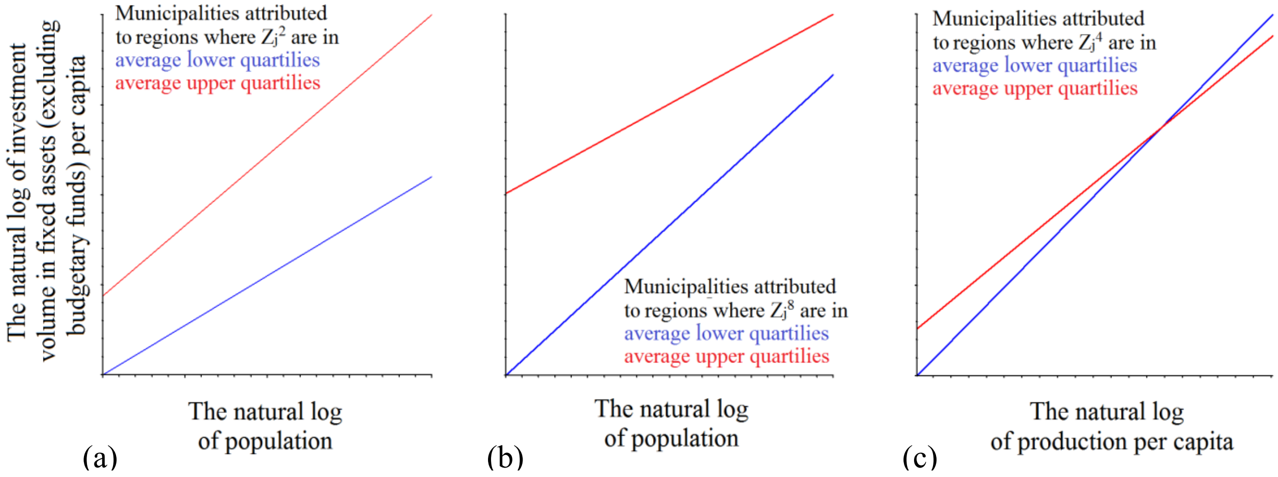

Figure 1. The investment in fixed assets (excluding budgetary funds) per capita, population and production relationships in the regional context: (a) the modulus of Slope 4 (Z_j^2); (b) the ratio of circulating water and sequentially used water to used fresh water per ruble of GRP (Z_j^8); (c) the share of extractive industries in GRP (Z_j^4).

These dependencies are reflected in the value of the population coefficient. In Model 2, the slope of regression determined by β coefficient for X_{ij}^3 is $\beta_3 = \gamma_{30}$=0.28; in Model 3 β is a function of regional dimension: $\beta_3 = \gamma_{30} + \gamma_{31} * Z_j^2 + \gamma_{32} * Z_j^2 = 0.2 + 0.06 * Z_j^2 - 0.008 * Z_j^2$.

A more complex relationship between production and investment features in the context of sectoral structure. The share of extractive industries in GRP was not statistically significant in the Model 2. However, Russia is strongly dependent on extractive industries and production is closely associated with industry specialization of the region.

The relationship between investment and production is dependent on regional industry specialization. Model 3 reveals that investment in municipalities with low production volume are higher with the high share of extractive industries. Moreover, municipalities with high production volume have low investment while the share of industry specialization is high. The slope of regression determined by β coefficient on X_{ij}^1 is a function of regional dimension: β_1=2.13-0.01 * Z_{ij}^4. Figure 1c demonstrates that the line reflecting the relationship between production and investment in regions with higher share of extractive industries is higher if they have low production volume, but it lower if they have high production volumes.

Calculations of the global Moran's index show a spatial dependence of the investment (Im = 0.388). Figure 2 illustrates spatial clusters based on local Moran's index. The cluster map augments the significant locations with an indication of the spatial association type. The regional boundaries are highlighted with a thicker line; spatial clusters overstep the boundaries encouraging investment of neighboring regions.

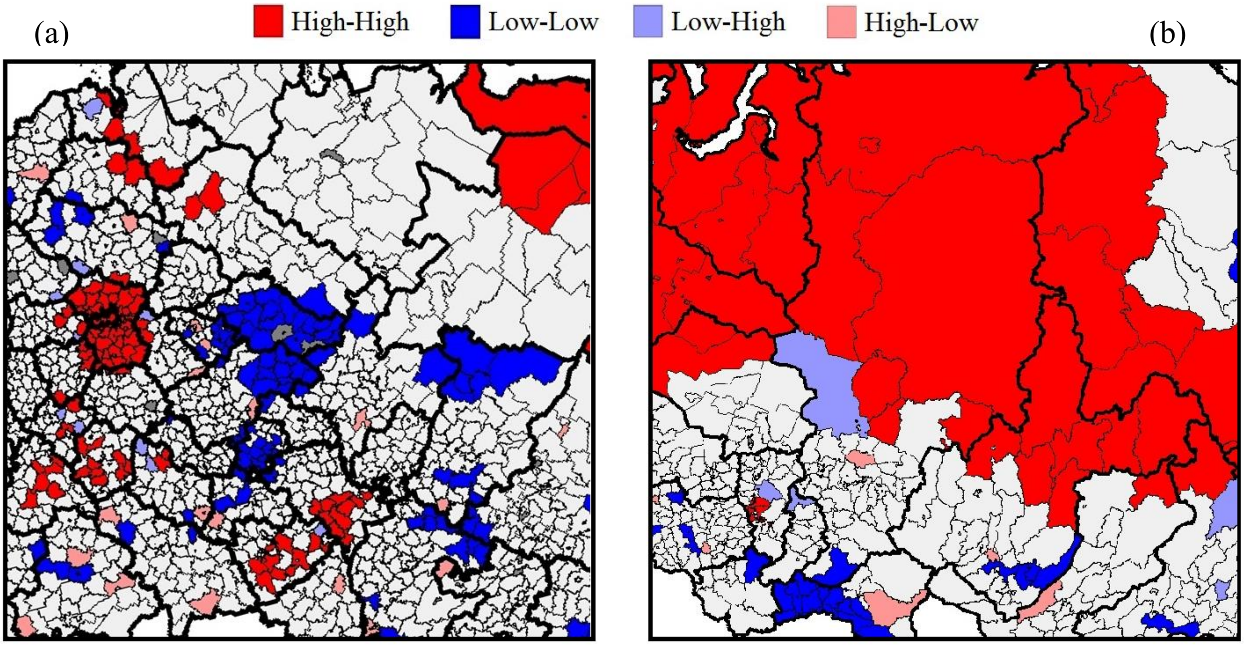

Figure 2. Local Moran's index for investment per capita, 2019: (a) the east part of Russia (b) Siberian part of Russia.

We included an estimate of the spatial error at the regional level in the null model to assess the significance of spatial relationships. Model 4 shows the significance of spatial error. In the next step, we enrolled all variables related to municipal scale including the investment amount of neighboring municipalities. Model 5 demonstrates the significance of investment in adjacent municipalities, while spatial error is statistically significant at regional level (Regular HLM vs. HLM with spatial dependence model comparison test: $\chi^2 = 6.35$, p-value = 0.011). Furthermore, the overall estimate of spatial error in the Model 6 that embraces regional factors and cross-level interaction reduced and became insignificant (Regular HLM vs. HLM with spatial dependence model comparison test: $\chi^2 = 0.8$, *p*-value = >0.500).

5. Discussion

Our study yields three essential findings.

First, we were interested in exploring the relationship between ecological factors and investment. Existing developments focus on investment impact on ecological dimension of territories (Okuma, 2019; Martini, 2021; Aghasafari et al., 2021; Zhang et al., 2023). However, we focus on the question if territories' ambitions to improve the ecology and responsible attitude to nature regulated by governmental restrictions influence investment attractiveness. Previous studies show that the influential effect of environmental regulation on the investment may have notable regional differences (Yang et al., 2019). We suppose that in regions actively using water reuse technologies, wastewater treatment plants and other environmental protection tools with a population aware of compliance with environmental standards in enterprises, enterprises will have less effort to implement the necessary environmental standards and they can invest gained savings in their development.

Constructed models showed that only factors related to usage of water were significant. Investment is positively associated with low use of freshwater per ruble of GRP and high values of the ratio of circulating water and sequentially used water to used fresh water. Thus, investment is higher in regions that demonstrate responsible attitudes to water resources use. Furthermore, pollutant emissions into the atmosphere and environmental protection expenditure showed their insignificance.

Second, we put emphasis on complex settlement patterns in Russia and their influence on investment. We enrolled four variables reflecting them: population size, share of the urban population in municipalities, population density and measures of polycentricity/monocentricity at a regional scale. Unlike other countries, these measures do not correlate in Russia (Appendix A).

It is assumed that the higher the population size, the larger the share of the urban population. This assumption is valid for the first 100 municipalities ranked by population out of the 2262 analyzed. It is not like that for the other municipalities. For instance, in Krasnoarmejskij rajon of Krasnodarskij kraj and gorodskoj okrug Berdsk Novosibirskaja oblast' embrace about 104 000 people. However, in the first case, the share of the urban population is 0%; in the second case it is 100%. Among the five smallest municipalities in terms of population, two of them have a share of urban population close to 100%. It is closely connected with peculiarities of the north and south.

In the north, people live in small cities while the share of indigenous minorities of the North is small and these people live outside the cities. In the south, many farming people live in suburban areas. Ultimately, there may be different settlement types: rural or urban while the population size is equal. The population density and the settlement structure do not correlate. In Russia, regions with the equal population density may be both polycentric (Jamalo-Nemeckij avtonomnyj okrug, Kemerovskaja oblast) or monocentric (Magadanskaja oblast, Ryazan Region (Krasnoselskaya and Timiryanova, 2022a, 2022b). Extractive industries contribute significantly to GDP; mining operations are usually carried out in the difficult conditions of the northern regions with a low population density. Therefore, in the models, the coefficient on population density is negative, indicating that there is more investment in the less populated northern areas endowed with petrol carbons. Furthermore, the population size has a positive effect on investment that is in line with the previous studies (Alsan et al., 2006; Perovic-Randelovic et al., 2017). Thus, considering both north and south, we can infer that the larger the municipality in relation to its neighbors, the higher the investment is. The share of urban population is insignificant that could be explained by different historical and climate conditions of settlement pattern formations in the north and south. Moreover, the monocentric structure has a positive impact on investment.

Third, we highlight spatial effects, trying to distinguish them from municipal and regional ones. In Model 6, the spatial error is insignificant at the regional scale. It is worth noting how spatial error is estimated at the regional level in the multilevel modeling with spatial dependence. The model error is decomposed into two parts, one of which has a spatial correlation ($b_0 = \lambda W b_0 + u_0$). In fact, spatial error autocorrelation established in Models 4 and 5 shows that some unenrolled factors of neighboring territories are similar and, therefore, they could have spatial dependence. However, spatial error autocorrelation occurs not because of mutual influence of territories, but due to similar territorial conditions. Multilevel modeling can explain the part of spatial autocorrelation throughout regional factors due to assessments of group effects.

In Model 6, which includes regional factors and cross-level interaction, the overall estimate of the spatial effect reduced and became insignificant (Regular HLM vs. HLM with spatial dependence model comparison test: $\chi^2 = 0.8$, p-value = > 0.500). Statistical estimates of Model 6 vary slightly from

Model 3. Thus, we conclude that the major cause of spatial effects in Model 5 is regional factors embedded in Model 6 that are similar in neighboring regions.

6. Conclusions

Investment as a part of national income predetermines the future developments of national accounts. The purpose of our study was to investigate the future development of investment by analyzing existing critical issues and considering the objectives set by the sustainable development goals while considering the environmental impact.

Our findings show that investment is associated with usage of water, but there is no relationship between investment and pollutant emissions into the atmosphere. The vast national territory determines different factors of investment growth; the relationship could vary for regions with monocentric and polycentric settlement patterns and high and low share of extractive industries. The volume of investment depends on these volumes in neighboring municipalities while spatial error autocorrelation at the higher level of the territorial hierarchy (regional level) can be explained by general regional conditions, but not by the proximity of regions.

However, our study has drawbacks. Because of the lack of official statistics' availability, we include ecological factors at the regional scale. Sustainable development encompasses not only ecological dimensions, but social ones which were, not included in this study. Future lines of research could focus on: a) including economic and social dimensions into spatial models; b) assessment of mutual and separate impacts of economic, social and environmental pillars on sustainable regional development and standards of living; c) prioritization of regional policies according to the role and impact of each dimension.

Despite the noted drawbacks, our findings contribute to a better understanding of the territorial context in attracting investment for the national income growth within the country as a whole.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

Conflict of interest

All authors declare no conflicts of interest in this paper.

References

Abdelmoula M, Etienne JM (2010) Determination of R&D investment in French firms: a two-part hierarchical model with correlated random effects. *Econ Innov New Technol* 19: 53–70. https://doi.org/10.1080/10438590903016435

Aghasafari H, Aminizadeh M, Karbasi A, et al. (2021) CO_2 emissions, export and foreign direct investment: empirical evidence from Middle East and North Africa region. *J Int Trade Econ Dev* 30: 1054–1076. https://doi.org/10.1080/09638199.2021.1934087

Aguinis H, Gottfredson RK, Culpepper SA (2013) Best-practice recommendations for estimating cross-level interaction effects using multilevel modeling. *J Manage* 39: 1490–1528. https://doi.org/10.1177/0149206313478188

Alsan M, Bloom DE, Canning D (2006) The effect of population health on foreign direct investment inflows to low- and middle-income countries. *World Dev* 34: 613–630. https://doi.org/10.1016/j.worlddev.2005.09.00

Andersson S, Svensson G, Molina-Castillo F, et al. (2022) Sustainable development—Direct and indirect effects between economic, social, and environmental dimensions in business practices. *Corp Soc Responsib Environ Manag* 29: 1158–1172. https://doi.org/10.1002/csr.2261

Brundtland G (1987) *Our common future: The world commission on environment and development*, Oxford, England: Oxford University Press.

Burger M, Meijers E (2012) Form follows function? Linking morphological and functional polycentricity. *Urban Stud* 49: 1127–1149. https://doi.org/10.1177/0042098011407095

Cheng Z, Li L, Liu J (2018) The spatial correlation and interaction between environmental regulation and foreign direct investment. *J Regul Econ* 54: 124–146. https://doi.org/10.1007/s11149-018-9366-x

Cheng Z, Li L, Liu J (2020) The impact of foreign direct investment on urban PM2.5 pollution in China. *J Environ Manage* 265: 110532. https://doi.org/10.1016/j.jenvman.2020.110532

Cicea C, Marinescu C (2020) Bibliometric analysis of foreign direct investment and economic growth relationship. A research agenda. *J Bus Econ Manag* 22: 445–466. https://doi.org/10.3846/jbem.2020.14018

Elkington J (1997) *Cannibals with forks – Triple bottom line of 21st century business*. Stoney Creek, CT: New Society Publishers.

Garson D (2013) *Hierarchical linear modeling: guide and applications*, New York: Sage Publications.

Goldstein H (2010) *Multilevel statistical models*, 4th ed. Hoboken: Wiley.

Huta V (2014) When to use hierarchical linear modeling. *Quant Meth Psychol* 10: 13–28. https://doi.org/10.20982/tqmp.10.1.p013

Kamenju AK, Olweny DrT (2021) The nexus between internal investment and economic growth in Kenya. *J Appl Financ Bank* 11: 29–93. https://doi.org/10.47260/jafb/1122

Kaneko Y, Nakagawa T, Phun VK, et al. (2019) Impacts of urban railway investment on regional economies: evidence from Tokyo using spatial difference-in-differences analysis. *Transp Res Rec* 2673: 129–140. https://doi.org/10.1177/0361198119846098

Kashefi-Pour E, Amini S, Uddin M, et al. (2020) Does Cultural Difference Affect Investment—Cash Flow Sensitivity? Evidence from OECD Countries. *Br J Manag* 31: 636–658. https://doi.org/10.1111/1467-8551.12394

Kleineick J, Ascani A, Smit M (2020) Multinational investments across Europe: a multilevel analysis. *Rev Reg Res* 40: 67–105. https://doi.org/10.1007/s10037-020-00139-2

Krasnoselskaya D, Timiryanova V (2022a) Do polycentric patterns influence the economic performance of municipalities? Empirical evidence from Russia. *Reg Sci Policy Pract* 14: 1201–1222. https://doi.org/10.1111/rsp3.12515

Krasnoselskaya D, Timiryanova V (2022b) Estimate of settlement systems polycentricity: sensitivity to methods, number of observations and a level of data aggregation. *Vestnik Magnitogorskogo Gosudarstvennogo Tekhnicheskogo Universiteta im. G.I. Nosova [Vestnik of Nosov Magnitogorsk State Technical University]* 20: 144–153. https://doi.org/10.18503/1995-2732-2022-20-4-144-153

Ledyaeva S (2009) Spatial econometric analysis of foreign direct investment determinants in Russian regions. *World Econ* 32: 643–666. https://doi.org/10.1111/j.1467-9701.2008.01145.x

Liu X, Yu L, Zhang Y, et al. (2020) Spatial spillover effect of financial flexibility on investment in China's convention and exhibition listed companies. *Math Probl Eng* 3926747: 1–10. https://doi.org/10.1155/2020/3926747

Martini A (2021) Socially responsible investing: from the ethical origins to the sustainable development framework of the European Union. *Environ Dev Sustain* 23: 16874–16890. https://doi.org/10.1007/s10668-021-01375-3

Moran P (1948) The Interpretation of Statistical Maps. *J R Stat Soc* 10: 243–251. https://doi.org/10.1111/j.2517-6161.1948.tb00012.x

Ndikumana L (2000) Financial determinants of domestic investment in Sub-Saharan Africa: evidence from panel data. *World Dev* 28: 381–400. https://doi.org/10.1016/s0305-750x(99)00129-1

Nogueira E, Gomes S, Lopes JM (2022) The key to sustainable economic development: a triple bottom line approach. *Resources* 11: 46. https://doi.org/10.3390/resources11050046

Ofosu-Mensah Ababio J, Sarpong-Kumankoma E, Osei KA (2018) Financing cost and private investment in Ghana. *Adv Econ Bus* 6: 99–113. https://doi.org/10.13189/aeb.2018.060203

Okuma K (2019) Potential mechanisms for the social regulation of economies on global and local scales: an institutional analysis of ESG investment and community renewables. *Evolut Inst Econ Rev* 16: 523–541. https://doi.org/10.1007/s40844-019-00133-5

Pain K, Shi Sh, Black D, et al. (2023) Real estate investment and urban density: exploring the polycentric urban region using a topological lens. *Territ Politic Gov* 11: 241–260. https://doi.org/10.1080/21622671.2020.1837665

Perovic-Randelovic M, Jankovic-Milic V, Kostadinovic I (2017) Market size as a determinant of the foreign direct investment inflows in the Western Balkans Countries. *Facta Univ Ser Econ Organ* 14: 93–104. https://doi.org/10.22190/FUEO1702093P

Raudenbush SW, Bryk AS, Cheong YF, et al. (2011) *HLM 7: Hierarchical Linear and Nonlinear Modeling*. Scientific Software International, Inc.: Linconwood, IL, USA.

Rossi MCT, Santos GF, Campos FAS (2016) Foreign direct investment and spatial linkages: third-country effects for Brazilian outward investment. *Lat Am Bus Rev* 17: 1–25. https://doi.org/10.1080/10978526.2015.1137460

Schweikert A, Espinet X, Chinowsky P (2018) The triple bottom line: bringing a sustainability framework to prioritize climate change investments for infrastructure planning. *Sustain Sci* 13: 377–391. https://doi.org/10.1007/s11625-017-0431-7

Stundziene A, Baliute A (2022) Link between tangible investment rate and labour productivity in the European manufacturing industry. *Panoeconomicus* 69: 609–633. https://doi.org/10.2298/PAN171208012S

Tafirenyika S (2023) The impact of foreign direct investment on Namibia's economic growth: A time series investigation. *Cogent Econ Finance* 11: 1. https://doi.org/10.1080/23322039.2023.2210857

Yang Y, Niu G, Tang D, et al. (2019) Does environmental regulation affect the introduction of foreign direct investment in China? — Empirical Research Based on the Spatial Durbin Model. *Pol J Environ Stud* 28: 415–424. https://doi.org/10.15244/pjoes/83692.

Zhang L, Zhang Z, Bieryt K, et al. (2023) Sustainable green financial system perspective of environmental protection investment and the government's environmental policy or public participation: evidence from Chinese A-share listed companies. *Econ Res-Ekon Istraž* 36: 2. https://doi.org/10.1080/1331677X.2023.2178019

Zubarevich N (2019) Inequalities of regions and large cities of Russia: what was changed in the 2010? *Obshchestvennye Nauki I Sovremennost* 4: 57–70. https://doi.org/10.31857/S086904990005814-7