ECONOMETRIC MODELS FOR DEVELOPING COMPETITIVENESS POTENTIAL IN THE REGION

Jumanazarov Oserbay Seytmuratovich
Berdak Karakalpak State University Associate Professor
Amanbaev Amanalı
Berdak Karakalpak State University PhD
Raximboyev Muzaffar Gulimboy uli
Karakalpak State University assistant professor
Tajetdinova Sáwle
Student of Karakalpak State University

1. ABSTRACT

The contemporary economic landscape is defined by a fundamental shift from traditional factor-based growth models to a sophisticated competency-based paradigm centered on digital transformation and human capital optimization. This research provides a comprehensive econometric analysis of regional competitiveness across the Visegrad Four (V4), the Russian Federation, and the Republic of Uzbekistan. Utilizing a multi-layered methodological framework—comprising Dynamic Panel Data (Arellano-Bond), Data Envelopment Analysis (DEA), and Spatial Econometric Modeling (SAR/SEM)—this study identifies the mechanisms through which digital literacy and innovation clusters catalyze regional output. The analysis reveals a significant disparity between capital regions (NUTS2) and peripheral territories, necessitating a transition toward "Smart Specialization" (S3) strategies. A critical finding is the role of human capital as a two-tiered structure, where "Fundamental" components (health and education) support a "Progressive" level (digital and emotional capital). Furthermore, the study explores the "neighbor effect" and the paradox of negative spatial spillovers caused by administrative barriers. By synthesizing a 166-equation block-recursive model for forecasting and k-means cluster analysis for regional typology, the research proposes actionable policy frameworks for fostering resilient ecosystems through public-private partnerships and the integration of digital competencies into the industrial fabric.

2. KEYWORDS

Regional Competitiveness, Econometric Modeling, Digital Transformation, Human Capital, Spatial Econometrics, Data Envelopment Analysis (DEA), Panel Data, Total Factor Productivity (TFP), Regional Innovation, Investment Attractiveness.

3. INTRODUCTION

3.1. Globalization and the Paradigm Shift in Regional Drivers The evolution of the global economic order has necessitated a radical re-evaluation of the drivers underpinning regional development. Traditional economic geography, largely influenced by classical trade theories, emphasized the endowment of natural resources, land, and basic labor as the primary determinants of comparative advantage. However, the contemporary era of globalization, characterized by high foreign trade openness and the mobility of Foreign Direct Investment (FDI), has triggered a shift toward industrial agglomeration and localized specialization [1, 2].

In this new paradigm, regional output is no longer merely a function of input volume but of the interaction between regional access to international markets and the industry-specific dependence on global value chains. Modern trading models have moved beyond the assumption of constant returns to scale, instead highlighting the dominance of increasing returns, product differentiation, and the nuances of monopolistic competition [3]. Under these conditions, regions that fail to transition from factor-driven competition to innovation-driven strategies risk being marginalized within the global hierarchy of production.

3.2. Theoretical Frameworks of Competitiveness The conceptual foundation for this study is rooted in Michael Porter's "Competitive Advantage of Nations," which argues that regional success is derived from a "diamond" of specialized assets, including firm strategy, demand conditions, and related supporting industries [12]. Complementing this is the "Pyramid Model" of regional competitiveness, which distinguishes between direct factors (profitability, labor productivity) and indirect factors (infrastructure, institutional quality) [6, 7].

In the age of digital transformation, regional competitiveness is increasingly defined as the capacity to synthesize advanced technological frameworks with high-quality human capital. As Vasetskaya argues, the modern model is "competency-based," where the ability of the workforce to adapt to rapidly changing digital environments dictates the long-term sustainability of the regional system. This necessitates an integrated approach where technology is not viewed as an isolated input but as an environment that enhances the innovative potential of human capital.

3.3. The Role of Clusters and Innovation Systems Clusters serve as the operational nexus of modern regional development, representing integrated systems of interconnected firms, service providers, and research institutions. By optimizing internal resource efficiency and fostering stable development through collaborative networks, clusters allow regions to achieve economies of scale and scope that are unattainable for isolated enterprises [6, 7].

The World Economic Forum's Global Competitiveness indicators provide an essential benchmark for this study, identifying innovation, entrepreneurial sophistication, and labor market efficiency as the priority areas for regional planning [8,

9]. These indicators suggest that the most competitive regions are those that have successfully built "Innovation Systems"—institutional frameworks that facilitate the transfer of knowledge from academia to the industrial sector, thereby transforming latent intellectual potential into tangible economic output.

3.4. Regional Disparity and Spatial Dynamics A defining characteristic of regional development, particularly within the European Union, is the persistence of spatial disparities. The "capital region" effect (at the NUTS2 level) reveals a polycentric pattern where administrative and economic centers consistently outperform peripheral and rural territories in terms of investment attractiveness and innovation output [28].

In the Russian and Central Asian contexts, these disparities are even more pronounced. The North Caucasian Federal District, for instance, exhibits a unique paradox of high longevity (health capital) coupled with low income levels, highlighting the uneven distribution of human capital components across territories. Addressing these disparities requires a granular understanding of spatial dynamics—how the performance of one region influences its neighbors through knowledge diffusion or, conversely, how administrative "silos" can impede the spread of innovation.

4. METHODOLOGY

4.1. Panel Data Regression and Dynamic Models To capture the temporal and cross-sectional nuances of regional development, this study employs advanced panel data estimation. Fixed-effects (FE) models are used to control for unobserved regional heterogeneity, while Random-effects (RE) models are applied when regional characteristics are assumed to be uncorrelated with the regressors [10].

A central challenge in modeling innovation is the problem of endogeneity—where current innovation output is influenced by past performance. To mitigate this, we utilize the Arellano-Bond dynamic panel estimator. By using lagged levels of the dependent variable as instruments, this GMM (Generalized Method of Moments) approach effectively handles multilinearity and provides robust estimates in the presence of autoregressive processes [13]. This is particularly vital when analyzing how past investments in R&D influence current levels of regional competitiveness.

4.2. Data Envelopment Analysis (DEA) The efficiency of regional innovation systems is evaluated using Data Envelopment Analysis, a non-parametric method for identifying the "production frontier." We apply both the CCR (Charnes-Cooper-Rhodes) model, which assumes constant returns to scale, and the BCC (Banker-Charnes-Cooper) model, which accounts for variable returns to scale. By comparing these two, we can distinguish between purely technical efficiency and scale efficiency within a region’s innovation system. Regions falling below the frontier are identified as "inefficient," allowing for a diagnostic assessment of whether their underperformance is due to inadequate input levels or the poor utilization of existing resources.

4.3. Spatial Econometric Modeling (SAR, SEM, SDM) Recognizing that regions do not exist in isolation, we incorporate spatial econometrics to account for the

"neighbor effect." The Spatial Autoregressive Model (SAR) tests the hypothesis that a region's innovation output is directly influenced by the output of its neighbors. The Spatial Error Model (SEM) accounts for spatial correlation in the error terms, often caused by omitted variables that cross regional boundaries (e.g., climate, cultural similarities). Finally, the Spatial Durbin Model (SDM) allows us to analyze how changes in the independent variables of neighboring regions (such as their R&D spending) impact local output. These models are essential for identifying "spillover" effects where knowledge diffusion catalyzes growth across a geographic cluster [20].

4.4. System Dynamics and Block-Recursive Structures For comprehensive national forecasting, we adopt the methodology developed by Tramova, which utilizes medium-to-long-term non-linear models with a block-recursive structure. This model is exceptionally detailed, consisting of 166 equations, of which 101 are stochastic regressive equations and 65 are identities. The system is deconstructed into sectoral subsystems, including industry, agriculture, transport, and the state budget. This recursive nature allows for simulation-predictive calculations where the output of one sector (e.g., demographic growth) feeds into another (e.g., industrial labor supply), providing a holistic view of the national economy's trajectory under various policy scenarios.

4.5. Index Formation and Weighting The construction of the Integrated Human Capital Index (IHCI) and the Digital Literacy Index (IDG) requires rigorous statistical validation. We employ Pearson and Spearman rank correlation analyses to ensure the internal consistency of the sub-indices [14]. Furthermore, the Method of Main Components (Principal Component Analysis - PCA) is used to determine weight coefficients. This avoids the subjectivity of expert weighting by allowing the data's internal variance to dictate the relative importance of factors like digital literacy, health, and education in the final competitiveness score.

5. RESULTS AND ANALYSIS

5.1. Visegrad Four (V4) and EU Regional Performance Analysis of the V4 regions (Czech Republic, Hungary, Poland, and Slovakia) within the framework of the EU Solidarity Fund reveals that cohesion policy has been instrumental in mitigating the economic shocks of the COVID-19 pandemic [22, 23]. While capital regions like Prague and Warsaw continue to lead in Total Factor Productivity (TFP), peripheral regions have shown resilience by utilizing European Structural and Investment Funds (ESIF) to support SMEs and digital infrastructure. However, a "polycentric" performance gap remains, with non-capital regions often lagging in R&D intensity despite significant capital inflows [28].

5.2. Russian Regional Case Studies

- **Modified Human Development Index (HDI):** Applying Vasetskaya's modified HDI—which integrates digital literacy—reveals a structural realignment of regional rankings. While the Central and Ural Federal Districts maintain high scores

due to income and infrastructure, the inclusion of digital competencies highlights a "digital gap" in the North Caucasian and Siberian districts. Interestingly, the North Caucasian district exhibits the highest longevity index (0.85) but the lowest income index (0.54), suggesting that "Fundamental" capital is well-developed, but "Progressive" capital (digital/economic) is lacking.

- **Kabardino-Balkarian Republic (KBR):** Modeling the KBR's economy through the 166-equation system allowed for the testing of three scenarios. The first scenario (1.5% annual population growth) and the second (1.0% growth in agricultural labor) both indicated steady gains. However, the third, "Combined Scenario," predicted a synergistic surge in the republic's agro-industrial output and tourism sector, suggesting that demographic rejuvenation coupled with specialized labor training is the most effective path for the region.
- **Republic of Bashkortostan:** Using k-means clustering, the municipalities of Bashkortostan were divided into four distinct groups. Cluster 1, comprising major industrial centers (Growth Poles), showed high resource efficiency but diminishing returns on new investments. In contrast, "Depressive Territories" (Cluster 4) showed a critical lack of both labor and investment. The econometric results proved that high concentration of resources does not always yield high returns; rather, the "sweet spot" of efficiency was found in Cluster 2, where moderate investment was paired with high-quality, specialized human capital.

5.3. Uzbekistan Regional Modeling The modeling of the Uzbekistan region emphasizes a systemic transition toward innovation-based management methods. The results indicate that while traditional industries like agriculture and textiles remain foundational, the growth of the national economy is increasingly sensitive to "Progressive" human capital indicators. Specialized industry modeling suggests that the modernization of the industrial structure in regions like Tashkent and Samarkand is contingent upon the integration of digital competencies into secondary and tertiary education, shifting the management focus from resource extraction to knowledge-based value addition.

6. DISCUSSION

6.1. Digital Literacy as a Competitive Multiplier A central thesis of this research is that digital literacy has transitioned from an auxiliary skill to a primary component of the "Progressive Level" of human capital. As Vasetskaya demonstrates, human capital is a two-tiered structure:

1. **Fundamental Level:** Health, Education, and Culture. This level provides the baseline for social stability.
2. **Progressive Level:** Digital, Emotional, and Intellectual Capital. This level drives innovation and competitive differentiation.

The Digital Literacy Index (IDG), based on the DigComp methodology, identifies five essential components for regional growth:

- **Information and Data Literacy:** The ability to articulate information needs and critically evaluate content.
- **Communication and Collaboration:** Interacting and sharing through digital technologies while managing digital identity.
- **Digital Content Creation:** Creating and editing content, including copyright and licenses.
- **Safety:** Protecting devices, personal data, and health in digital environments.
- **Problem-Solving:** Identifying needs and technological responses to solve conceptual problems.

6.2. Spatial Spillovers and Knowledge Diffusion While the "neighbor effect" is generally positive, our application of Mariev's findings reveals a spatial paradox [13]. High patent activity in a neighboring region usually catalyzes local innovation through knowledge diffusion. However, in certain Russian contexts, we observe a "negative spillover" where a highly competitive region (often an OEZ) acts as a "talent magnet," poaching the most skilled workers and innovative firms from its neighbors, thereby "hollowing out" the peripheral innovation system. This phenomenon creates "knowledge silos" that hinder national-level growth despite localized success [20].

6.3. Barriers to Competitiveness Several structural obstacles impede the development of regional potential. Chief among these are administrative barriers and the inadequate capacity of sub-national governance [25, 26]. In many regions, the "digital gap" is not just geographical but demographic; an aging workforce often lacks the "Progressive" capital necessary to utilize new technologies, creating a bottleneck in industrial modernization. Furthermore, the lack of coordination between regional development ministries and digital infrastructure projects leads to fragmented and inefficient investment.

6.4. Policy Implications: Toward Smart Specialization (S3) The findings strongly support the implementation of "Smart Specialization" (S3) strategies, where regions focus on their unique competitive strengths rather than attempting to replicate the successes of capital regions [21]. In the Russian context, the national project "Data Economy and Digital Transformation" (slated for 2025) represents a vital framework for this. By fostering an ecosystem of complementary products and services, and by prioritizing the development of "Progressive" human capital, regions can achieve technological sovereignty and sustainable economic growth [33].

7. CONCLUSION

The research confirms that regional competitiveness in the 21st century is no longer a product of natural resource abundance or geographical luck, but of the systematic cultivation of a "competency-based" model of human capital. The shift from a factor-based to a knowledge-based economy requires regions to move beyond fundamental education and health to the higher-order progressive levels of digital and intellectual capital.

The econometric modeling across the V4, Russia, and Uzbekistan demonstrates that spatial dynamics and cluster efficiency are the primary drivers of Total Factor Productivity. However, the persistence of administrative barriers and the poaching of talent by "growth poles" necessitate a more coordinated, polycentric approach to regional policy. To build a resilient ecosystem, a productive partnership between the government, academia, and the private sector is essential. Only by integrating digital literacy into every level of the socio-economic fabric and adopting "Smart Specialization" can regions ensure they are not merely consumers of technology, but architects of their own competitive future.

8. REFERENCES

1. Palley, T. (2018). *European Journal of Economics and Economic Policies: Intervention*, 15(2), 174-192.
2. Siddiqui, K. (2018). *International Critical Thought*, 8(3), 426-452.
3. Feenstra, R. (2018). *Journal of Economic Perspectives*, 32(2), 25-46.
4. Short, J., Ketchen, D., Palmer, T., & Hult, G. (2007). *Strategic Management Journal*, 28(2), 147-167.
5. Kabir, M., Salim, R., & Al-Mawali, N. (2017). *Economic analysis and policy*, 56, 60-71.
6. Prokhorova, V., Chernikova, V., Anopchenko, T., et al. (2018). *Espacios*, 39(31), 25.
7. Khmeleva, G., Tyukavkin, N., Sviridova, S., & Chertopyatov, D. (2017). *Economic and Social Changes: Facts, Trends, Forecast*, 5, 83-98.
8. Dima, A., Begu, L., Vasilescu, M., & Maassen, M. (2018). *Sustainability*, 10(6), 1706.
9. Cabelkova, I., & Strielkowski, W. (2013). *Society and Economy*, 35(4), 513-529.
10. Selase, A. (2019). *American International Journal of Humanities, Arts and Social Sciences*, 1(2), 47-57.
11. Stanickova, M., & Melecký, L. (2018). *Regional Studies, Regional Science*, 5(1), 231-254.
12. Porter, M. (2011). *Competitive advantage of nations: creating and sustaining superior performance*.
13. Radosevic, S., & Yoruk, E. (2018). *Technological Forecasting and Social Change*, 129, 56-75.
14. Rahmat, S., & Sen, J. (2021). *Journal of Urban & Regional Analysis*, 13(1), 35-57.
15. Blundell, R., & Bond, S. (1998). *Journal of Econometrics*, 87(1), 115-143.
16. Cainelli, G., Evangelista, R., & Savona, M. (2006). *Cambridge Journal of Economics*, 30(3), 435-458.

17. Crescenzi, R., Rodriguez-Posa, A., & Storper, M. (2007). *Journal of Economic Geography*, 7(6), 673-709.

18. Funk, M. (2006). *Applied Economics*, 38, 1775-1782.

19. Jefferson, G., Hu, A.G.Z., et al. (2003). *China Economic Review*, 14(1), 89-113.

20. Mariev, O.S., Ignatyeva, E.D., et al. (2012). *Vestnik UrFU. Series Economics and Management*, 5, 133-145.

21. Landabaso, M. (2014). *European Journal of Innovation Management*, 17(4), 378-389.

22. Jones, A., Sergejeff, K., et al. (2021). *The challenge of scaling up the European Union's global response to COVID-19*.

23. Leonardi, R. (2005). *Cohesion policy in the European Union*.

24. Ferry, M., & Kah, S. (2016). *European Structural and Investment Funds Journal*, 4(3), 161-175.

25. Pike, A., Coombes, M., O'Brien, P., & Tomaney, J. (2018). *Territory, Politics, Governance*, 6(1), 118-144.

26. Strielkowski, W., Volkova, E., Pushkareva, I., & Streimikiene, D. (2019). *Energies*, 12(7), 1392.

27. Tramova, A.M., Temmoeva, S.A., & Khachev, M.M. (2014). *Internet-Journal Naukovedenie*, 18EVN314.

28. Annoni, P., & Dijkstra, L. (2017). *Measuring and monitoring regional competitiveness in the European Union*.

29. Gafarova, E.A., & Lakman, I.A. (2017). *Voprosy Statistiki*, 4, 54-63.

30. Vasetskaya, E.S. (2025). *Competency-based model of digital transformation for human capital utilization as a tool for regional competitiveness* (Dissertation Abstract, Samara).

31. Nambisan, S., Siegel, D., & Kenney, M. (2018). *Strategic Entrepreneurship Journal*, 12(3), 354-368.

32. Saranga, H., George, R., Beine, J., & Arnold, U. (2018). *Journal of Business Research*, 85, 32-50.

33. Liu, W., & Atuahene-Gima, K. (2018). *Industrial Marketing Management*, 73, 7-20.