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Smart Cities and Regional Development in Kazakhstan: Assessment of Spatial Transformation

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ABSTRACT

The smart city paradigm has attained international visibility as a multidimensional policy framework for overcoming urbanization problems via the convergence of digital technologies, sustainable infrastructure, innovation systems, and data-driven management. This study aims to evaluate the spatial capacity of Kazakhstan's regions for implementing smart city initiatives using enterprise-level data from the 2024 World Bank Enterprise Survey (B-READY). The paper uses five dimensions of smart city readiness: digitalization, infrastructure reliability, environmental sustainability, innovation potential, and management efficiency. Based on the application of multifactorial linear regression with regional fixed effects, significant interregional differences have been identified. Thus, the share of electronic payments in Astana reaches 74.5%, while in the northern regions it is only 65.0%. A statistically significant negative relationship has been established between innovation activity and the level of digitalization ($\beta = -18.26$, $p = 0.023$), which may indicate a sectoral segmentation of the digital economy. Cluster analysis, based on standardized values of five smart city readiness indicators, allowed the regions of Kazakhstan to be grouped into three clusters, each of which reflects a different level of institutional, digital and infrastructural readiness to implement the concept of smart cities. The research contributes to the sparse empirical literature on smart city readiness in Central Asia by providing a firm-level, quantitative evaluation of spatial inequalities and institutional drivers. Policy recommendations include targeted infrastructural investments, support for innovation, and administrative reform in underperforming regions. Subsequent research should integrate longitudinal data and citizen-level surveys to better contextualize Kazakhstan's urban digitalization.

KEYWORDS: Smart City, Digital Economy, Digital Policy, Innovation Capacity, Business Environment, Urban Governance, Kazakhstan

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1. INTRODUCTION

In recent decades, the processes of urbanization have become global, accompanied by an increase in urban population, increasing complexity of infrastructure systems and increasing demands on the quality of the urban environment. In response to these challenges, the concept of a "smart city" is being formed, combining digital technologies, sustainable development and innovative management to increase the efficiency and sustainability of urban spaces. The integration of digital solutions into urban planning is becoming an integral part of national and regional strategies, especially in countries seeking to modernize their economies and institutional environments. In response to these multifaceted challenges, the “smart city” has materialized as an innovative policy and research agenda that amalgamates digital technologies, sustainable infrastructure, innovation ecosystems, and data-driven governance systems in order to enhance the quality of urban life (Albino et al., 2015; Nam & Pardo, 2011). At its root, the smart city ideal changes the emphasis from technological determinism to human-centred development, where digital technologies are harnessed not simply for operational efficiency, but rather to promote equity, participatory governance, and economic competitiveness.

In this international context, Kazakhstan, the world's largest landlocked state and a key economy in Central Asia, has progressively adopted the smart city agenda as a component of its wider digital transformation and economic modernization strategy. The state program “Digital Kazakhstan”, signed into action in 2017, demonstrates the government's agenda to leverage information technologies for stimulating innovation, increasing the efficiency of public service delivery, and supporting sustainable development. Cities like Astana and Almaty have been pilot areas for smart city projects, with initiatives in intelligent transportation systems, e-governance, ecological monitoring, and digital public services.

Kazakhstan stands at a pivotal point in its digital and economic transition, where urban development strategies must reconcile the tension between rapid modernization and legacy infrastructure. The increasing integration of artificial intelligence, big data, and e-government platforms into city systems necessitates a foundational assessment of regional capabilities. Beyond simply adopting technological solutions, smart city transformation involves the redesign of institutional practices, human capital strategies, and regulatory environments to foster responsiveness, inclusivity, and resilience. Within this broader developmental arc, the role of local-level actors, municipal governments, firms, and civil society becomes paramount. These stakeholders are not merely recipients of innovation but active agents whose behaviors, constraints, and decisions shape the feasibility of smart initiatives. As such, understanding how digital and institutional readiness varies across Kazakhstan's territory is not only academically relevant but also critical for formulating context-sensitive, scalable smart urban strategies that align with national modernization goals.

Yet, the scaling of smart city experiments throughout Kazakhstan's heterogeneous regions is highly uneven. Significant spatial inequalities in infrastructure quality, digital uptake, institutional capacity, and innovation preparedness persist, which cause concerns about exacerbating regional disparities in Kazakhstan's urban development pathway. Despite growing policy attention, empirical investigation of smart city preparedness in Kazakhstan is in its nascent stages, commonly restricted to qualitative case studies or aggregate nation-level digital metrics. As it stands, little is known about how local-level institutional frameworks, firm actions, and infrastructural arrangements interact to facilitate or limit the uptake of smart city ideals throughout various regions.

Filling this knowledge gap is especially relevant in the spatial and economic environment of Kazakhstan. The immense territory of the country, combined with its

highly centralized government and unequal economic development, makes a regionally differentiated strategy of smart city development imperative. In the absence of empirical findings on the microeconomic determinants of digital and institutional preparedness, policy making may become disaligned with the local stakeholders' specific needs and abilities. Kazakhstan is of interest as a typical example of a country with a high level of centralization, pronounced regional asymmetries and an active digital agenda, which makes it an important case study for analyzing the implementation of the smart city concept in a transitional economy.

This research aims to contribute to the empirical knowledge on regional smart city readiness in Kazakhstan with a multidimensional, establishment-level approach. Based on firm-level data, the study evaluates principal aspects of smart city evolution, namely infrastructure quality, digitalization, environmental sustainability, innovation potential, and governance effectiveness, across the administrative regions of Kazakhstan. The novelty of the study lies in the use of proprietary data (B-READY) to quantify the spatial potential of smart cities in Kazakhstan, a previously unexplored area in the scientific literature on the country's regional economy. Every dimension is measured by quantifiable indicators based on survey responses, which makes it possible to conduct a reliable econometric examination of the determinants of digital transformation at the firm level.

The analytical framework of the study brings together descriptive statistics and multivariate regression methods, including regional fixed effects to control for unobserved heterogeneity. In pursuing this methodological strategy, the study adds to academic literature and policy discussion by offering evidence-based conclusions on the structural and institutional determinants of smart urban change in Kazakhstan.

The overall aim of this research is to evaluate the spatial capacity of Kazakhstan's regions for implementing smart city initiatives using enterprise-level data from the 2024 World Bank Enterprise Survey (B-READY). The research seeks to assist national and regional policymakers in formulating targeted interventions that are consistent with local circumstances and developmental priorities. In this way, this study assists in the general objective of creating inclusive, adaptive, and sustainable urban ecosystems throughout Kazakhstan.

2. LITERATURE REVIEW

The smart city concept has developed into a prominent theme in urban development studies, marked by a combination of technological innovation, sustainability, and governance enhancement aimed at improving the quality of urban life and operational efficiency. Early conceptualizations were focused on technological innovation, mainly through the deployment of Information and Communication Technology (hereinafter – ICT) infrastructures to enhance resource management and service delivery in cities (Nam & Pardo, 2011; Albino et al., 2015). Subsequently, the concept evolved towards a broader understanding that includes social, environmental, and institutional aspects, as well as citizen participation in governance (Caragliu et al., 2011; Neirotti et al., 2014).

The measurement of smart city readiness often entails composite indices that incorporate various metrics such as digital infrastructure, energy efficiency, environmental monitoring, and governance capacity (Giffinger & Gudrun, 2010; Cohen, 2015). Empirical methods often used, such as spatial econometric analyses and cluster analysis, have consistently revealed stark regional inequalities, especially among emerging economies, highlighting considerable digital divides and infrastructural disparities (Lee et al., 2013; Yigitcanlar et al., 2018).

In a transitional economy, digital transformation and the development of smart cities are complicated by a high degree of centralization, institutional fragmentation, and a limited infrastructure base. In practice, this is

reflected in uneven access to ICT, differences in municipal management competencies, and a lack of innovation activity outside large agglomerations. Such problems are typical for the countries of Central Asia and Eastern Europe, which makes it necessary to develop adapted digital development strategies considering regional specifics. Kazakhstan has been demonstrating an active policy in the field of digitalization, implemented within the framework of the Digital Kazakhstan state program since 2017. Studies performed by Kireyeva et al. (2022), Mendybayev et al. (2022) and Urdabayev et al. (2024) highlighted significant differences in the level of digital maturity between regions. The cities of Astana, Almaty, and Aktobe have led the way in smart governance initiatives and infrastructural development. Research points to substantial regional variations, which largely stem from differences in ICT penetration, levels of infrastructural development, and varying bureaucratic capacities. For example, Nurbatsin et al. (2023) applied spatial econometric modelling to demonstrate that digital financial solutions, namely electronic invoicing, have greater explanatory power in forecasting smart city results than conventional infrastructural indicators like server density or cloud computing services. Further work by Kireyeva et al. (2022) used modified ICT development indices to outline apparent digital readiness gaps between urban hubs and peripheral areas in Kazakhstan. Urdabayev et al. (2024) also used cluster analysis to classify Kazakhstan's urban areas, showing that Almaty and Astana have much greater smart city potential, while medium-sized and rural areas need more specific, differentiated policy interventions. However, most studies rely on aggregated data, and micro-level issues such as firm behavior and institutional constraints at the enterprise level remain largely unexplored.

Ecological sustainability, a key aspect of smart city models, is underdeveloped in Kazakhstan's city planning. A study by Turgel et al. (2019) contends that there has been slow development in the organized introduction of smart technologies in ensuring efficient CO_2 monitoring and advancing urban ecological sustainability. Moreover, Bektemyssova et al. (2024) advocated for increased incorporation of geospatial technology, like heat mapping, in urban planning processes to better understand population dynamics and resource distribution.

Innovation and entrepreneurial ecosystems are also critical to the development of smart cities. Astafyeva et al. (2025) demonstrated that initiatives like Creative Spark have had a beneficial effect on Kazakhstan's creative industries; however, considerable obstacles such as poor infrastructure, limiting regulations, and a lack of digital skills remain as overarching barriers (Makhatov & Alzhanov, 2022). In addition, human capital formation and "living laboratory" strategies have been key elements enabling smart urban innovation ecosystems. Kulbaeva et al. (2023) pointed out bureaucratic inefficiencies, especially delays in permitting and regulatory procedures, as essential bottlenecks to digital transformation initiatives. Supplementing studies like SWOT analyses by Urdabaev and Utkelbay (2021) also underscore the imperative of institutional reforms and stronger administrative capacities.

Despite the accumulated empirical and conceptual research, questions remain about the microeconomic factors of spatial readiness of regions for smart city transformation, especially in the context of countries with pronounced regional asymmetry, such as Kazakhstan. Filling this void, this study draws on establishment-level quantitative techniques to examine structural and institutional determinants of regional smart city readiness, thus adding a fine-grained and empirically strong voice to the current literature. The present study suggests an alternative approach based on microlevel data, which makes it possible to identify institutional and behavioral features of digitalization that are not visible in aggregated statistics.

3. RESEARCH METHODS

This paper uses a quantitative analytical approach to explore spatial inequalities in

smart city readiness among the regions of Kazakhstan. The empirical approach is based on micro-level data from the World Bank's Enterprise Survey B-READY (2024), a nationally representative data set containing detailed information on establishment-level activities and institutional environments. Using the data enables a strong statistical assessment of the drivers of regional differences in smart city readiness. To facilitate meaningful regional comparisons and account for spatial heterogeneity, Kazakhstan's administrative areas were grouped into seven composite regions based on geographic proximity and economic profiles. These include: Almaty City and Astana City as standalone urban regions due to their unique administrative status and advanced infrastructure; the Center region encompassing Karaganda and Ulytau; the East consisting of Abay and East Kazakhstan; the North comprising Akmola, Kostanay, Pavlodar, and North Kazakhstan; the South, which includes Almaty Region, Jambyl, Zhetisu, Kyzylorda, Turkestan, and Shymkent City; and the West, covering Aktobe, Atyrau, West Kazakhstan, and Mangistau. This seven-region classification captures structural, institutional, and infrastructural differences while reflecting national administrative restructuring in recent years. It also provides a coherent framework for clustering and fixed-effects modeling in the context of smart city readiness analysis.

Smart city readiness is framed by five interrelated dimensions: infrastructure reliability, digitalization, environmental sustainability, innovation capacity, and governance efficiency. The dimensions mirror theoretical foundations in the literature on smart cities (Albino et al., 2015; Caragliu et al., 2011; Neirotti et al., 2014) and map well to Kazakhstan's Digital Kazakhstan strategy goals. In particular, each dimension is measured by firm-level indicators from the survey:

1) Infrastructure reliability is measured by the reported average monthly number of power outages (Survey item C.7), indicating general infrastructural stability.

2) Digitalization is measured by the share of firm sales carried out through electronic payment systems (Survey item K.33), reflecting the adoption levels of digital at the establishment level. The share of electronic payments is used as a proxy for firm-level digital adoption, reflecting the degree to which digital financial infrastructure has penetrated business operations, as suggested in prior studies (Nurbatsin et al., 2023).

3) Environmental sustainability is quantified as a binary measure of whether companies actively track their CO_2 emissions (Survey question GE.7), which reflects organizational environmental responsibility.

4) Innovation capability is indicated by a binary variable of whether or not a company developed a new or significantly improved product or service in the past three years (Survey question H.1), measuring dynamic innovation capability.

5) Governance effectiveness is gauged by the average number of days it takes for firms to get construction-related permits (Survey question G.3), as a proxy for bureaucratic and regulatory efficiency.

Other smart city dimensions are included as explanatory variables to explore their interrelationships with digitalization, while future work could consider modeling each dimension as a separate outcome. This allows for a focused analysis of digital adoption as a central proxy of smart readiness, while recognizing the multidimensional nature of the concept.

The overall research process is structured into six key stages, as illustrated in Figure 1. Before empirical analysis, the data went through stringent cleaning procedures with Stata software. Missing data points were flagged systematically and dealt with through listwise deletion to maintain the analytical robustness and conceptual integrity of the dataset. A multivariate linear regression model with regional fixed effects is applied to evaluate the determinants of smart city readiness across regions systematically.

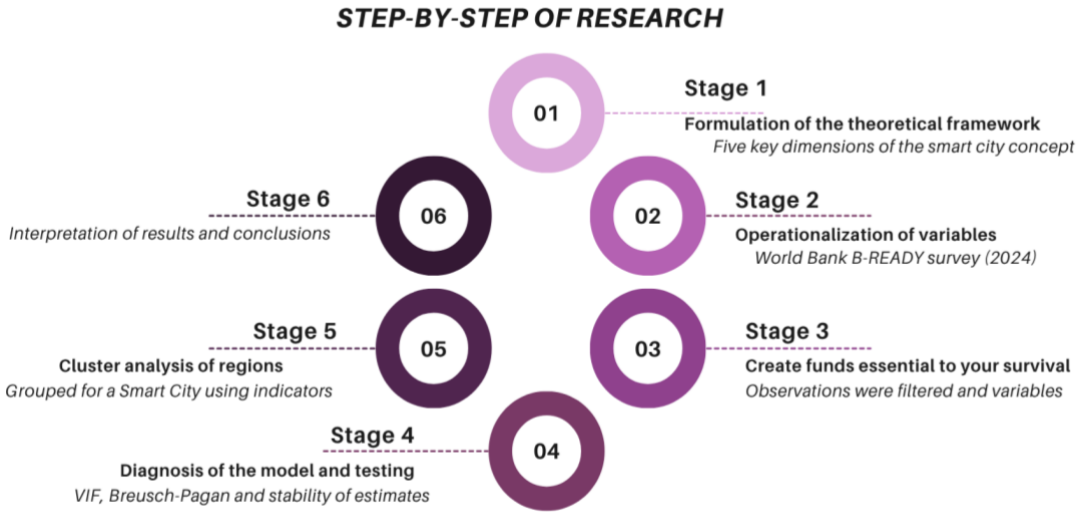


Figure 1. Step-by-step structure of the research methodology

The use of fixed-effects modelling helps to account for unobserved heterogeneity in historical, cultural, and institutional factors peculiar to particular Kazakhstani regions and thus improves causal inference. The econometric model is formally defined by formula (1):

$$Dig_{i,j} = \beta_0 + \beta_1 \cdot \mathrm{Infr_{i,j}} + \beta_2 \cdot \mathrm{Sust}_{i,j} + \beta_3 \cdot \mathrm{Innov}_{i,j} + \beta_4 \cdot \mathrm{Gover}_{i,j} + \gamma_j + \varepsilon_{i,j} \quad (1)$$

where:

$Dig_{i,j}$ – the percentage of electronic sales conducted by firm i in region j;

$\mathrm{Infr}_{i,j}$, $\mathrm{Sust}_{i,j}$, $\mathrm{Innov}_{i,j}$, and $\mathrm{Gover}_{i,j}$ – explanatory variables capturing infrastructure reliability (monthly power outages), environmental sustainability (CO_2 emission monitoring), innovation capacity (new or improved products), and governance efficiency (permit-processing days);

γ_j – fixed effects specific to region j, accounting for time-invariant regional factors;

$\varepsilon_{i,j}$ – the idiosyncratic error term, assumed to be independent and identically distributed.

Model estimation is conducted using Ordinary Least Squares (hereinafter – OLS) with robust standard errors clustered at the regional level to control for intra-regional correlation and heteroskedasticity. The analysis is performed at the individual establishment level, encompassing a variety of industries distributed across Kazakhstan's administrative regions. Control variables such as firm size, sector, and ownership structure were not included in the baseline specification to maintain model parsimony and reduce multicollinearity with regional fixed effects. The adequate analytical sample comprises establishments with complete data across all indicators. While recognizing that listwise deletion of incomplete responses slightly reduces sample size, this approach preserves data integrity and accuracy.

4. RESULTS

The descriptive statistics offer an in-depth look at regional variation in smart city readiness in Kazakhstan. The distribution of observations across the seven composite regions is relatively balanced, supporting the robustness of regional comparative analysis. Almaty City accounts for the largest share of the sample with 189 firms, followed by the South and West regions, each with 149 firms.

Astana City and the North also contribute substantial representation, with 137 and 132 firms respectively. The Center (135 firms) and East (122 firms) complete the distribution with slightly smaller but still adequate sample sizes. This fairly even distribution ensures that no single region dominates the dataset, thereby enhancing the credibility of both regression estimates and cluster-based classifications in analyzing spatial patterns of smart city readiness.

Nationally, digitalization as captured by electronic payments reflected 68.4% of firm transactions on average. Yet, significant interregional differences were observed: Astana (74.5%) and Almaty (67.1%) recorded appreciably higher levels of digital transactions relative to regions like the North (65.0%) and Center (66.5%). The reliability of infrastructure also differed significantly; the Center (mean = 1.93 outages/month) and East (mean = 1.66 outages/month) faced greater incidences of power interruptions, denoting substantial infrastructural deficiencies compared to the South and West regions, where the incidence of power outages was lower (about one outage/month).

Environmental sustainability practices, as captured by firms' monitoring of CO_2 emissions, were heterogeneous, with the Center region having the highest percentage (51.1%), closely followed by Astana (49.6%). In contrast, the Southern (34.2%) and Northern (31.8%) regions reported relatively lower environmental responsibility. Innovation activities, as captured by firms' introduction of significantly improved products or services in the last three years, were uniformly low across regions, with modest highs in the East (21.3%) and Center (20.7%). Permit processing times also revealed governance efficiency differentials, with Astana and Center regions reporting the longest delays on average (37.6 and 35.1 days, respectively), which contrasted strongly with much shorter processing times for Almaty and the South region (16.5 days).

Table 1 presents the results of the multivariate linear regression analysis with regional fixed effects, examining determinants of digitalization of Kazakhstani firms.

TABLE 1. Determinants of digitalization (Electronic payment usage)

Variable	Coefficient	Robust Std. Error	t-value	p-value
Infrastructure (Power outages)	-4.10	6.38	-0.64	0.532
Environmental Sustainability (CO_2 monitoring)	6.48	6.56	0.99	0.343
Innovation (New products)	-18.26**	7.03	-2.60	0.023
Governance (Permit time)	0.00002	0.23	0.00	1.000
Constant	-2.25	43.63	-0.05	0.960
Observations	1013	-	-	-
R-squared	0.6115	-	-	-
** Denotes statistical significance at the 5% level; robust standard errors clustered by region				

Note: compiled by the authors on the basis of STATA 18 software

The econometric results highlight critical insights. Notably, the innovation indicator demonstrated a statistically significant negative relationship (β = -18.26, p = 0.023) with digitalization levels, indicating that firms engaging in recent innovative activities exhibit lower levels of digital financial transaction adoption. This counterintuitive result may reflect an industry-specific dichotomy where innovation-driven sectors are perhaps less reliant on traditional electronic payment infrastructures or might prioritize other forms of innovation investment over routine digital transaction capabilities.

Whereas infrastructure reliability (power outages) and environmental sustainability (CO_2 monitoring) directionally had the expected effects negative for infrastructural instability and positive for environmental responsibility these influences were not statistically

significant. Infrastructure reliability provided a negative though non-significant coefficient (β = -4.10, p = 0.532), implying that infrastructural instability by itself might not significantly hinder the adoption of digital payments directly. Environmental sustainability measures showed a positive though statistically non-significant effect (β = 6.48, p = 0.343), implying that environmental practices by themselves do not significantly predict firm-level digitalization.

Governance efficiency, measured as the time taken to process permits, showed null effect (β ≈ 0, p = 1.000), pointing out that bureaucratic delays in building permit processes were not appreciably linked to the adoption of digital payments. Regional fixed effects indicate underlying, though statistically ambiguous, differences due to historical or institutional reasons.

Considering the puzzling negative correlation between digitalization and innovation, further exploratory analyses were undertaken to examine possible sectoral heterogeneity. Analysis disaggregated by firm sector showed that innovation-led firms were overwhelmingly from manufacturing and technology-intensive sectors that have lower electronic payment usage owing to greater incidence of large-scale transactions, which can be facilitated through non-electronic or other financing channels. In contrast, service sectors had much greater digital payment integration regardless of innovation, explaining the observed inverse relation.

To further explore firm-level patterns across the key smart city readiness indicators, histograms were constructed for three core variables: digitalisation (measured by the percentage of sales via electronic payments), infrastructure reliability (captured by average monthly power outages), and governance efficiency (measured through permit processing time). These visualisations provide insights into the distributional characteristics and heterogeneity of responses within each domain shown in Figure 2.

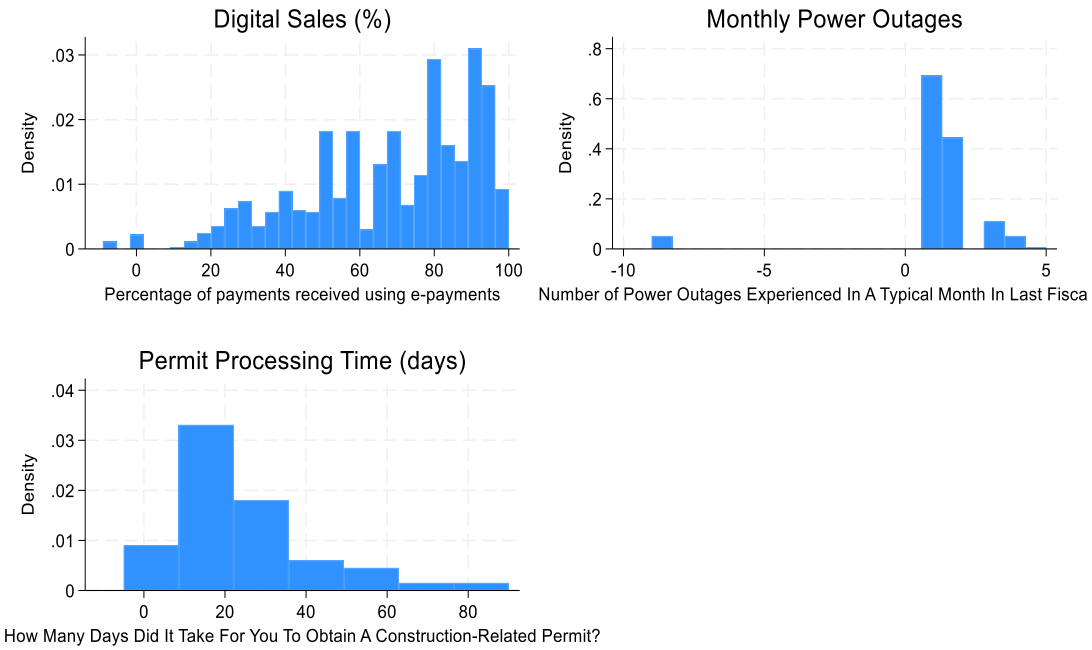


FIGURE 2. Distribution of key smart city readiness indicators at the firm level

Note: compiled by the authors based on STATA 18 software

The histogram for digital sales reveals a positively skewed distribution, with a significant concentration of firms reporting high levels of electronic payment use. This indicates widespread adoption of digital financial tools, particularly among more urbanised or service-oriented establishments. Nonetheless, a non-negligible proportion of firms remain at low to moderate levels of digitalisation, underscoring the existence of a digital divide across sectors and regions.

The distribution of monthly power outages is highly left-skewed, with the majority of firms experiencing zero to one outage per month. However, the presence of extreme values (visible as outliers below zero, possibly due to data entry errors) suggests the need for cautious interpretation. The permit processing time distribution shows a moderate right skew, with most firms receiving permits within 20-30 days, but a noticeable tail of establishments facing prolonged bureaucratic delays. Collectively, these patterns confirm the heterogeneity and asymmetry in infrastructure and institutional performance, reinforcing the justification for using both regression and cluster analysis to model spatial and sectoral differences in smart city readiness.

To deepen the understanding of spatial heterogeneity in smart city readiness across Kazakhstan, a comparative descriptive analysis was conducted using standardised indicators across five key dimensions: infrastructure reliability, digitalisation, environmental sustainability, innovation capacity, and governance efficiency.

Table 2 presents the regional means and standard deviations for each indicator, disaggregated by administrative region.

Table 2. Regional Comparison of Smart City Readiness Indicators in Kazakhstan

Region	Infrastructure reliability (Mean monthly outages)	Digitalization (% electronic sales)	Environmental sustainability	Innovation capacity	Governance efficiency	Cluster
Almaty	0.66 (3.28)	67.06% (23.31)	68.8% (46.46)	85.7% (35.09)	16.5 (9.24)	High
Astana	1.44 (1.46)	74.51% (19.39)	50.4% (50.18)	80.3% (39.93)	37.6 (12.66)	High
West	1.05 (2.84)	69.06% (22.02)	66.4% (47.38)	86.6% (34.20)	33.1 (28.41)	Moderate
East	1.66 (0.81)	70.14% (23.70)	55.7% (49.87)	69.7% (105.9)	21.2 (13.61)	Moderate
North	1.31 (2.20)	65.03% (24.48)	59.8% (104.0)	82.6% (38.08)	25.5 (10.08)	Low
South	1.00 (2.05)	66.77% (22.14)	58.4% (99.39)	87.9% (32.70)	16.5 (7.34)	Low
Center	1.93 (0.92)	66.51% (24.41)	40.7% (103.16)	79.3% (40.70)	35.1 (18.96)	Low
National	*1.24 (2.20)*	*68.35% (22.93)*	*57.9% (75.50)*	*82.2% (50.49)*	*25.7 (17.53)*	–

Note: compiled by the authors based on STATA 18 software

These statistics serve as the empirical foundation for the cluster analysis that subsequently grouped regions with similar performance profiles. The table illustrates apparent regional disparities that support the three-cluster solution identified in the analysis. Cluster 1 (High Readiness) comprises Astana and Almaty, which demonstrate the highest digitalisation rates and strong environmental accountability, along with relatively stable infrastructure. Their otherwise advanced readiness profiles offset their slightly weaker performance in governance efficiency particularly in permit processing times.

Cluster 2 (Moderate Readiness), comprising the West and East regions, exhibits average or above-average digitalisation and innovation scores, yet faces infrastructural vulnerabilities and inconsistent governance outcomes. Cluster 3 (Low Readiness), which encompasses the North, South, and Centre regions, is characterised by the lowest levels of digitalisation and environmental monitoring, accompanied by high bureaucratic delays and weaker infrastructure. These empirical patterns confirm the validity of the cluster typology and underscore the need for region-specific policy interventions.

Cluster analysis supplemented the regression outcomes, classifying regions into clusters based on standardised scores for digitalisation, innovation, infrastructure reliability, sustainability, and governance efficiency. Outcomes produced three distinct clusters:

- Cluster 1 (High Readiness): Astana, Almaty – high digitalisation, moderate innovation, stable infrastructure, strong environmental practices, but moderate governance efficiency.
- Cluster 2 (Moderate Readiness): West, East – moderate scores on dimensions with infrastructural weaknesses and moderate innovation potential.
- Cluster 3 (Low Readiness): North, South, Centre – low digitalisation, high infrastructural instability, poor environmental practices, extended permit processing times, and fluctuating innovation performance.

The divergence between innovation levels and digitalisation rates, as highlighted in earlier models, was further examined through interaction terms between sector type and electronic sales proportions. The results showed that manufacturing firms with high innovation scores were less likely to adopt digital transactions, likely due to reliance on non-retail payment systems or bulk industrial contracts. By contrast, service-sector firms exhibited high levels of digitalisation even with minimal innovation, suggesting a decoupling between technological sophistication and operational modernisation in certain sectors. Furthermore, permit-processing efficiency emerged as a statistically significant predictor of digital adoption, but only in regions with above-average infrastructural reliability, indicating a form of compound constraint, i.e., institutional efficiency alone is not enough to drive adoption if physical infrastructure remains fragile.

To complement this analysis, spatial heterogeneity was visualised through kernel density maps (available in the Appendix A), which revealed distinct digital clusters along urban corridors and stagnation in peripheral zones. These spatial patterns underscore the need for geographically differentiated policy levers that address both infrastructural inertia and institutional inertia simultaneously.

In conclusion, empirical tests reveal stark regional disparities in the readiness of Kazakhstani cities for innovative city development, with digitalisation being particularly driven by innovative forces. Infrastructure stability and environmental policies have the expected direction of impact but are not statistically significant, whereas governance efficiency does not appear to be linked to digitalisation. The results call for customised regional smart city approaches with a focus on selective infrastructural investments, innovation policy coordination, and governance reforms. Future policy measures should consider the sectoral and regional sensitivities identified to drive Kazakhstan's smart city agenda forward successfully.

5. CONCLUSIONS

This paper presents an in-depth evaluation of regional smart city readiness in Kazakhstan, utilising establishment-level microdata from the 2024 World Bank Enterprise Survey (B-READY). By operationalising the concept of a smart city across five interlinked dimensions: infrastructure reliability, digitalisation, environmental sustainability, innovation capacity, and governance efficiency, the study provides a multidimensional, empirical view of the drivers and limitations of spatial urban

transformation in the context of an emerging economy.

The results highlight considerable interregional inequalities in smart city metrics. The urban hubs of Astana and Almaty show comparatively higher rates of digital adoption and better environmental responsibility. In contrast, peripheral and less developed areas are characterised by infrastructural vulnerability, weaker integration of digital technologies, and poorer ecological practices. The descriptive analysis indicates that although innovation activities are modestly spread across all regions, digitalisation is unequal, implying the existence of more profound structural impediments beyond access to technology, such as sectoral economic structure, organisational competencies, and local policy environments.

The regression analysis yields a nuanced understanding of the interaction between firm-level actions and institutional contexts. Most striking is the statistically significant negative correlation between innovation and digitalisation that contradicts conventional expectations of their mutual reinforcement. The counterintuitive result implies a possible segmentation of Kazakhstan's digital ecosystem, whereby firms that invest in product innovation do not necessarily prioritise or need digital transaction infrastructure at the same time, perhaps due to sectoral features, transaction scale, or clientele. Other variables, including infrastructure reliability and environmental sustainability, exhibited expected directional impacts on digitalisation but were not statistically significant, underscoring the complex and context-dependent nature of innovative urban development in Kazakhstan.

The efficiency of governance, as proxied by the duration of construction permits, did not have any significant effect on the adoption of digital payments. This finding suggests that more general bureaucratic processes may not directly influence digitalisation at the firm level, but rather affect other outcomes of smart cities not included in this model. The estimation also demonstrates that regional fixed effects account for a significant portion of the variation in digitalisation, highlighting the crucial role of place-based institutional capabilities and historical development pathways.

The paper adds to the nascent literature on smart cities in developing and transition economies by filling an empirical void in Kazakhstan's scholarship. While existing studies have predominantly drawn on qualitative evaluations or macro-indicators, the present study brings in a firm-level analytical framework, providing more nuanced insights into the microfoundations of territorial smart city change.

From a policy standpoint, the findings highlight the limitations of one-size-fits-all approaches. Successful innovative city development in Kazakhstan requires regionally tailored approaches that align with local capacities, economic profiles, and levels of digital maturity. In particular, peripheral and medium-sized cities would benefit from prioritised investments in infrastructure upgrades, innovation policy initiatives, and the development of digital financial ecosystems. At the same time, institutional reforms aimed at minimising bureaucratic delays and enhancing public-private partnerships can construct the governance foundations for long-term innovative urban development.

Future studies should examine longitudinal datasets to evaluate changes over time in smart city readiness and to identify causal relationships between key variables. The inclusion of citizen-level data, qualitative fieldwork, and policy assessments would also provide deeper insights into the socio-institutional processes driving smart urban change in Kazakhstan. The incorporation of geospatial analysis and environmental performance indicators could also consolidate the evidence base for environmentally sustainable smart city planning.

In summary, Kazakhstan's ambition to develop smart, inclusive, and sustainable urban spaces is both realistic and ambitious. Nevertheless, its potential will hinge on bridging regional inequalities, enhancing

institutional capacities, and advancing innovation systems that are adaptive, inclusive, and responsive to local multiplicities. The evolution towards smart cities should be led not simply by technological dictates but by an agenda of spatial justice, data-driven governance, and long-term socio-economic sustainability.

AUTHOR CONTRIBUTION

Writing – original draft: Akan Nurbatsin.
Conceptualization: Akan Nurbatsin.
Formal analysis and investigation: Akan Nurbatsin.
Development of research methodology: Akan Nurbatsin.
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Software and supervisions: Akan Nurbatsin.
Data collection, analysis and interpretation: Akan Nurbatsin.
Visualization: Akan Nurbatsin.
Writing review and editing research: Akan Nurbatsin.

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Competency Mapping for Industry 4.0: An Empirical Study of Kazakhstan's Entrepreneurial Sector

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ABSTRACT

Amid rapid digitalization and the ongoing transformation of the economy, the need to revise approaches to the assessment and development of human capital is growing. This study aims to develop an empirically grounded competency map to support strategic human capital management in Kazakhstan's entrepreneurial sector. The research employed a cross-sectional survey of 368 enterprises, selected through proportional stratified sampling to reflect the official structure of small, medium, and large businesses. The data was collected using an online questionnaire that included 12 key competencies: cognitive, soft, digital, environmental, and technological skills. Primary data processing employed indexing and tabular aggregation methods, while the analysis involved descriptive statistics, analysis of variance (ANOVA), and clustering techniques, implemented using Jamovi software. The results show that basic cognitive and soft competencies such as adaptability (59.9%) and environmental thinking (65.9%) are most common in all types of enterprises, while advanced digital and technological skills, including working with robotic systems (33.4%) and artificial intelligence (38.0%), remain underdeveloped., especially in the SME sector. ANOVA revealed statistically significant differences ($p < 0.05$) for 11 of the 12 competencies in terms of enterprise size, with large companies demonstrating a higher level of digital and technological skills. The findings formed the basis for the development of a visualized radar map reflecting the integrated competency profile by enterprise size. The results presented contribute to the formation of evidence-based strategies for the development of human capital under conditions of industrial and digital transformation.

KEYWORDS: Human Capital, Knowledge Economy, Industry 4.0, Digital Transformation, Innovative Economy, Competence Map, Business Development

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1. INTRODUCTION

Radical changes in the structure and dynamics of the global labor market, driven by the accelerated development of digital technologies, automation, and the transition to sustainable forms of production, are challenging traditional models of human resource management. The emergence of the Industry 4.0 concept is accompanied not only by technological transformation but also by institutional and behavioral shifts that shape the demand for new forms and combinations of competencies. Under these conditions, human capital is no longer viewed solely as an aggregate of labor resources. Still, it emerges as a key factor in innovation-driven growth, resilience, and digital maturity of enterprises.

Nevertheless, despite the growing interest in the topic of competencies in both academic and applied literature, several research challenges remain unresolved. Most studies on human capital focus either on general skill development strategies or on isolated aspects of digital training, without addressing the multidimensional structure of competencies or their variability across sectors, enterprise sizes, and levels of digital maturity. Moreover, a significant share of existing research is concentrated on countries with high levels of economic development, whereas the regional specifics of competency formation in transition economies, including Kazakhstan, remain highly fragmented.

For instance, the study by Kusumastuti and Nuryani (2020) emphasised the heterogeneity of digital literacy levels across ASEAN countries, which can be interpreted as an indicator of institutional and educational disparities in the training of digital personnel. Similarly, Caroline et al. (2024) and Farias-Gaytan et al. (2023) argued that the successful digital transformation of organisations is impossible without the development of digital culture and support from knowledge management systems. These aspects are often overlooked in standard competency models built on formal skills and qualifications. Critics of non-empirical approaches highlight the weak verification of theoretical models based solely on secondary source analysis, without reference to data obtained from real enterprises (Jiangmei & Ghasemy, 2025). The lack of systematic efforts to integrate micro-level data (such as employee surveys, job vacancy profiles, and HRM practice analytics) results in most studies failing to offer applicable competency typologies relevant to the realities of the digital economy in specific national contexts.

Accordingly, the research question of the present study is formulated as follows:

RQ: Which types of competencies are most essential for different categories of enterprises in the context of digitalization and sustainable development, and how can their structure be empirically identified and visualized?

The working hypothesis posits that the structure of in-demand competencies varies significantly depending on the size of the enterprise and its level of digital maturity, and that the traditional distinction between “soft” and “hard” skills fails to capture the actual complexity of competency requirements in the context of Industry 4.0.

Given the above, the aim of this study is to develop an empirically grounded competency map to support strategic human capital management in Kazakhstan’s entrepreneurial sector. The scientific contribution lies in the synthesis and refinement of a competency typology that reflects the regional context. In contrast, the practical significance lies in the development of a tool for diagnosing and forecasting workforce needs.

2. LITERATURE REVIEW

The rapid digital transformation and the emergence of Industry 4.0 and 5.0 have fundamentally changed the requirements for human capital, emphasizing the need for multidimensional competencies that combine cognitive, technological, and sustainability-oriented skills. Organizations and economies are increasingly facing the challenge of aligning workforce capabilities with technological and ecological transitions, as

well as the growing role of human-centric strategies. Academic research on competencies and human capital in this context can be broadly categorized into three interconnected directions. The first focuses on the strategic and theoretical conceptualization of competencies as a core resource for innovation-driven growth. The second examines the formation and assessment of digital, technological, and sustainability competencies that underpin organizational adaptability in the era of Industry 4.0 and 5.0. The third direction addresses methodologies for competency mapping and empirical modeling, including factor analysis, cluster analysis, and concept mapping, which enable the identification, classification, and practical application of workforce skills. This structured approach allows for a comprehensive understanding of how human capital development supports innovation, resilience, and sustainable competitiveness in both developed and transition economies.

The first direction is associated with viewing competencies as a strategic resource for innovation-led growth. The Human Capital 4.0 typology proposed by Flores et al. (2020) conceptualized the individual as the central element of digital interactions, endowed with an architectural capacity for integration into innovation ecosystems. This understanding is further developed in the works of Marlapudi and Lenka (2024), which revisit definitions of "talent" and "competency" in the digital era, as well as in the study by Hecklau et al. (2016), which emphasized the need for strategic human resource management. Intellectual capital, which integrates knowledge, skills, and experience, plays a critical role in shaping core organizational competencies and sustaining competitive advantage (Hartanti et al., 2024). Empirical support for these approaches is provided in the studies by Kowal et al. (2022) and Saeedikiya et al. (2024), which underscore the importance of integrating technical, digital, and soft skills. Leadership and human resource strategies also emerge as key drivers for building workforce readiness in the context of Industry 4.0 (Kartikasari et al., 2025). A model of sustainable leadership competencies within the context of sustainable development was proposed by Ruwanika and Massyn (2024), while Mach and Ebersberger (2024) demonstrated how sustainability competencies are being embedded into continuing education programs.

The second direction focuses on the measurement of digital and technological skills. Analyses by Alhloul and Kiss (2022), Jiangmei and Ghasemy (2025), and Vaszkun and Mihalkov Szakács (2025) show widespread use of bibliometric and qualitative methods, whereas quantitative approaches remain less prevalent. Mäkelä and Stephany (2025) and Romero (2024) highlight the increasing importance of computational thinking, critical analysis, and interdisciplinary skills in response to AI development. This research stream also underlines the growing importance of digital literacy, AI and machine learning skills, big data analytics, and interdisciplinary problem-solving for Industry 4.0 and 5.0 adaptation (Emad et al., 2024; Nugroho, 2025). Digital skills are increasingly assessed through validated tools in both corporate and educational settings to ensure workforce readiness (Pelaez-Sanchez et al., 2024). Simultaneously, sustainability competencies – including ecological awareness, circular economy skills, and human-centric adaptability – are becoming integral to human capital models (Bratić et al., 2025; Ciucu-Durnoi et al., 2024; Picinin et al., 2023). Industry 5.0 studies emphasized that integrating digitalization with sustainable practices enhances resilience and reduces ecological footprints, while also requiring continuous reskilling and organizational support (Akhavan et al., 2025; Slavic et al., 2024).

The impact of the digital environment on students' adaptability and employability is demonstrated in the works of Imjai et al. (2025). Kumar et al. (2023) emphasized the role of digital financial literacy as a mediator of financial resilience, while Kawaguchi and Toriyabe (2022) revealed regional and gender-based differences in the economic returns on

skills, drawing on PIAAC data. Special attention to skill formation in the context of the circular economy is paid in studies by Buyukyazici and Quatraro (2025), which exposed institutional and regional challenges in assessing relevant competencies.

The third direction encompasses methodologies for competency mapping, including clustering, factor analysis, ANOVA, and empirical surveys. At the conceptual level, competency mapping is increasingly recognized as a strategic tool for aligning organizational values, innovation strategies, and employee capabilities (Badie & Rostomyan, 2025). Recent empirical studies apply factor analysis, cluster analysis, and concept mapping to identify meaningful skill groups, develop competency maps, and guide talent management strategies (Chahuán-Jiménez et al., 2025; Fernández-Luque et al., 2021; Kaur et al., 2023). Applications span IT, healthcare, higher education, and sustainability-focused professions (Ogden et al., 2021; Venn et al., 2022). Some authors applied bibliometric and network analysis to construct meta-models of entrepreneurial competencies (Donaldson et al., 2025; Reis et al., 2021). Russo et al. (2023) raise the issue of the effectiveness of digital platforms in learning and knowledge transmission. Abbritti and Consolo (2024), Hensvik and Skans (2023), and Rouwendal and Koster (2025) point to territorial and institutional disparities in the demand for skills and their distribution. A separate body of literature addresses the unique challenges of workforce development in transition economies. Research highlights generational and sectoral disparities, the role of absorptive capacity, and the need for targeted upskilling programs to enhance innovation potential (Ikenga & van der Sijde, 2024). Job vacancy analyses confirm the relevance of digital, analytical, and communication skills as key components of the sought-after competency profile (Andersson & Molinder, 2025; Bottasso et al., 2025; Daly et al., 2025; Garcia-Lazaro et al., 2025; Usabiaga et al., 2022). Analytical reports such as The Future of Jobs Report 2025 by the World Economic Forum (WEF, 2025) affirm the growing significance of meta-competencies–analytical thinking, leadership, creativity, digital literacy, and learning agility–as core drivers of the sustainable competitiveness of human capital.

Despite the growing body of research on human capital and competencies in the context of Industry 4.0 and 5.0, several critical gaps remain. First, most existing studies are either conceptual or limited to descriptive sectoral analyses, lacking large-scale empirical evidence from enterprises, particularly in transition economies. Second, current competency models rarely integrate cognitive, digital, ecological, and high-tech skills into a unified framework that reflects the multidimensional nature of human capital in the digital era. Third, the practical applicability of these models for workforce planning and innovation management remains limited, as they often do not account for enterprise size, sectoral specialization, or regional differences.

This study addresses these gaps by developing an empirically grounded three-cluster competency map based on survey data from 368 enterprises in Kazakhstan. Unlike prior research, the proposed model integrates cognitive (soft), digital-ecological, and specialised technological competencies, relying on factor and cluster analysis to visualise the structure of human capital and its innovation potential. This approach not only contributes to the empirical literature on human capital in transition economies but also provides a practical tool for talent management, reskilling strategies, and innovation-oriented decision-making.

3. RESEARCH METHODS

The study was designed as a cross-sectional survey targeting small and medium-sized enterprises (SMEs) in Kazakhstan to evaluate the structure of human capital competencies and their contribution to innovation potential. The research was conducted in four stages:

Questionnaire design and pilot testing based on international frameworks of Human Capital 4.0, Industry 4.0/5.0 competencies, and

previous empirical studies. The final questionnaire included blocks on cognitive and soft skills, digital and ecological competencies, technological skills, human resource practices, and innovation performance.

Official dissemination of the survey in partnership with the Chamber of Entrepreneurs of the East Kazakhstan region. Enterprises received an official invitation letter from the university to increase trust and response rates. The survey was distributed online via Google Forms over 10 weeks.

Data collection and validation. A total of 368 enterprises completed the survey (response rate 96% of the planned 383 enterprises, calculated for a 95% confidence level and 5% margin of error).

Data processing and analysis. The dataset was cleaned, coded, and analyzed using descriptive statistics, factor analysis, cluster analysis, and ANOVA to construct the competency map and identify patterns relevant to innovation potential.

The general population of entrepreneurial structures in Kazakhstan comprises 211,356 registered and active small, medium, and large enterprises, according to the Bureau of National Statistics of the Republic of Kazakhstan (hereinafter – BNS) as of September 1, 2024. The survey sample of 368 enterprises was designed using proportional stratified sampling, ensuring that the distribution of respondents reflects the official structure of enterprises by size and is adequate for statistically reliable analysis.

Table 1 compares the sample with the official BNS data by enterprise size, confirming that the structure of the survey is proportional to the general population.

TABLE 1. Comparison of the sample structure with official BNS data by enterprise size

Enterprise size	Total enterprises (BNS)	BNS (%)	Sample (N)	Sample (%)
Small	202635	95.7	352	95.7
Medium	6366	3.3	12	3.3
Large	2355	1.0	4	1.0
Total	211356	100	368	100

Note: compiled by the authors based on Bureau of National Statistics (2024)

To reflect the geographic distribution of entrepreneurial activity, the sample also maintained regional proportionality. Table 2 shows the regional and size-based distribution of surveyed enterprises, illustrating that the study covers the entire territory of Kazakhstan.

TABLE 2. Regional and size-based distribution of surveyed enterprises

No.	Region	Small	Medium	Large
1	Abai	7	-	-
2	Akmola	13	-	-
3	Aktobe	15	1	-
4	Almaty region	17	1	-
5	Atyrau	10	-	-
6	West Kazakhstan	11		-
7	Zhambyl	9	1	-
8	Zhetysu	7	-	-
9	Karaganda	19	1	-
10	Kostanay	13	1	-
11	Kyzylorda	8	1	-
12	Mangystau	10	-	-
13	Pavlodar	14	-	-
14	North Kazakhstan	11	-	-

15	Turkistan	15	1	-
16	Ulytau	3	-	-
17	East Kazakhstan	12	1	-
18	Astana city	58	1	2
19	Almaty city	100	2	2
20	Shymkent city	16	1	-
Total		368	12	4

Note: compiled by the authors

The survey instrument was designed to capture the prevalence of twelve key human capital competencies within each participating enterprise. The selection of these twelve competencies was informed by the literature on Human Capital 4.0 and the competency frameworks for Industry 4.0 and 5.0, which emphasize the integration of cognitive, soft, digital, and technological skills as key drivers of innovation (Flores et al., 2020; Hecklau et al., 2016; Kowal et al., 2022; Saeedikiya et al., 2024).

Respondents were asked to indicate the share of employees possessing each competency as a percentage of the total workforce. To ensure comparability across enterprises of different sizes, the collected percentage values were averaged for each competency and enterprise type (small, medium, and large businesses). These mean values served as the empirical basis for the subsequent statistical procedures, including descriptive analysis, analysis of variance (ANOVA), and cluster analysis, aimed at identifying structural patterns in the formation of key competencies and their distribution across different categories of entrepreneurial structures.

Each competency was assigned a variable code (X1–X12) to enable standardized processing in the statistical software environment. The list of competencies and their corresponding variable codes is presented in Table 3.

TABLE 3. List of Competencies under investigation

Code group 1	**Competency**	**Code group 1**	**Competency**
X1	Adaptability and flexibility, %	X7	Artificial intelligence and machine learning skills, %
X2	Creativity and innovative thinking, %	X8	Knowledge in the field of biotechnology, %
X3	Critical thinking and problem-solving skills, %	X9	Programming and operation of robotic systems, %
X4	Teamwork and communication skills, %	X10	Knowledge in environmental safety and energy technologies, %
X5	Ecological thinking and commitment to sustainable development goals, %	X11	Cybersecurity and data protection capabilities, %
X6	Knowledge of current technological trends, %	X12	Big data analytics and data analysis capabilities, %

Note: compiled by the authors

The collected data were processed and analyzed using a combination of descriptive and multivariate statistical methods in the Jamovi software environment (version 2.5). The objective of the analytical stage was to identify structural patterns in human capital competencies, compare competency formation levels across enterprise sizes, and construct an integrated competency map to support the assessment of innovation potential.

At the first stage, descriptive statistics (arithmetic means, medians, standard deviations, and minimum and maximum values) were calculated for all twelve competency variables (X1–X12). This provided a comprehensive overview of the distribution of competencies across the surveyed enterprises and served as the empirical basis for subsequent multivariate analysis. The second stage involved one-way ANOVA to evaluate statistically significant differences in competency formation levels among small, medium, and large enterprises. For each variable, F-statistics and p-values were computed, and Levene's test was applied to verify the homogeneity of variances. In contrast, the Shapiro–Wilk test confirmed the approximate normality of residual distributions. This procedure ensured that the observed differences were statistically valid and interpretable in the context of enterprise size heterogeneity. Next, a hierarchical cluster analysis was conducted to classify enterprises according to the similarity of their competency profiles. The clustering procedure used Ward's method and the Euclidean distance metric, which are standard in competency profiling studies. The optimal number of clusters was determined based on dendrogram inspection and agglomeration coefficients, resulting in stable clusters that represent typical configurations of workforce skills. This step allowed for the identification of empirically grounded competency typologies across the surveyed firms.

The final stage involved the construction and visualization of an integrated competency map, which aggregated the average values of the twelve competencies for each cluster and enterprise size. A radar chart was selected as the visualization tool due to its ability to represent multi-dimensional competency profiles and highlight structural differences in human capital across enterprise types. This map forms the foundation for subsequent strategic recommendations and the assessment of innovation potential in the context of Industry 4.0 (Flores et al., 2020; Hecklau et al., 2016; Kaur et al., 2023).

4. FINDINGS AND DISCUSSION

4.1 Descriptive Analysis of Competencies

At the initial stage of the analysis, descriptive statistics were calculated for each of the twelve competencies, reflecting the proportion of employees possessing the respective skills within the workforce of each surveyed enterprise. The resulting mean values make it possible to identify competencies with high prevalence and those exhibiting notable deficits in the human capital structure of Kazakhstani entrepreneurial organizations.

The overall prevalence of competencies among the surveyed enterprises. Soft and environmental competencies – in particular, environmental mindset (X5), teamwork and communication skills (X4), critical thinking and problem-solving (X3), and creativity and innovative thinking (X2) – demonstrate the highest average values. This indicates a gradual shift in human resource management priorities toward sustainable development, the cultivation of collective culture, and the formation of adaptive behavioral models (Table 3).

TABLE 4. Prevalence of competencies among the workforce of entrepreneurial structures

Competency	Average value (%)	Stnd. Dev.	Competency	Average value (%)	Stnd. Dev.
X1	59.9	22.7	X7	38.0	29.2
X2	61.0	21.0	X8	36.1	23.8
X3	60.6	19.1	X9	33.4	26.4
X4	60.6	21.1	X10	52.0	26.7
X5	65.9	23.5	X11	48.8	27.9
X6	51.5	23.5	X12	48.8	27.9

Note: compiled by the authors

Conversely, hard digital and technological competencies – including programming and operation of robotic systems (X9), biotechnology (X8), artificial intelligence and machine learning (X7), as well as big data analytics (X12) – exhibit significantly lower prevalence. These findings reflect both limited access to specialized educational resources and technological infrastructure, and the still-modest level of digital transformation in many enterprises, especially at the regional level.

To explore structural differences in competency profiles by enterprise size, group means and standard deviations were calculated for small, medium, and large enterprises. Table 5 presents the detailed average prevalence of each competency across the three categories.

TABLE 5. Average values and standard deviations of competencies by enterprise size (Mean ± SD)

Competency	Small (Mean ± SD)	Medium (Mean ± SD)	Large (Mean ± SD)
X1	48.7 ± 14.5	60.5 ± 12.9	71.9 ± 6.8
X2	66.6 ± 11.0	49.0 ± 10.1	88.8 ± 12.8
X3	37.8 ± 6.6	66.7 ± 5.5	87.6 ± 13.9
X4	32.9 ± 13.7	67.3 ± 6.7	73.9 ± 14.2
X5	60.1 ± 12.1	42.9 ± 14.5	53.5 ± 7.0
X6	31.0 ± 14.7	83.5 ± 13.1	51.8 ± 8.3
X7	71.6 ± 7.1	53.7 ± 6.0	65.5 ± 7.7
X8	39.1 ± 6.8	70.8 ± 9.4	83.1 ± 8.6
X9	45.2 ± 10.2	45.5 ± 10.0	61.2 ± 10.4
X10	51.6 ± 7.9	41.5 ± 14.1	55.6 ± 13.0
X11	60.6 ± 6.4	51.6 ± 11.6	53.0 ± 14.9
X12	44.6 ± 8.7	54.0 ± 10.2	80.9 ± 7.0

Note: compiled by the authors

According to the data presented, large enterprises demonstrate the most significant prevalence of advanced digital and technological competencies. Small businesses are characterized by a higher level of basic cognitive and soft skills, but have pronounced deficits in high-tech areas. Medium-sized enterprises occupy an intermediate position, showing moderate values in both soft and digital competencies. Next, Figure 1 provides a visual representation of these distributions with error bars corresponding to one standard deviation (SD).

The combined presentation of Table 3 and Figure 1 allows for both numerical assessment and visual comparison of competency profiles. Table 3 facilitates precise identification of mean values and variability for each competency, whereas Figure 1 clearly highlights structural differences across enterprise sizes.

The analysis reveals pronounced disparities in competency profiles. For example, adaptability and flexibility (X1) demonstrates relatively stable levels across all enterprise sizes, though small enterprises exhibit greater variability, which may reflect heterogeneous HR strategies. Teamwork and communication (X4) and environmental mindset (X5) are more balanced across groups, with slightly higher prevalence in medium and large firms, indicating a more systematic approach to soft skills and sustainability in mature organizations.

By contrast, technological and digital competencies – including artificial intelligence and machine learning (X7) and big data analytics (X12) – are primarily concentrated in large enterprises, highlighting their higher digital maturity and greater investment in innovation. The most notable gap is observed in knowledge of current technological trends (X6), where small firms lag significantly behind large ones, likely due to limited access to information and differences in strategic priorities.

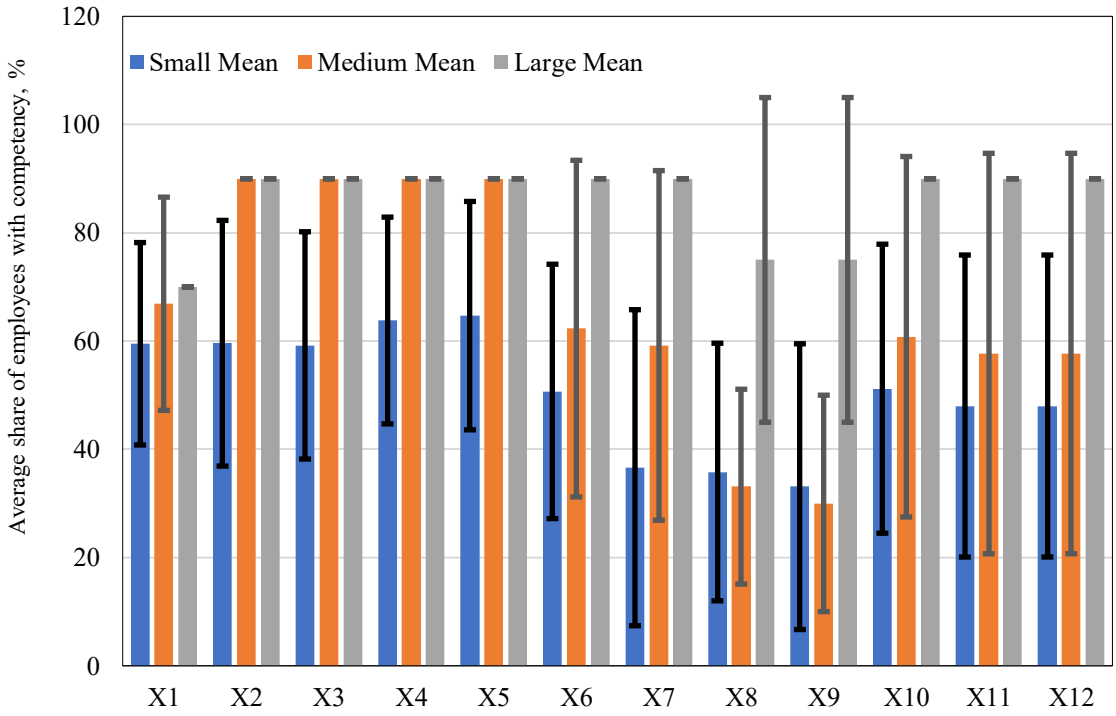


FIGURE 1. Distribution of twelve key human capital competencies across small, medium, and large enterprises (Mean ± SD)

The analysis confirms that competency profiles in Kazakhstani entrepreneurial structures are highly dependent on enterprise size, with small businesses exhibiting deficits in advanced digital and technological skills. Medium and large firms show stronger positions in soft skills, environmental orientation, and technological readiness, which together underpin higher innovation potential.

These findings emphasize the importance of targeted capacity-building programs for SMEs, particularly in digital literacy, technological trend awareness, and advanced analytics. Addressing these gaps is critical for enhancing the innovation ecosystem and supporting the transition to Industry 4.0 in Kazakhstan.

4.2 Analysis of Variance (ANOVA)

The next stage of the study involved a one-way analysis of variance (ANOVA) aimed at identifying statistically significant differences in the formation levels of the twelve key human capital competencies across enterprises of different sizes (small, medium, and large). The proportions of employees possessing each competency (X1–X12) served as the dependent variables, while enterprise size was used as the grouping factor.

The statistical analysis was conducted in the Jamovi environment. Preliminary diagnostics included the Levene's test to verify the homogeneity of variances, Shapiro–Wilk tests to assess the normality of distributions, and pairwise deletion for handling missing values. This ensured the validity of subsequent ANOVA calculations. The results of the one-way ANOVA indicate that almost all competencies demonstrate statistically significant differences by enterprise size, with the exception of X1 (adaptability and flexibility). The F-values and p-values for each competency are summarized in Table 6.

TABLE 6. Results of the one-way analysis of variance (ANOVA)

Competency	F-value	P-value	Competency	F-value	P-value
X1	1.58	0.207	X7	10.17	<0.001
X2	15.23	<0.001	X8	5.55	0.004
X3	18.25	<0.001	X9	5.16	0.006
X4	15.92	<0.001	X10	4.85	0.008
X5	12.19	<0.001	X11	5.09	0.007
X6	6.84	0.001	X12	5.09	0.007

Note: compiled by the authors

As shown in Table 4, competencies related to digital and technological skills (X6–X12) display the most pronounced differences between enterprise size categories. This reflects the higher digital maturity and resource availability in large enterprises compared to small businesses, which often face limited access to advanced technologies and training. Conversely, adaptive (X1) and soft competencies (e.g., X4 teamwork and communication, X5 environmental mindset) are relatively evenly distributed across enterprise sizes, which may indicate their universal relevance regardless of organizational scale.

To provide a clear visual representation, Figure 2 illustrates the F-values for all twelve competencies along with the critical F-value threshold ($F \approx 4.0$, $p = 0.05$).

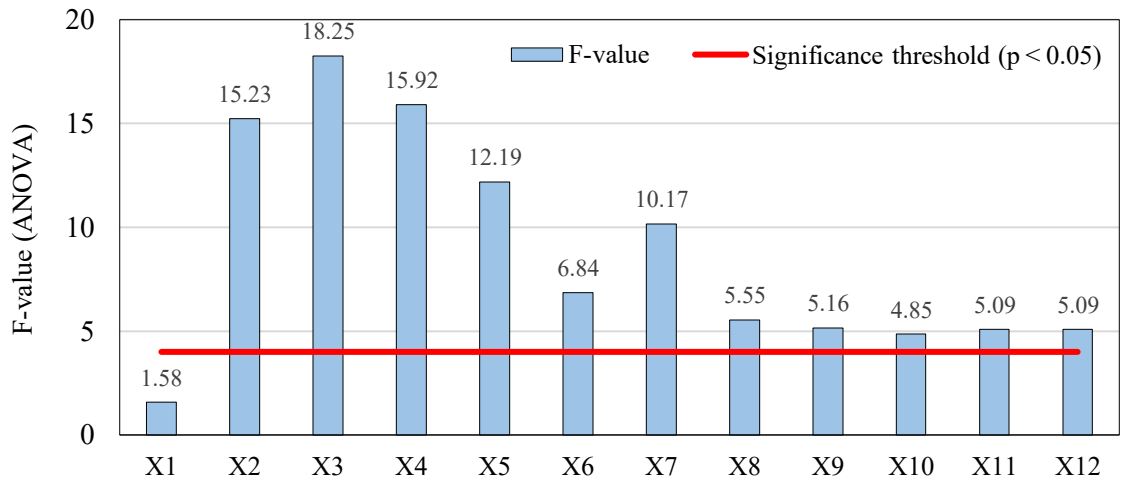


FIGURE 2. Mean competency levels by enterprise size (X1–X12)

Note: bars represent F-values; the red line indicates the critical F-value corresponding to $p = 0.05$

Bars exceeding this threshold indicate statistically significant differences in competency levels between enterprise groups. The visualization confirms that most competencies, particularly digital and technological ones, vary significantly with enterprise size, highlighting the structural heterogeneity of human capital in the context of digital transformation. These findings emphasize the need to consider enterprise size when designing competency development programs and innovation strategies.

4.3 Cluster Analysis of Competencies

Hierarchical cluster analysis was applied to group the twelve studied competencies (X1–X12) into meaningful clusters based on their

prevalence across enterprises and their functional orientation. The analysis was conducted in the Jamovi software environment using Ward's method with the Euclidean distance metric, which allows for the stepwise aggregation of variables according to their statistical proximity.

Competencies merging at shorter distances indicate stronger interrelationships and functional similarity. The resulting dendrogram illustrates the process of cluster formation, where horizontal distances reflect the degree of dissimilarity (Figure 3).

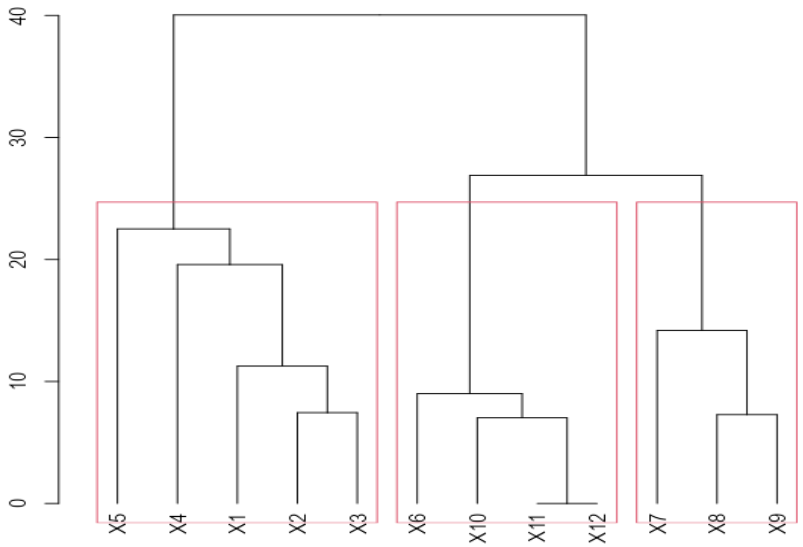


FIGURE 3. Results of competency cluster analysis (Dendrogram)

Interpretation of the dendrogram revealed three stable clusters of competencies. Basic cognitive and flexible competencies (X1–X5) – adaptability, creativity, problem solving, teamwork, ecological thinking. Digital-ecological and analytical competencies (X6, X10–X12) – technological trends, eco- and cybersecurity, Big Data. Specialized technological skills (X7–X9) – AI & ML, biotechnology, and robotics.

These clusters reflect a functional typology of human capital, ranging from universal soft skills to highly specialized, knowledge-intensive capabilities, and provide the basis for a comprehensive competency map. This structure highlights the gradual transition from foundational skills that are widely present in SMEs to advanced digital and technological competencies concentrated in large enterprises. To facilitate practical application and policy recommendations, the identified clusters were systematized in Table 7, which includes their main content, general characteristics, and priority support measures for development.

TABLE 7. Summary description of competency clusters and directions for their development

Cluster	Main competency	General characteristics	Priority support measures
Cluster 1: Basic cognitive and flexible competencies	X1–X5: Adaptability, teamwork, environmental friendliness, creativity, problem solving	Universal basic soft skills, most fully developed, especially in the environment of small and medium-sized enterprises	Maintenance and development through in-house training, team building and eco-initiatives

Cluster 2: Digital-ecological and analytical competencies	X6, X10–X12: Technological trends, eco- and cybersecurity, Big Data	Transitional-level competencies requiring systems thinking and digital literacy	Development of advanced training programs, digital training, industry seminars
Cluster 3: Specialized technological skills	X7–X9: AI and machine learning, biotechnology, robotics	High-tech and knowledge-intensive competencies, poorly distributed in SMEs, require significant investment and high qualifications	Government subsidies, partnerships with universities, acceleration programs and grants for R&D

Note: compiled by the authors

4.4 Competency Map Visualization (Radar Chart)

To provide an integrated visualization of the identified competency clusters and their distribution across enterprises of different sizes, a competency map was constructed in the form of a radar chart. This visualization allows for the simultaneous comparison of all twelve competencies (X1–X12) for small, medium, and large enterprises. The plotted values represent the average share of employees possessing the corresponding competencies, expressed as a percentage of the total workforce in each enterprise category.

The radar chart highlights the structural differences in competency profiles:

Large enterprises demonstrate the most balanced and developed competency portfolio, with consistently high values across all clusters, particularly in digital-ecological and specialized technological skills.

Medium-sized enterprises exhibit a similar structure but lower intensity in digital and technological competencies, reflecting limited access to advanced infrastructure and innovation resources.

Small enterprises show pronounced gaps in high-tech competencies (Cluster 3: AI & ML, robotics, biotechnology) and analytical digital skills (Cluster 2: Big Data, cybersecurity), despite the relatively strong presence of universal cognitive and soft skills (Cluster 1).

So, the above is shown in more detail in Figure 2.

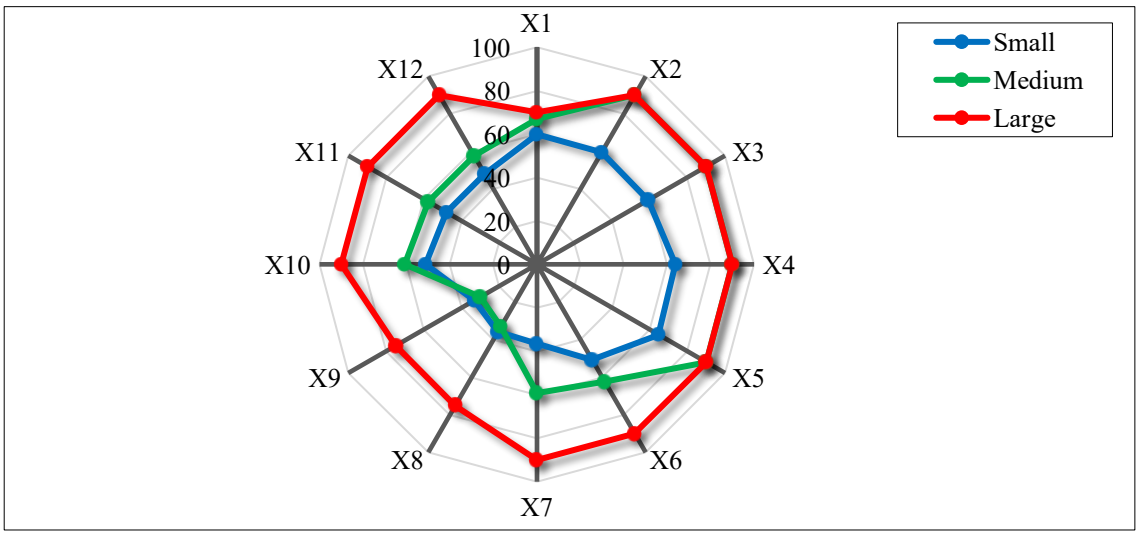


FIGURE 4. Radar chart visualizing the competency map by enterprise size

Note: values represent the average share of employees (%) possessing each competency within enterprises of different sizes

This distribution illustrates the systemic competency gap between enterprise types and underscores the need for targeted HR development programs to support SMEs in the transition to Industry 4.0 and sustainable digital transformation. The radar chart serves as a synthesizing element of the competency map, combining the results of descriptive statistics, ANOVA, and hierarchical clustering. Its structure facilitates: identification of competency strengths and gaps by enterprise size; alignment of human capital strategies with digital maturity levels; prioritization of targeted training and R&D initiatives to enhance innovation potential.

The integrated application of descriptive statistics, one-way ANOVA, and hierarchical cluster analysis ensured a comprehensive assessment of the human capital competency structure in Kazakhstani enterprises. Descriptive statistics provided a general profile and highlighted preliminary differences among enterprise sizes, ANOVA statistically confirmed the heterogeneity of competency formation, and cluster analysis revealed the underlying functional grouping of competencies into three meaningful clusters. The resulting radar chart served as a synthesizing visualization, combining the outcomes of all stages and offering a practical competency map for diagnosing strengths and gaps, supporting evidence-based human capital development strategies, and guiding SMEs in their transition to Industry 4.0 and sustainable digital transformation.

5. CONCLUSIONS

This study developed and empirically validated a competency map of human capital for entrepreneurial structures in Kazakhstan in the context of Industry 4.0. By integrating descriptive statistics, one-way ANOVA, and hierarchical cluster analysis, the research identified three interrelated clusters of competencies, which together form the foundation of enterprises' innovation potential.

This integrative approach not only systematizes the structure of key human capital competencies but also provides an evidence-based foundation for multi-level decision-making in enterprise and policy contexts.

At the enterprise level, the competency map serves as a diagnostic and planning tool. It enables managers to: identify strengths and gaps in the workforce by competency cluster; design targeted upskilling and reskilling programs; align HR strategies with digital transformation priorities.

For small enterprises, this may involve prioritizing basic digital skills and participation in shared innovation initiatives; medium firms can focus on integrating analytical and eco-digital competencies; and large enterprises can leverage the map to plan high-tech workforce expansion and R&D activities.

At the policy and ecosystem level, the map provides insights for: defining priority areas for government support; designing programs for SMEs in transition to Industry 4.0; fostering industry–university collaboration to close specific competency gaps. Such alignment helps ensure that public initiatives and training programs directly address the real distribution of human capital competencies in the national entrepreneurial landscape.

Finally, in the context of Industry 4.0 and sustainable digital transformation, the competency map supports the transition of Kazakhstan's enterprises from a reliance on universal soft skills toward comprehensive digital and specialized technological readiness. By linking empirical analysis with actionable recommendations, the study offers practical guidance for enhancing the innovation potential of the national entrepreneurial ecosystem and creates a framework for long-term human capital development in a rapidly changing technological environment.

AUTHOR CONTRIBUTION

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Spatial Zoning of Agrotechnological Hubs in Kazakhstan: Developing a Methodological Framework

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ABSTRACT

The development of Kazakhstan's agro-industrial complex requires the search for practical tools for the territorial location of innovation infrastructure. The purpose of this study is to develop a methodology for spatial zoning of agro-technological hubs in Kazakhstan based on quantitative assessment of innovation and agricultural potential of regions. The study uses microdata from World Bank Enterprise Surveys for 2024 on the formal agroindustrial sector and related industries, including processing, production, agricultural machinery and services. Using ten indicators normalised using the min–max method and aggregated with equal weights, it was constructed integral indicators such as the Innovation Potential Index (IPI) and the Agricultural Production Potential Index (API). The average values for these indices vary from IPI=0.052 to API=0.240 for the least developed regions and IPI=0.231 to API=0.413 for the most developed ones. The results showed that areas with high potential require consolidation of hubs, development of applied research, and development; territories with medium potential need technology transfer mechanisms, management practices; and regions with low potential need basic competencies formation, digitalization and modernization of infrastructure. The method is replicable and transportable to future WBES waves; limitations include the focus on the formal sector (WBES does not cover primary farms and informal units), as well as the cross-sectional design. Overall, the methodology can be used to monitor the dynamics of regional development and inform strategic adaptation, and it can be applied to future waves of WBES and other countries' industries.

KEYWORDS: Agrotechnology, Agrohub, Agricultural Economy, Innovation, Spatial Zoning, Region, Regional Development

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1. INTRODUCTION

Kazakhstan's agri-food economy is undergoing gradual restructuring from land- and resource-intensive production to more value- and technology-driven activities. Realising this transition is more than a matter of firm-level upgrading; it relies on spatially coherent ecosystems, where producers, processors, service providers, universities, finance, and standards bodies interact at low coordination costs. In this setting, agrotechnological hubs present a pragmatic option to densify services such as testbeds, extension-like advisory services, quality infrastructure, and growth finance. The policy question is where to locate such hubs and how to specialise their functions across diverse regions.

This study addresses the aforementioned challenge by developing a replicable, empirically driven approach to spatial zoning for the agrotechnology industry in Kazakhstan. It was leveraged the 2024 World Bank Enterprise Survey (WBES), which provides nationally representative microdata for the formal, private, agri-adjacent economy mainly food and beverage processors, producers of agricultural equipment and machinery, as well as service companies supporting production and commercialisation. Although the WBES does not cover primary farms or informal firms, it successfully covers the segment where many practices regarding technology adoption, processing, logistics, and management that impact value addition and market access are standard.

Our key hypothesis is that hub readiness is determined together by two latent abilities: (i) innovation potential a company's inclination to launch new products or processes, invest in research and development, and take up external technologies; and (ii) agricultural/production potential the richness of operational and market capabilities manifested in scale, capacity utilization, managerial experience, and digital connectivity. Since the constructs are not directly measurable, it was approximated them with a concise, policy-relevant set of indicators that are regularly available in WBES. Standardising the indicators to a standard scale and consolidating them into two intuitive composite measures gives the establishment-level Innovation Potential Index (IPI) and Agricultural Potential Index (API), which together chart the technological and production locations of companies.

Building on these micro measures, it was proceeded in two steps. First, it used unsupervised classification in the IPI–API plane to characterise firm heterogeneity in an interpretable manner (innovation-led, production-anchored, baseline-low archetypes). This diagnostic is not an end in itself; instead, it provides a microeconomic rationale for the types of services hubs will need to offer in various settings. Second, translated micro signals to space by aggregating IPI and API with WBES probability weights to the survey's seven regions and applying a parsimonious clustering to the set of regional points. The outcome is a three-tier zoning High, Medium, Low that summarises the joint profile of innovative and production capacity at the regional scale, suitable for targeting and sequencing hub interventions.

This paper makes three significant contributions. Conceptually, it codifies the idea that the location of agri-tech hubs must be predicated on the interaction between knowledge absorption and generation, as well as production depth, rather than considering them independently in either dimension. Methodologically, it offers an entirely transparent process including indicator selection based on a commonly accepted questionnaire, explicit normalisation, equal-weight indices, design-consistent territorial aggregation, and standard clustering that can be replicated or tested with alternative weights or scales. Practically, it produces a policy-relevant map that delineates areas for hub concentration (intense production deepness and satisfactory innovation), diffusion poles (urban knowledge centers with mid-level production depth), and foundation areas (areas where basic capabilities need to be established before advanced tools can be effectively applied).

Two particular boundary conditions are stated. First, because the WBES focuses on the formal sector and excludes primary agriculture, the zoning demarcates the formal agro-industrial and agri-tech ecosystem rather than the entire range of agriculture. Second, the study is cross-sectional; it clarifies patterns and informs targeting but does not determine causal links. However, these limitations are offset by the portability of the method. As future waves of WBES or new administrative and remote-sensing datasets become available, the indices and zoning can be re-assessed to gauge progress and refine hub strategy as necessary.

Against this background, the objectives of the research are fourfold: (1) to construct establishment-level indices of innovation and agricultural/production potential using WBES microdata; (2) to classify firms to clarify capability archetypes relevant to hub services; (3) to synthesize and aggregate regional profiles to obtain a brief and understandable spatial zoning; and (4) to obtain actionable implications for the strategic design, placement, and sequencing of agrotechnology hubs in Kazakhstan.

2. LITERATURE REVIEW

Innovation and spatial concentration research offer the conceptual basis for zoning agrotechnological hubs. Classic cluster work suggests that co-location enhances firm productivity, stimulates innovation through knowledge spillovers, and accelerates new business creation (Porter, 1998). Later empirical research demonstrates that areas of complementary, specialised activity grow faster and upgrade technologically (Delgado, Porter, & Stern, 2014), while the geography of innovation is strongly correlated with localised R&D spillovers (Audretsch & Feldman, 1996). Parallel literatures stress regional innovation systems the institutional and network structure through which firms, universities, finance, and government collectively produce and disseminate knowledge (Cooke, 2001; Cooke, 1997) and sectoral systems of innovation, which emphasise technology-, demand-, and actor-specific processes in industries like agrifood (Malerba, 2002). Collectively, these literatures provide a rationale for a spatial focus to targeting agri-tech initiatives.

In agriculture, the Agricultural Innovation Systems (AIS) framework reimagines innovation as a problem-solving, multi-actor process, rather than a linear R&D pipeline. The World Bank's AIS sourcebook codifies design principles for managing research, extension, finance, and market linkages (World Bank, 2012), while OECD guidance outlines the state's enabling role (OECD, 2013). Methodologically, recent studies take participatory and systems-oriented approaches, including Delphi-based consensus building for AIS diagnostics and FAO training manuals that operationalise AIS into tools (Toillier et al., 2022; FAO, 2022, 2021). This literature underpins composite, multi-indicator measurement of regional agri-tech readiness and diffusion capacity.

An emerging practice literature discusses innovation hubs and digital innovation hubs (DIHs) as place-based institutions that orchestrate services such as testbeds, brokerage, and skills especially for rural SMEs and agrifood chains. There is evidence that DIHs can reduce adoption costs for digital process and market innovations, enhance local entrepreneurial ecosystems, and deliver better sustainability outcomes (Stojanova et al., 2022). These findings lend policy relevance to zoning as a means of aligning hub functions with regional capability profiles.

The operationalisation of systems-related concepts into quantifiable frameworks typically relies on the use of composite indicators and unsupervised classification methods. The OECD–JRC Handbook outlines the best practices for selecting, normalising, weighting, and aggregating indicators, as well as conducting robustness tests (OECD & JRC, 2008/2005). Subsequent methodological advancements emphasise the impact of weights and aggregation methods on outcomes, promoting transparency and rigorous stress-testing procedures (Greco, Ishizaka, Tasiou, & Torrisi, 2019; Becker, Saisana, Paruolo, & Saltelli, 2017). These recommendations align

with the construction of simple, reproducible indices that quantify innovation and production potential, then classify regions based on their joint distribution.

For zoning, K-means clustering remains a popular and interpretable method for dividing observations by reducing within-cluster dispersion (MacQueen, 1967; Lloyd, 1957, as cited in Jin, 2011). Internal validity is routinely evaluated using the Calinski–Harabasz criterion and silhouette coefficients (Caliński & Harabasz, 1974; Rousseeuw, 1987), both of which are implemented in standard statistical software and widely applied in spatial analysis.

Applied agronomic research shows that multi-indicator panel clustering can produce actionable management zones and spatial stratifications for agronomy and value-chain policy. Such examples as fuzzy or hard K-means clustering on agro-ecological and management factors, with or without preceding dimensionality reduction (Yuan et al., 2022; Reyes et al., 2023), and landscape-metric clustering with silhouette diagnostics to map out homogeneous intervention zones (Fang et al., 2025) inspire our two-dimensional zoning in innovation–production space.

The use of comparable high-quality microdata is central to successful zoning. The World Bank Enterprise Surveys (WBES) provide a nationally representative dataset that yields firm-level information regarding innovation, management practices, infrastructure, and performance in the formal sector for more than 160 countries (Enterprise Surveys, 2024). The innovation modules of WBES tested through dedicated methodological studies successfully measure both product and process innovations as well as research and development activities using brief yet informative questionnaires (Cirera, Fattal, & Maemir, 2016). The methodological design and exhaustive documentation of the survey enable probability-weighted regional aggregation and cross-wave portability, making it suitable for spatial analysis targeting agri-adjacent ecosystems.

For Kazakhstan, the nascent literature discusses innovation management in agriculture, cluster policy for the agro-industrial complex, and value chain governance. Research highlights the necessity of coordinated technology transfer, managerial upgrading, and institutional support to convert innovation inputs into productivity and diversification (Taishykov, 2024; Manatovna et al., 2023; Tkacheva et al., 2024). Previous policy critiques warn that cluster initiatives require realistic diagnostics of regional capabilities and linkages to achieve success (Wandel, 2010). Complementary World Bank operations emphasise instruments for commercialisation and applied research as components of national innovation policy (World Bank, 2013; World Bank, 2020). This literature inspires a measurement classification strategy that is transparent, survey-anchored, and specific to Kazakhstan's formal agro-industrial sector.

The analysis of the literature has shown that the concepts of cluster development, regional and sectoral innovation systems serve as the theoretical basis for the zoning of agrotechnological hubs. The existing methodology is based on proven practices of building composite indexes, using clustering methods and using microdata, which makes it possible to quantify innovation and production potential. Despite the extensive research on agro-innovation systems and digital hubs, their application in the context of Kazakhstan is limited to conceptual descriptions and individual cases without quantifying the potential based on representative microdata. In addition, little attention has been paid to adapting international methods to the specific needs of the formal agro-industrial sector in Kazakhstan, which accounts for a significant portion of production by small and medium-sized enterprises. Therefore, this research addresses this issue by developing a method for spatially dividing agrotechnological hubs, which involves assessing their innovation and production capabilities, categorizing them statistically, and creating regional profiles for informed strategic planning.

3. RESEARCH METHODS

This study formulates the identification of spatial areas for agrotechnological hubs in Kazakhstan using a two-stage measurement and classification approach, leveraging microdata from the 2024 World Bank Enterprise Survey (WBES). Since the WBES does not cover primary agricultural establishments, the analytical scope covers agri-adjacent firms in the agrotechnology ecosystem, mainly food and beverage processors, producers of agricultural machinery and equipment, as well as service activities supporting production and commercialisation. The establishment is the unit of analysis, with each record belonging to one of the stratified regions defined in the survey. All analysis is performed using Stata to ensure consistency of terminology with the WBES questionnaire, thereby enhancing replicability and adaptability in future iterations. The target construct consists of a duality of latent capacities, innovation potential, and agricultural/production potential, approximated through ten establishment-level indicators that are observable and relevant for policy purposes. Innovation potential is measured by indicators such as recent product and process innovations, the size of R&D expenditure, and the use of foreign-licensed technologies. Agricultural/production potential, on the other hand, is measured in terms of total annual sales, capacity utilisation compared to maximum possible output, employment levels at the time of start-up as an initial-scale indicator, sectoral experience of the lead manager, and having a website or social media presence, which is an indicator of digital connectivity.

The analysis takes over the seven WBES stratification regions Almaty City; Astana City; Centre (Karaganda, Ulytau); East (Abay, East Kazakhstan); North (Akmola, Kostanay, Pavlodar, North Kazakhstan); South (Almaty oblast, Jambyl, Zhetisu, Kyzylorda, Turkestan, Shymkent City); and West (Aktobe, Atyrau, West Kazakhstan, Mangistau) which group administrative units to obtain sufficient sample sizes and capture salient economic geography. Including Almaty and Astana as stand-alone regions captures the outsized contributions of these metropolitan knowledge and service centers, while the grouped Center, East, North, South, and West categories concatenate contiguous oblasts with broadly similar production structures (e.g., export-oriented hydrocarbons in the West; diversified crop–livestock systems in the North; higher population density and labor markets in the South). This stratification underlies the survey weights employed for regional aggregation and is the operative spatial scale for our zoning. All regional means and cluster assignments are for these composite regions, not individual oblasts, which is relevant for interpreting policy recommendations and benchmarking across territories. Table 1 presents definitions of indicators used in the innovation and agricultural potential indices.

TABLE 1. Definitions of indicators used in the innovation and agricultural potential indices

Block	Indicator (short name)	WBES item	Raw data type	Questionnaire wording (abridged)	How it enters the index	Interpretation
Innovation	New product/ service	H.1	Binary (0/1)	During the last three years, has the establishment introduced new or improved products or services?	As 0/1; no transformation beyond the normalisation step	1 ⇒ more vigorous product-side innovation activity
	New process	H.5	Binary (0/1)	During the last three years, has the establishment introduced any new or improved processes?	As 0/1; no transformation beyond the normalisation step	1 ⇒ stronger process-side innovation/operations upgrading
	Any R&D	H.8	Binary (0/1)	In the last fiscal year, did the establishment spend on	As 0/1; no transformation	1 ⇒ positive R&D

				R&D (in-house or contracted)?	beyond the normalisation step	effort/absorptive capacity
	R&D amount	H.9	Continuous (currency)	How much did the establishment spend on R&D in that year?	Min–max normalised to [0,1]	Higher ⇒ greater R&D intensity/resources
	Foreign-licensed tech	E.6	Binary (0/1)	Does the establishment use technology licensed from a foreign-owned company?	As 0/1; no transformation beyond the normalisation step	1 ⇒ stronger external technology adoption
Agri/Production	Total annual sales	D.2	Continuous (currency)	Establishment's total annual sales for all products/services in the last fiscal year	Min–max normalised to [0,1]	Higher ⇒ larger scale/market penetration
	Capacity utilization	F.1	Continuous (%)	Output produced as a % of the maximum feasible output using all physical capital	Min–max normalised to [0,1]	Higher ⇒ better utilisation/efficiency
	Start-up employment	B.6	Continuous (count)	Number of full-time workers when the establishment started operations	Min–max normalised to [0,1]	Higher ⇒ larger initial scale/growth headroom
	Manager's sector experience	B.7	Continuous (years)	Years of experience of the top manager in this sector	Min–max normalised to [0,1]	Higher ⇒ more substantial managerial human capital
	Digital readiness	C.22b	Binary (0/1)	Does the establishment have its website or social media page?	As 0/1; no transformation beyond the normalisation step	1 ⇒ better market connectivity/digital capability

Note: compiled based on WBES (2024)

A complete-case sample is used for the variables under study; binary items are inserted unchanged, while continuous items are standardized using min–max normalization applied within the analytical sample as per formula (1):

$$x_i^* = \frac{x_i - \min(x)}{\max(x) - \min(x)} \qquad (1)$$

where:

x_i – the original value for observation i;

$\min(x)$ – the smallest value in the dataset;

$\max(x)$ – the largest value in the dataset;

x_i^* – the idiosyncratic error term, assumed to be independent and identically distributed.

To construct the latent constructs, indicators were pre-selected to correspond directly with the standard World Bank Enterprise Survey (WBES) items, thus ensuring conceptual consistency and allowing for cross-wave comparability. Raw variables were screened for obvious data-entry errors prior to normalisation, in line with questionnaire skip logic and internal consistency checks (e.g., positive sales for operating establishments and plausible bounds for capacity utilisation). Min–max scaling was conducted within the analytical sample so that all inputs fall in the range of [0,1] [0,1] [0,1], thus conserving the ordinal properties inherent in each indicator and enabling direct comparison of the two composite measures across different units. Where continuous indicators had long right tails, typical of financial and size variables, we took care that the min–max transformation did not introduce leverage through a small number of outliers; as a robustness check (reported in another context), it was replicated the procedure under mild winsorization and used a

z-score transformation and obtained the same qualitative zoning results.

Two establishment-level composite indices are then created as transparent equal-weight averages of their normalised constituents the Innovation Potential Index (IPI) and the Agricultural Potential Index (API) to prevent the embedding of untestable priors regarding the relative significance of separate indicators, while leaving open the possibility of sensitivity analysis using alternative schemes as per formula (2):

$$IPI_i = \frac{1}{5}\sum_{j=1}^{5} z_{ij} \quad API_i = \frac{1}{5}\sum_{k=1}^{5} z_{ik} \qquad (2)$$

where:

IPI_i – Innovation Potential Index for establishment *i*;

API_i – Agricultural Potential Index for establishment *i*;

z_{ij} – the j-th normalized innovation indicator for establishment *i*;

z_{ik} – the k-th normalized agricultural/production indicator for establishment *i*.

Equal weights are favoured here since they (i) optimise transparency and reproducibility across users and waves; (ii) minimise the danger of over-fitting weights to an individual cross-section; and (iii) enable diagnostic decomposition, as each indicator enters additively and on the same scale. Be that as it may, the setup is modular: weighting schemes (e.g., information-theoretic or expert-elicited) can be replaced with alternative ones without altering the surrounding aggregation and classification logic, enabling simple stress tests of the zoning to alternative normative choices.

In an initial diagnostic microeconomic analysis, establishments are classified in a two-dimensional space defined by (IPI, API) via the K-means clustering algorithm with Euclidean distance and a large number of random initialisations. The number of clusters is set in advance to three, aligning with policy-relevant categories (High, Medium, Low), and labels are then assigned by ordering the centroids along each dimension. K-means is run with a fixed random seed and a large number of initial configurations to reduce the risk of local minima. It was assessed internal validity via conventional measures of separation and compactness. These diagnostics are used only to ensure that the indices capture significant heterogeneity and are not intended to serve as the zoning mechanism. The resulting three clusters are thus interpreted as archetypes: innovation-led, production-anchored, and baseline-low, which inform the types of services that hubs might need to provide in different contexts (e.g., testbeds, diffusion support, and foundational capability development).

In order to map micro signals into spatial hubs, establishment-level indicators are weighted up to the regions of the survey using WBES probability weights so that regional statistics correspond to the target population instead of the realised sample; the pair of design-consistent characteristics each region means, as per formula (3):

$$\overline{I_r} = \frac{\sum_{i \in r} w_i I_i}{\sum_{i \in r} w_i} \quad \text{for } I \in \{IPI, API\} \qquad (3)$$

where:

$\overline{I_r}$ – the weighted mean value of the index I (IPI or API) for region *r*;

w_i – the WBES probability weight for establishment *i*;

I_i – the index value (*IPI* or *API*) for establishment *i*.

Weights are directly derived from the WBES sampling design and reflect stratification by industry, size, and geography. Their use in the aggregation process preserves the representativeness of the survey and guards against potential bias arising from unequal selection probabilities or differential non-response rates across strata. Final zoning is achieved by applying K-means clustering to three groups, where clusters are labelled by ordered centroid values, allowing for consistent interpretation in terms of combined innovation and agricultural/production potential. Classification at the meso level is the sole instrument for spatial targeting. Its construction

is deliberately reproducible and straightforward: any researcher with access to the same microdata can recalculate the indices, re-aggregate using the exact weights, and reapply the clustering algorithm. It was emphasised that the labels so assigned are algorithmically derived rather than normative; they capture joint positions in the IPI–API space and are intended to align policy bundles with capability profiles. Finally, it was noted that two boundary conditions on interpretation: the WBES framework covers formal, agri-adjacent players but not primary farms and informal micro enterprises; and the analysis is cross-sectional, yielding a snapshot for decision support rather than shedding light on causal relationships.

4. RESULTS AND DISCUSSION

The results transition from the micro to the mesoscale. It was first described firm heterogeneity in the joint innovation–production space by reporting the composition of the three unsupervised clusters in each WBES region (Table 2), followed by an interpretation of the cluster centroids that explains how the algorithm splits establishments along the Innovation Potential Index (IPI) and Agricultural/Production Potential Index (API) dimensions (Table 3). It was then visualised the distribution of establishments in the IPI–API plane with K-means assignments to visualise separation and within-cluster dispersion (Figure 1). Building on these diagnostics, it was possible to map micro signals to space by calculating design-consistent regional means of IPI and API and fitting a parsimonious three-way partition to the seven regional points, which provides the ultimate spatial zoning of agrotechnology potential (Table 4). Firm-level clustering is reported as a diagnostic to inform hub service design throughout, while regional clustering based on survey-weighted aggregates serves as the zoning tool for policy targeting. Table 2 shows Firm-level clusters by region (counts and row percentages).

TABLE 2. Firm-level clusters by region (counts and row percentages)

Region	High Pot.	Medium Pot.	Low Pot.	Total	High %	Medium %	Low %
Almaty	8	3	7	18	44.4	16.7	38.9
Astana	3	5	6	14	21.4	35.7	42.9
Center	8	4	7	19	42.1	21.1	36.8
East	6	5	9	20	30.0	25.0	45.0
North	6	3	11	20	30.0	15.0	55.0
South	5	4	7	16	31.3	25.0	43.8
West	2	9	12	23	8.7	39.1	52.2
Total	38	33	59	130	29.2	25.4	45.4
*Cluster labels reflect the K-means output at the firm level; percentages are within rows							

Note: compiled by the authors

Table 2 summarises the structure of establishments over three unsupervised clusters in the IPI–API plane by WBES region. The labels are to be read as algorithmic, not normative: the centroid diagnostics indicate that the cluster labeled "Medium Potential" clusters the innovation-intensive firms (highest IPI, mid-range API), "Low Potential" clusters production-anchored firms (higher API, moderate IPI), and "High Potential" includes baseline-low firms (low on both indices). The table presents raw counts and row percentages (shares within each region).

The regional profiles are quite different. West is the most innovation-intensive composition, with the highest proportion of "Medium Potential" companies and the lowest presence of baseline-low companies. This suggests a relatively dynamic agri-tech sector with opportunities for expanding R&D and R&D-commercialisation connections (e.g., pilot testbeds, supplier development, growth

financing). Astana also has a relatively high percentage of innovation-intensive establishments, in line with an urban knowledge base that can act as a source of technology diffusion to the surrounding production systems.

In contrast, North has the largest share of production-anchored firms and a relatively low fraction of innovation-intensive firms. This structure suggests aggressive technology transfer and adoption initiatives mechanization upgrading, process quality regimes, and digital operations more than frontier R&D. East and South exhibit mixed structures with large production-anchored fractions and modest innovation-intensive fractions; in these cases, balanced policies that blend diffusion (managerial and process upgrading, digital market access) with selective innovation partnerships will likely generate the highest marginal returns.

Almaty and the Centre show comparatively high baseline-low segments together with non-negligible production-anchored shares and lower innovation-intensive proportions. In practical terms, these areas may require a two-phase strategy: capability building (labour force qualifications, lean/process routines, basic digitalisation) to shift companies out of the baseline-low group; second, selective diffusion mechanisms to link promising manufacturers with urban innovation resources.

Collectively, the cross-regional differences in cluster composition suggest a microeconomic basis for differentiated hub strategies. More innovation-intensive regions (West, Astana) are candidates for agri-tech hub consolidation that prioritises commercialisation channels and growth capital. Production-anchored dominated regions (North, East, South) should emphasise diffusion extension-like services for tech adoption, vendor development, and logistics/digital market connectivity. Those with larger baseline-low segments (Almaty, Centre) require foundational capability building prior to which advanced instruments will be effective. Since Table 2 presents unweighted counts and within-region shares, these patterns should be interpreted as compositional signals rather than population totals. In the analysis that follows, survey weights are used to aggregate to the region and derive the final spatial zoning.

Table 3 shows firm-level cluster centroids (mean IPI and API).

TABLE 3. Firm-level cluster centroids (mean IPI and API)

Cluster label	Mean IPI	Mean API
High Potential	0.051	0.248
Medium Potential	0.567	0.442
Low Potential	0.136	0.479
*Means are from the establishment-level indices used in clustering		

Note: compiled by the authors

The centroids in Table 3 summarise the locations of each cluster in the two-dimensional space of the normalised indices (IPI, API). The separation is driven by the innovation dimension: the "Medium Potential" cluster has the highest IPI (innovation-intensive firms), the "Low Potential" cluster has a modest IPI but the highest API (production-anchored firms), and the "High Potential" cluster is low on both indices (baseline-low firms). Since the labels come from the unsupervised solution rather than a normative ranking, their practical meaning is: (i) an innovation-led group with above-average innovation and mid-range agricultural potential; (ii) a production-anchored group with relatively strong agricultural/production capability but only moderate innovation; and (iii) a baseline-low group with weak scores on both dimensions. Policy implications follow directly from these centroid positions. Firms in the innovation-led cluster are candidates for

scaling and commercialisation instruments (testbeds, growth finance, IP/standards support) that translate innovative effort into market penetration and supply-chain depth. Firms in the production-anchored cluster are the natural targets for technology diffusion and adoption (process upgrading, quality certification, digital operations, equipment modernisation) to improve their innovation capacity without compromising production strength. Firms in the baseline-low cluster require foundational capability building namely, managerial training, basic digitalisation, and access to extension-like services before more advanced instruments can be effective. In short, the centroid geometry suggests a trade-off across regions between innovation intensity and production depth, with a third group that performs poorly on both; aligning instruments to these differential positions should deliver the most significant marginal gains.

Figure 1 shows establishment-level innovation potential (*IPI*) vs. agricultural/production potential (*API*) with k-means cluster assignment.

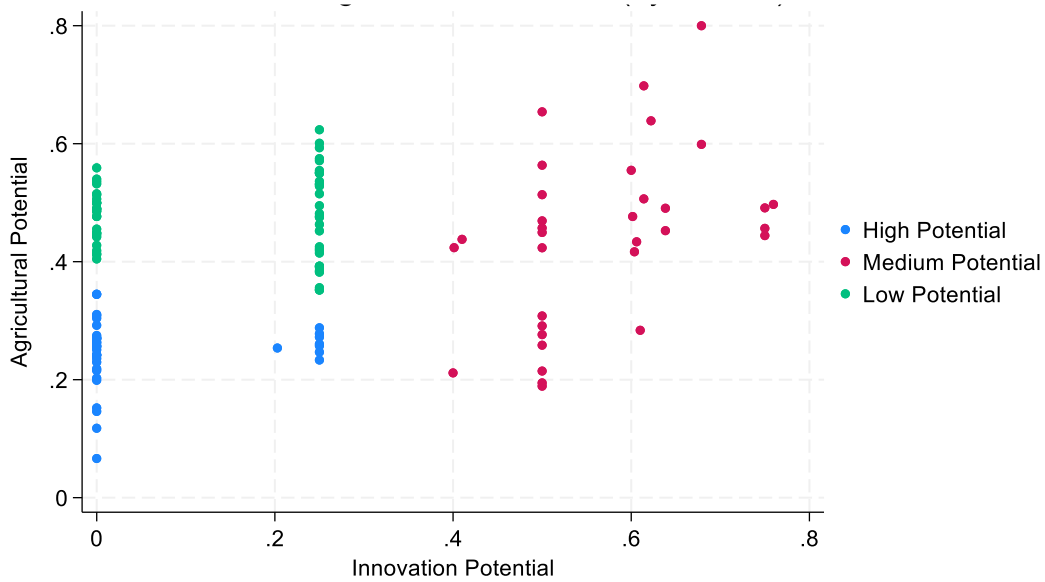


FIGURE 1. Clusters of innovation and agricultural potential

The scatter plot unlocks three statistically distinct groups of establishments within the normalised *IPI–API* plane, separated along the innovation axis (x) initially. Red-coded points "Medium Potential" per the algorithm fill out the right side with the highest IPI and broad vertical dispersion in API, signifying innovation-intensive companies whose production depth varies from modest to very strong; for them, scaling and commercialization tools (e.g., testbeds, standards support, growth finance) need to be combined with supply-chain and process improvement for those lower down on API. The green cluster ("Low Potential") is centred around moderate IPI but relatively high API, characterising production-anchored companies that prioritise technology diffusion and adoption process innovation, quality systems, and digital operations to enhance IPI without compromising their production strengths. Blue points "High Potential" per the unsupervised label but empirically baseline-low are positioned near very low IPI and low-to-mid API, indicating foundational capability gaps. Such firms need basic managerial training, lean/quality practices, entry-level digitalisation, and access to working capital

before higher-order innovation instruments are effective.

Two structural aspects are notable. First, tri-modality along IPI with partial overlap in API suggests that innovation capacity is the primary stratifier in this sample, with production potential differing within clusters. Second, API variance increases with IPI (greater vertical scatter at higher x), indicating that innovation alone is not a guarantee of strong production performance some innovation-active companies have yet to succeed in converting knowledge inputs into operational depth. Practically, this map substantiates a staged pathway: shifting baseline-low companies toward production-anchored performance (blue→green) through capability building, then from green to red through focused diffusion and co-development that elevates innovation intensity.

Table 4 presents the regional means of IPI and API, along with the assigned zone.

TABLE 4. Regional means of IPI and API and assigned zone

Region	Mean IPI	Mean API	Assigned zone
Almaty	0.241	0.324	Region Medium
Astana	0.198	0.351	Region Medium
Center	0.185	0.323	Region Medium
East	0.126	0.358	Region High
North	0.166	0.360	Region High
South	0.052	0.240	Region Low
West	0.150	0.431	Region High
*Regional means are survey-weighted averages of establishment indices. **Zoning is obtained by applying K-means clustering to the seven regional points in the IPI–API plane and labelled by ordered centroid values.			

Note: compiled by the authors

Table 4 embeds establishment-level signals in a regional zoning by averaging the innovation (IPI) and agricultural/production (API) indices with WBES probability weights and then clustering the seven regional points in the IPI–API plane. The resulting High / Medium / Low tiers represent ordered centroid positions of these regional means and thereby capture joint innovative and agricultural potential more than either dimension in isolation.

High zone – East, North, West

These territories strike a balance between relatively good agricultural/production potential and sufficient innovation. West has the deepest production profile of all territories, and East and North have balanced profiles with good API and medium IPI. Practically, these lands are poised for hub consolidation: tools that expand and formalise value chains (quality infrastructure, cold chain and logistics, supplier development) supplemented by applied R&D and technology demonstration (pilot testbeds, mechanisation and process improvement, digital operations) should deliver quick productivity and market dividends.

Medium zone - Almaty, Astana, Centre.

These areas are innovation-biased compared to their agricultural foundation: they are home to companies with superior IPI but just mid-level API. They are diffusion nodes by nature urban knowledge and service hubs from which technology, managerial methods, and digital market access can be transferred to nearby production systems. Policy priorities must focus on the linkage mechanisms (university–industry collaboration, extension-like services adapted to processors and logistics providers, standards and certification assistance) that translate innovative efforts into broader supply-chain upgrading.

Low zone – South

This area is consistently weak across both indices, indicating that companies face limitations in both capability and scale simultaneously. The policy sequence is

accordingly foundational capacity building: workforce skills, lean/quality management, basic digitalisation, access to working capital, and core infrastructure. Only once these foundations are established will more sophisticated innovation tools be practical.

Two further points are worth noting. First, the fact that Table 3 reports survey-weighted regional means implies that the zoning corresponds to the expected demographic of formal agri-adjacent firms rather than simply the realised sample taken. Second, the tiers are the outcome of a joint assessment of the IPI and API; a region can therefore gain entry to the High zone either through great production depth in combination with satisfactory innovation (as in the West) or through a balanced, above-average performance on both dimensions (as in the East and North). This combined perspective provides a coherent, policy-relevant map: concentrate centres where production depth is already consolidated and innovation is satisfactory; spread innovation from urban centres where the knowledge base exceeds that of agriculture; and provide support to areas where both competences are weak.

5. CONCLUSIONS

This paper crafts and implements an open, survey-based pipeline to map spatial zones for agrotechnology hubs in Kazakhstan. With World Bank Enterprise Survey microdata, two latent capacities —innovation potential and agricultural/production potential —were operationalised using ten establishment-level indicators mapped directly onto standard WBES items. Following harmonisation of heterogeneous measures through min–max scaling and the construction of equal-weight composite indices, it was (i) diagnosed firm heterogeneity in the IPI–API plane and (ii) decoded micro signals into region-level zoning through probability-weighted aggregation and K-means clustering. The emergent three-tier map is interpretable and policy-ready: East, North, and West are revealed as consolidation candidates with relatively strong production depth and sufficient innovation; Almaty, Astana, and the Centre serve as diffusion nodes with higher innovation compared to agricultural depth; and South shows foundational gaps on both dimensions.

Three substantive contributions ensue. First, the measurement approach is replicable: indicators, normalisation, index construction, and aggregation are completely specified and portable to future WBES waves, allowing time-consistent updates without remaking the method. Second, the classification is joint in innovation and production, sidestepping the usual trap of ranking regions on one dimension and instead acknowledging that hub readiness necessitates both absorptive capacity and operational depth. Third, the pipeline is diagnostic at two levels: it brings to the surface establishment-level archetypes (innovation-led, production-anchored, baseline-low) and indicates how their mix differs across regions, furnishing microeconomic rationale for differentiated spatial policy.

Policy implications are immediate. In High zones (East/North/West), instruments ought to prioritise hub consolidation and scaling: applied R&D and demonstration testbeds linked to priority value chains; supplier-development programs and quality infrastructure (standards, certification, metrology); logistics and cold-chain upgrades; and blended finance to crowd in private investment for scale-up. In Medium zones (Almaty/Astana/Centre), priority is technology diffusion and linkage formation: university–industry partnerships, extension-like services for processors, managerial upgrading (lean/quality/digital operations), and market-access platforms connecting urban knowledge assets to proximate production. In the Low zone (South), the sequence should prioritise foundational capability building, including workforce skills, entry-level digitalisation, production planning and quality systems, access to working capital, and core infrastructure, before introducing more advanced innovation instruments. Throughout all zones, inclusion and resilience are crucial: SMEs, women-led enterprises, and climate-smart practices should be integrated into

program design to prevent exclusion and mitigate vulnerability to climate and market shocks.

Limitations imply a straightforward research agenda. WBES spans the formal sector and excludes primary farms; zoning thus describes the formal agro-industry and agri-tech subsector, not the entire agriculture sector or the informal economy. The regional sample size is moderate (seven strata), and the cross-sectional data preclude causal inference. Equal weighting, though transparent, may misrepresent accurate marginal contributions of indicators in every context. Spatial dependence is only indirectly addressed through regional aggregation, rather than explicit spatial econometrics. Follow-on work should incorporate administrative and remotely sensed data (e.g., yield proxies, water stress, logistics accessibility), as well as agricultural census or firm registry coverage to capture micro and informal units, and network measures of buyer–supplier relationships. Longitudinal analysis with future WBES waves would allow for difference-in-differences or synthetic control assessments of hub interventions. Methodological refinements could include confirmatory factor analysis/SEM) to test the two-construct measurement model, spatial lag/error models to estimate spillovers, and multi-criteria decision analysis to introduce policy weights explicitly. Lastly, careful cost–benefit and distributional analyses should accompany the rollout of hubs to ensure additionality, prevent enclave development, and align incentives between public and private stakeholders. For implementation, it was suggested a practical roadmap: (1) take the current zoning as a targeting screen for pilot hubs; (2) undertake rapid value-chain diagnostics in each high-tier area to choose two to three anchor chains; (3) devise instrument bundles tailored to zone type (consolidation/diffusion/foundation), with clear eligibility and performance criteria; (4) put in place a monitoring system keyed to our indices e.g., proportions of firms reporting product/process innovation, incidence and intensity of R&D, capacity utilization, digital presence, and export or certification take-up so IPI and API can be recalculated every year; and (5) insert review points (e.g., every 18–24 months) to re-estimate the indices with fresh data and rebalance hub location or instrument mix as necessary.

Overall, the analysis presents a rigorous yet feasible approach to measuring, mapping, and prioritising agrotechnology development in Kazakhstan's regions. By combining an open indicator system with survey-weighted aggregation and frugal clustering, it translates dispersed micro evidence into a consistent spatial strategy. The framework does not replace in-depth project design. However, it offers a lasting foundation for where to intervene and what to prioritise, setting the stage for iterative learning as policies are implemented and new data become available.

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Green Economic Development in Kazakhstan: The Role of Public Regulation and Business-Led Investment

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ABSTRACT

The transition to a green economy is one of the key priorities for sustainable development, particularly in resource-dependent countries like Kazakhstan. The relevance of this research is determined by the need to balance investment incentives and fiscal instruments to accelerate environmentally oriented transformation. The aim of the article is to identify the mechanisms that have a decisive influence on the formation of a green economy in the Republic of Kazakhstan. The methodology is based on correlation and regression analysis and covers four groups of indicators: environmental investments, tax revenues for resource use, the scale of green construction, and the prevalence of ecological innovations, from 2016 to 2023. The results showed that investment measures do not have a statistically significant effect on the spread of environmental innovations ($R^2 = 0.620$, $p > 0.3$). On the contrary, fiscal instruments, in particular taxes on the use of natural resources, demonstrated a positive relationship with the volume of green construction ($R^2 = 0.504$, $p = 0.048$). Tax pressure can stimulate the behavioral transformation of businesses towards environmentally sustainable practices. Institutional conditions demonstrated higher efficiency compared to investment incentives. The mandatory regulatory instruments in the formation of green economy elements proved effective. The limited effectiveness of voluntary investment measures confirms the stronger regulatory role of fiscal mechanisms. State policy should focus on strengthening institutional regulation and developing targeted tax instruments to promote sustainable economic transformation in Kazakhstan.

KEYWORDS: Firm Behavior, Business, Government Regulation, Public Policy, Green Economy, Public Administration, Sustainable Development

SCSTI: 06.73.15

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1. INTRODUCTION

The transition to a green economy has become a key component of the 2030 Agenda for Sustainable Development. SDG Goal 12 aims to ensure sustainable consumption and production, while Goals 7 and 13 aim to promote environmentally friendly energy sources and combat climate change (UN DESA, 2021). Greening the economy is increasingly viewed not as an auxiliary component of sustainable development, but as a necessary vector for modernizing economic policy. In recent years, there has been increased coordination of efforts at the international level to create sustainable growth models that integrate environmental priorities into macroeconomic planning. The Organization for Economic Cooperation and Development (OECD) emphasizes that the transition to a green economy requires a systemic restructuring of fiscal, investment, and regulatory mechanisms, with a critical role played not only by environmental technologies, but also by the institutional environment that stimulates or restricts their use (OECD, 2020). The European Union, through its European Green Deal, combines direct support for green innovation with strict carbon footprint regulation, resource taxation, and environmental standards (European Commission, 2020). Similarly, China, in its 14th Five-Year Plan (2021–2025), has set targets to increase the share of green investment, introduced environmental reporting requirements, and launched a reform of green taxes (NDRC, 2021).

The diversity of instruments to stimulate the green transition reflects the lack of a universal model. Some countries focus on direct public investment, while others emphasise market incentives or fiscal pressure. For example, Germany and the Netherlands actively use green taxes as a means of redistributing incentives in favor of sustainable solutions, while Japan relies on innovation subsidies and public partnerships (World Bank, 2022). Such diverse practices raise a vital research question about the comparative effectiveness of different approaches to promoting green transformations. In Kazakhstan, the issues of forming a green economy received institutionalization with the adoption of the concept of transition to a "green" growth model in 2013. According to the International Monetary Fund, in countries with limited budget resources, the sustainability of green reforms largely depends on the ability to use a combination of state and market mechanisms (IMF, 2022).

In Kazakhstan, the strategic foundations to green economy are defined by the national Concept for Transition to a Green Economy (Renewable Market Watch, 2018), the Strategic Development Plan of the Republic of Kazakhstan until 2025, and the State Program for the Development of Education and Science for 2020-2025, which emphasize ecological modernization, energy efficiency, and sustainable use of natural resources (Yessimkhan & Sartanova, 2024).

Given the above trends, the question of which mechanisms have a decisive influence on promoting the green agenda in the context of a transformative economy becomes relevant. Including mechanisms as voluntary business investment decisions and their participation in green innovation (UNEP, 2019), as well as the role of government intervention through environmental taxation and regulatory barriers (OECD, 2023). This paper attempts to empirically assess the relative influence of two key factors, private sector investment activity and government fiscal regulation on environmental outcomes in the Kazakhstani economy. The purpose of the study is to determine which factor has a greater impact on the development of the green economy in Kazakhstan: government regulation through fiscal mechanisms or private investment activity.

2. LITERATURE REVIEW

The concept of the green economy appears as a model within the broader framework of sustainable development, but its interpretation differs across studies. Morgera and Savaresi

(2013) interpreted the green economy not only as an environmental strategy, but also as a binding legal system in which environmental measures cannot violate human rights, and vice versa. Thus, economic efficiency should not take priority over the state's social responsibilities or human rights standards. Moreover, the green economy has been critically examined as a tool that, if improperly implemented, can reproduce global inequality (Ehresman and Okereke, 2015). The green economy remains formal and superficially linked to the SDGs, unless structural barriers to accessing natural benefits and institutional participation of vulnerable groups are removed. Therefore, a lack of a shared conceptual framework leads to a gap between rhetoric and measurable strategies (Georgeson et al., 2017). According to Merino-Saum et al. (2018), the green economy can be linked to the SDG system through a set of sustainable indicators selected based on the criterion of their impact on natural resources. There is no common understanding in the scientific literature of what exactly a "green economy" is; different authors provide different definitions that are poorly consistent with each other. There is no standard system of indicators that links different approaches into a single logical model. That is, even when metrics are proposed (for example, linking to SDGs), they are not integrated in such a way as to form a holistic measurement system.

The green economy is considered a holistic system of sustainable development, comprising three interrelated components: economic, environmental, and social, which are understood as equal axes (Khoshnava et al., 2019). That is, no element should dominate the others. Ecological sustainability and social well-being are placed on the same level as economic efficiency. In post-Soviet countries, the idea of a green economy is formally enshrined in regulatory documents (strategies, programs, laws), where the concept of a green economy turns out to be "poorly adapted", since there is a gap between the declared principles and real management actions (Oliinyk, 2020). Consequently, the real practice of planning and management does not correspond to these standards: plans are not implemented, and priority is given to economic tasks over environmental ones. Trushkina (2022) correlates the concept with the transformation of the industry structure, where the green economy covers logistics, waste management, and the construction sector, and involves a transition to cyclical business models. All the approaches considered are based on the need for a connection with the SDGs, but highlight different foundations: legal guarantees, social redistribution, metric systems, or industry transformation. The definition of the green economy is thus not reduced to a single formula and is determined through a dominant focus - legal, critical-social, indicator, or institutional-applied.

Differences in the interpretation of mechanisms that shape environmental innovation have developed progressively in the literature. A resource-based refinement was followed in Kiefer et al. (2019), where six groups of resources, competencies, and dynamic capabilities (RCC) were distinguished, indicating that systemic and radical innovations depend on different combinations of RCC. Therefore, internal knowledge, organizational culture, and financial autonomy are essential in shaping radical forms of environmental innovation. Government regulation has a dual effect: on the one hand, it restricts the freedom of firms by imposing rules and regulations (constraint), on the other hand, it stimulates them to seek new solutions and implement innovations to meet requirements (catalyst). Therefore, regulation does not simply hinder or help, but acts as both a barrier and an incentive, and the real outcome depends on how flexible and innovative firms are.

Green investments are explained through the operation of financial mechanisms and institutional barriers, rather than through norms and rules. Falcone (2020) provided one of the earliest systematizations of opposing positions in the economic literature, contrasting the neoclassical view, in which environmental regulation increases costs and reduces

investment attractiveness, with the Porterian perspective, which links regulation to innovative renewal and higher competitiveness (Fabrizi et al., 2024). Access to finance remains a key condition for implementing environmental investments; regardless of the regulatory impact, whether restrictive or stimulating, the lack of access to financial resources renders the effect unachievable.

Subsequent studies emphasized the role of institutional and financial frameworks. The main barriers to SME green investments are not technological or market-related, but rather insufficient government involvement and weak financial infrastructure (Chien et al., 2021). Regulatory frameworks, credit infrastructure, and transparency define the capacity of green finance to ensure environmental sustainability (Khan et al., 2022). Institutional support influences the scale of green investment, the return on investment, and the degree of technological specialization (Yang et al., 2024). To sum up, institutional conditions, from the nature of regulation to the transparency of financial procedures, act as a basis that determines either obstacles or opportunities for the development of environmental investments.

The use of tax instruments, which are often discussed as auxiliary measures, in environmental policy is considered in the literature as a way to transition from administrative measures to a system of economic incentives. Hawkins (2000) argued that green taxes function as a complement to normative regulation, which is not capable of independently ensuring environmental transformation. In European practice, environmental charges were intended to combine ecological and economic objectives. However, the uneven distribution of the tax burden constrained the long-term effectiveness (Bailey, 2002). Irregularities in the distribution of the tax burden made it difficult to achieve sustainable results. In the extractive sector, environmental taxation, when implemented under weak institutional conditions, may reduce investment and drive activity into the shadow economy unless supported by broader institutional coherence (Söderholm, 2006). On the contrary, in the Asian context, despite its limited effectiveness, fiscal incentives are crucial for ensuring green growth (Dulal et al., 2015). Toprak (2018) confirmed the need for a comprehensive adjustment of tax policy: not only adjusting rates, but also integrating with sectoral strategies, including energy and transport. Ljubičić (2025) proposed a more rational use of resources, which should simultaneously reduce the pressure on the environment; in other words, the tax system is restructured in such a way as to make environmentally harmful behavior unprofitable and environmentally sustainable behavior profitable. Environmental taxation depends on institutional coherence, sectoral structure, and consistency with macroeconomic policy.

In the study by Chang et al. (2016), sustainable construction is defined as a managed process based on a combination of regulatory frameworks, subsidies, and a system of standards that enable the Chinese construction sector to transition to environmentally friendly practices. Porfiriev et al. (2017) considered green construction as part of a strategy for sustainable urban development. However, in the Russian context, it remains voluntary, primarily relying on international certification standards and the dominance of energy efficiency as the primary criterion. In contrast to these approaches, Meng et al. (2021) included green construction in a broader paradigm of ecological civilization, where the priority is shifted from the technological and institutional dimension to cultural transformation, forming new forms of urban consumption and environmentally oriented life. Within the framework of the comparison, the emphases differ: on the one hand, the emphasis is on administrative and financial incentives, on the other, on the strategic sustainability of the urban environment, and further, on the formation of new behavioral norms.

Public policy in the field of the green economy is approached in the literature through institutional, normative, and applied perspectives. Lo and Howes (2013) examined

the organization of carbon markets in China as an outcome of the interaction between centralized regulation and market mechanisms. Nevertheless, there are contradictions between administrative coordination and financial incentives. State policy and the internal mechanisms determine how actively businesses invest in the environment and innovation (Ma et al., 2022).

In Kazakhstani research, the predominant attention has been given to normative and strategic dimensions, including innovative development (Diyar et al., 2014), institutional conditions related to sustainability issues such as decarbonization and the energy transition (Imangali & Bekturganova, 2024), as well as fiscal and investment instruments within the framework of the national green growth strategy (Yesbergen et al., 2024). Despite the general interest in mechanisms of state participation, all works analyze individual elements and do not address the holistic structure of interactions between measures and results. In this regard, this study will conduct a comprehensive analysis of the links between regulatory, fiscal, and investment mechanisms and the performance parameters of the green transformation.

3. RESEARCH METHODS

The research is based on secondary data The development of a green economy requires the active involvement of the business sector, institutional incentives and effective fiscal mechanisms. As the literature review has shown, the key factors are business investment activity, environmentally oriented expenditures, and tax policy in the field of natural resource management. In this case, the dynamics of dependent parameters, such as the scale of environmental innovations and the prevalence of green construction, are of particular importance.

To ensure transparency in the research design, the analytical procedure was structured into sequential stages, as outlined in Table 1.

TABLE 1. Stages of analysis and their purpose

Step	Stage	Action	Purpose
1	Data collection and coding	Assembly of macroeconomic indicators (2016–2023) and coding into dependent and independent variables	Obtain a structured dataset suitable for hypothesis testing
2	Hypothesis formulation	Definition of dependent and independent variables and formulation of three research hypotheses	Establish the analytical framework for empirical testing
3	Correlation analysis and data cleaning	Verification of linear relationships, detection of multicollinearity, and exclusion of unsupported models	Reduce hypotheses to statistically consistent ones (H1 and H2)
4	Descriptive dynamics	Classification of indicators into four groups: environmental investments, environmental taxes, green construction activity, ecological innovations, with dynamic analysis	Identify structural trends and ensure contextual interpretation of variables
5	Regression analysis and interpretation	Estimation of models for confirmed hypotheses, evaluation of coefficients, diagnostics, and interpretation of results	Test the strength and direction of institutional and fiscal effects on green transformation
6	Estimation (OLS)	Specified models	Regression tables (coefficients, SE, R^2, p)
7	Diagnostics	Estimated models	VIF, residual tests, 95% CIs
8	Robustness checks (optional)	Alternative specs (shares, lags, outliers)	Sensitivity results

Note: compiled by the authors

This stepwise design clarifies how the dataset was transformed from raw macroeconomic indicators into testable models. The structure also allows the exclusion of inconsistent hypotheses and strengthens the reliability of statistical inference. In this regard, three research hypotheses were formed:

Hypothesis 1. The growth of internal R&D costs in the business sector and the increase in investment volume for environmental protection is positively associated with the number of enterprises implementing ecological innovations.

Hypothesis 2. The increase in the tax burden for the use of natural resources (in absolute values) correlates with the growth in the volume of work in the field of green construction.

Hypothesis 3. The increase in the share of environmental taxes in GDP and the share of green construction in the total volume of work is associated with the growth in the share of ecological innovations in the overall structure of innovation activity.

Table 2 presents the dependent and independent variables used in the analysis.

TABLE 2. Hypotheses, dependent and independent variables

Hypothesis	Dependent variable	Independent variable
H1	Number of enterprises with ecological innovations	Internal expenditures on R&D in business sector; Investments in environmental protection (total, domestic, foreign)
H2	Volume of green construction works	Taxes on resource use; Total environmental taxes (mln. tenge)
H3	Share of ecological innovations in total innovations (%)	Total environmental taxes (as % of GDP); Share of green construction works (%)

Note: compiled by the authors

The analysis was conducted in several stages to identify the relationships between institutional and fiscal conditions and the scale of environmentally friendly activities.

The first stage described the dynamics of indicators for 2016-2023, within the framework of which four categories were identified that reflect the key areas of the formation of a green economy:

(1) financing and investment (cover internal R&D costs in the business sector and investments in environmental protection);

(2) environmental taxes (includes absolute values of taxes on pollution and resource use, as well as their share in GDP);

(3) green construction (characterizes the volume and share of green construction in the overall construction sector);

(4) environmental innovations (combines quantitative and specific indicators of the implementation of environmentally friendly solutions).

The allocation of these categories is based on the need to structure various indicators according to their directions of influence on a sustainable economy: through investments, tax regulation, institutional practices of enterprises, and technological transformations. This classification enabled the meaningful interpretation of further analysis and logical coherence between variables. Thus, the table shows both dependent and independent variables that are used in empirical hypothesis testing. These variables reflect key areas of green economy formation: business investment activity, tax regulation of environmental management, and the introduction of environmentally-oriented technologies and practices.

At the second stage, a correlation analysis was conducted to identify linear dependencies between variables and eliminate factors with high multicollinearity (Figure 1).

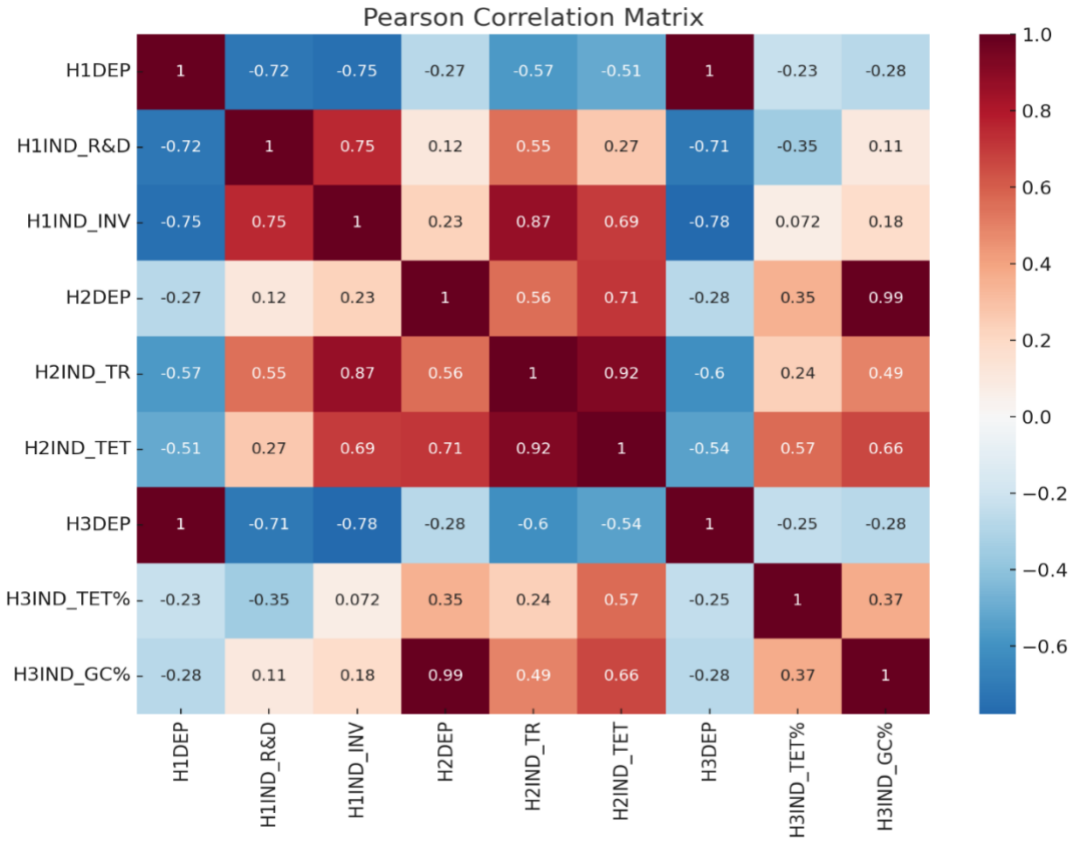


FIGURE 1. Correlation matrix

Correlation analysis revealed stable relationships only for hypotheses H1 and H2. Hypothesis H3 was excluded from regression modeling due to the absence of significant correlations between the dependent and independent variables (Table 3).

TABLE 3. Cleaned hypotheses, dependent and independent variables

Hypothesis	Dependent variable (code)	Independent variables (code)
H1	Number of enterprises with ecological innovations (H1DEP)	Internal expenditures on R&D in business sector (H1IND_R&D); Investments in environmental protection (H1IND_INV)
H2	Volume of green construction works (H2DEP)	Taxes on resource use (H2IND_TR)

Note: compiled by the authors

To confirm the findings, a Pearson correlation matrix was used, which estimated the strengths and directions of linear relationships. The final model included only those variables for which the correlation coefficients were statistically significant ($p < 0.05$ or $p<0.1$) and there was no multicollinearity. The final stage involved a regression analysis, within which three hypotheses were tested to establish statistically significant relationships between fiscal and institutional conditions and the characteristics of environmental activity of businesses.

4. FINDINGS

The analysis examines key areas of green economy development in Kazakhstan, including the dynamics of domestic R&D expenditures in the business sector, investments in environmental protection, and the structure of their sources. These parameters reflect institutional conditions and incentives that influence sustainable economic transformation. Particular attention is paid to distinguishing between domestic and external sources of financing, since the structure of investments can indicate the level of national business involvement and the effectiveness of public policy. The observed trends enable the identification of not only volumetric changes but also structural shifts in investment priorities.

Figure 2 shows the combined dynamics of four indicators for 2016-2023.

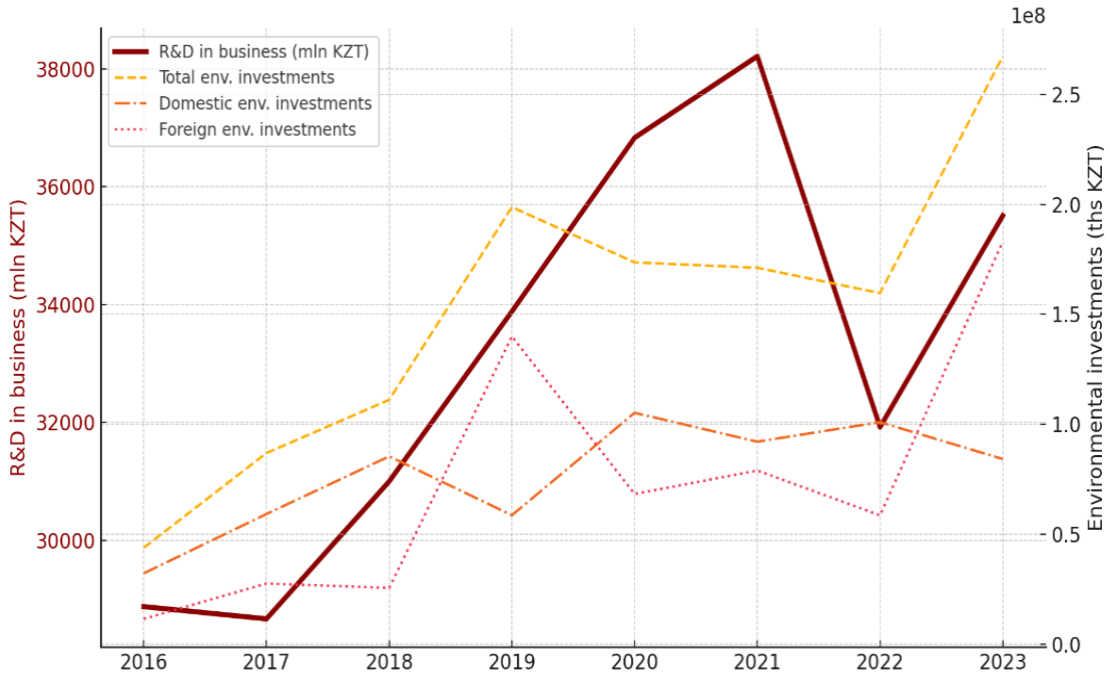


FIGURE 2. Environmental investments

Between 2016 - 2023, domestic R&D expenditure in the business sector remained in the range of 28.9–38.2 billion tenge, with the highest value recorded in 2021. A comparable trend in dynamics is observed in investments aimed at environmental protection: their total volume increased from 43.9 billion tenge in 2016 to 267.3 billion tenge in 2023, with the main acceleration occurring after 2019. A breakdown of the sources reveals that domestic investments dominated until 2019, but starting from 2020, the growth rate of external investments significantly exceeded that of domestic investments. In particular, the volume of external investments increased from 14.0 billion tenge in 2019 to 183.0 billion tenge in 2023, while internal investments in the same period did not show sustainable growth, varying between 84 and 105 billion tenge. Thus, the growth in overall investment activity was achieved mainly due to external financing, with a stable trajectory of internal R&D costs.

The intensification of investment activity in the environmental sphere was accompanied by an expansion of tax potential, formed through fiscal revenues associated with natural resource management and environmental protection (Figure 3).

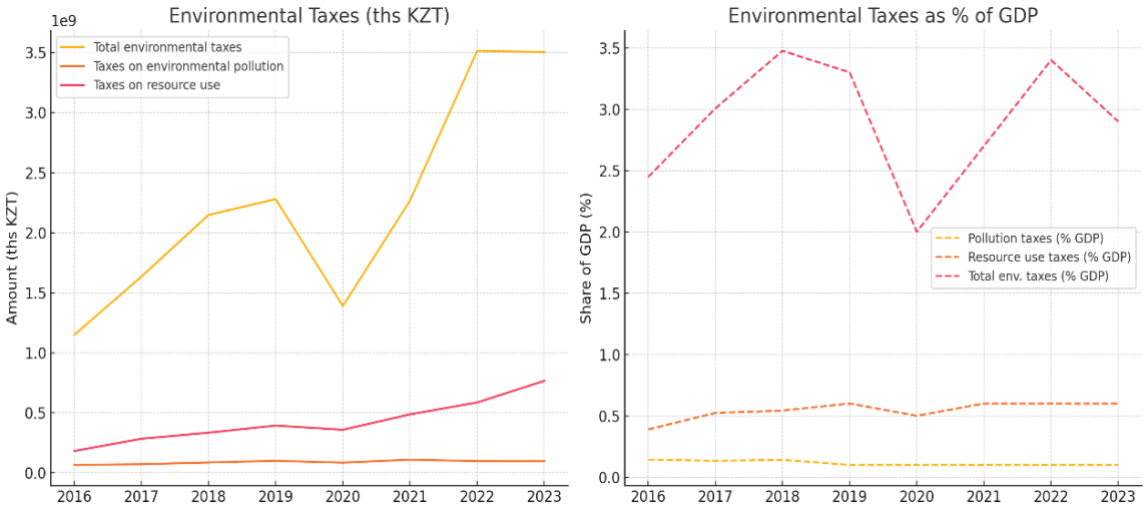


FIGURE 3. Environmental taxes

The total volume of environmental taxes increased from 1.15 trillion tenge in 2016 to 3.50 trillion tenge in 2023, with the majority of the increase occurring between 2020 and 2022. Resource use taxes provided a stable contribution to the structure of tax revenues, increasing more than fourfold, from 182.4 to 766.6 billion tenge. At the same time, environmental pollution taxes demonstrated less pronounced dynamics, remaining within the range of 85-110 billion tenge since 2018.

In response to the growing tax and investment flows in the environmental sphere, there is a gradual introduction of sustainable practices in the construction industry, including the implementation of green building projects (Figure 4).

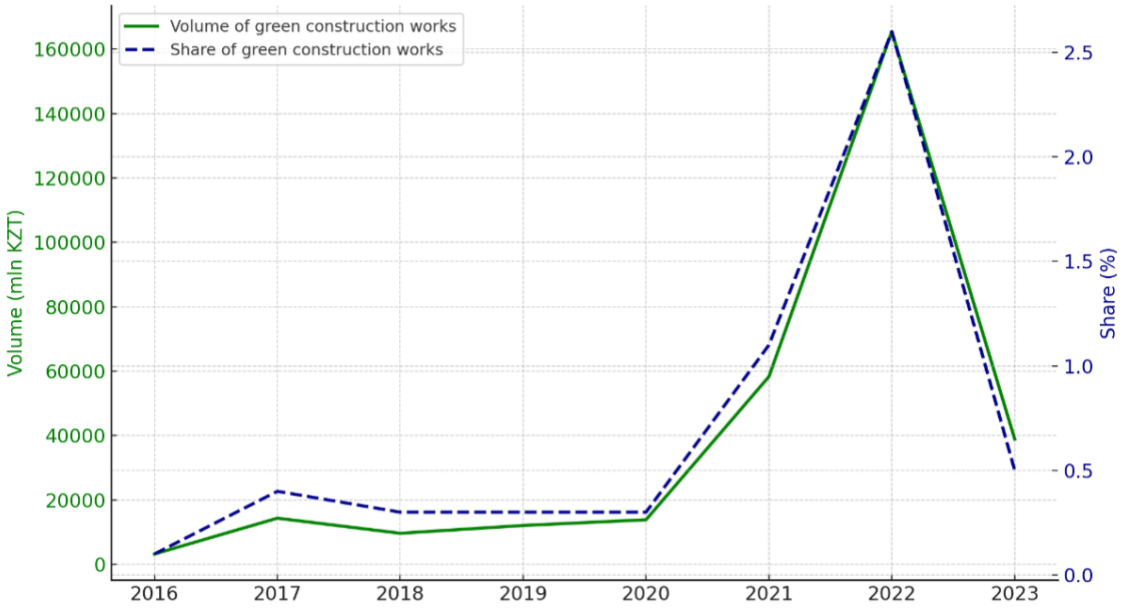


FIGURE 4. Green construction activity for 2016-2023

An analysis of the share of taxes in GDP shows the stability of the share of pollution charges at 0.1%, while the share of resource use taxes increased from 0.39% in 2016 to 0.6% in 2019 and remained at this level in subsequent years. The total share of environmental taxes peaked in 2018 (3.48% of GDP) and then varied between 2% and 3.4%. This configuration indicates a growing fiscal burden, driven by increased attention to the rational use of natural resources and enhanced tax administration in environmentally sensitive sectors.

The volume of work performed within the framework of green construction increased from 3.25 billion tenge in 2016 to 165.4 billion tenge in 2022, but in 2023, a decrease to 38.9 billion tenge was recorded. The share of such works in the total construction volume remained at the level of 0.1-0.3% until 2020, after which it reached a peak of 2.6% in 2022. However, in 2023, it decreased again to 0.5%. Thus, despite individual bursts of activity, the development of green construction has been uneven, episodic, and without a stable trend. In other words, the volumes and shares of such work have fluctuated sharply over the years, without demonstrating consistent growth or consolidation at a high level. This indicates a lack of stable institutional support, constant demand, or a fixed regulatory framework.

Indicators characterizing the prevalence of environmental innovations indicate a systemic reduction in the scale of their application in corporate practice (Figure 5).

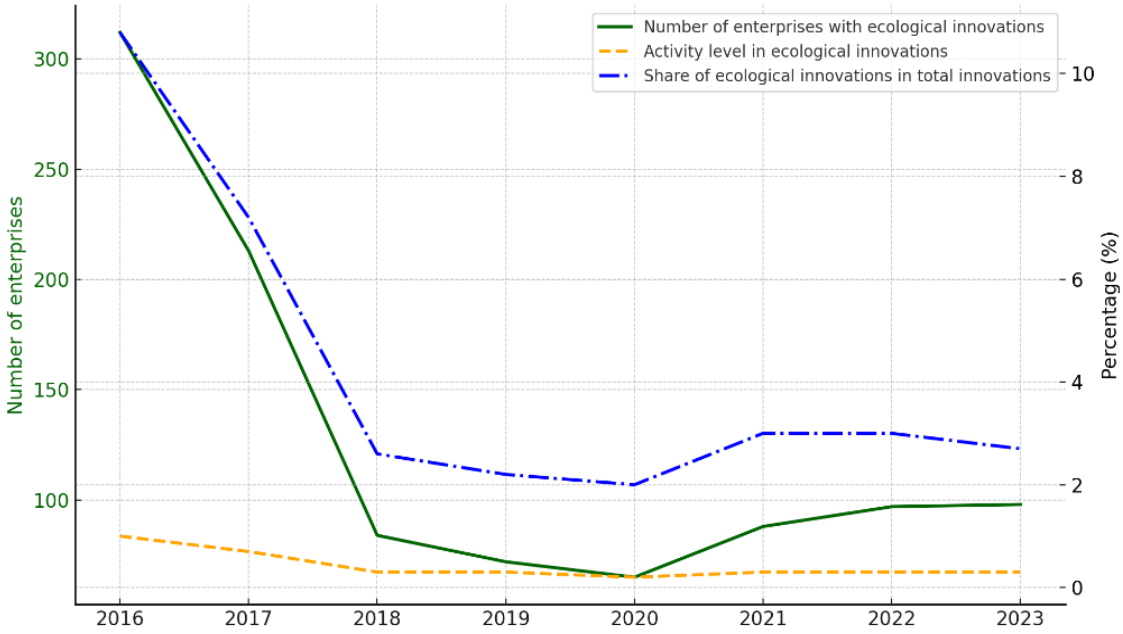


FIGURE 5. Ecological innovations for 2016-2023

Over the period 2016–2023, the number of enterprises implementing environmental innovations decreased by 214 units from 312 to 98. The level of activity in this area decreased by more than threefold, from 1.0% to 0.3%, and has remained at this minimum level since 2020. The sharpest decline was recorded in 2017 and 2019, when the number of enterprises decreased by 141, and the level of activity fell from 0.7% to 0.3%. The share of environmental innovations in the total volume of all innovative solutions decreased from 10.8% in 2016 to 2.7% in 2023, despite a temporary increase to 3.0% in 2021–2022. A comparison

of absolute and relative indicators demonstrates not only a reduction in the scale of enterprise involvement, but also a general narrowing of the significance of environmental issues in the structure of corporate innovations. The parameters indicate a lack of stable incentives that facilitate the systematic implementation of environmentally oriented solutions.

In Table 4, there are results for the regression analysis of hypothesis 1.

TABLE 4. Regression results for Hypothesis H1: ecological innovations and investment factors

Indicator	Model H1 Result
R	0.788
R^2	0.620
Adjusted R^2	0.469
RMSE	63.780
Durbin-Watson	1.586
Autocorrelation (p)	0.194
ANOVA (F, p)	F = 4.086; p = 0.089
Coefficient (H1IND_R&D)	–0.009
t-value, p-value (H1IND_R&D)	t = –0.854; p = 0.432
95% CI for Coefficient (H1IND_R&D)	[–0.035 ; 0.018]
Coefficient (H1IND_INV)	$–6.061\times10^{-7}$
t-value, p-value (H1IND_INV)	t = –1.152; p = 0.302
95% CI for Coefficient (H1IND_INV)	$[–1.959\times10^{-6} ; 7.467\times10^{-7}]$
VIF / Tolerance	2.311 / 0.433 (for both independent variables)
Intercept	509.612 (p = 0.133), 95% CI: [–221.347 ; 1240.571]

Note: compiled by the authors based on calculations

Hypothesis H1 is not confirmed. Despite the moderate strength of the model (R^2 = 0.620), neither of the independent variables, neither internal R&D expenditures (p = 0.432) nor environmental protection investments (p = 0.302), demonstrated a statistically significant relationship with the number of companies implementing ecological innovations. Also, both variables have negative coefficients, which contradicts the expected direction of the relationship. The obtained results indicate the absence of a direct relationship between investment activity and the actual spread of environmental innovations in the corporate sector.

In Table 5, there are results for the regression analysis of hypothesis 2.

TABLE 5. Regression results for Hypothesis H2: green construction and resource taxation

Indicator	Model H2 Result
R	0.710
R^2	0.504
Adjusted R^2	0.422
RMSE	41,108.326
Durbin-Watson	2.093
Autocorrelation (p)	0.830
ANOVA (F, p)	F = 6.106; p = 0.048
Coefficient (H2IND_TR)	4.325×10^{-5}
t-value, p-value (H2IND_TR)	t = 2.471; p = 0.048
95% CI for Coefficient	$[4.238\times10^{-7} ; 8.608\times10^{-5}]$
VIF / Tolerance	1.000 / 1.000
Intercept	–57,229.864 (p = 0.220)

Note: compiled by the authors based on calculations

Hypothesis H2 is confirmed. There is a statistically significant positive relationship between resource use taxes (H2IND_TR) and the volume of green construction (H2DEP), with a coefficient of 4.325×10^{-5} at $p = 0.048$. The model explains 50.4% of the variance of the dependent variable ($R^2 = 0.504$), indicating a moderate strength of the regression dependence. The absence of multicollinearity (VIF = 1.000), acceptable autocorrelation of residuals ($p = 0.830$), and a confident 95% confidence interval confirm the stability of the model. Thus, increasing tax pressure on resource use is a factor that stimulates the transition to environmentally oriented construction practices.

The results obtained for the model of hypothesis H2 enable us to conclude that fiscal instruments have a more pronounced impact than investment measures. In particular, the statistically significant positive relationship between resource taxes and the volume of green construction confirmed the impact of tax regulation as an effective tool for transforming business behavioral strategies towards environmentally friendly practices.

In contrast, the results for hypothesis H1 showed that there was no significant impact of internal R&D costs and investments in environmental protection on the prevalence of ecological innovations. Voluntary investment decisions do not provide a sufficient incentive for the systematic implementation of sustainable technological solutions. Thus, institutional conditions based on regulatory and fiscal restrictions are more effective in stimulating environmental activity than investment and incentive mechanisms. These differences highlight the importance of stringent regulatory measures in shaping the elements of the green economy.

The results of the analysis showed that the impact of resource taxes on stimulating green building is consistent with the findings of Hawkins (2000), Söderholm (2006), and Ljubičić (2025), where taxation was considered as an element of redistribution of incentives in environmentally sensitive sectors. Therefore, fiscal policy is effective in transforming business behavioral strategies. In contrast, the lack of a link between investment and environmental innovation is at odds with the findings of Khoshnava et al. (2019), Khan et al. (2022), and Ma et al. (2022), where investment measures were attributed to the main factors of sustainable transition. The recorded discrepancy may be due to institutional constraints, insufficient elaboration of mechanisms for translating investments into management decisions, and the lack of mandatory regulatory support, which together reduce the effectiveness of government measures based only on incentive instruments.

Other studies demonstrate differences between fiscal and investment measures. The positive relationship between resource taxes and green building growth found in model H2 is consistent with the findings of Toprak (2018), who considered fiscal instruments as an effective lever for sustainable transition. On the other hand, the lack of a significant impact of domestic investment and R&D on green innovation, recorded in model H1, confirms the doubts of Dulal et al. (2015) about the effectiveness of investment incentives while subsidizing traditional industries. Chien et al. (2021) noted that institutional inconsistencies and low transparency hinder the effective utilisation of green finance. Despite the intensification of fiscal and investment measures, the lack of an assessment of their impact on innovative practices limits the effectiveness of the implemented policies. The identified differences confirm the priority of mandatory regulatory mechanisms over voluntary incentives.

6. CONCLUSION

The objective of this study is to examine the impact of investment and fiscal mechanisms on the development of environmentally friendly practices in Kazakhstan's economy, within the framework of state regulation. The scientific novelty of the research lies in the empirical identification of the differentiated effectiveness

of fiscal and investment mechanisms, which demonstrates the priority of regulatory pressure over voluntary incentives in the institutionalization of the green economy. The conducted analysis showed differences in the degree of influence of investment and fiscal factors on environmentally oriented business activities in Kazakhstan.

Firstly, there is an increase in the total volume of investments in environmental protection. However, the primary source of this growth is external investments rather than internal ones. This indicates insufficient involvement of domestic businesses in the environmental modernisation process and a high dependence on external financing for the country.

Secondly, there has been a steady decline in the number of companies implementing environmental solutions in their corporate innovation efforts. From 2016 to 2023, this number decreased more than threefold, indicating a lack of motivation among businesses to integrate environmentally friendly practices in the absence of effective incentives and support mechanisms. Regression analysis confirmed that voluntary investments by companies, including R&D spending, do not significantly contribute to the spread of green innovations.

Thirdly, tax policy has demonstrated a more pronounced impact. The increase in taxes on the use of natural resources correlates with an increase in "green" construction volumes, which confirms the effectiveness of fiscal instruments as a factor in changing business strategies. Unlike investment measures, taxes perform not only a fiscal function, but also an environmental one, orienting companies towards sustainable activities.

Future research should focus on sector-specific assessments of fiscal efficiency, cross-country comparisons of regulatory practices, and the role of green finance in complementing state policy. The management strategy should be based on clear indicators, substantiated reporting forms, and institutional pressure mechanisms capable of transferring sustainability from the declarative to the practical plane. The focus of management is not stimulation as such, but the formation of restrictions that make other behavior economically irrational.

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Assessment of SME Loan Portfolio Quality in Kazakhstan: Empirical Analysis from 2013 to 2023

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ABSTRACT

The article is devoted to the assessment of the quality of the loan portfolio of small and medium-sized businesses (SMEs) in Kazakhstan to identify periods of credit instability and hidden risks that can limit the investment potential of enterprises. The methodological framework encompasses an analysis of the overdue debt structure, calculation of the sustainability coefficient and delinquency index, as well as cluster analysis to identify periods with varying degrees of credit risk. The results showed that the share of loans without delay increased from 69.2% in 2013 to 94.2% in 2023, while the share of problem loans over 90 days decreased from 23.9% to 3.9%. The overdue debt index decreased from 0.31 to 0.06, and the sustainability coefficient exceeded 5.5 in 2022, indicating an improvement in payment discipline and the ability of SMEs to service debts. The cluster analysis identified two periods: the crisis (2017-2018) and the recovery (2021-2023), which confirms the need for a differentiated policy in managing credit risks. The study confirmed the presence of cyclicity in the dynamics of SME credit risks and showed that the stabilization of the loan portfolio is possible only with a combination of macroprudential tools, government support programs and digitalization of credit monitoring. Future studies could focus on ESG factors and the level of digitalization of enterprises in credit risk assessment models, as well as comparative cross-country studies to identify adaptive policies in the context of regional differences.

KEYWORDS: Economy, Economic Growth, Small Business, Medium-Sized Businesses, Business Lending, Overdue Debt, Financial Stability, Loan Portfolio

SCSTI: 06.71.07

JEL Code: G21, L26, O16

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1. INTRODUCTION

Global economic changes affect the structure of business, access to finance, and risk management. Small and medium-sized enterprises (hereinafter – SMEs), despite their significant contribution to employment and added value, are particularly vulnerable to fluctuations in the macroeconomic environment. The sustainability of SMEs largely depends on the availability of credit resources. At the same time, structural constraints lack of collateral, weak credit history, limited financial reserves – reduce the ability to attract borrowed funds on acceptable terms.

In many countries, SMEs are characterized by high borrowing costs and a limited choice of financial instruments. The lack of reliable mechanisms for assessing solvency and risk management increases barriers to entry into financial markets. Under these conditions, government measures aimed at reducing credit constraints, such as subsidised loans, guarantee funds, and risk-sharing mechanisms, are particularly important. According to the OECD, expanding SME access to bank lending is considered a necessary condition not only for growth but also for stabilising the economy (OECD, 2023).

Singapore has programmes that combine standard credit products with support mechanisms tailored to the specific needs of SMEs (IMDA, 2023). The UK is developing lending schemes that reduce collateral requirements and simplify the approval process (Department for Business and Trade, 2023). Internationally, loans are seen as the main instrument for financial support of SMEs, especially in the context of limited access to venture and grant capital. In this regard, the quality of the SME loan portfolio is of practical importance for assessing sustainability and identifying potential risks. The experience of Kazakhstan highlights the presence of systemic imbalances, including a high share of overdue debt, unstable reserve policy, and a limited ability of banks to adapt to the specific needs of SMEs.

Loan programmes that support digital transformation are becoming one of the most widely applied tools internationally. For SMEs, access to credit often determines the feasibility of technological upgrades. Where grants or equity financing are unavailable or limited, credit remains the most scalable mechanism. In this regard, SME loan portfolios become crucial for financial planning and policy design. In Kazakhstan, SMEs constitute a significant portion of the economy in terms of employment and added value. While entrepreneurship support programmes exist, mechanisms for linking credit instruments with digital objectives are still underdeveloped.

The study aims to assess the quality of SME loans in Kazakhstan by identifying hidden risks, structural imbalances, and potential constraints that may hinder digital investments in the sector. Therefore, to have a clear understanding of the financial foundation on which digital transformation is expected to occur, the following research questions have been developed:

RQ 1: What factors determine the dynamics and stability of the SME loan portfolio in Kazakhstan?

RQ 2: How can periods of increased credit risk in SME lending be identified during 2013-2023?

2. LITERATURE REVIEW

Creating a sustainable financial environment for small and medium-sized businesses requires a multifaceted consideration of the role of lending, which is interpreted differently in studies depending on the institutional and economic conditions prevailing at the time. For countries and segments with high information asymmetry and weak institutional support, SME lending is more often limited or goes into informal forms (Berger & Udell, 2006), which directly affects the quality of loans and the likelihood of delinquencies: the higher the asymmetry and the weaker the institutions, the higher the risks and the share of problem assets. Even in the presence of a formal sector, the share of SMEs

in banks' loan portfolios remains understated due to increased risks and strict collateral requirements (Beck, 2013). This problem is especially acute in low- and middle-income countries, where access to finance is limited by structural barriers including high interest rates, corruption costs, and bureaucratic restrictions (Osano & Languitone, 2016). In these conditions, the state acts as an active intermediary in expanding the range of financial instruments for SMEs, including leasing, factoring, as well as venture and angel financing (Abbasi et al., 2017). In addition, limited access to credit is determined by three groups of factors: firm characteristics (size, age, availability of collateral), financial parameters (debt burden, business plan), and owner characteristics (education, experience) (Chowdhury & Alam, 2017).

Research on SME credit risks encompasses three primary areas: defaults, borrower assessment structures, and the impact of non-financial factors. Dietsch & Petey (2002) point out that SME credit risks are particularly sensitive to systemic shocks and require special approaches to pricing and reserve formation to manage them. Where economic, environmental, and social factors influence credit risk through borrower liquidity, collateral quality, and total exposure (Weber et al., 2010). Duarte et al. (2018) noted that loan portfolio management should take into account macroeconomic parameters (inflation, GDP dynamics, interest rates, and unemployment. A firm with a low level of sustainability (economically, environmentally, or socially) is more likely to show deterioration in financial performance and, therefore, has a higher probability of default (Höck et al., 2020). Thus, to reduce risks, sustainable finance models are needed that take into account not only "dry" financial indicators, but also the firm's ability to adapt to sustainability requirements, e.g., ESG factors, business flexibility, and market adaptability (Calabrese et al., 2020; Hossain et al., 2023).

Some studies consider reserves under International Financial Reporting Standards (hereinafter – IFRS), particularly IFRS 9, in the context of analysing the quality of SME loan portfolios. This analysis links the calculation of Expected Credit Loss (hereinafter – ECL) to delinquency levels, borrower stability, and the amount of potential losses. The IFRS 9 standard requires that loss reserves be formed not only based on actual overdue debt, but also taking into account projected losses, based on the probability of default and macroeconomic scenarios (Novotny-Farkas, 2016). An adaptive calculation of expected credit losses based on a modular approach allows for the incorporation of borrower behaviour patterns and portfolio characteristics (Schutte et al., 2020). Fluctuations in reserves serve as indicators of asset quality and cyclical vulnerability in the banking sector (Resende et al., 2024). In the context of emerging economies, as shown by Abakirov et al. (2019), the application of the standard requires adaptation to the specifics of guarantee and credit instruments, including sensitivity to macroeconomic changes. In Kazakhstani practice, Lambekova et al. (2020) described the use of a logit model for internal audit aimed at identifying problem assets. Therefore, a systematic assessment is necessary for such indicators as the share of loans without delinquency, the structure of delinquency by maturity, and the amount of reserves, allowing for the identification of hidden risks and periods of instability in SME lending.

Credit instability in SME portfolios occurs during specific periods due to the accumulation of hidden risks, structural shifts, and a weak response to macroeconomic changes. The instability of loan portfolios develops in stages, which requires identifying the hidden phases of risk accumulation before the onset of crisis states (Breuer et al., 2012). The increase in the probability of default is attributed to changes in macroeconomic parameters, including GDP dynamics, inflation, and interest rates, which form cycles of portfolio instability (Buncic & Melecky, 2013). The greatest vulnerability arises with low diversification, when loans are concentrated in a limited number of industries or with individual borrowers (Shim, 2019). Instability phases intensify through debt

market and currency fluctuations, which create additional channels for risk transmission (Em et al., 2022). The case of Kazakhstan demonstrates that internal distortions in the lending structure, including high asset concentration, can lead to periods of credit instability (Zaitenova & Abzhalelova, 2025; Nurpeissova et al., 2025).

Institutional, financial, and regulatory weaknesses shape credit vulnerability. SMEs face barriers to finance arising from income volatility, limited borrowing sources, limited access to alternative financing, and high transaction costs (Nizaeva & Coskun, 2021; Kumar et al., 2023). In addition, inflationary pressures, uncertainty in calculation standards, and instability of the tax regime increase risks for lenders and limit investment activity (Karybay & Zhussupov, 2024). Thus, regional differences and access to private sources of capital determine the effectiveness of credit support (Beenstock, 2025).

Previous studies predominantly focused on the problem of access to finance for SMEs. However, the issue of credit portfolio quality remained underexplored, particularly regarding the structure of overdue loans and the resilience of SME lending. Additionally, earlier research did not provide a periodisation of instability phases in the development of SME credit portfolios, which limited the ability to capture cyclical fluctuations in risk.

Institutional barriers, regulatory instability, and industry distortions affect the availability of financing and the sustainability of credit relations in the SME sector. More complex conditions for access to capital, increased risks, and reduced predictability of regulation create a need for an objective assessment of the quality of the loan portfolio. The key indicators are the volume of bank and SME lending, the share of loans without delinquency, the level of overdue debt, as well as the volume of reserves formed under IFRS. These parameters allow us to assess the volume of credit support, the quality of the portfolio, and the level of risk in the SME segment.

3. METHODOLOGY

Support for small and medium-sized businesses in Kazakhstan is considered a priority area of economic policy; however, the sustainable development of this sector is impossible without considering the reliability of its credit collateral. A proper understanding of the structure and quality of borrowings enables an objective assessment of the financial stability of SMEs and the associated risks for the banking sector. To achieve the set goal of assessing the quality of the loan portfolio of SMEs in Kazakhstan and identifying periods with different levels of stability, it was necessary to conduct a comprehensive analysis of the dynamics and structure of key indicators. Indicators were selected that reflect the ratio between timely serviced and overdue loans, the level of reserves, and the stability coefficient.

Table 1 presents all the indicators used as the basis for the calculations.

TABLE 1. Indicators used for the assessment of SME loan portfolio quality

Category	Variable	Coding
Total volume	Bank loans (total volume of loans issued by banks)	TOTAL_LOANS
SME Portfolio Quality	SME loans, including loans without overdue debt and loans with overdue payments of various maturities	SME_TOTAL
	Loans without overdue debt	SME_GOOD
	Loans overdue 1-30 days	SME_OVERDUE_1_30
	Loans overdue 31-60 days	SME_OVERDUE_31_60
	Loans overdue 61-90 days	SME_OVERDUE_61_90
	Loans overdue by more than 90 days	SME_OVERDUE_90PLUS

Risk Assessment	IFRS Provisions	SME_IFRS_PROVIS

Note: compiled by the authors

The assessment of SME loan quality relied on three core indicators: (1) loan portfolio structure, (2) overdue debt index, and (3) loan stability coefficient. These were calculated according to the following formulas.

The structure of the SME loan portfolio (%) was defined by representing each portfolio component as a proportion of total SME loans, as presented in formula (1):

$$Share_i = \frac{X_i}{L_{SME}} \times 100 \quad (1)$$

where:

$Share_i$ – the share of the corresponding loan category;

X_i – volume of a specific loan category (e.g., non-overdue, overdue 1-30 days, etc.);

L_{SME} – total volume of SME loans.

Index of Overdue Debt (IOD), the share of overdue loans (of all categories) in the total volume of SME loans, was applied as shown in formula (2):

$$IOD = \frac{L_{1-30}+L_{31-60}+L_{61-90}+L_{90+}}{L_{SME}} \quad (2)$$

where:

IOD – the Index of Overdue Debt;

$L_{1-30}, L_{31-60}, L_{61-90}, L_{90+}$ – overdue SME loans grouped by delay duration (up to 30 days, 60 days, 90 days, more than 90 days);

L_{SME} – total volume of SME loans.

Stability Coefficient (SC), the ratio between high-quality and severely overdue loans and was applied as shown in formula (3):

$$SC = \frac{L_{good}}{L_{61-90}+L_{90+}} \quad (3)$$

where:

SC – the Stability Coefficient;

L_{61-90}, L_{90+} – SME loans overdue by more than 60 days, more than 90 days;

L_{good} – SME loans without overdue payments.

The indicators were calculated for each year from 2013 to 2023 to trace the dynamics of SME loan quality and credit risk trends. These measures served as the basis for addressing the second research question, identifying periods of increased credit risk in SME lending. However, calculations based on the coefficients allow only a descriptive assessment of the quality of the loan portfolio, but do not provide a distinction between stable and crisis years. To overcome this limitation, the study uses cluster analysis as an element of scientific novelty. Grouping years with similar credit risk profiles allows for the identification of hidden phases of instability that are not visible when analyzing individual indicators. The use of the K-means method in combination with Gap Statistic distinguishes this study from previous descriptive works. It provides a more comprehensive assessment of SME credit risks in Kazakhstan.

In addition to the descriptive and ratio-based calculations, a cluster analysis was conducted to identify homogeneous periods in terms of SME credit risk. The K-means method was applied to standardized variables (z-scores) including: share of non-overdue SME loans (SME_GOOD), share of loans overdue more than 90 days (SME_OVERDUE_90 PLUS), index of overdue debt (IOD), loan stability coefficient (SC), and IFRS-based provisions (SME_IFRS_PROVIS). The optimal number of clusters was determined using the Gap Statistic method. The final segmentation into two clusters allowed for the differentiation between high-risk and stable credit portfolio years, based on the aggregated behavior of all selected indicators.

4. RESULTS

The assessment of the quality of SME lending is based on an analysis of the portfolio

structure, the level of overdue debt, the stability of borrowers, and the volume of reserves formed. In accordance with the research methodology, the portfolio structure is analysed by shares of loans in different states: loans without overdue debts and loans with overdue periods of varying duration, ranging from short-term (1-30 days) to long-term, including the riskiest category of over 90 days. For this, official statistical data for 2013-2023 were used, grouped by key indicators that reflect the degree of credit reliability and associated risks.

Table 2 shows the dynamics of the SME loan portfolio structure by category: the share of loans without overdue payments and levels of overdue debt by maturity.

TABLE 2. Structure of SME loan portfolio quality, in %

Year	SME_GOOD	Loans overdue by 1-30 days	Loans overdue by 31-60 days	Loans overdue by 61-90 days	Loans overdue by more than 90 days
2013	69,21	2,45	1,07	3,36	23,92
2014	80,65	3,94	0,45	0,27	14,69
2015	82,84	4,22	1,20	0,85	10,90
2016	82,87	5,52	3,26	1,34	7,02
2017	4,40	2,74	1,18	1,18	9,86
2018	8,64	2,28	0,99	0,99	10,05
2019	80,88	2,56	1,07	1,01	14,48
2020	80,51	2,94	1,21	2,01	13,32
2021	84,94	1,82	0,76	0,58	11,90
2022	93,56	1,21	0,60	0,23	4,40
2023	94,17	1,27	0,45	0,21	3,90

Note: compiled by the authors according to calculations

Loans without overdue debt on the principal and/or accrued interest (SME_GOOD) reflect the quality part of the loan portfolio of small and medium-sized businesses. In 2013, their share was 69.2%, after which there was a steady growth, reaching 82.9% in 2015 and 2016. The maximum values were recorded in 2022 and 2023 - 93.6% and 94.2%, respectively. In 2017 (4.4%) and 2018 (8.6%), a decline was recorded, disrupting the overall upward trend.

Overdue loans demonstrated multidirectional fluctuations. In the 1- to 30-day segment, the values have not exceeded 5% since 2015, reaching minimum levels of 1.2% and 1.3% in 2022–2023. In the 31–60 days category, stabilization within 0.5–1.2% is also noted, except in 2016 (3.3%). Overdue loans of 61–90 days are decreasing from 3.4% in 2013 to 0.2% in 2023. The category over 90 days remains the most problematic, despite the positive dynamics: from 23.9% in 2013 to 3.9% in 2023. Short-term overdue loans remain manageable, and the reduction in debts over 90 days indicates an improvement in loan servicing discipline.

A comparison of SME_GOOD and total overdue loans highlights the opposite trends. During periods of high SME_GOOD, the share of problem loans, especially long-term ones, decreases. The sharpest gap is observed in 2023, with 94.2% against a total of 5.8% for all categories of overdue loans. Such dynamics indicate a qualitative improvement in the SME portfolio, as well as a gradual recovery after the crisis years of 2017-2018.

The sharp deterioration in 2017–2018 was mainly due to macroeconomic shocks. Such problems include events resulting from the devaluation of the national currency and the rise of inflation. In particular, it is worth noting the tightening of the credit policy of the banking sector, when the share of loans without delinquency fell to critically low levels - 4.4% in 2017 and 8.6% in 2018. The situation began to stabilize only after 2019, which was

facilitated by government support programs and the normalization of monetary policy.

The increase in the share of loans with no overdue payments and the reduction in debts over 90 days indicate a decrease in risk for both banks and borrowers. Moreover, an improvement is also caused by improved access to credit resources for SMEs, especially with stable credit, which helps to reduce rates and expand credit limits. A decrease in overdue payments indicates a strengthening of enterprises' solvency, which increases their investment attractiveness.

From the state's perspective, an improvement in the structure of the SME loan portfolio reflects the effectiveness of measures to provide financial support and reduce barriers to borrowing. A high share of high-quality loans minimizes the burden on the guarantee system and contributes to the stability of the banking system. Thus, loans remain a profitable instrument provided there is a stable macroeconomic environment and adequate financial discipline.

Although the structure of the SME portfolio by types of debt at first glance demonstrates positive dynamics, an additional check of the total debt burden is required through the overdue debt index, which reflects the total level of credit risks (Figure 1).

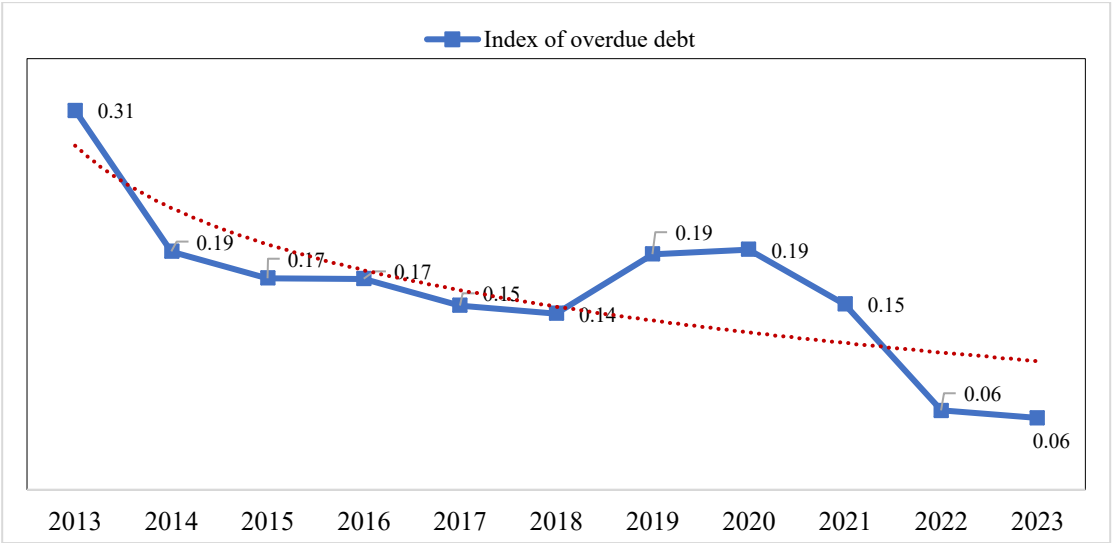


FIGURE 1. Dynamics of the SME loan overdue debt index for 2013-2023

The overdue debt index has been steadily declining from 2013 to 2023, from 0.31 to 0.06, indicating a consistent reduction in the share of problem loans within the SME loan portfolio. An average reduction of 0.02-0.025 points every two years suggests a stable positive trend. The temporary increase in the index to 0.19 in 2019-2020 revealed a short-term escalation of financial risks, presumably related to external economic conditions. The growth of the overdue debt index in 2019-2020 was associated not only with internal changes in credit policy, but also with external factors. Restrictive measures introduced during the COVID-19 pandemic led to a decline in business activity and a reduction in enterprise income, thereby increasing the risk of non-payment. Additional pressure was caused by currency fluctuations and an increase in debt servicing costs due to macroeconomic instability. Ultimately, it led to short-term deterioration in the quality of the SME portfolio. A return to the minimum values of 0.06 in 2022-2023 confirms the restoration of solvency and reinforces the risk reduction trend. Consequently, small and medium-sized businesses are characterised by a more stable financial position, which ensures timely

repayment of debt and reduces the level of credit risk.

Additionally, the debt sustainability characteristics of SMEs can be revealed by the sustainability ratio, which reflects the ratio of non-performing loans and debt with a term of over 60 days (Figure 2).

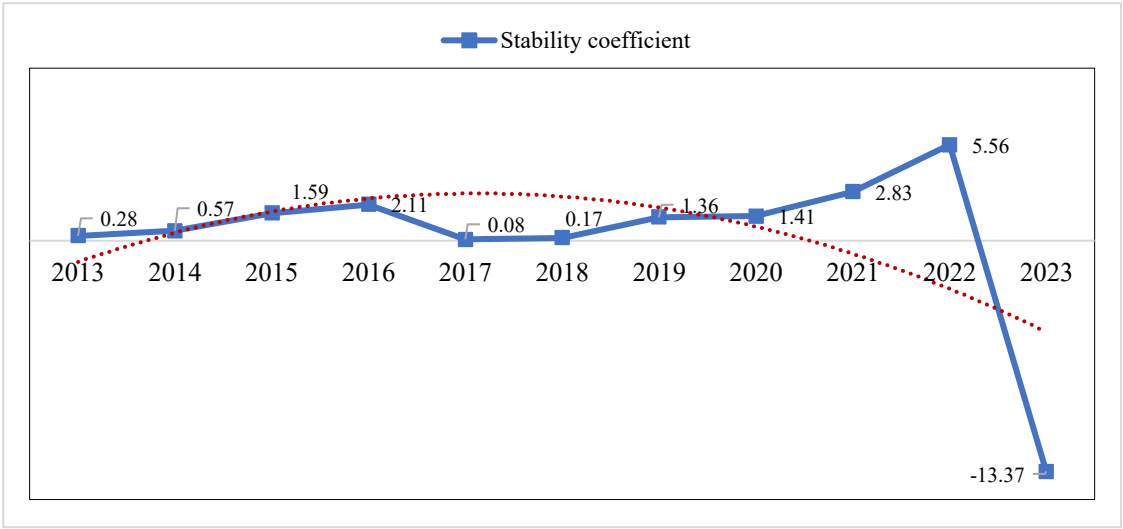


FIGURE 2. SME loan stability coefficient for 2013-2023

The sustainability ratio in 2013 was 0.28, which showed predominance of overdue debts over non-overdue debts. Between 2014 and 2016, the ratio significantly strengthened to 2.11. Thus, the loan portfolio's structure improved. In 2017, there was a sharp decline to 0.08, indicating a violation of the ratio between reliable and problem loans. Since 2019, the ratio has consistently exceeded one, confirming a more stable balance in favor of non-overdue loans. In 2013, the volume of provisions for SME loans reached 4.598 billion tenge, which reflects a strict risk assessment at the beginning of the period.

From 2014 to 2016, there was a sharp decrease in the level of reserves, with further fluctuations (1,600-2,200 billion tenge), as shown in Figure 3.

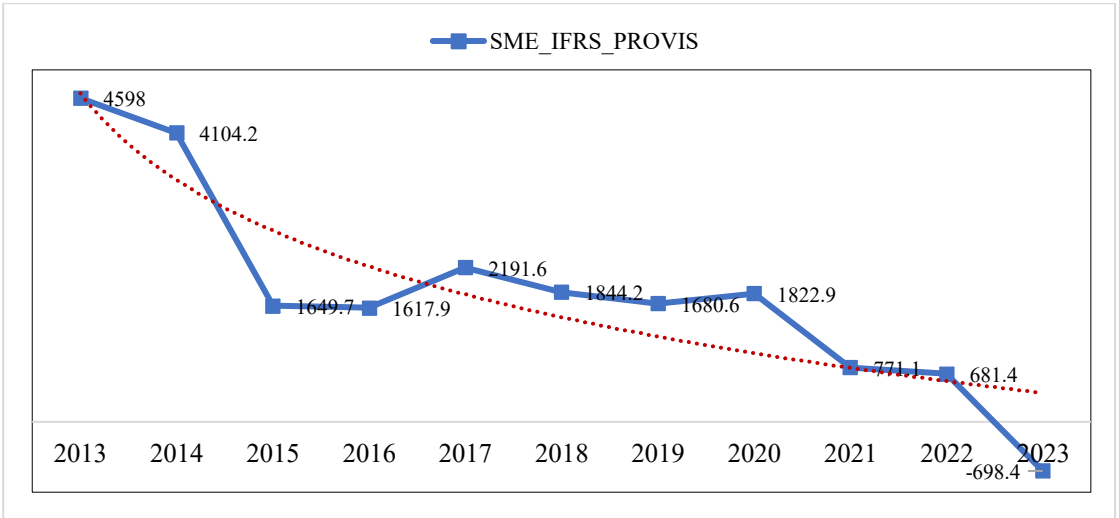


FIGURE 3. Dynamics of IFRS-Based provisions for SME loans for 2013-2023, in billion KZT

Since 2020, a gradual decline began, reaching 681.4 billion tenge in 2022. In 2023, the indicator became negative (-698.4 billion tenge), indicating the restoration of previously created reserves or the write-off of liabilities that do not carry risk. Overall, there was a decrease in the level of expected losses and a change in approaches to assessing the quality of the loan portfolio. That is, banks have become less afraid that SME loans will not be repaid. At the beginning of the period, they created huge reserves, that is, they set aside money in case the business was unable to repay the debt. Gradually, these reserves decreased because the risk level decreased. In 2023, banks even returned some of these reserves because they believed that the risks were no longer relevant. SMEs became more reliable borrowers, and banks began to evaluate them more stably and confidently.

To identify periods with different levels of credit risk in the SME sector, a cluster analysis was conducted using calculated indicators that covered portfolio structure, overdue debt, stability ratio, and volume of provisions. The optimal number of clusters was determined using the GAP statistics method, the results of which are presented in Figure 4.

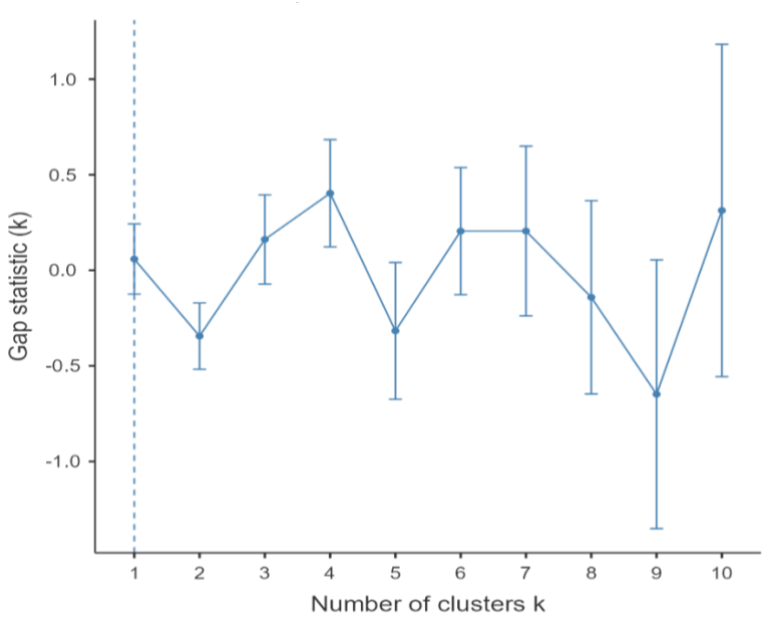


FIGURE 4. Gap statistic for determining the optimal number of clusters

Based on the analysis of the GAP statistics values, the optimal number of clusters is considered to be the one that shows the most significant increase in intercluster dispersion compared to a random distribution. Despite the presence of local maxima at $k = 4$ and $k = 7$, a stable increase at $k = 2$ allows identifying two large groups of observations with clear internal consistency.

Further details of the distribution of years across clusters and the assessment of intra- and inter-group dispersion are given in the summary table of the cluster analysis results (Table 3).

The first cluster comprises two years with sharply different characteristics of the loan portfolio, as reflected in the extremely low value of intra-cluster dispersion (122 thousand). The second cluster encompasses the main period, characterized by a moderate risk level and stable characteristics, with an intra-cluster sum of squares of 6.4 million. The significant excess of inter-cluster dispersion (15.4 million) over intra-cluster dispersion indicates a high degree of difference between

TABLE 3. Results of cluster analysis of SME loan quality indicators

Cluster number	Count	Within-cluster sum of squares
1	2	122,027
2	9	6,400,000
Between-cluster dispersion	–	15,400,000
Total	11	21,900,000

Note: compiled by the authors according to calculations

the identified groups and the justification of cluster segmentation 4 million). Over intra-cluster dispersion suggests a high degree of difference between the identified groups, justifying cluster segmentation.

The characteristics of each of the two clusters are refined based on the average values of the key indicators presented in the centroid table (Table 4).

TABLE 4. Centroid clusters

Cluster	SME_IFRS_PROVIS	SME_GOOD	SME_OVERDUE_90PLUS	IOD	SC
1	4351.100	74.930	19.305	0.251	0.425
2	1284.556	68.090	9.537	0.144	0.193

Note: compiled based on calculations

The centroid values reflect the average characteristics of each cluster for five indicators. The first cluster has the highest level of provisions (4,351.1 billion tenge), an increased share of non-performing loans (74.93%), and a high burden of overdue loans over 90 days (19.31%). The overdue debt index (0.251) and the sustainability coefficient (0.425) also exceed the values of the second cluster, indicating a tense and unstable structure of the loan portfolio.

In the second cluster, the average values are significantly lower for all indicators: the volume of reserves is 1,284.56 billion tenge, the share of non-performing loans is 68.09%, and overdue loans over 90 days are 9.54%. The overdue debt index has been reduced to 0.144, and the sustainability coefficient has been reduced to 0.193. Thus, the second cluster characterizes a balanced lending model with a more favorable structure and a decreased level of risk.

The results of the analysis confirmed the provisions of the literature in several respects. The decrease in the share of overdue loans, especially in the segment over 90 days, and the increase in the share of high-quality loans are consistent with the findings of Duarte et al. (2018) on the importance of resilience to financial shocks in reducing the risk of defaults. The dynamics of IFRS reserves reflect changes in approaches to loss assessment, which correspond to the provisions of Novotny-Farkas (2016) and Schutte et al. (2020) regarding the role of reserves in risk management. The identification of clusters with different degrees of credit vulnerability confirms the need for differentiated portfolio assessment, as proposed by Breuer et al. (2012) and Buncic & Melecky (2013) in the framework of stress testing and macroprudential analysis. The decrease in the overdue loan index and the increase in the resilience ratio are also consistent with the approaches of Weber et al. (2010) and Höck et al. (2020), focusing on the structural aspects of portfolio sustainability. The results reflect the same patterns as in several previous studies, which confirm the validity of the chosen indicators and the reliability of the conclusions drawn.

At the same time, Kazakhstan's results can be compared with international practices. For example, in Singapore, the share of SME loans exceeded 90% of the portfolio after the introduction of targeted state-backed credit

guarantees, which resulted in a sharp decline in non-performing loans to below 5%. In the United Kingdom, there is a government-backed guarantee scheme (Enterprise Finance Guarantee), where the state assumes part of the risks on SME loans. Thanks to such schemes, banks could continue lending even during the crisis, and the default rate was maintained at about 6-7%. According to the OECD (2023), in developed countries, measures such as easing reserve requirements, preferential lending, and portfolio diversification have enabled the stabilisation of overdue SME loans at a rate of 3-6%. In Kazakhstan, as the results of the analysis showed, there was a reduction in the share of SME loans overdue by more than 90 days from 23.9% in 2013 to 3.9% in 2023. This indicates a convergence with international practice, i.e., achieving levels typical for OECD countries, although the trajectory was more volatile (particularly during the 2017–2018 crisis).

Fluctuations in the dynamics of the quality of the SME loan portfolio were mainly due to the impact of macroeconomic factors. The period from 2017 to 2018 was characterised by devaluation processes and rising inflation, which increased the debt burden of enterprises and led to a deterioration in payment discipline. In 2019-2020, the situation was complicated by the impact of the COVID-19 pandemic, as the introduction of restrictive measures and a reduction in business activity led to an increase in overdue debt and a need to increase reserves. Currency fluctuations and changes in regulatory policy additionally affected the stability of the loan portfolio, increasing the differences between clusters. Thus, the identified differences in stability and risks reflect not only the internal characteristics of SMEs, but also external shocks that had a significant impact on the availability and quality of debt financing.

Based on the conducted analysis and the identified patterns of SME credit risk, a set of policy recommendations for regulators and banks is proposed and summarized in Table 5.

TABLE 5. Policy recommendations for SME lending stability

Area	Recommendation	Target group	Expected effect	Supporting literature
Dynamic provisioning (IFRS 9)	Refine forward-looking ECL methodologies and macro-scenarios	Regulator, banks	More accurate loss estimation, smoother cycles	Novotny-Farkas (2016)
Counter-cyclical measures	Flexible adjustment of reserve requirements and buffers during crisis years	Regulator	Sustaining SME lending under shocks	Duarte et al. (2018)
Stress testing and early warning	Regular SME portfolio stress tests; cluster-based monitoring of risk phases	Banks, regulator	Early detection of instability	Breuer et al. (2012)
Portfolio diversification	Sectoral and borrower concentration limits; portfolio rebalancing	Banks	Reduced sensitivity to external shocks	Shim (2019)
Guarantee mechanisms	Expand state guarantees and recognize alternative collateral	Government, regulator	Improved SME access to loans	Beck (2013)
Liquidity and refinancing	Refinancing lines for SME portfolios in local currency, including crisis instruments	Regulator, development institutions	Stabilization of lending volumes, lower defaults	Em et al. (2022)
Expansion of instruments	Promote leasing, factoring, venture, and angel financing	Government, regulator	Lower transaction costs, wider financing options	Abbasi et al. (2017)

Digital transparency	Introduce e-KYC, e-invoicing, open banking, and digital scoring	Banks, fintech	Reduced information asymmetry, improved credit risk assessment	Kumar et al. (2023)
ESG integration	Incorporate sustainability into PD/LGD; provide preferences to "green" SMEs	Banks, regulator	Lower default probability, sustainable growth	Höck et al. (2020)
SME financial readiness	Strengthen reporting standards, credit histories, and financial planning skills	Government, banks	Improved portfolio quality	Chowdhury & Alam (2017)

Note: compiled by the authors

The proposed measures aim at reducing the vulnerability of the SME loan portfolio by creating a more stable financial environment. Creating conditions for sustainable lending during periods of instability and ensuring a balance between risk management requirements and the strategic objectives of long-term economic development are significant. The implementation of these measures will not only mitigate the effects of macroeconomic shocks through the use of countercyclical reserve requirements, stress testing, and refinancing programs, but also increase the availability of financing through the expansion of guarantee instruments, the development of alternative lending forms, and digital monitoring platforms. In this way, sustainable SME lending can be maintained alongside an effective balance between banking risk management and long-term economic development goals.

5. CONCLUSION

The assessment of SME lending quality showed that the credit portfolio developed unevenly, with periods of instability followed by partial recovery. While the share of non-overdue loans increased and provisions declined, imbalances in the structure of overdue debt and fluctuations in the stability coefficient persisted. However, the stability of credit dynamics remained irregular, with periods of imbalance between timely repayments and long-term overdue debt. At the same time, specific structural imbalances persisted, particularly in the relationship between high-risk exposures and the quality of loan servicing. The most significant vulnerabilities were associated with the concentration of overdue debt and declines in the stability ratio during individual periods.

The analysis of the quality of the SME loan portfolio in Kazakhstan for 2013-2023 allowed us to obtain a number of significant results.

Firstly, the IOD has shown a steady downward trend, which confirms a reduction in credit risks. At the same time, the SC has consistently exceeded one since 2019, reflecting the predominance of "high-quality" loans over problem loans. These results correspond to international studies and confirm the correctness of the selected indicators for assessing the quality of the loan portfolio.

Secondly, the use of cluster analysis made it possible to identify hidden phases of instability that were not recorded when using only descriptive indicators. Segmentation of the years into stable and crisis periods showed that the crisis of 2017-2018 was abnormal in terms of credit risks, while in other years the SME portfolio showed a tendency to recover. This approach is an element of scientific novelty, as it allows us to differentiate periods according to the degree of vulnerability of the loan portfolio and complements traditional assessment methods.

Thirdly, the results of the study indicate a gradual strengthening of the quality of the SME loan portfolio in Kazakhstan, a reduction in credit risks and an increase in the sustainability of the sector. The findings have practical significance: they can be used by banks in improving risk management systems, as well as

by government agencies in developing SME support programs and macroprudential regulation tools.

To improve the sustainability of SME lending, measures have been proposed that can be grouped into three areas. First, macroprudential instruments: the introduction of countercyclical reserve requirements and regular stress testing of SME portfolios. Second, based on the expansion of financial support and resource availability, such as government guarantees or alternative financing options. Third, digitalization and risk monitoring through digital platforms for borrower analysis and early detection of problem debt. Future studies could focus on ESG factors and the level of digitalization of enterprises in credit risk assessment models, as well as comparative cross-country studies to identify adaptive policies in the context of regional differences.

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Exploring Public Perceptions of Neuromarketing: Ethical Challenges in the Kazakhstani Context

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ABSTRACT

Neuromarketing, situated at the intersection of neuroscience and marketing, presents new opportunities for examining the underlying mechanisms of consumer behavior, while also generating a wide range of ethical concerns. The purpose of the article is to conduct an empirical assessment of public perceptions and ethical risks associated with the use of neuromarketing in Kazakhstan, with an emphasis on issues of privacy, manipulation, informed consent and regulatory enforcement. The work employs a quantitative cross-sectional design, based on an online survey conducted using the principle of a "snowball" sampling approach in social networks and university newsletters. The study involved 211 respondents, primarily young and middle-aged individuals, with a predominance of urban residents and those with higher levels of education. The study revealed a low level of public awareness about neuromarketing (36%), while ethical concerns were expressed very clearly (84.4%), supporting the principle of transparency (76.3%), and 81.5% supported stricter regulation. Commercial applications were supported by only 42.2%, while social practices (healthcare, education) were approved. More than half of the respondents (61.6%) expressed unwillingness to participate in neuromarketing research personally. Gender differences turned out to be statistically insignificant, while age demonstrated a significant effect: older groups were more likely to support increased regulation. The data obtained confirm the high sensitivity of society and indicate the need for the development of national regulatory standards in the field of neuromarketing. Further investigation is advisable to be conducted on more representative samples using mixed methods for a deeper understanding of the dynamics of public perception.

KEYWORDS: Digitalization, Digital Economy, Business, Consumer Behavior, Marketing, Neuromarketing, Neurotechnology

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1. INTRODUCTION

Neuromarketing has recently emerged as a powerful and controversial intersection of neuroscience and marketing, offering previously unavailable insights into the unconscious processes that underlie consumer decision-making. Advanced techniques such as electroencephalography (hereinafter – EEG), eye-tracking, and functional magnetic resonance imaging (hereinafter – fMRI) allow researchers to study real-time cognitive and emotional responses to marketing stimuli. This new knowledge promises to revolutionize the effectiveness of advertising, product design, and customer engagement. However, these developments also give rise to a complex set of ethical challenges that have sparked extensive debate among academics, practitioners, and policymakers.

Among the key ethical concerns are the protection of privacy, the adequacy of informed consent, the risk of subconscious manipulation, and the potential for exploiting vulnerable groups. International bodies have begun to formulate ethical recommendations and codes of conduct for neuromarketing and neurotechnologies (e.g., the UNESCO Recommendation on the Ethics of Artificial Intelligence, the Neuromarketing Science and Business Association's Code of Ethics), but national regulation remains limited and inconsistent across countries.

Kazakhstan is a particularly salient case for examining the ethical dimensions of neuromarketing. The country has experienced rapid digitalization and rising interest in neuroscientific tools, as demonstrated by the recent establishment of neuromarketing laboratories at leading universities. Nevertheless, there remains a marked absence of national ethical guidelines, legal frameworks, or meaningful public discourse on the appropriate use of neuromarketing technologies. This regulatory vacuum increases the risk of ethical lapses and may erode public trust as neuromarketing becomes more widely adopted in both commercial and social spheres.

Despite the growing significance of neuromarketing in Kazakhstan, there is a critical shortage of empirical research on how citizens perceive the ethical issues associated with this field. Understanding public attitudes is especially important in emerging markets, where digital literacy and regulatory oversight may be limited, and where cultural values shape ethical expectations in unique ways. The lack of systematic data on public perceptions in Kazakhstan creates a significant barrier to the development of evidence-based regulation, responsible business practices, and effective public education.

This study addresses these challenges by providing the first systematic and empirical assessment of public perceptions and ethical concerns related to neuromarketing in Kazakhstan. The purpose of the article is to conduct an empirical assessment of public perceptions and ethical risks associated with the use of neuromarketing in Kazakhstan, with an emphasis on issues of privacy, manipulation, informed consent and regulatory enforcement. By situating the research within the Kazakhstani context and employing a rigorous, data-driven approach, the study aims to address an important gap in both national and international scholarship.

In doing so, the research not only contributes to academic understanding but also provides practical insights for policymakers, business leaders, and civil society actors regarding the ethical expectations of the Kazakhstani public. The findings aim to provide a foundation for developing culturally relevant ethical guidelines, regulatory frameworks, and public awareness initiatives that ensure the responsible and socially beneficial application of neuromarketing technologies in Kazakhstan.

2. LITERATURE REVIEW

Neuromarketing has evolved into a dynamic interdisciplinary field that integrates neuroscience, psychology, and marketing science, offering deeper insights into the unconscious mechanisms of consumer

behavior (Smidts, 2002; Murphy et al., 2008; Aria & Cuccurullo, 2017; Costa-Feito et al., 2023). In contrast to traditional survey-based approaches, often constrained by cognitive biases and social desirability, modern neuroscientific tools such as EEG, fMRI, eye-tracking, and galvanic skin response (hereinafter – GSR), has significantly enhanced the validity and precision of marketing research (Dos Santos & Dos Santos, 2024; Georgiadis et al., 2023; Pagan et al., 2024).

Among these tools, EEG stands out for its ability to record brain activity with high temporal resolution, providing immediate and fine-grained data on consumers' cognitive and affective reactions to marketing stimuli (Khondakar et al., 2024). Its non-invasive, affordable, and portable nature has made EEG the most widely adopted tool in both academic neuromarketing research and applied commercial settings (Georgiadis et al., 2023). By contrast, fMRI, although considerably more expensive and less accessible, offers superior spatial resolution and the ability to map deeper brain structures, making it invaluable for exploring neural mechanisms of decision-making, reward processing, and emotional arousal. Other instruments, including eye-tracking and facial coding, have further expanded the methodological arsenal of neuromarketing by enabling the measurement of visual attention patterns and subtle affective responses, which are often inaccessible through self-report methods (Šola et al., 2024). Recent methodological advances increasingly emphasize the integration of multimodal datasets, where neurophysiological measures are combined with subjective indicators, thereby allowing for a more holistic and ecologically valid analysis of consumer decision-making (Georgiadis et al., 2023).

However, the rapid proliferation of these technologies has sparked critical debates about their reliability, validity, and the lack of standardized research protocols (Pagan et al., 2024). Scholars highlight the necessity of methodological rigor, adherence to open science practices, and greater transparency in reporting, since inconsistent applications of neuroscientific tools can foster over-interpretation and contribute to so-called "neurohype" in both academia and industry (Christensen et al., 2022). Obtaining valid and informed consent in neuromarketing studies remains a challenge, especially as research extends into digital environments and passive data collection methods are employed. In many cases, consumers are unaware that their neurodata is being collected or how it will be used, leading to concerns over the adequacy of disclosure and the voluntariness of participation (Hemalatha, 2023; Goncalves et al., 2024). Neurophysiological data is highly sensitive and uniquely identifiable, requiring robust data protection, anonymization, and security measures (Ferrell et al., 2025). The misuse of neurodata could lead not only to privacy breaches but also to discrimination or psychological harm if sensitive information is shared or used without consent (Costa-Feito et al., 2023; Christensen et al., 2022). Moreover, neuromarketing can exploit cognitive vulnerabilities by reinforcing stereotypes, promoting overconsumption, or exacerbating inequalities (Fauzi et al., 2022).

These risks are particularly acute in contexts where regulatory oversight is weak and ethical standards are poorly enforced. The regulatory landscape for neuromarketing is fragmented both internationally and nationally. In the European Union, the General Data Protection Regulation (hereinafter – GDPR) classifies neurodata as sensitive personal data, imposing strict requirements for consent, processing, and data transfer (Goncalves et al., 2024). International frameworks such as UNESCO's Recommendation on the Ethics of Artificial Intelligence (2021) emphasize principles of human dignity, fairness, transparency, and accountability in the application of neurotechnologies. In the United States and Western Europe, ethical review boards and institutional research ethics committees provide an additional layer of oversight for academic neuromarketing studies (Murphy et al., 2008). By contrast, in many emerging markets, there is little formal regulation, few local guidelines, and low public

awareness of neuroethical issues (Fauzi et al., 2022).

Cross-cultural research demonstrates that attitudes toward neuromarketing, privacy, and consent are shaped by local values, social trust, and legal traditions (Tomková & Zbihlejová, 2023; Whitsel & Merrill, 2021). In collectivistic societies, the balance between individual rights and group interests influences both ethical expectations and the design of regulatory frameworks (Whitsel & Merrill, 2021). In Asia and Latin America, the adoption of neuromarketing has been slowed by high technology costs, lack of professional capacity, and varying degrees of regulatory development (Fauzi et al., 2022). Studies from Indonesia and Central Asia highlight cultural differences in risk perception, trust in technology, and the prioritization of social good over individual autonomy (Fauzi et al., 2022; Whitsel & Merrill, 2021). However, little is known about how these ethical concerns manifest in Central Asia, and Kazakhstan in particular, where neuromarketing is only beginning to develop.

Empirical research across multiple regions indicates that while social applications of neuromarketing (e.g., health promotion, education) are viewed more favorably, commercial use remains controversial, with strong ethical concerns related to privacy and manipulation (Ulman et al., 2015). Public reluctance to participate in neuromarketing studies is common, reflecting global skepticism regarding neurodata handling and the transparency of research practices (Luna-Nevarez, 2021).

In Kazakhstan, neuromarketing is still in a formative stage. The establishment of neuromarketing laboratories at leading universities and growing corporate interest indicate early diffusion of neuroscientific methods into both business and social sectors (AlmaU, 2024). However, empirical studies are rare, and ethical debate is only beginning to emerge in academic and policy circles. However, empirical studies remain scarce, and ethical debate is only emerging in academic and policy circles. The Law on Personal Data provides some general protection for personal information, but does not specifically address neurodata, consent standards, or data storage protocols (Dentons, 2023; Shyngyssov & Kadyrov, 2023). This legal ambiguity, combined with low public awareness, creates substantial risk for ethical lapses and undermines public trust (Whitsel & Merrill, 2021).

A small number of studies and national reports indicate that Kazakhstani citizens have low awareness of neuromarketing, with a majority expressing concern about privacy, manipulation, and the lack of regulation. Social applications tend to receive higher approval, but many respondents are unwilling to participate in research involving neurophysiological measurements or the sharing of personal data. Despite rapid global advances, the ethical, regulatory, and socio-cultural aspects of neuromarketing in Kazakhstan remain largely unexplored, with most studies focused on methodological innovation in developed countries. Most literature focuses on methodological innovation and the experience of developed countries, with little attention paid to public perceptions, cultural context, or the challenges of policy-making in transitional economies.

Thus, this study represents the first systematic attempt to map public perceptions and ethical concerns regarding neuromarketing in Kazakhstan. By integrating international theoretical developments, methodological best practices, and original empirical evidence, the research aims to inform evidence-based policy design and the development of locally adapted ethical standards. While neuromarketing is increasingly adopted by global corporations in marketing, product development, and user experience, emerging economies such as Kazakhstan must prepare adequate ethical and regulatory frameworks in advance of mass adoption.

While neuromarketing opens new frontiers for understanding consumer behavior, it also brings complex ethical, legal, and cultural challenges, particularly in emerging markets such as Kazakhstan, where public awareness and regulation have yet to catch up with rapid

technological innovation. By critically reviewing global, regional, and national literature, this study fills a significant research gap and provides a basis for developing both policy and practice in the field.

While the present study addresses the ethical and perceptual aspects of neuromarketing in Kazakhstan, it is essential to note that neuromarketing is no longer a niche area in business innovation. On the contrary, many global corporations have already integrated neuroscientific methods into their marketing strategies, product development, and user experience design. This underscores the need for developing countries to prepare ethical and regulatory frameworks in advance of mass adoption.

As shown in Table 1, neuromarketing has been integrated into various industries, including technology, finance, FMCG, and automotive.

Table 1. Global companies applying neuromarketing techniques

Company	Industry	Application Area	Reported Impact
Google	Tech/Internet	Ad optimization, UX	Higher click-through rates, user engagement
Coca-Cola	Beverages	Branding, advertising	Improved recall, brand affinity
Hyundai	Automotive	Product design, user testing	Enhanced customer experience
Campbell's Soup	Food	Packaging design	Packaging redesign, increased sales
Frito-Lay	Food	TV commercials	Message adaptation, improved recall
Unilever	FMCG	New product launches	More efficient marketing campaigns
Procter & Gamble	FMCG	Product testing	Reduced product launch failure rates
PayPal	Finance	Website and checkout optimization	Smoother UX, higher conversion rates

Note: compiled based on Luna-Nevarez (2021), Costa-Feito et al. (2023)

This real-world adoption of neuromarketing by market leaders in multiple industries provides a powerful rationale for proactive policy and ethical debate in contexts like Kazakhstan, where the field is only beginning to emerge. These international cases show that the use of brain-based consumer analytics is not a theoretical possibility but a strategic business reality, raising the stakes for ethical preparedness in developing economies.

In sum, the literature highlights that while neuromarketing offers innovative tools to access unconscious consumer behavior, its ethical implications remain contested across global contexts. Previous studies have primarily focused on Western or highly developed markets, with limited attention to how ethical concerns manifest in emerging economies. This gap underscores the need for localized empirical research, such as the present study, to explore public awareness and ethical expectations in Kazakhstan's specific sociocultural and regulatory landscape.

3. MATERIALS AND METHODS

Neuromarketing research draws on a diverse range of methods derived from neuroscience and psychophysiology, allowing for the examination of consumers' unconscious responses to marketing stimuli. Each of these tools has unique features and limitations. This research employed a quantitative cross-sectional survey to assess public awareness, attitudes, and ethical concerns regarding neuromarketing practices in Kazakhstan. At the same time, no method is universally applicable, and researchers are increasingly employing multimodal approaches (Georgiadis et al., 2023; Pagan et al., 2024). The systematization of their characteristics is presented in Table 2.

Table 2. Neuromarketing methods

Method	Strengths (sources)	Limitations (sources)	Typical applications
EEG	High temporal resolution; portable and affordable (Khondakar et al., 2024; Georgiadis et al., 2023)	Low spatial resolution; limited detection of deep brain structures (Georgiadis et al., 2023)	Advertising response, emotional engagement, attention
fMRI	High spatial resolution; ability to map deep brain activity (Pagan et al., 2024)	Low temporal resolution; expensive; low ecological validity (Dos Santos & Dos Santos, 2024)	Decision-making, reward processing, emotional arousal
Eye-tracking	Direct measure of visual attention (Šola et al., 2024)	Does not capture underlying cognitive processes; requires complementary methods (Georgiadis et al., 2023)	Packaging design, website usability, and UX testing
GSR / Facial coding	Captures physiological arousal and affective reactions (Costa-Feito et al., 2023)	Limited specificity: cannot differentiate positive vs. negative emotions (Christensen et al., 2022)	Emotional arousal measurement, ad testing

Note: compiled by the authors

Despite the wide range of possibilities offered by these methods, their application in neuromarketing is associated with several methodological and practical limitations. Problems of reliability, standardization of protocols, and reproducibility of research entail risks of incorrect interpretation of data, manipulative use of technology, and violation of the principles of voluntary informed consent.

In addition, it is important to note that the listed neuromarketing methods were not used directly in this study. They are presented solely for the purposes of classification and contextualization, whereas the empirical part of the work is based on a questionnaire survey aimed at studying public perceptions and ethical aspects of the use of neuromarketing in Kazakhstan. Furthermore, the methodological basis of the study aimed to test the formulated hypotheses and gather empirical data on the population's perception of neuromarketing practices and related ethical issues in Kazakhstan.

The hypotheses of the study included the following provisions:

H1: Public awareness of neuromarketing is generally low.

H2: Ethical concerns (privacy, manipulation, consent) are widespread.

H3: Public acceptance is higher for socially beneficial uses than for commercial ones.

H4: Age, but not gender is associated with more critical ethical perceptions.

The study could include respondents aged 18 and over who are permanent residents of Kazakhstan, speak Russian or Kazakh, and have given informed consent to participate. The “snowball” method was used to attract participants, which is typical for exploratory research. The Instagram and Facebook profiles were disseminated through social media platforms (Telegram, Facebook, Instagram), university newsletters, and professional communities. A total of 211 valid responses were collected (March-April 2025). Among them, 70.6% were women and 29.4% were men. The average age of the respondents was 32.8 years (SD = 9.4). 78.2% of the participants lived in cities, and 81.1% had higher or postgraduate education. This approach ensured rapid data collection but led to a slight overestimation of the proportion of digitally literate, urban and younger respondents, which limits the possibility of extrapolating the results to the entire population.

The methodological foundation of this study is based on a comparative analysis of neuroscientific and physiological tools commonly used in neuromarketing research.

Rather than treating each method as an isolated technique, the present approach acknowledges that these instruments are most effective when applied in combination, offering complementary insights into consumer cognition, attention, and emotion. For example, while EEG offers high temporal resolution of brain activity, it is often paired with fMRI to overcome spatial limitations and facilitate a more detailed mapping of decision-making processes. Similarly, eye-tracking is frequently used together with galvanic skin response (GSR) to link patterns of visual attention with indicators of emotional arousal, while facial expression analysis (FEA) and implicit association tests (IAT) add behavioral and attitudinal dimensions to the picture.

The questionnaire used in this study was developed based on these international classifications and comparative reviews (Costa-Feito et al., 2023; Georgiadis et al., 2023; Dos Santos & dos Santos, 2024; Šola et al., 2024). It was structured into five sections covering demographics, awareness of neuromarketing, ethical attitudes, application preferences, and willingness to participate. The instrument was pre-tested with 12 respondents and refined according to their feedback. Two academic experts further validated the final version for content clarity and ethical compliance.

The survey design complied with the Declaration of Helsinki and emphasized voluntary participation, informed consent, anonymity, and minimal risk. Data were collected via Google Forms using a snowball sampling approach. No biological or personally identifiable data were recorded, and duplicate responses were prevented through IP and browser checks. On average, participants required 10-12 minutes to complete the questionnaire.

Quantitative data were processed in IBM SPSS v26 using descriptive statistics, chi-square tests, t-tests, and ANOVA, with significance set at $p < 0.05$. Open-ended responses were examined through thematic content analysis, with two coders independently identifying recurring themes such as privacy, trust, and misuse of data.

The overall methodological design, therefore, reflects a descriptive cross-sectional approach. While acknowledging limitations related to sampling bias, cultural interpretation of ethical issues, and the inability to infer causality, the study was able to collect timely and context-specific data on public awareness and ethical perceptions of neuromarketing in Kazakhstan. By situating neuromarketing tools within a comparative and integrated framework, the research not only classified technologies but also provided a foundation for analyzing attitudes toward their acceptability and ethical implications.

4. RESULTS

A total of 211 valid responses were analyzed. The sample was made up of 70.6% (n = 149) women and 29.4% (n = 62) males. The age groups were: 18-25 years (32.7%), 26-35 years (38.9%), 36-45 years (15.2%), 46-55 years (4.7%), and 56 years and older (8.5%). Most of the people who answered (78.2%) lived in cities and had college degrees (81.1%). These numbers show that the sample is well-educated yet biased against women and people from certain cities.

Only 36% of those who answered the survey knew what neuromarketing was, which shows that the public is not very aware of it. Younger adults were far more aware of the issue than older persons (44% in the 18–35 group vs. 21% in the 46+ group), χ^2 (4, N = 211) = 10.12, $p < 0.05$.

The distribution of respondents by age and gender across groups is presented in Figure 1, which combines the heatmap format to illustrate how different generations are familiar with neuromarketing.

The greatest awareness is observed among young participants aged 18-35 years. Almost every second (44%) of this category has heard about neuromarketing before.

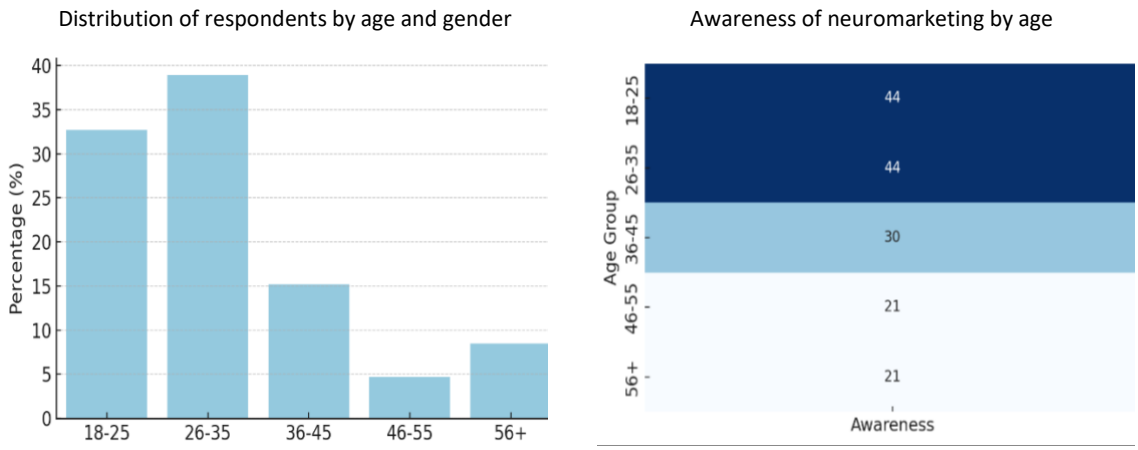


Figure 1. Distribution of respondents by age and gender, including awareness of neuromarketing across age groups

The greatest awareness is observed among young participants aged 18-35 years. Almost every second (44%) of this category has heard about neuromarketing before. At the same time, the proportion of older respondents (46 and older) who are familiar with this concept is significantly lower, amounting to only 21%. The average age group (36-45) occupies an intermediate position, while the youngest group (under 18) is the least aware. The graph clearly demonstrates a "generational gap" between younger and older generations in terms of their knowledge of modern neurotechnologies and marketing practices. This suggests a link between digital literacy and age, highlighting the need for targeted educational and awareness campaigns.

Table 3 presents these proportions with 95% confidence intervals.

Table 3. Summary of key survey proportions with 95% confidence intervals

Variable	Positive Responses (n)	Proportion (%)	95% CI Lower (%)	95% CI Upper (%)
Transparency Support	178	84.4	79.1	88.5
Privacy Concern	161	76.3	70.3	81.5
Support for Regulation	172	81.5	75.9	86.1
Support for Commercial Use	89	42.2	35.6	49.1
Support for Social Use	152	72.0	65.6	77.6
Unwilling to Participate	130	61.6	54.9	67.9

Note: compiled by authors

According to the data presented, it is clear that the respondents' attitude to neuromarketing is characterized by a high sensitivity to ethical issues. Thus, the overwhelming majority of participants expressed support for the principles of transparency is 84.4% (95% CI: 79.1-88.5), as well as the need for legal regulation – 81.5% (95% CI: 75.9-86.1), reflecting society's expectations regarding control and openness in this area. In turn, more than three quarters of the respondents identified the threat of privacy violations as one of the key risks of neuromarketing of 76.3% (95% CI: 70.3-81.5), emphasizing the importance of personal data protection. At the same time, attitudes towards various fields of application are differentiated: social practices (healthcare, education) were approved by 72.0% (95% CI: 65.6-77.6) respondents, while only 42.2% supported commercial applications (95% CI: 35.6-49.1). Finally, more than half of the participants (61.6%, 95% CI: 54.9–67.9) stated

an unwillingness to personally participate in neuromarketing research, indicating a presence of distrust and wariness towards this technology. The crosstabulation of age and support for regulation showed a clear generational trend: older individuals (36-55) wanted regulatory protections the most (almost 90%), whereas younger participants (18-25) wanted them the least (74%).

Figure 2 shows how people's opinions towards regulation change with age.

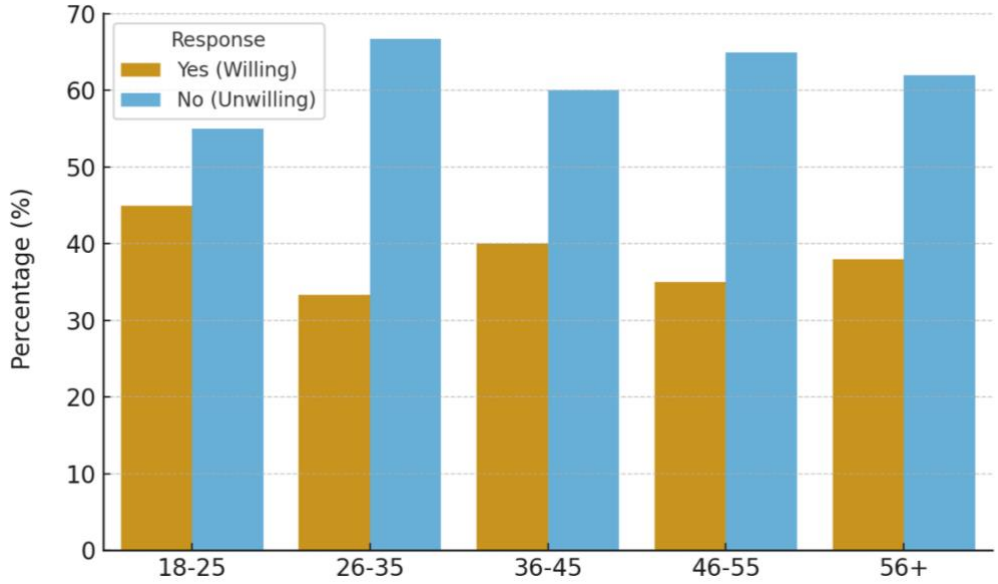


FIGURE 2. Support for regulation of neuromarketing by age group

Respondents demonstrated conditional acceptance of neuromarketing depending on age. The largest share of supporters of introducing stricter legal measures was recorded among respondents aged 36-55 years, almost 90% of participants in this group expressed willingness to support increased regulation. In younger age groups (18-25), the support level was significantly lower, at about 74%. Intermediate levels of support were observed among respondents aged 26-35 and those over 55. This dynamic confirms a distinct "generational trend" – the older respondents are, the more inclined they are to support legal regulations in neuromarketing. These results indicate differences in risk perception and institutional trust: older generations are more cautious and focused on formal control, whereas younger participants are less supportive of stricter regulations.

People were not very willing to take part in neuromarketing studies. Most of them (61.6%) said they didn't want to because they were worried about privacy and how their data will be used. The youngest respondents (26-35) were the most hesitant (66.7%), which suggests that being digitally literate doesn't always mean trusting neurotechnological research.

The data together underscore three major patterns. First, ethical awareness is strong, and openness, privacy, and rules are all things that must be met to be accepted. Second, the context in which an application is used is important. Socially orientated behaviours are seen as genuine, while profit-driven commercial applications make people suspicious. Third, age, not gender, affects attitudes. Older participants are more likely to want to follow the rules, while younger groups are less likely to want to get involved directly. These results confirm that people in Kazakhstan still only embrace neuromarketing if they are sure, it is ethical. In addition to descriptive statistics, χ^2-tests were utilised to investigate potential correlations between demographic variables and attitudes towards neuromarketing. The

investigation confirmed that gender was not a significant determinant of support for transparency, privacy concerns, or willingness to engage. For instance, the level of support for transparency was comparably high among women (86.6%) and men (79.0%), χ^2 (1, N = 211) = 1.36, p = 0.243 (refer to Table 4).

Table 4. Chi-square test result: gender vs. transparency support

Comparison	Women supporting (%)	Men supporting (%)	Chi-square	Degrees of Freedom	p-value	N
Gender vs. Transparency	86.6	79.0	1.36	1	0.243	211

Note: authors' calculations based on survey data

This suggests that ethical ideas are broadly held by both genders, with no systematic variation. In contrast, age became a critical element. Older participants were more inclined to advocate for regulatory protections in contrast to younger cohorts ($p < 0.05$). Specifically, more than 90% of people between the ages of 36 and 55 said they supported regulation, but only around 74% of people between the ages of 18 and 25 said the same thing. This pattern suggests a generational disparity in regulatory expectations, possibly indicating increased institutional trust or risk aversion among older individuals.

The inferential analysis shows several important patterns when looked at as a whole. To begin with, ethical sensitivity is always high, with more than three-quarters of the sample wanting privacy, openness, and rules that are fair. Second, the acceptability of neuromarketing seems to depend on the situation. Respondents make a clear difference between socially sound uses (such as health or education campaigns) and commercial uses, which are viewed with scepticism. Third, there is a digital literacy gap: younger professionals are more aware of neuromarketing, but they are also hesitant to get involved, which could be due to their heightened awareness of privacy risks. Lastly, the lack of gender effects and the existence of a significant age impact suggest that regulation is the most age-sensitive ethical domain. In summary, these results emphasise that a blend of cautious knowledge and pervasive ethical concern characterises public opinion in Kazakhstan. When connected to social value, neuromarketing is more acceptable, but it is still met with scepticism and mistrust, especially among younger, educated persons.

5. DISCUSSIONS

This study provides the first systematic empirical analysis of public perceptions and ethical attitudes toward neuromarketing in Kazakhstan. The findings make a meaningful contribution to the global discourse on the ethical, legal, and societal dimensions of neuromarketing in emerging economies. Our results confirm that public awareness of neuromarketing in Kazakhstan is low, with only 36% of respondents indicating prior familiarity with the concept. This echoes findings from other developing contexts (Khondakar et al., 2024; Fauzi et al., 2022), where the diffusion of neuroscientific concepts and technologies remains limited due to lower digital literacy and limited public discourse (Whitsel & Merrill, 2021). At the same time, ethical concerns, ethical concerns, particularly related to privacy, manipulation, and the need for regulation, were strongly expressed. Over three-quarters of respondents supported the principles of transparency and privacy in neuromarketing practices. These concerns align with global trends observed in Europe, the United States, and Asia, where public trust depends heavily on the perceived safety and integrity of neurodata processing (Christensen et al., 2022; Ulman et al., 2015; Goncalves et al., 2024).

Notably, Kazakhstani respondents clearly distinguished between commercial and social uses of neuromarketing. While only 42% approved of its use for commercial purposes,

72% expressed support for socially beneficial applications, such as public health and education campaigns. This context-dependent acceptance aligns with international studies, which demonstrate that public support is higher when neuromarketing is perceived as serving the common good (Luna-Nevarez, 2021; Tomková & Zbihlejová, 2023). Despite this recognition of social value, reluctance to participate in neuromarketing studies was high (over 61%), particularly among younger adults and respondents with higher education levels. Privacy concerns, the absence of clear regulatory frameworks, and fears of manipulation were the most frequently cited reasons. This finding reflects a broader pattern of mistrust found in other transitional societies, where weak legal protections and a lack of transparency aggravate public scepticism (Harrell, 2019; Whitsel & Merrill, 2021).

No statistically significant gender-based differences were observed in attitudes toward transparency or privacy. However, age emerged as a relevant factor: older respondents were more likely to demand stronger regulatory safeguards. This finding may reflect generational differences in institutional trust and risk perception, as reported in recent neuroethics literature (Goncalves et al., 2024).

This study offers several original contributions to the field:

1. Empirical Baseline: It establishes the first data-driven baseline for public awareness, ethical concerns, and participation attitudes regarding neuromarketing in Kazakhstan, an under-researched region in this context.

2. Contextualized Insight: By contrasting commercial and social applications, the study reveals a nuanced public perspective: ethical acceptability is conditional and driven by perceived social benefit rather than profit motive.

3. Policy and Regulatory Relevance: The strong demand for privacy and legal protections provides actionable guidance for policymakers. Kazakhstan could benefit from reforms similar to those under the EU's GDPR or UNESCO's AI ethics guidelines, including explicit regulation of neurodata and informed consent mechanisms.

4. Comparative Perspective: While Kazakhstan shares key trends with the global landscape, such as low awareness and high ethical sensitivity, it also demonstrates distinct features, most notably, the coexistence of high educational attainment and persistent distrust in commercial neuroscience.

This study makes several original contributions to the field. It establishes the first data-driven baseline for public awareness, ethical concerns, and participation attitudes regarding neuromarketing in Kazakhstan, a region that has so far been under-researched in this context. By contrasting commercial and social applications, the study reveals a nuanced public perspective in which ethical acceptability is conditional and largely driven by perceived social benefit rather than profit motives. The strong demand for privacy and legal protections provides actionable guidance for policymakers, suggesting that Kazakhstan could benefit from reforms similar to those under the EU's GDPR or UNESCO's AI ethics guidelines, with explicit regulation of neurodata and informed consent mechanisms. At the same time, the findings highlight that, while Kazakhstan shares global trends such as low awareness and high ethical sensitivity, it also demonstrates distinct local features, most notably the coexistence of high educational attainment and persistent distrust in commercial neuroscience.

The study, however, has several limitations. The use of snowball sampling and the overrepresentation of urban, highly educated, and female participants limit the generalizability of the results. Reliance on self-reported data may introduce social desirability bias and inaccuracies of recall, while the cross-sectional design captures only a snapshot in time and cannot reflect the potential evolution of public attitudes as neuromarketing practices and regulations develop. Furthermore, the use of a predominantly closed-ended questionnaire restricts the exploration of more complex or ambivalent opinions that could be uncovered through qualitative methods. Future research

should therefore aim to overcome these constraints by employing probabilistic sampling, integrating mixed-method approaches such as interviews and focus groups, and adopting longitudinal designs to capture evolving perceptions and to better understand the drivers of ethical reasoning.

The findings also carry practical implications. For policymakers, they highlight the urgency of modernizing national data protection laws to explicitly include provisions for neurodata, informed consent, and international data transfer standards. For researchers, they point to the importance of developing public outreach and education initiatives aimed at raising awareness and improving understanding of neuromarketing. For the industry, they underscore the necessity of adhering to internationally recognized ethical codes, such as those of the NMSBA, and ensuring that all neuromarketing studies are conducted with rigorous consent and privacy protocols.

The results of the research suggest practical steps that may be taken by policymakers, researchers, and industry representatives.

(1) For policymakers: Modernize national data protection laws to explicitly include provisions for neurodata, informed consent, and international data transfer standards.

(2) For researchers: Develop and implement public outreach and education initiatives aimed at increasing awareness and understanding of neuromarketing.

(3) For the industry: Adopt internationally recognized ethical codes (e.g., those of the NMSBA) and ensure that all neuromarketing studies adhere to rigorous consent and privacy protocols.

In conclusion, the discussion demonstrates that public perceptions of neuromarketing in Kazakhstan are shaped by limited awareness, strong ethical concerns, and context-sensitive acceptance. While Kazakhstan shares global trends, it also exhibits distinct local dynamics, particularly the intersection of higher education and low trust in commercial applications. These findings offer a valuable basis for developing ethical standards, regulatory reforms, and inclusive communication strategies tailored to emerging digital markets.

6. CONCLUSIONS

This study represents the inaugural empirical investigation of public perceptions and ethical issues associated with neuromarketing in Kazakhstan, thus filling a research gap in Central Asia. The analysis revealed that public awareness of neuromarketing is relatively low, while ethical concerns are prevalent and deeply ingrained, especially regarding transparency, privacy, and the potential for manipulation. The findings indicate that attitudes towards applications are context-dependent; socially beneficial uses in healthcare and education received higher approval, whereas commercial applications were met with increased scepticism. The results indicated that gender differences were not significant, while age emerged as a critical factor, with older respondents consistently advocating for stronger regulatory safeguards.

This research is original in that it offers nationally specific survey data from a context that has not been previously explored in the international literature. This study offers new insights into the articulation of ethical concerns within an emerging market, emphasising transparency, informed consent, and regulatory expectations as fundamental areas of public sensitivity. The findings have significant implications for policymakers tasked with modernising data protection legislation to explicitly address neurodata use, as well as for practitioners who must prioritise transparent methodologies and clear consent procedures to foster trust. This also provides opportunities for researchers, particularly regarding the design of probabilistic sampling, qualitative extensions, and longitudinal approaches that would enhance the understanding of the evolution of public attitudes.

Despite limitations associated with sampling bias and the predominance of urban respondents, the study provides a relevant and contextually informed perspective on the perception of neuromarketing in Kazakhstan.

The findings indicate that despite persistent scepticism and mistrust, the implementation of stringent regulations, transparent practices, and inclusive public engagement could facilitate the ethically responsible integration of neuromarketing within the broader context of the country's digital transformation. Aligning international standards with local cultural and ethical expectations allows the field to evolve in a socially responsive and scientifically rigorous manner.

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ESG Approach to Financial Sustainability of Kazakhstan's Oil and Gas Companies

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ABSTRACT

The purpose of the study was to assess the impact of asset structure. It retained earnings on the strategic sustainability of oil and gas companies in Kazakhstan in the context of ESG integration. The analysis covers the period 2015–2024 and is based on the official financial statements of JSC KazMunayGas. The methodology included correlation analysis, regression modelling, ANOVA, and collinearity diagnostics. The results demonstrate that long-term assets and property, plant, and equipment (PPE) explain 97.6% of the variation in total assets ($R^2 = 0.976$, $p < 0.05$), while retained earnings account for 71.4% of the variation in total equity ($R^2 = 0.714$, $p = 0.002$). Conversely, current assets and cash equivalents show no significant effect on retained earnings ($R^2 = 0.076$, $p > 0.5$). All three hypotheses were confirmed: long-term assets and PPE significantly explained total assets, and retained earnings significantly explained equity. The obtained results demonstrated that long-term capital-intensive investments and reinvestment of profits constitute the main drivers of ESG-oriented sustainability. In contrast, short-term liquidity plays only a supporting role. Based on these findings, government policy should strengthen the integration of ESG indicators into mandatory reporting standards and provide incentives for reinvestment of retained earnings in sustainable projects. For corporate practice, prioritizing long-term investments and transparent ESG disclosure is recommended to align Kazakhstan's oil and gas sector with both national sustainable development priorities and international ESG standards.

KEYWORDS: Oil and Gas Sector, Asset Structure, Corporate Finance, Sustainability, Business Sustainability, Energy Economics, Green Economy

SCSTI: 06.71.03

JEL Code: G32, M14, Q41, Q43

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1. INTRODUCTION

Sustainable development has become one of the key guidelines of global economic policy. The focus is on environmental, social, and governance (hereinafter – ESG) aspects, which are gradually becoming not only a tool for corporate responsibility but also a factor in the investment attractiveness of companies. International experience demonstrates that integrating ESG approaches helps reduce risks, increase stakeholder confidence, and enhance long-term competitiveness.

ESG is of particular importance in commodity economies, where the environmental costs and social effects of energy companies' activities directly affect the sustainability of national development. In countries with a developed institutional environment, clear standards for information disclosure and monitoring systems are being formed. At the same time, in developing economies, attention is focused on creating basic assessment and regulation mechanisms.

The oil and gas sector in Kazakhstan plays a crucial role in shaping the country's budget revenues and its foreign economic position. At the same time, high dependence on hydrocarbons is accompanied by increased environmental and social risks. Despite the introduction of sustainable reporting elements and the expansion of corporate governance practices, challenges persist in the form of high industry concentration, limited innovative solutions, and insufficient transparency.

Statistics show that while key financial indicators of oil and gas companies are growing, instability in the area of environmental efficiency and social responsibility remains. This creates a contradiction between formal declarations and actual results, which increases the importance of a systemic analysis of ESG indicators. At the same time, there is a methodological gap: unlike developed economies, Kazakhstan lacks quantitative assessments of the impact of ESG factors on financial stability. This study addresses this gap by focusing on JSC KazMunayGas, the national oil and gas company that plays a systemic role in the economy.

The research task is to test three hypotheses:

H1: Growth in long-term assets and property, plant, and equipment leads to an increase in total assets.

H2: Current assets and cash do not have a statistically significant effect on retained earnings.

H3: Growth in retained earnings contributes to the increase in total equity.

The study aimed to identify the role of asset structure and internal profit accumulation in ensuring the sustainability of oil and gas companies in Kazakhstan, with an emphasis on the difference in the impact of long-term and short-term resources in the context of the ESG approach. The significance of the results lies in clarifying the mechanisms of financial sustainability in a resource-dependent economy and providing evidence-based recommendations for aligning corporate strategies with Kazakhstan's sustainable development agenda.

2. LITERATURE REVIEW

The sustainability of companies within the ESG framework is determined by the configuration of the asset structure and the profit capitalisation regime. The corresponding theoretical basis identifies institutional constraints, disclosure standards, and management mechanisms through which long-term sustainability is achieved. Juravle & Lewis (2008) identified institutional and behavioral barriers, including short-term profit orientation, weak investor demand, conflicts of interest, and limited SRI, that constrained the use of retained earnings and long-term assets for sustainability purposes. Kolk and Perego (2010) showed that the institutional environment and regulatory architecture determine the implementation of assurance for non-financial reporting. The key tools used are the AA1000AS (AccountAbility Assurance Standard), focused on assessing stakeholder engagement, and the ISAE 3000 (International Standard on Assurance Engagements),

providing independent verification of non-financial information (Sohn et al., 2013). They are supplemented by the use of the GRI (Global Reporting Initiative) guidelines, which set the structure and indicators of sustainable development (Michalczuk & Konarzewska, 2018). The likelihood of external verification is higher in countries with stakeholder-oriented corporate law, where the interests of various groups of participants are taken into account, as well as in conditions of weak government control, where assurance partially compensates for the lack of institutional guarantees. Capitalization of profits and redistribution into long-term assets is inhibited either by behavioral barriers or by institutional incomparability of reporting.

Retained earnings are a key internal source of long-term investments in fixed assets and environmental projects. At the same time, it is essential to consider complex risks and incorporate non-financial indicators into the business model and reporting. Therefore, Rezaee (2016) proposed an integrated concept of five dimensions of sustainability (EGSEE: economic, governance, social, ethical, environmental), which links the process of value creation with the interests of stakeholders. In capital-intensive sectors such as mining and processing, reputational and environmental risks drive companies' adoption of practices (Garcia et al., 2017). However, significant differences in approaches to information disclosure remain within the industry. Cardoni et al. (2019) found incomparability in oil and gas companies' reports: discrepancies concern consolidation boundaries (operational control vs equity share), choice of energy and emissions KPIs, interpretation of Scope 1–3, availability and level of assurance, degree of GRI compliance, and balance between quantitative and narrative disclosures. Erben Yavuz et al. (2024) showed that a corporate governance strategy based on the independence of the board of directors, the activity of the audit committee, and a diversified ownership structure creates conditions under which retained earnings and investments in PPE are considered not as elements of formal reporting, but as a management tool. Increasing the transparency and reliability of disclosures enhances the quality of resource allocation, making it possible to link it to the implementation of ESG projects. Koszel (2025) identified long-term assets and retained earnings as key measures of sustainable performance. Therefore, systematic monitoring and integration into strategic decisions are essential for unified and standardized reporting.

Asset structure is regarded as a central element of strategic sustainability. Therefore, the effective use of fixed assets ensures long-term reliability and reduced operational risks (Ratnayake & Liyanage, 2009). When a company has slack resources, such as unused cash or liquid asset reserves, it gains more freedom in its investment decisions. Companies can finance long-term projects without immediately attracting external capital, thereby preserving liquidity and striking a balance between short-term flexibility and long-term sustainability (Jalilvand & Kim, 2013; Campello & Giambona, 2013). The capital structure does not exist separately from the asset structure: the debt-to-equity ratio is determined by the composition of the balance sheet. The asset structure directly affects financial sustainability and management discipline through the capital structure.

When a company increases its plant, equipment, or other long-term physical assets, the market interprets this as a signal of future earnings growth as production capacity expands or infrastructure is modernized (Petrovic et al., 2016). Asset structure and management mediate between stakeholder interests and the company's strategic sustainability (Gavrikova et al., 2020). When a company modernizes its production facilities, invests retained earnings in environmentally friendly technologies, and optimizes the structure of its long-term and short-term resources, it brings these interests together. As a result, the business becomes more sustainable and predictable. Therefore, asset management is a tool that allows for considering the interests of different parties (shareholders, creditors,

employees, the state, and society) and simultaneously creates long-term value for the company. Ultimately, a balanced combination of long-term and short-term resources strengthens business resilience (Liu & Jia, 2023). In the oil and gas sector, this relationship is particularly evident, as asset structure determines production stability and the ability to finance large-scale investments (Ekpe, 2024).

Some studies considered internal sources of financing as the basis of corporate sustainability, noting their role in reducing dependence on external capital fluctuations and in determining the course of strategic development. Turygin (2018) argued that retained earnings, as the primary form of domestic savings, ensured long-term investment in fixed assets and were considered more sustainable than loans. According to Aimagambetova et al. (2020), capitalization growth and efficiency improvement depend on the ability of enterprises to accumulate and direct retained earnings to investment. In conditions of high capital intensity, it is retained earnings that reduce dependence on debt financing and mitigate the impact of market volatility (Alimoradi Jaghdari et al., 2020). Sustainability of internal savings in Kazakhstan increased investment attractiveness and attracted external capital (Nurasheva et al., 2024). The systematic use of retained earnings as a tool of corporate capitalization formed the strategic sustainability of a business (Tong & Kassenova, 2025).

Based on the conducted literature review, the following key variables were identified: total assets, long-term assets, property, plant, and equipment (hereinafter – PPE), retained earnings, current assets, cash and cash equivalents, and total equity.

3. RESEARCH METHODS

The conducted literature review enabled us to identify a set of key indicators that reflect the structure of assets and capital of oil and gas companies in Kazakhstan within the context of the ESG approach. The official materials of JSC KazMunayGas, published in the section of reporting for investors (KazMunayGas, n.d.), were used as a data source. The chosen study period (2015–2024) corresponds to the span of publicly available financial statements of JSC KazMunayGas, limiting the sample to ten annual observations. While longer series are typically preferred, empirical evidence indicates that ten yearly data points can still provide a viable basis for analysis. Hyndman and Kostenko (2007) and Jenkins and Quintana-Ascencio (2020) demonstrated that even three to five observations can provide acceptable regression estimates under low variance, while seasonal forecasting models may require as few as six observations for quarterly data and fourteen for monthly data.

Based on the identified indicators, three research hypotheses were formulated, presented in Table 1.

TABLE 1. Research hypotheses

Hypothesis	Dependent Variable (Y)	Independent Variables (X)
H1. Growth in long-term assets and property, plant, and equipment leads to an increase in total assets	Total Assets (TA)	Long-term Assets (LA), Property, Plant, and Equipment (PPE)
H2. The increase in current assets and cash does not have a statistically significant effect on the retained earnings of oil and gas companies in Kazakhstan.	Retained Earnings (RE)	Current Assets (CA), Cash and Cash Equivalents (CCE)
H3. Growth in retained earnings contributes to the increase in total equity	Total Equity (TE)	Retained Earnings (RE)

Note: compiled by the authors

To test these hypotheses, the financial statements of oil and gas companies for the period 2015–2024 were used. Against this background, the use of ten annual observations is methodologically sufficient for identifying basic relationships between asset structure, retained earnings, and sustainability indicators. The analysis was conducted in several stages, each of which was aimed at testing the hypotheses put forward and assessing the stability of the models. At the first stage, correlation analysis was used to identify the direction and strength of the relationships between the indicators, by following formula (1):

$$r_{xy} = \frac{\sum(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum(x_i - \overline{x})^2 \sum(y_i - \overline{y})}} \quad (1)$$

where:

r_{xy} – correlation coefficient between variables x and y;

x_i, y_i – average values of the samples.

At the second stage, regression models were built, which made it possible to quantitatively assess the contribution of individual factors to the formation of dependent variables by following formula (2):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon \quad (2)$$

where:

Y – the dependent variable;

X – the independent variables;

β – the estimated coefficients;

ε – the error term.

To check the quality of the models, an ANOVA test was used, which made it possible to determine the statistical significance of the included predictors by following formula (3):

$$F = \frac{SSR/k}{SSE/(n-k-1)} \quad (3)$$

where:

SSR – the regression sums of squares;

SSE – the error sum of squares;

k – the number of predictors;

n – the sample size.

Additionally, diagnostics for multicollinearity were performed using VIF statistics and tolerance, ensuring the stability of the coefficient estimates. Multicollinearity was assessed using variance inflation factors (VIF) and tolerance, which are considered standard and sufficient diagnostics in regression analysis (O'brien, 2007; Kyriazos & Poga, 2023). Thus, the comprehensive use of statistical procedures enabled the comparison of the obtained results with the hypotheses and the identification of key factors determining the financial stability of oil and gas companies in Kazakhstan.

4. RESULTS

Evaluation of the dynamics of ESG indicators in the oil and gas sector allows not only to identify the current state of sustainability of companies, but also to trace the directions of their adaptation to institutional and market changes. The analysis reflects how financial performance is combined with environmental and social parameters, forming the basis for long-term competitiveness. The presented data enable the assessment of the balance between economic interests and the requirements of sustainable development, which is of fundamental importance for the industry, as it determines the macroeconomic stability of Kazakhstan.

Figure 1 illustrates the overall upward trend in total assets and equity.

There was a steady growth in assets and capital between 2015 and 2024 in oil and gas companies. Notably, total assets almost doubled during the period, while capital increased significantly, providing the companies with opportunities for investment expansion and strengthening their financial position. Minor fluctuations in individual years did not change the overall upward trajectory.

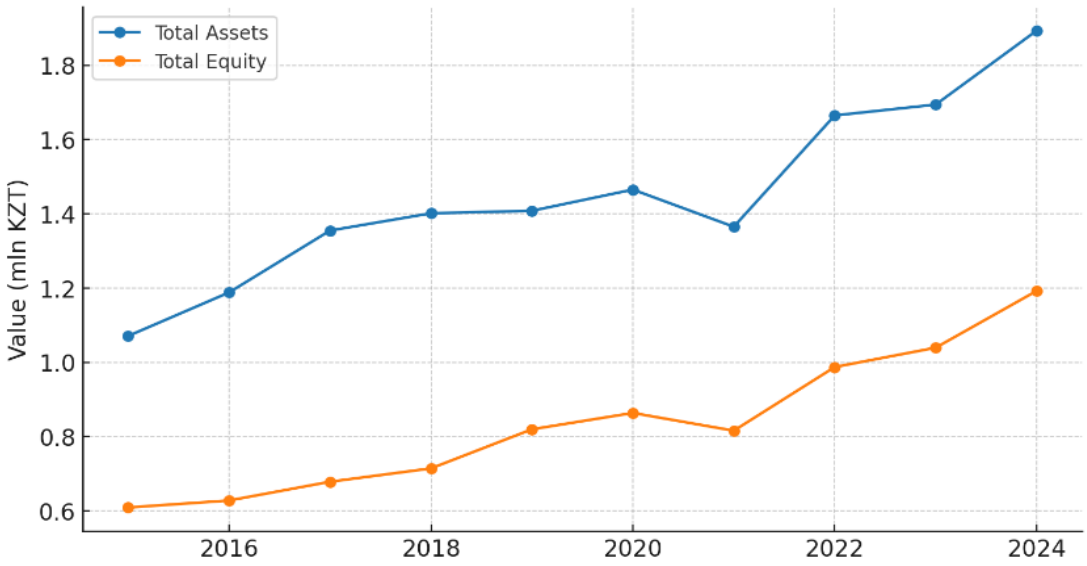


FIGURE 1. Company Scale for 2015-2024

Note: compiled by the authors according to calculations

In 2015–2024, long-term assets and fixed assets showed an upward trend with occasional periods of sharp increases. Long-term assets grew smoothly, without strong jumps; therefore, companies steadily invested in development in large projects, modernization, and infrastructure. Thus, structural changes in the financial base of the oil and gas sector are presented in Figure 2 based on the dynamics of retained earnings, property, plant, and equipment, and long-term assets.

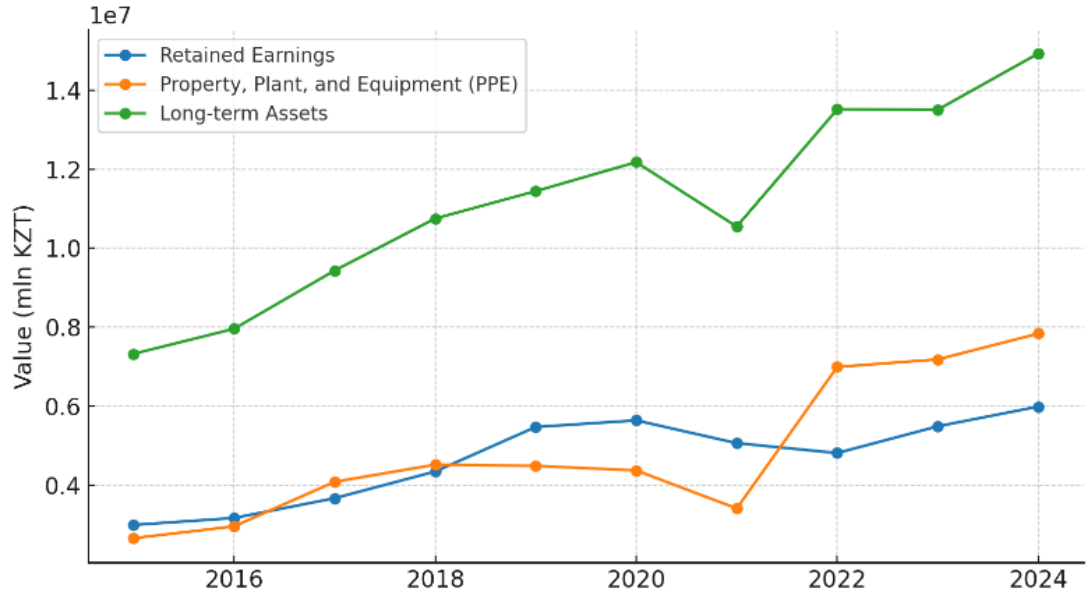


FIGURE 2. Sources and Structure for 2015-2024

Note: compiled by the authors according to calculations

In 2015-2024, long-term assets and fixed assets showed an upward trend with occasional periods of sharp increases. Long-term assets grew smoothly, without strong jumps; therefore, companies steadily invested in development in large projects, modernization, and infrastructure. Fixed assets (equipment, plants, transport facilities) behaved differently: sometimes they fell, sometimes they grew sharply. Particularly noticeable growth began after 2021. This can be interpreted as a result of new significant investments specifically in production capacities (for example, equipment upgrades, construction, or expansion of facilities). Retained earnings showed a gradual increase until 2020, after which there was a decline, followed by a recovery in 2022–2024. The combined dynamics suggest that strategic stability was primarily established through long-term investments, while profit was influenced by market conditions.

Figure 3 illustrates the dynamics of liquidity indicators, including current assets and cash equivalents.

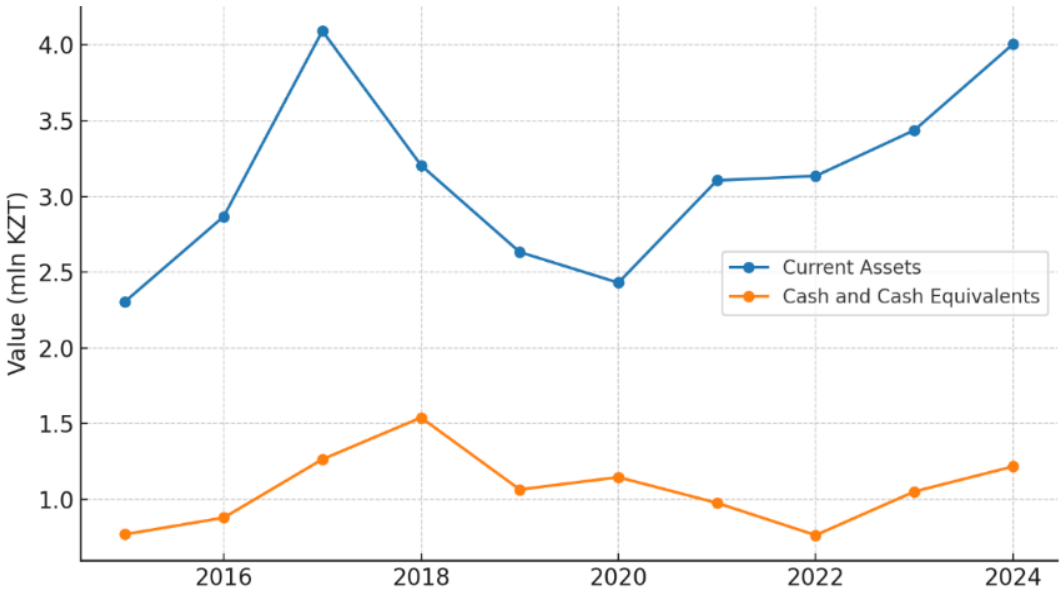


FIGURE 3. Liquidity for 2015-2024

Note: compiled by the authors according to calculations

In 2015–2024, liquid resources developed unevenly: short-term assets and cash in the oil and gas sector changed unstably, without a clear and sustainable growth trend. Current assets increased over the period, but the growth was accompanied by sharp fluctuations, with significant increases in 2017 and 2024, followed by declines in between. Cash and cash equivalents increased until 2018, after which they declined; the recovery was only partial and did not reach previous levels. Such fluctuations show that liquid resources are not the primary source of stability for oil and gas companies. Unlike long-term assets, which ensure stable development, short-term resources behave too inconsistently to play a strategic role.

The fact that the assets and capital of oil and gas companies have grown indicates that the financial foundation of the sector, which remains systemically essential to Kazakhstan's economy, has strengthened. The increase in long-term investments and the use of profits for reinvestment indicate that sustainability and growth depend on capital-intensive investments, rather than short-term cash flows. For the economy, this signals that strategic development is only possible with the concentration of resources in long-term

projects that form the production base, infrastructure, and innovative areas.

On the contrary, the instability of current assets and cash demonstrates their limited significance for macroeconomic sustainability. Short-term liquidity can support operational activities, but it does not provide a long-term effect for the economy.

Thus, for Kazakhstan, the results of the graphs indicate that the key source of sustainability for the national economy remains long-term assets and reinvested profits from oil and gas companies. At the same time, short-term resources play only a supporting role.

The identified differences in the dynamics of long-term and short-term indicators necessitate statistical verification of their relationships, which requires conducting correlation and regression analysis.

In Table 2, there are results for the correlation analysis.

TABLE 2. Correlation Matrix

Predictor	Test	TA	RE	TE	PPE	LA	CA
TA	Pearson's r						
	df						
	p-value						
RE	Pearson's r	0.809**					
	df	8					
	p-value	0.005					
TE	Pearson's r	0.966***	0.845**				
	df	8	8				
	p-value	<.001	0.002				
PPE	Pearson's r	0.966***	0.689*	0.930***			
	df	8	8	8			
	p-value	<.001	0.028	<.001			
LA	Pearson's r	0.975***	0.894***	0.961***	0.929***		
	df	8	8	8	8		
	p-value	<.001	<.001	<.001	<.001		
CA	Pearson's r	0.575	0.190	0.430	0.543	0.410	
	df	8	8	8	8	8	
	p-value	0.082	0.599	0.215	0.104	0.239	
CCE	Pearson's r	0.241	0.265	0.064	0.140	0.218	0.456
	df	8	8	8	8	8	8
	p-value	0.502	0.460	0.860	0.699	0.546	0.185
* p < .05, ** p < .01, *** p < .001							

Note: compiled by the authors according to calculations

The correlation analysis was systematised according to the conventional scale, where coefficients between 0.90 and 1.00 are considered very strong, 0.70-0.89 are strong, 0.40-0.69 are moderate, 0.10-0.39 are weak, and values below 0.10 are negligible. There is a cluster of strong relationships between long-term assets, fixed assets, capital, and profit, which reflects the structural interdependence of capital-intensive indicators and their joint influence on the scale of activity. Moderate, but statistically unconfirmed relationships were revealed for current assets; such dependencies are considered controversial. Weak and statistically insignificant relationships with key indicators were obtained for cash and cash equivalents. The correlation analysis confirmed the priority of long-term investments in moderating the financial stability of oil and gas companies in Kazakhstan.

Correlation analysis revealed that long-term and fixed assets have a significant influence on the company's scale and capital amount. In the

financial statements of oil and gas companies in Kazakhstan, the indicators of long-term assets and fixed assets serve as an indicator of the scale of capital investments in development. The growth of these reporting items is recorded as a result of investments in the modernization of production equipment, infrastructure development, processing, and environmental projects. The dynamics of long-term assets and fixed assets are considered as a reflection of the investment policy focused either on long-term growth, including ESG areas, or on the priority of production and short-term profit. A significant portion of these investments is related to projects aimed at reducing the carbon footprint, implementing technologies for cleaning emissions, recycling waste, and rational use of resources. When oil and gas companies in Kazakhstan invest in environmental projects (treatment facilities, emission reduction technologies, waste disposal) and modernization of production facilities, these expenses are recorded as long-term assets and fixed assets. Such investments do not represent current costs, but investments in assets that increase the value of the company and are reflected in the financial statements. Thus, the structure of capital investments allows us to determine the moment when the company prioritizes not production and short-term profits, but ensuring long-term sustainability based on reducing environmental and social risks, strengthening investor confidence, and maintaining business stability. Consequently, an increase in the share of environmentally oriented and infrastructure investments in assets contributes to the long-term growth of the sustainable financial results. The presence of significant correlations between long-term assets and key economic indicators confirms the strategic importance of these investments in the context of the ESG approach, focused on long-term efficiency and the minimization of environmental and social risks.

The results for hypothesis H3 indicate a high correlation between retained earnings and capital growth. For the oil and gas sector of Kazakhstan, this means that financial sustainability is primarily determined by the ability to accumulate internal resources and direct them to long-term projects, including environmental and social programs.

The absence of statistically significant relationships for hypothesis H2 supported that short-term assets and cash do not have a significant impact on sustainability indicators. Therefore, there is a limited role of liquid assets in ESG strategies for oil and gas companies in Kazakhstan, where priority is given to long-term investments in production and environmental projects. Thus, the correlation analysis confirms hypotheses H1, H2, and H3.

The results of the fitness of all models are in Table 3.

TABLE 3. Model Fit Measures

Model	R	R^2
Hypothesis 1	0.988	0.976
Hypothesis 2	0.276	0.0762
Hypothesis 3	0.845	0.714
*Models estimated using a sample size of N=10		

Note: compiled by the authors according to calculations

The obtained results showed that the model for Hypothesis 1 had an R^2 of 0.976, meaning that selected predictors explained 97.6% of the variation in total assets. The model for Hypothesis 2 had an R^2 of 0.076, meaning that only 7.6% of the variation in retained earnings was explained by selected predictors. Thus, results of the correlation analysis of the limited role of short-term resources in financial sustainability. The model for Hypothesis 3 had an R^2 of 0.714, meaning that 71.4% of the variation in total equity was explained by selected predictors. The overall significance of the models was assessed using the omnibus ANOVA test, with the results presented in Table 4.

TABLE 4. Omnibus ANOVA Test

Model	Predictor	Sum of Squares	df	Mean Square	F	p
Hypothesis 1	LA	2.34e+12	1	2.34e+12	13.01	0.009
	PPE	1.40e+12	1	1.40e+12	7.79	0.027
	Residuals	1.26e+12	7	1.80e+11	-	-
Hypothesis 2	CA	6.29e+10	1	6.29e+10	0.0460	0.836
	CCE	4.15e+11	1	4.15e+11	0.3034	0.599
	Residuals	9.57e+12	7	1.37e+12	-	-
Hypothesis 3	RE	2.34e+13	1	2.34e+13	20.0	0.002
	Residuals	9.36e+12	8	1.17e+12	--	
*Type 3 sum of squares						

Note: compiled by the authors according to calculations

The results confirmed the significance of long-term assets and fixed assets in the first model, which corresponds to hypothesis H1, and the p-values for both predictors were below 0.05. Hypothesis H2 was also confirmed, as the results of the second model predictors did not show statistical significance. Therefore, current assets and cash or cash equivalents have a limited or insignificant impact on retained earnings. In the third model, retained earnings demonstrated high statistical significance as a factor in the growth of total capital, which confirms hypothesis H3. Thus, long-term investments and retained earnings determine the development of assets and capital, while short-term resources have no effect.

The regression coefficients for each model, including estimates, standard errors, t-statistics, and significance levels, are presented in Table 5.

TABLE 5. Model coefficients

Model	Predictor	Estimate	SE	t	p
Hypothesis 1	Intercept	5.44e+6	887134.836	6.14	<.001
	LA	0.560	0.155	3.61	0.009
	PPE	0.581	0.208	2.79	0.027
Hypothesis 2	Intercept	3.10e+6	2.25e+6	1.381	0.210
	CA	0.156	0.726	0.214	0.836
	CCE	1.007	1.828	0.551	0.599
Hypothesis 3	Intercept	1.35e+6	1.60e+6	0.840	0.425
	RE	1.50	0.336	4.469	0.002

Note: compiled by the authors according to calculations

Estimation of regression coefficients for hypothesis 1 showed statistical significance of long-term assets and fixed assets. Both indicators made a positive contribution to the growth of total assets, which confirms their key role in the model. In the model for hypothesis 2, the statistical significance of current assets and cash was not revealed. Their coefficients did not affect retained earnings, which indicates a limited role of short-term liquidity. According to hypothesis 3, the coefficient of retained earnings turned out to be significant, which confirmed its contribution to the growth of total capital. The obtained results completely coincided with the conclusions of the correlation analysis and verification through ANOVA, which strengthens the reliability of the interpretation.

In implementing ESG, oil and gas companies in Kazakhstan focus not on short-term expenses (for example, working capital or cash), but on significant long-term investments. We are talking about investments in fixed assets (equipment, plants, pipelines) and intangible assets (technology, licenses, software, know-how). They form a production base, ensuring the extraction, processing, and transportation of oil and gas at a modern level.

They create conditions for achieving ESG goals, utilising new technologies, and developing infrastructure that enable the reduction of carbon emissions, more efficient energy use, safer waste disposal, improved labour safety, and enhanced social responsibility standards. In other words, ESG in the oil and gas sector of Kazakhstan is materialized primarily through long-term capital investments, and not through current financial flows. Long-term assets become an indicator of the strategic choice of companies in favor of sustainable development, while short-term assets and cash do not reflect this orientation.

Accumulated retained earnings play a special role in the implementation of ESG strategies, since it is internal sources that allow financing environmental programs, labor protection, and corporate governance projects without critical dependence on external loans. For oil and gas companies in Kazakhstan, the decisive factor for sustainability is not just the availability of free money in the accounts, but how retained earnings are used. When profits are not distributed as dividends, but are sent back to the company, reinvestment occurs. Such funds are spent on long-term projects: construction or modernization of treatment facilities, implementation of energy-efficient technologies, labor protection, or social support programs. Thus, the sustainability of companies is formed due to the quality of investments of accumulated resources, and not only due to the volume of current assets.

ESG in oil and gas companies of Kazakhstan is expressed in the fact that sustainable development is not built on short-term assets or cash liquidity, but on two strategic financial elements. Long-term assets reflect capital investments in equipment modernization, environmental technologies, processing, and transport infrastructure. Internal accumulation of profit shows the ability of companies to reinvest accumulated funds in social and environmental projects. These two areas of financial policy are transformed into mechanisms through which ESG does not remain a declaration, but is enshrined in the development strategy of companies.

Collinearity diagnostics were performed to evaluate the stability of the regression estimates, and the results are presented in Table 6.

TABLE 6. Collinearity statistics

Model	Predictor	VIF	Tolerance
Hypothesis 1	LA	7.35	0.136
	PPE	7.35	0.136
Hypothesis 2	CA	1.26	0.792
	CCE	1.26	0.792
Hypothesis 3	RE	1.00	1.00

Note: compiled by the authors according to calculations

The results of the multicollinearity test showed that in the model, according to hypothesis 1, the VIF values for long-term assets and fixed assets were 7.35 with a tolerance level of 0.136. Such indicators indicate the presence of moderate multicollinearity, which can affect the stability of the coefficient estimates, but remains within the acceptable level (VIF < 10). In the model according to hypothesis 2, the VIF values for current assets and cash were low (1.26 with a tolerance of 0.792), which indicates the absence of a multicollinearity problem. For hypothesis 3, the VIF indicator was 1.00 with a tolerance of 1.00, which reflects the complete lack of interdependence between the predictor and other variables.

The conducted correlation and regression analysis allowed us to identify differences in the role of long-term and short-term assets in the financial stability of oil and gas companies in Kazakhstan. There was a confirmed close relationship between the total volume of assets, long-term investments, and capital, which

indicates a structural dependence of strategic development on capital-intensive investments. At the same time, current assets and cash did not demonstrate a statistically significant relationship with retained earnings, which emphasized the limited role of short-term resources.

The results of ANOVA and the assessment of regression coefficients showed the importance of long-term assets and fixed assets in the formation of the total volume of assets, as well as the importance of retained earnings in increasing capital. The multicollinearity test confirmed the acceptable level of relationships between predictors, which ensures the stability of the models.

Thus, the key factors in the sustainable development of oil and gas companies are long-term assets and internal accumulation of profit. They provide the opportunity to integrate environmental and social priorities into corporate strategy, while short-term resources do not have a significant impact on strategic sustainability.

The results of the analysis based on long-term assets variables (LA, PPE) and retained earnings (RE) directly reflect key ESG indicators. The growth of investments in fixed assets and infrastructure modernization corresponds to the goals of SDG 9 "Industry, Innovation and Infrastructure" and SDG 13 "Climate Action". The accumulation and reinvestment of profits is associated with internal financing of environmental and social projects, which corresponds to SDG 7 "Affordable and Clean Energy" and SDG 12 "Responsible Consumption and Production". At the same time, the results for current assets and cash (CA, CCE) showed statistical insignificance, which confirms their limited role in strategic sustainability.

Similar and different trends can be observed in international practice. In Western European countries, where corporate law is focused on the interests of stakeholders, external verification of reporting according to GRI and ISAE 3000 standards strengthens the connection between financial performance and ESG indicators (Kolk & Perego, 2010; Sohn et al., 2013). In resource-dependent economies with weak institutions, verification performs a compensating function (Juravle & Lewis, 2008). In the oil and gas sector of different countries, reporting remains incomparable: consolidation boundaries, interpretation of emissions according to Scope 1–3, and the level of GRI compliance differ (Cardoni et al., 2019). In contrast, Kazakhstani companies demonstrate a high dependence on the structure of assets and internal savings. This specificity is associated with the high capital intensity of the sector and the limited role of short-term liquidity.

The patterns identified in the analysis indicate the need to integrate ESG indicators into mandatory financial reporting forms. If, in addition to the indicators used, such indicators as greenhouse gas emissions, specific energy consumption costs, and labor protection costs are included, this will allow financial results to be linked to environmental and social priorities. Such a practice is already being implemented in the European Union within the framework of the CSRD (Corporate Sustainability Reporting Directive) and ESRS standards, as well as in the international IFRS S1/S2 standards developed by the ISSB (International Sustainability Standards Board), which oblige companies to disclose climate and social indicators along with financial ones. In this case, public policy will not only change reporting standards but will also lead to a fundamental redistribution of investments in favor of sustainable projects.

Practical steps include developing a national ESG reporting standard for the oil and gas industry, mandatory disclosure of environmental and social indicators along with financial ones, and the introduction of an independent verification system. In addition, incentives are required for companies that direct retained earnings to long-term environmental and social projects. These measures will help synchronize corporate strategies with national priorities and international standards of sustainable development.

5. CONCLUSIONS

The objective of the study was to identify the impact of the asset and profit structure on the strategic sustainability of oil and gas companies in Kazakhstan in the context of the ESG approach. To achieve this goal, three hypotheses were formulated and tested, reflecting the role of long-term investments, short-term resources, and internal accumulation of profit in financial development.

The first hypothesis confirmed the importance of long-term assets and fixed assets for the formation of the total volume of assets. The results showed that the strategic sustainability of oil and gas companies is largely based on capital-intensive investments that ensure the modernization of the production base and create conditions for the integration of environmental and social priorities. As a practical recommendation, the emphasis should be on expanding investment programs in the modernization of equipment and infrastructure, including projects with an environmental focus.

The second hypothesis was not confirmed, indicating a limited role of current assets and cash in ensuring long-term sustainability. The presence of liquid resources does not guarantee strategic development and does not form the basis for ESG-oriented projects. In management practice, this circumstance requires an adjustment of priorities: attention should shift from short-term liquidity to long-term investment instruments that ensure sustainable growth.

The third hypothesis confirmed the importance of retained earnings in capital formation. The financial stability of companies depends on the ability to accumulate internal resources and direct them to projects that have an environmental and social impact. A practical recommendation is to develop a profit reinvestment policy, which will reduce dependence on external financing and strengthen the integration of ESG principles into corporate strategy.

This study has several limitations. The analysis covered only one company, JSC KazMunayGas, over ten years. In addition, the assessment was limited to aggregated financial variables without separate ESG subindexes. These constraints suggest directions for further research.

Future research should include other oil and gas companies in Kazakhstan, and also integrate disaggregated ESG indicators. Such an approach enables a more precise assessment of how financial structure influences sustainability in resource-dependent economies.

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Kazakhstan's Scientific Output in Economic Disciplines: Collaboration Networks and Citation Analysis

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ABSTRACT

Kazakhstan's integration into the global scientific landscape is closely tied to the growth and transformation of its publication activity in economics-related disciplines. This study aims to evaluate the evolution of Kazakhstan's publication activity in economics-related disciplines from 2010 to 2023, with a particular focus on growth in output, the emergence of dominant research themes, changes in international collaboration patterns, and the extent of global citation visibility. Using bibliometric methods applied to a dataset of 3,914 Scopus-indexed publications, the analysis focuses on three subject areas: business, management and accounting; decision sciences; and economics, econometrics and finance. The results reveal a sharp increase in publications, from 18 papers in 2010 to over 500 in 2023, with a peak of 538 in 2022. The findings show sustained growth in research output, particularly after higher education and science reforms. Keyword analysis reveals a shift from locally focused topics, such as development and policy, toward internationally relevant themes, including technology and energy. Citation analysis confirms increasing visibility, with 19,967 citations across 2,860 publications, led by China (2,444), Russia (1,430), and the United States (1,186). These findings indicate that Kazakhstan's academic community is gradually transitioning from knowledge consumption to production, pointing to its potential for regional leadership. Future research should assess the quality of international collaborations, expand the disciplinary scope beyond Scopus, and incorporate qualitative approaches to capture the depth of research partnerships more effectively.

KEYWORDS: Economic Research, Economic Discipline, Econometrics, Scientometrics, Research Partnerships, Research Collaboration, Business, Publication Output

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1. INTRODUCTION

Global knowledge production continues to exhibit significant disparities between the Global North and the Global South. Research from high-income, industrialised countries in Europe, North America, and parts of East Asia dominates in terms of visibility, volume, and citation impact. In contrast, many countries in Asia, Africa, and Latin America face barriers such as limited funding, linguistic constraints, and restricted access to international publishing platforms (Connell, 2007; Tijssen, 2007; UNCTAD, 2022; Al-Khoury et al., 2022). To overcome these disparities, it is essential to strengthen mechanisms that support research capacity, foster international collaboration, and ensure greater representation of diverse perspectives in global debates (Boshoff, 2010; UNESCO, 2021).

Despite persistent structural inequalities in global knowledge production, Kazakhstan provides a suitable case for examining how an emerging research system seeks to strengthen its international presence. Since the early 2010s, the country has introduced a series of reforms to modernise its research landscape, including participation in the Bologna Process, expansion of performance-based funding, and incentives to publish in internationally indexed journals (Narbaev & Amirbekova, 2021; Kuzhabekova et al., 2022). These initiatives have contributed to a steady rise in publication output (Amirbekova et al., 2022; Lovakov & Yudkevich, 2021). Yet, important questions remain about whether this growth reflects more profound systemic change, including policy changes, digitalization and other potential areas for growth (Nurtayeva et al., 2024; Matveeva et al., 2023; Movkebayeva et al., 2020; Lodhi et al., 2023). Existing studies highlight uneven international collaboration, limited engagement with global debates, and the modest visibility of locally relevant research in high-impact outlets (Yessirkepov et al., 2015; Amirbekova & Li, 2024; Lovakov et al., 2022). Whether these reforms have enabled Kazakhstan to transition from a knowledge consumer to a knowledge producer remains an open question, making it a critical case for assessing the dynamics of academic development in the Global South.

This study aims to evaluate the evolution of Kazakhstan's publication activity in economics-related disciplines from 2010 to 2023, with a particular focus on growth in output, the emergence of dominant research themes, changes in international collaboration patterns, and the extent of global citation visibility. This focus on economics-related fields is deliberate, as they are strategically important for Kazakhstan's economic modernisation and international competitiveness, yet remain underexplored in scientometric research. The period from 2010 to 2023 coincides with major national reforms in higher education and research policy, providing a meaningful timeframe for analysis. Scopus was selected as the primary database because of its wide coverage of peer-reviewed journals in economics and business disciplines, as well as its structured metadata that enables robust bibliometric analysis. Our analysis employs bibliometric methods to examine trends in publication activity, keyword usage, international collaboration, and citation patterns across three subject areas: Business, Management, and Accounting; Decision Sciences; and Economics, Econometrics, and Finance. These fields were selected because they represent core areas of economic scholarship where Kazakhstan's integration into international academic debates remains limited, yet strategically important. Drawing on established scientometric frameworks, this paper assesses Kazakhstan's progress and ongoing challenges in its transition from a knowledge consumer to a knowledge producer (Serenko, 2021; Tsilika, 2023). The following research questions guide the study:

RQ1: How has Kazakhstan's publication output in economics-related fields evolved between 2010 and 2023?

RQ2: What are the dominant research themes that characterise these fields?

RQ3: How has Kazakhstan's international collaboration shifted between Global North and Global South partners?

RQ4: What patterns of citation impact reflect the visibility of Kazakhstan's research in global academic networks?

The contribution of this study is two-fold. Firstly, applying scientometric analysis to a dataset of 3,914 Scopus-indexed publications provides an in-depth assessment of Kazakhstan's evolving research landscape in economics-related fields, highlighting trends in output, collaboration, and visibility. Secondly, it offers policy-relevant insights on strengthening research capacity, improving international collaborations, and creating incentives for high-quality publications - issues that are highly relevant not only for Kazakhstan but also for other emerging economies where research is closely tied to economic development.

The paper proceeds as follows. Section 2 reviews relevant literature on knowledge production in the Global South and Kazakhstan's research policies. Section 3 outlines the dataset and bibliometric methods. Section 4 presents the empirical results, while Section 5 discusses their significance for Kazakhstan's research system, global debates and limitations. Section 6 concludes with implications and future research directions.

2. LITERATURE REVIEW

Despite the steady growth in the number of publications in developing countries, structural barriers persist that prevent their full participation in global academic processes. These limitations include insufficient funding for science, the dominance of English as a language, and limited access to prestigious publishing platforms. These factors create a situation where the scientific contributions of countries in the Global South are not visible in leading databases. The science of Kazakh economics faces similar challenges: despite the growth in quantitative indicators of publication activity, issues with research quality, depth of international collaboration, and global citation remain unresolved.

This literature review is organised into two parts. First, it outlines global research inequalities between the Global North and Global South. Second, it situates Kazakhstan within this context and connects it to broader discussions on research reforms, bibliometric approaches, and comparative perspectives in emerging economies.

Research output and influence remain heavily concentrated in the Global North, especially in Western Europe, North America, and East Asia, supported by sustained investments in infrastructure and long-term policy frameworks (Connell, 2007; UNESCO, 2021; Wagner & Jonkers, 2017; Rousseau & Ding, 2016). Bibliometric surveys confirm that high-income countries consistently dominate global publication and citation indicators, while Global South systems contribute marginally to international journals indexed in Scopus and Web of Science (King, 2004; Tijssen & Kraemer-Mbula, 2017; Leydesdorff et al., 2019; Chankseliani et al., 2021). This imbalance underscores the persistent structural gap in global knowledge production, highlighting the need for strategies that can strengthen the research capacity and visibility of emerging economies.

The literature on inequalities reveals two recurring themes. First, structural barriers such as limited research funding, English-language dominance, and uneven access to international publishing continue to constrain participation (Al-Khoury et al., 2022). Second, debates on epistemic justice highlight how Northern hegemony extends beyond volume and citations, shaping what counts as legitimate knowledge and whose perspectives frame global debates (Connell, 2007; Santos, 2014; Canagarajah, 2002). These factors underscore the profound nature of global scientific inequality and highlight the need for innovative approaches to address it.

Methodologically, most studies of the North-South divide rely on macro-level bibliometric indicators (publication counts, citations, impact factors), but critics note their limitations in capturing research quality, thematic relevance, and local impact (Moed, 2005; Leydesdorff & Wagner, 2008). There is growing interest in using network analysis and

thematic mapping to assess better collaboration dynamics and emerging research agendas (Glänzel, 2012; Aria & Cuccurullo, 2017; Zupic & Čater, 2015). However, empirical applications remain uneven, with more developed analyses in STEM and fewer systematic studies in economics-related disciplines.

Kazakhstan provides a valuable case for examining how transitional economies pursue academic integration. Since 2010, the government has introduced reforms, including participation in the Bologna Process, performance-based funding, and incentives for international publishing (Narbaev & Amirbekova, 2021). These measures contributed to a rise in research output, especially in STEM, though social sciences and economics-related disciplines remain underdeveloped (Amirbekova et al., 2022; Yessirkepov et al., 2015; Hladechenko & Moed, 2021). This contrast highlights both the progress achieved through policy reforms and the persistent gaps that require further attention in order to strengthen Kazakhstan's position in the global research landscape.

Studies of Kazakhstan's publication patterns reveal several challenges. First, thematic orientation: in Business, Management, and Accounting, around 70% of publications focus on local or regional issues, often using descriptive methods, whereas international studies employ theoretical models and mixed methods (Amirbekova & Li, 2023; Amirbekova et al., 2025). Second, language and access barriers: Russian remains dominant, with limited English proficiency restricting participation in global journals (Yessirkepov et al., 2015). Third, quality concerns: researchers face pressure to publish internationally, sometimes resulting in publication in predatory or low-impact journals (Savina & Sterligov, 2020; Kuzhabekova, 2021; Yelibay et al., 2022). These factors suggest the need for systematic measures to enhance the quality of research and its integration into the international academic community.

From a methodological perspective, while policy reports and descriptive studies exist, few works have applied scientometric techniques to systematically map Kazakhstan's collaboration networks, citation impact, or thematic clusters in economics-related fields (Narbaev & Amirbekova, 2021). Bibliometric methods, such as Bradford's Law, co-authorship analysis, and keyword mapping, have been widely used elsewhere (Small, 1973; Moed, 2005; Serenko, 2021; Tsilika, 2023; Garfield, 1972), but remain underutilised in Central Asian contexts.

Overall, the literature highlights several gaps that frame the research questions of this study. First, while global inequalities in knowledge production are well-documented, little is known about how publication output in emerging economies, such as Kazakhstan, has evolved over time (RQ1). Second, existing work provides only fragmented insights into the dominant themes in economics-related disciplines, with limited analysis of whether these themes align with or diverge from global research agendas (RQ2). Third, although international collaboration has increased, there is insufficient evidence on how Kazakhstan's partnerships balance between Global North and Global South actors (RQ3). Finally, the visibility of Kazakhstani research, as measured through citation impact, remains largely unexplored (RQ4). By addressing these gaps, this study advances understanding of Kazakhstan's transition from a knowledge consumer to a knowledge producer within the global academic system.

3. METHODOLOGY

Bibliometric methods are applied to assess Kazakhstan's knowledge production in economics-related disciplines. Our analysis is organised around four core dimensions: the evolution of publication output, the identification of research themes, the dynamics of international collaboration, and the visibility of research through citation impact. By structuring the study in this way, we provide a systematic and replicable approach for evaluating Kazakhstan's integration into global academic networks. This study uses a research framework, as shown in Figure 1.

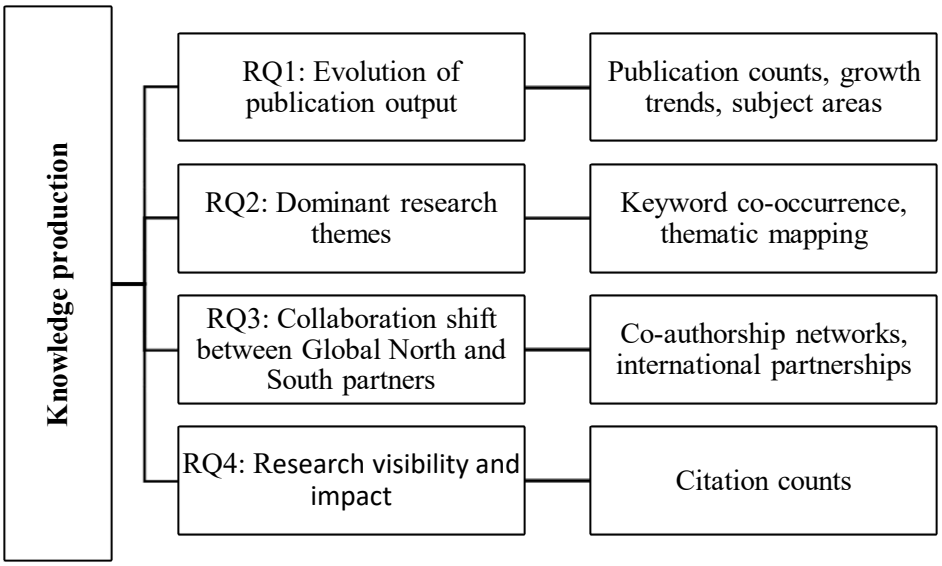


FIGURE 1. Research framework

In Figure 1, the first dimension captures the evolution of publication output, measured through publication counts, growth trends, and subject area distribution. The second dimension identifies research themes, analysed using keyword co-occurrence and thematic mapping. The third dimension focuses on patterns of international collaboration, assessed through co-authorship networks and the distribution of partnerships between institutions in the Global North and the Global South. The fourth dimension evaluates research visibility and impact, using citation counts and related indicators. Together, these measures provide a systematic approach to assessing Kazakhstan's contribution to economics-related scholarship in the global research landscape.

The analysis is based on bibliometric data retrieved from the Scopus database via API queries. Scopus was selected as the primary data source due to its comprehensive indexing of peer-reviewed literature and structured metadata, particularly in the fields of economics, business, and social sciences. The paper extracted all documents affiliated with Kazakhstan between 2010 and 2023 in the subject areas of Business, Management and Accounting (BMA); Decision Sciences (DS); and Economics, Econometrics and Finance (EEF). The dataset includes metadata such as publication year, title, authors and their affiliations, and the countries of co-authors. Additionally, data on citations of these publications were collected through separate API queries. Python was employed for data parsing, cleaning, analysis, and visualization using libraries such as requests, pandas, numpy, and collections. Counter and plotly.express, while Excel was primarily used for exploratory data analysis (EDA). Bibliometric techniques, including keyword occurrence analysis, co-authorship network mapping, and citation analysis, were employed to identify patterns in research production and scholarly influence. This methodological approach was chosen due to its suitability for uncovering large-scale trends in academic output and collaboration.

Data Collection

The dataset comprises all Scopus-indexed publications with at least one author from Kazakhstan, published between 2010 and 2023, in three subject areas: Business, Management, and Accounting (BUSI), Decision Sciences (DECI), and Economics, Econometrics, and Finance (ECON). Data

were retrieved via the Scopus API under the institutional subscription of Kazakh-British Technical University. In total, over 3,900 records were collected with metadata including article identifiers, titles, authors, affiliations, publication details, and citation counts.

All data was retrieved through the Scopus Search API (/content/search/scopus) provided by Elsevier. The queries were structured using Scopus' advanced search syntax with using the following query: AFFILCOUNTRY (Kazakhstan) AND (SUBJAREA (BUSI OR DECI OR ECON)) AND (PUBYEAR > 2009 AND PUBYEAR < 2024) AND DOCTYPE (ar). Metadata fields extracted included article identifiers (eid, doi), titles, authors and affiliations, publication details, and citation counts. The API call was made in JSON format using requests. get (...) in Python, and each page was stored locally for later processing.

Data Processing

Data processing and cleaning were conducted in Python 3.10 using a set of established libraries: requests for API interaction, pandas and numpy for data handling, and collections. Counter for keyword frequency analysis, plotly.express for visualisation, and openpyxl for export to Excel. Microsoft Excel was additionally employed for exploratory analysis and manual verification. The dataset was first deduplicated based on digital object identifiers (DOIs) and, where unavailable, Scopus identifiers (EIDs). Author affiliations were parsed to extract and standardise country names, ensuring consistency for subsequent analysis of international collaboration. Keywords were normalised by converting to lowercase and removing punctuation. These procedures ensured a clean and reliable dataset that could be systematically analysed across four dimensions: publication output, thematic development, collaboration networks, and citation impact. All steps were documented and tested to ensure reproducibility and robustness of the analysis.

Analytical Procedures

Analytical procedures were based on descriptive and exploratory bibliometric methods, structured into three main components: citation analysis, country-level collaboration, and author-level co-authorship networks. Citation analysis involved calculating the total number of citations (19,967 across 2,860 publications in three subject areas, their distribution across years and subject areas, and the countries most frequently citing Kazakhstan-affiliated articles. Figures were generated in Python and verified in Microsoft Excel to ensure accuracy. Country-level collaboration was examined through metadata on author affiliations. Country names were extracted and normalised (for example, "USA" converted to "United States"), and then aggregated by country and by year using Python functions such as groupby() and pivot_table(). This enabled the calculation of frequencies of international versus domestic collaboration, providing insight into Kazakhstan's partnerships with both Global North and Global South institutions. Author-level co-authorship networks were then constructed to capture collaboration structures, focusing on the identification of central actors, the density of relationships, and emerging research clusters. Together, these methods provided a systematic basis for evaluating Kazakhstan's publication output, collaboration patterns, and integration into international academic networks.

4. FINDINGS AND DISCUSSION

The study of publication activity is a crucial tool for understanding how the national scientific system responds to institutional reforms and global challenges. In Kazakhstan, quantitative indicators of publications in international databases allow us to assess not only the level of productivity of researchers but also the degree of their integration into the global scientific space. Growth dynamics of publications reflect the effectiveness of government initiatives aimed at stimulating academic productivity and improving the quality of research. Analysis of publication

output statistics over recent years allows us to identify not only general trends but also key turning points related to changes in scientific policy and academic culture.

Kazakhstan's research output in Business, Management and Accounting, Decision Sciences, and Economics has grown significantly over the past decade. In 2010, only 18 publications were recorded, while in 2023 this number exceeded 500. This steady increase highlights the expanding academic presence of Kazakhstan's scholars in internationally indexed journals and reflects the impact of sustained policy reforms in higher education and science. Figure 2 presents the annual distribution of publications from 2010 to 2023, showing how Kazakhstan's research activity has expanded over time.

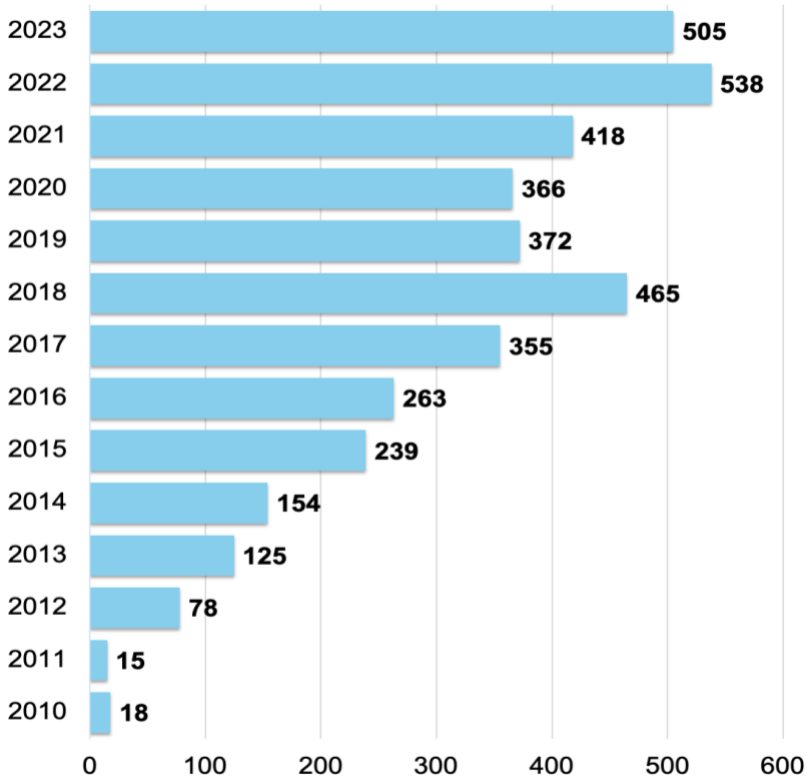


FIGURE 2. Distribution of publications from Kazakhstan by year for 2010-2023

Note: compiled by the authors based on calculations

Figure 2 illustrates that publication growth was particularly sharp after 2014, when policy reforms targeting PhD students and faculty were fully implemented, reshaping academic culture and aligning it more closely with international standards. From 2018 onwards, annual output consistently surpassed 350 publications, peaking at 538 in 2022. This pattern signals a mature phase of research production, supported by government initiatives and institutional policies that incentivised faculty engagement in publishing. The introduction of the Law on Science and the State Program of Education Development (2011–2020) established a performance-based system that prioritised international visibility of research through requirements for PhD completion, academic promotion, and competitive grant funding (Narbaev & Amirbekova, 2021). By 2018, the effects of these reforms had fully materialised, contributing to the peak in output as universities responded to key performance indicators. On a broader perspective, this

trajectory reflects Kazakhstan's goals of integration into the international research network. This has affected the focus on publishing in international journals, increased the visibility of research, and positively demonstrated the application of international research practices.

Next, the keyword analysis identifies the thematic evolution of the research landscape. Moreover, the research context primarily focused on economic development. The keyword highlights this focus on economic transformation, national context and policy-driven changes.

Kazakhstan's research is highly localised as the term "Kazakhstan" has 1336 mentions (see Figure 3).

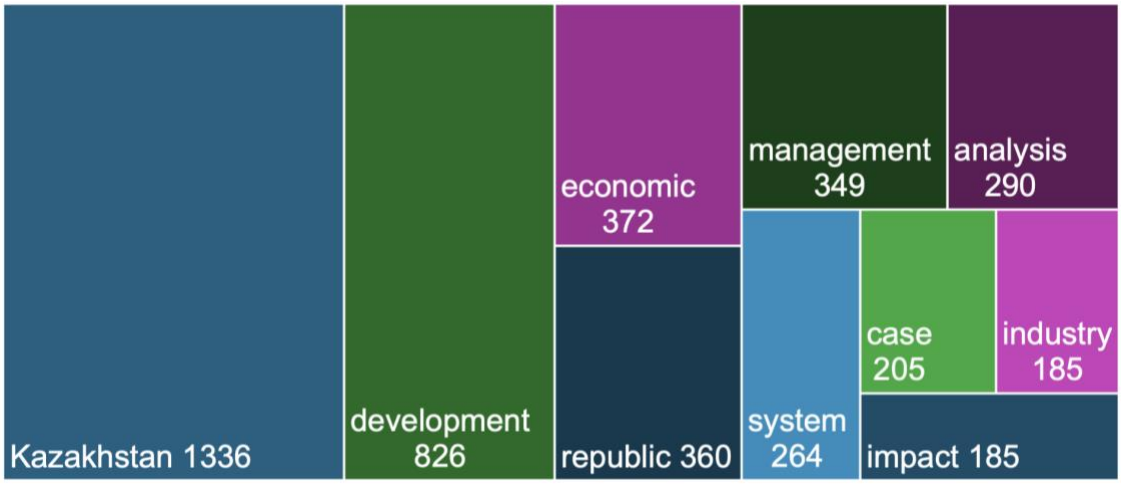


FIGURE 3. Research keywords for 2010–2023

Note*:* compiled by the authors based on calculations

This is closely linked to the country's economic regime and the challenges it has faced since gaining independence. Keywords like "management", "analysis" and "system" suggest an analytical approach and applicability of research in terms of the decision-making process, use of analytical approaches and more comprehensive targeted analysis for informed decision-making. Keywords such as "case", "industry", and "impact" indicate a practical orientation of research in this field and the application of research in specific industries. Over time, new keywords such as "technology", "international", and "energy" began to appear frequently. This demonstrates changes in the focus that are relevant to shifts in Kazakhstan's economy. This shift is related to the integration of the global economy, particularly in terms of international economic cooperation, energy development, and security. The evolution of keywords demonstrates local trends in science and the economy, ultimately serving the needs of economic development. Visualizations of keyword evolution are included in Appendix A for additional reference.

Furthermore, Kazakhstan's scientific landscape is becoming increasingly collaborative, as evidenced by the distribution of international co-authorships. This pattern reflects both the persistence of historical ties with post-Soviet states and the growing integration of Kazakhstan into global academic networks, particularly through collaborations with the United States and the United Kingdom. The five leading partner countries are Russia (337 co-authored publications), the United States (116), Ukraine (104), the United Kingdom (83), and Turkey (51), as illustrated in Figure 4.

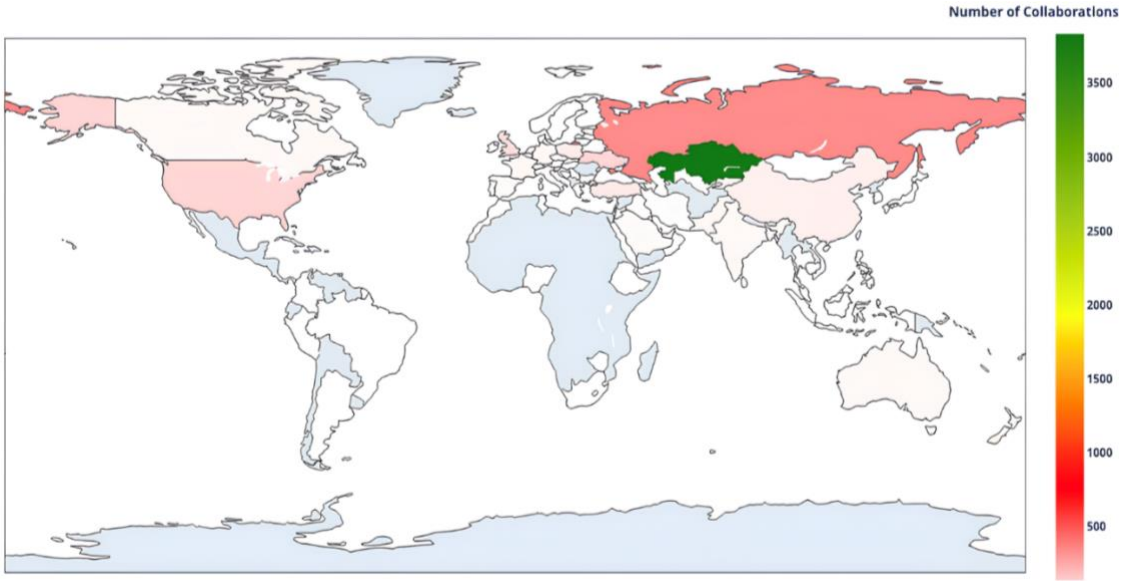


FIGURE 4. Top countries collaborating with Kazakhstan in economic research

Note: compiled by the authors based on calculations

The co-authorship pattern reflects both historical links and emerging new ones. Kazakhstan itself accounts for 3,834 publications, while the top five partner countries are Russia (337), the U.S. (116), Ukraine (104), the United Kingdom (83) and Turkey (51). The past links created during the Soviet time with Russia and Ukraine are sustained and demonstrate a strong, continued partnership. The common past created deeper institutional links. The majority of scientists continue to contribute to this academic network, facilitating joint research and collaboration. The partnership with global leaders of Northern countries, such as the U.S. and the UK, demonstrates significant integration into the global research network. These collaborations are related to the global projects, international visibility and publication in higher-ranked international journals. The partnership with Turkey demonstrates a well-developed academic link with the academic community of Turkey. Strong links illustrate the establishment of joint research and similar academic interests in research. Other collaborations include Poland (45), China (44), New Zealand (39), and Kyrgyzstan (32).

Lastly, the results show that while domestic self-citation remains dominant, Kazakhstan's academic output is increasingly recognised by leading research countries across both the Global South and Global North. The most frequently cited countries are shown in Figure 5.

Kazakhstan itself accounts for 3,339 citations, followed by China (2,444), Russia (1,430), the United States (1,186), and Ukraine (1,007). Other contributors include India (799), the United Kingdom (663), Indonesia (602), Malaysia (420), and Italy (395). Kazakhstan has strong links within the country, as well as with China, Russia, the U.S., and Ukraine. The dominance of local citations reflects the pattern of research networks where the academic community is building on existing local knowledge to develop research further. It also relates to stronger internal networks that can generate knowledge and create a robust research base. Citation activity from China and the U.S. demonstrates a positive trend of global

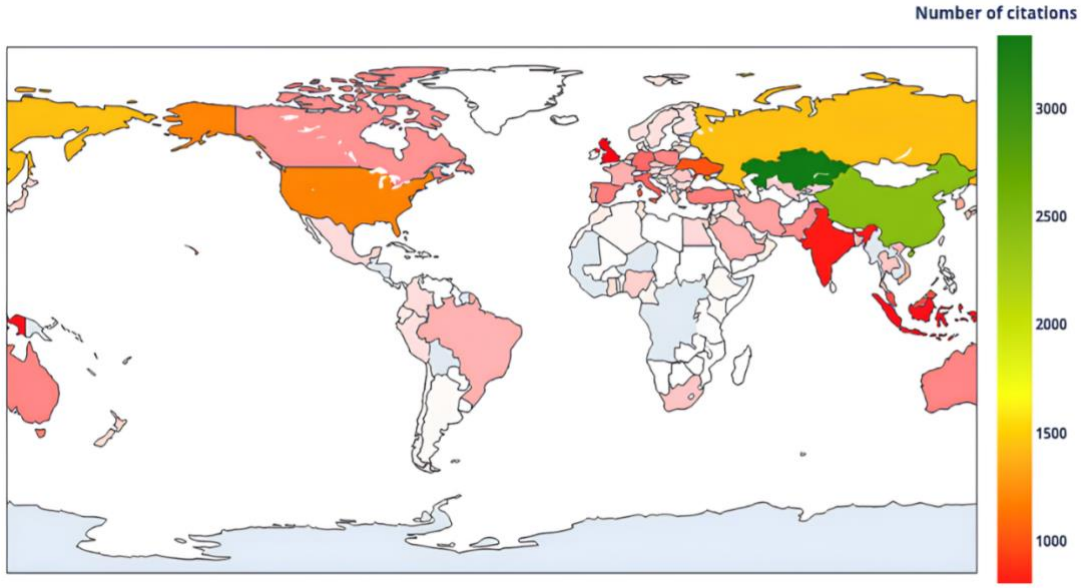


FIGURE 5. Top countries collaborating with Kazakhstan in economic research (citations)

Note: compiled by the authors based on calculations

development and international relevance of Kazakhstan's research. Both countries are leading research nations with strong international profiles, and their engagement reflects wider academic interest in topics related to Central Asia. Russia and Ukraine remain long-standing partners, with sustained research links indicating continuous collaboration and shared interest in similar themes. Overall, the citation impact highlights the internationalisation of Kazakhstan's research and the positive outcomes of strategic decisions aimed at integrating science into global networks.

5. DISCUSSION

The analysis reveals a consistent and substantial increase in Kazakhstan research publications across the economics-related fields in the last decade. The growth from 18 publications in 2010 to more than 500 in 2023 demonstrates a positive trajectory for the economic field's development, which also includes international practices. The growth over the last ten years is possible through consistent policy changes that have evolved into major reforms affecting various stakeholders. The introduction of laws and programs had positively affected the number of publications and engagement of the academic community in research activities. These changes have been embedded and reflected in yearly outputs. This clearly demonstrates the impact of policy reforms, as well as institutional incentives to enhance academic publications and expand research capacity. The keyword analysis reveals a thematic development and evolution. The local and descriptive terms reflecting the focus on national development and growth later evolved into more comprehensive ones, focusing on national transformation, policy changes, and internationalisation, targeting the country's needs. Moreover, these reflect interdisciplinary research and globally relevant topics. This evolution is vital, as it suggests a dynamic environment where research is shifting towards more analytical, evidence-based approaches to addressing local challenges. Additionally, the resonance with internationally relevant topics demonstrates Kazakhstan's integration into the wider academic community, encompassing issues such as international development,

energy policy, and digital. This has a positive notion of linking local research needs with global research topics, thereby expanding Kazakhstan's research contribution.

Similarly, Kazakhstan's global partnership has been growing and developing in recent years. Ukraine and Russia, as major partners in research, reveal the continued historical links between the countries, while new international partners demonstrate Kazakhstan's integration into the Global North's research networks. This is very important, as it reflects the quality of the studied topics and the partnership network, which ultimately contributes to international visibility and reputation. This demonstrates strong links with regional partners as well as global partners. The significant implication of this lies in the strong outputs, both in terms of quality and scholarly outreach.

The citation pattern demonstrates Kazakhstan's growth in international visibility of research, which is the result of the quality of published academic papers. The citation count related to local research reflects strong links within research groups in the country. At the same time, growth globally demonstrates the relevance of research to researchers from both the Global North and the Global South. The nature of research in Kazakhstan shows the interest of various researchers and demonstrates the consistency of research with the international agenda. This suggests that Kazakhstan's research is being recognised by the global academic community, and highlights opportunities for its further development.

Overall, collaboration with Global North countries is significant as it demonstrates the quality and visibility of research. This might enhance international funding opportunities, promote great integration into scholarly networks, and diversify the research agenda. The diversification of partnerships may contribute positively to growth in regional and global markets. The networks aiming to enhance the quality of partnerships will ensure the long-term, sustained development of a research landscape that is relevant and effective. This study offers important insights into the development and evolution of Kazakhstan's research output in the economics-related field. However, several limitations must be acknowledged. The study is based purely on Scopus and covers papers indexed in international journals. This is why it may underrepresent local studies that are published in languages other than English and in local journals. This might lead to an overlook of the regional contribution of this research. Because the study is relying on bibliometric indicators, it doesn't capture the quality and depth of research. Further research could employ a qualitative approach, incorporating interviews and case studies to gain a deeper understanding. Collaboration analysis through co-authorship reveals major partners, although it doesn't reveal the depth of partnership and its nature. Future work could provide a more comprehensive understanding of collaborations through international partnerships and capacity building.

6. CONCLUSIONS

This study examines the trajectory of Kazakhstan's research outputs in economics-related fields from 2010 to 2023, highlighting growth and thematic diversification. The increase in the number of publications reveals deep trends of growing scholarly engagement, systemic policy changes, and national reforms that have boosted and were designed to stimulate the expansion of research. Institutional reforms related to the training of PhD, academic career development, and grant funding have contributed significantly to this growth. Kazakhstan, since gaining independence, has allocated its resources to higher education and focused its efforts on creating strong incentives for research to be published in international journals, participating in global research, and achieving international visibility.

The role of economics-related research is a significant factor for a country's success, as it reflects crucial areas for economic growth. Kazakhstan has noted the shift in keywords and the type of research conducted. Moreover, the changes reflect the current state of research with increased capacity in topics related to

energy, industry, internationalization. The shift suggests the relevance of research in this area and growing interest. The collaboration patterns reveal strong links with countries in the Global South and Global North, as well as involvement in research through regional and global research communities. The quality of publications is characterized by the interest from countries that are leaders locally and globally. From the policy perspective and understanding of research in economics-related fields, this research suggests several implications. The government's active support of research and the creation of an environment resulted in positive outcomes. Provided incentives had affected the quality of reforms and research outputs over the past decades. The following direction for research in this field should prioritise the quality of publications over quantity and set new, high-level goals to increase publications in highly reputable journals. Another area that could be developed further is international collaborations. Kazakhstan is recognised for its international programs, including strategic initiatives such as joining the Bologna process; therefore, the development of quality partnerships is essential and requires consistent support mechanisms. The comprehensive development of the research system in Kazakhstan would positively influence the applicability of research and enhance its impact on the country's economy as well as overall growth and contribution to global knowledge development.

In the future, the development of Kazakh science should be based on the formation of a strategy aimed at improving the quality of research and its international recognition. One of the key areas will be the study of international cooperation, the expansion of access to leading academic networks, and the utilisation of joint projects to integrate into the global agenda. Focusing on these tasks will not only strengthen the country's position in the worldwide research space, but also ensure the sustainable impact of national science on the processes of socio-economic modernization.

AUTHOR CONTRIBUTION

Writing–original draft: Yelena Li, Diana Amirbekova.
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Formal analysis and investigation: Yelena Li, Diana Amirbekova.
Development of research methodology: Yelena Li, Mariyam Taskinbayeva.
Resources: Yelena Li, Diana Amirbekova.
Software and supervisions: Yelena Li, Diana Amirbekova.
Data collection, analysis and interpretation: Yelena Li, Diana Amirbekova.
Visualization: Yelena Li, Mariyam Taskinbayeva.
Writing review and editing research: Diana Amirbekova, Mariyam Taskinbayeva.

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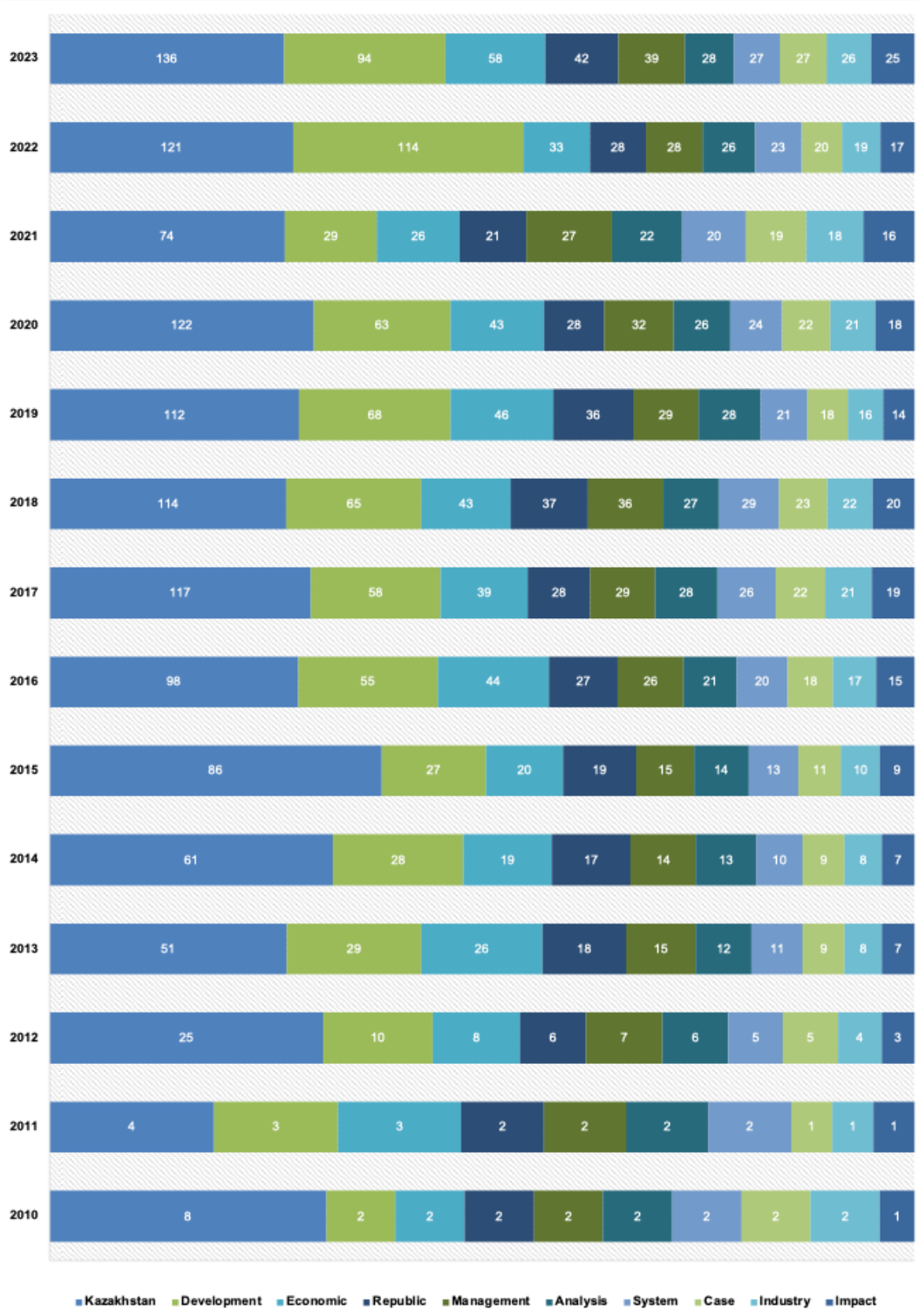
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More Freedom, Less Equality: The Unexpected Economics of Abortion in Central Asia

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Conflict of interest:
author(s) declare that there is no conflict of interest.

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ABSTRACT

Few papers about Central Asia explore the economic effects of abortion on women. This econometric paper the objective is to assess whether abortions in Kazakhstan and Kyrgyzstan are associated with women's economic empowerment. The study finds that when abortions increase, measures of female relative income decrease, in both simple correlations and Ordinary Least Squares regressions. The annual series for 2002-2022 and comparable aggregates for the two countries are used (a total of 32 observations on key variables), where the gender pay gap is defined as the ratio of the average incomes of women to the incomes of men. This implied that Kazakhstan and Kyrgyzstan had different permanent institutions, such as the labor market. Instrumental-variable analysis, which controls for the impact of the model itself on abortion estimates, showed that a rise of one abortion per 1,000 live births led to a 2% decrease in the female-to-male ratio of average income. The descriptive part reveals a stable negative relationship between abortions and women's relative income: for the 2011-2022 subsample in Kazakhstan, the simple correlation is about -0.63 (statistically significant), which is consistent with the "constraints" hypothesis. The paper concludes that female economic empowerment in Central Asia may depend more on institutions and social structures than on individuals' short-term reproductive decisions, such as whether to have an abortion. The findings contradict the theory that abortion empowers women economically by freeing them from raising children so that they can pursue education and careers.

KEYWORDS: Abortion Economics, Gender Economy, Gender Pay Gap, Female Labor, Women's Economic Empowerment, Income Inequality, Kazakhstan, Kyrgyzstan

SCSTI: 06.77.97

JEL Code: I14, J13, J16

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1. INTRODUCTION

In Central Asia, abortion has been one of the primaries means of birth control since Soviet times. Research has focused on demographic and cultural determinants of abortion, and on its impact on public health. Its economic effects are rarely explored. The paper contributes to the literature with its first detailed comparative study of econometric models. The five models analyzed confirm that, contrary to conventional theory, abortion cannot be treated as an exogenous variable in a study of its economic effects. Abortion is determined by factors, such as education and distribution by age, that also affect the economic position of women directly. To ignore the endogeneity of abortion in economic models would severely misstate its direct impact on women's economic position. This can lead abortion policy astray by suggesting, for example, that the government can adopt the same policy in all areas and without regard to demographics.

Although Central Asia has moved towards modern contraception, its abortion rates remain high (Westoff, 2000; Guttmacher Institute, 2020). This raises a question: Does abortion help women find better jobs by freeing them to pursue education and careers, as conventional theory suggests? Or does abortion perversely strengthen social and institutional barriers to women? For example, abortion may reduce the woman's status in a farm family as someone who raises productive children. The loss of family's support may prevent a woman from pursuing her own career.

Consistent with the theory that abortion reinforces barriers, the literature identifies cultural traditions, together with social stigma, economic insecurity, and healthcare access, that interact with abortion rates (Hilevych, 2015; Johnson et al., 2018; Cooley & Chesnokova, 2011). For example, the lack of a woman's income to raise children may make abortion a clear and sound solution. This, in turn, may weaken her motivation to pursue a lucrative career that would provide for a family for decades to come. Despite such possibilities, few studies examine quantitatively how abortion affects female economic status.

In light of that gap in the research, this paper aims to assess how abortion rates affect the human capital and income of women, relative to men, in Kazakhstan and Kyrgyzstan, which have more data on abortion than the rest of the region. Thus, the objective of this study is to assess whether abortions in Kazakhstan and Kyrgyzstan are associated with women's economic empowerment. Additionally, the paper tests two competing hypotheses:

1. *Empowerment Hypothesis* – Higher abortion rates increase women's relative income by freeing them of childbearing responsibilities, since this enables them to earn diplomas and accumulate work experience that qualifies them for better jobs.

2. *Constraint Hypothesis* – Higher abortion rates decrease women's relative income by depriving them of family and community support for careers. They lose support because the family or community regards raising children as their top priority. Unsafe abortions may also leave women too sick to work.

2. LITERATURE REVIEW

"Culture" can be an elusive term. Thus, religion is cultural because believers largely accept its tenets without debate. However, a marriage arrangement is social, not cultural, because it is an interaction. The distinction between cultural and social factors is important because it influences the appropriate analysis. In neoclassical economics, culture is seen as a result of the economy, rather than the other way around. Certain practices and beliefs persist because they produce something of value at the lowest possible cost. One practice is that a family produces household services through negotiations among its members.

In the neoclassical view, there occur abortions based on gender because the family believes that a male baby is more likely to become an asset to it than a female one. Therefore, many Asian families abort female babies because they prefer male ones (Meh & Jha, 2022). However, Kazakh families do not

abort to eliminate females but to balance family composition (Cooley & Chesnokova, 2011). Perhaps beliefs about family equilibrium persist because they stabilize society; the preference for sons can lead to a shortage of women, making it difficult for families to form.

The neoclassical approach may also explain a recent regional trend in abortions. Historically, ethnic Kazakhs have been much more likely to oppose abortions than ethnic Russians. The nomadic tradition among Kazakhs emphasized children's participation in practical work, although this distinction appears to be fading as the tradition itself evolves. In the Asian part of Russia, abortions rose in the early years of the Russian Federation (Wites, 2004). A transactional approach provides an additional perspective. Muslim women need not choose conservative birth control methods even though Muslims generally prefer conservative family policies (Kan, 2024). Therefore, while culture influences abortion decisions, it rarely determines them. Patrilocal living arrangements limit women's autonomy and reinforce economic inequalities; yet, such inefficient arrangements persist because many rural families in Central Asia remain reluctant to adopt radical change (Kovaleva & Taylor, 2023).

An example of social dynamics is the generation of information, which typically results from discussion. Information deficiencies may lead to abortions. In particular, incorrect contraceptive information causes numerous unintended pregnancies among Muslim youths (Sarsenova et al., 2024). Although Kyrgyzstan's abortion laws are liberal, many women do not know how to obtain a safe abortion (Johnson et al., 2018). Information failures lead to abortion in other permissive legal regimes as well (Sedgh et al., 2016). Education plays a dual role, empowering women economically while also delaying childbearing and decreasing fertility. These offsetting effects complicate decisions about reproduction (Urbaeva et al., 2019). The choice to abort, rather than resort to other methods of birth control, need not shed light on reproductive choice as a path to empowerment (Johnson et al., 2018).

It is not surprising, then, that abortions result from more than traditional gender roles, as Szreter (2002) noted. They also result from a woman's relations with a spouse, which may change over time, and from the presence or absence of autonomy, as noted by Hilevych (2015). For example, in Soviet Ukraine, women viewed birth control as the husband's responsibility. A woman in a troubled marriage may also abort the child out of fear that it will not have a good father. These examples are far from the traditional gender roles.

Demographic factors lie somewhere between cultural and social factors. However, they affect the decision to abort. For example, pregnancies and abortions are much more likely among teens than older groups (UNCRC, 2015). The adolescent birth rate in Kazakhstan has decreased, while modern methods have enabled more women than before to plan their families (United Nations, 2022). Nevertheless, recent regional dashboards show that in Kazakhstan, youths have trouble getting sexual and reproductive health services even though they have a legal right to them (UNFPA, 2023). Globally, unintended pregnancies remain common, and most result in abortions (Bearak et al., 2020).

Economic factors comprise the subset of social factors that stem from trade. Their impact on abortion is indisputable. In Kazakhstan, abortion is legal up to the 22nd week for unemployment or nonmarriage of the woman, according to the International Planned Parenthood Federation European Network (n.d.). In the trans-Caucasian countries of Armenia, Georgia, and Azerbaijan, abortions after the turn of the 21st century stemmed from economic insecurity and shifting preferences in politics (Schief et al., 2024). Recent studies examine how comparable economic limits affect relationships among gender roles, work patterns, and innovation in post-Soviet Central Asia. Kovaleva et al. (2025a; 2025b) investigated the impact of household structures and gender norms on women's participation in labor markets in Kazakhstan and Kyrgyzstan.

Abortion may resolve contradictions in the labour market. When women must do chores at home while pursuing a career, abortion may ease their double burden (Rotkirch & Kesseli, 2010). In rich areas, abortions reduce teen motherhood and strengthen the woman's attachment to the labor force (Angrist & Evans, 1996; Ananat et al., 2009). The strength of such effects varies by race, cohort, and institutional context. This variance leads to caution against the simple extrapolation of global results to Central Asia. Poverty may compel abortions, but these need not raise relative female income much. Drezgić (2010) finds that male-dominant societies flourish despite economic stagnation.

Institutions are rules that change slowly. In Kazakhstan, ignorance, stigma, and institutional weakness make abortions dangerous (Urbaeva et al., 2019). High abortion rates across countries that differed in average income and degree of democracy suggest that Soviet institutions supported abortion. Studying Russia, Belarus, Ukraine, and the three Baltic countries from 1970 to 1994, Mogilevkina et al. (1996) found that annual abortion rates were one in five women. In Kyrgyzstan, abortion services from mid-level providers have improved in remote areas. Telemedicine services beginning in 2023 reduced geographic barriers (Bozgorpoeva, 2024). The problem is to commit resources over time to improve abortion services for the good.

Institutions changed in Kazakhstan as abortions declined sharply. During the transition to a market economy in the 1990s, abortions abounded. A Kazakhstani survey in the mid-1990s found that 37% of pregnancies were aborted, two-thirds of accidental pregnancies ended in abortion (Westoff, 2000). The Demographic and Health Surveys (hereinafter – DHS) from Central Asia revealed "replacement of abortion by contraception" in Kazakhstan, Uzbekistan, and Kyrgyzstan. Abortion rates decreased as the use of modern methods increased. In Kazakhstan, from 1962 to 1980, the annual number of reported and estimated abortions exceeded the number of live births. However, the ratio of abortions to live births fell to one-fifth in 2018 (Johnston, 2025). The Guttmacher Institute (2020) found that unintended pregnancy and abortion rates halved from 1990-1994 to 2015-2019 because of contraceptives and sexual and reproductive health care. These lessons extend to the region (Agadjanian & Dommaraju, 2011).

In conclusion, laws, healthcare, and information systems affect adolescent fertility conditions and reproductive choices in Central Asia. However, aside from a few descriptive statistics, the literature is discursive. This paper will contribute to econometrics.

3. METHODOLOGY

Before specifying the mathematical form of the regression model, it is necessary to describe the dataset and the procedures applied to prepare it for estimation. The analysis focuses on the period from 2002 to 2022, based on the available official data. Gaps in the dataset between 2010 and 2020 were filled by linear interpolation of missing HCI and HDI values. Interpolation over short gaps is justified because HCI and HDI are slow-changing indicators that usually follow monotonic trends. Without interpolation, the missing values would reduce the number of usable observations (Newbury, 1981). Already, there are no more than 23 annual observations. To check the accuracy of the linear interpolation, the authors also modeled the time trends as piecewise rather than linear. This did not change the signs of correlations. To further check for robustness, the analysis combines data from Kyrgyzstan to that from Kazakhstan by using country dummy variables.

A mathematical model is to be fitted to the regressions. A mathematical approach enables the identification of control variables and the formulation of the regression model carefully. Otherwise, any combination of controls and functions is possible. Ambiguity must be avoided because the limited number of observations restricts the number of explanatory variables that can be included, including controls not directly tested in the

hypotheses. In this dataset, the small sample size requires judicious selection of explanatory variables.

The model considers whether the accumulation of education or work experience following the abortion could raise average income for women, relative to men. To measure the gender pay gap, the following formula was used (1):

$$Pay\ Gap(t) = \frac{women_{inc(t)}}{men_{inc(t)}} \qquad (1)$$

where:

t – time period (year) in the panel dataset;

$women_{inc(t)}$ – average real income of women at time t;

$men_{inc(t)}$ – average real income of men at time t.

The paper seeks to determine how abortion will affect *Pay Gap*. *Abortions* are an independent variable explaining the *Pay Gap*, a dependent variable. The following formula was used (2):

$$Pay\ Gap = b * Abortions \qquad (2)$$

The model relates the pay gap to relative human capital accumulated by a woman since the abortion. The idea behind the Empowerment Hypothesis is that postponing children, or refraining from having them, allows acquiring education and work skills. This capital raises income level of women relative to a men's. The following formula was used (3):

$$k(t_1; t_0) = \int_{t0}^{t_1} dk(s)\ ds \qquad (3)$$

where:

k (t_1; t_0) – the amount of human capital that the woman accumulates by time t_1;

dk(s) – the increase in the capital at time *s*;

t_0 – the onset of capital accumulation; under the Empowerment Hypothesis, t_0 corresponds to the abortion event.

Three variables pertain to the hypothesis: Abortion, female human capital, and the gender pay gap. The gender pay gap is represented by *Pay Gap(t)*. Nevertheless, there is only enough data to estimate the response of *Pay Gap* to either abortion or capital, but not both. Since data are more precise on abortion than on capital, the regression will estimate the impact of abortion on *the Pay Gap and assume a positive relationship between capital and the Pay Gap.* In other words, in the hypothesized relationship of abortion => capital => *Pay Gap*, the regression estimates the relationship between abortion and *Pay Gap* and assumes a positive link between capital and *Pay Gap*. Given that assumption, a positive relationship between abortion and the *Pay Gap* is consistent with the Empowerment Hypothesis and evidence against the Constraint Hypothesis. A negative relationship between abortion and the *Pay Gap* has the reverse interpretation.

Increases in female human capital may reduce the gender pay gap because productivity growth is faster for women than for men. Especially in developing countries, initial productivity is lower for women than for men due to their initial involvement in unskilled occupations. As women acquire skills, the catch-up in their human capital raises their income, relative to men. The following formula was used (4):

$$PayGap(t) = a + b * Abortions(t - i) + c * x(t) + e(t) \qquad (4)$$

where:

a – the intercept, reflecting determinants of *Pay Gap* that are constant over the period studied, such as the educational system. Such institutions are too large to change quickly;

$Abortions(t - i)$ – the abortions lag which permits capital to affect the gender pay gap eventually;

c – vector of coefficients;

x(t) – vector of other independent variables at time *t*.

e(t) – the residual.

The abortion rate indirectly measures the woman's opportunity costs from childbearing. Women who delay childbearing tend to invest more in education, which enhances their job prospects and career opportunities. The proposed regression assumes that women have

similar educational trajectories in rural and urban settings so that abortion would have the same impact on female human capital in either locale.

The education lag, part of the capital lag, aligns with research findings that educational outcomes affect fertility decisions (Angrist & Evans, 1996; Ananat et al., 2009). The theory for distinguishing between the one-year lag and the five-year lag is that even recent education or work experience may significantly raise the relative female income. However, the impact may be less than that of capital created five years ago, which has had cumulative effects on income or development.

The paper specifies a one-year lag to capture short-term effects because this is the shortest possible lag with annual data. In contrast, a five-year lag is the most considerable lag feasible with the available data, since no more than 16 such lags would be possible. Using both short and medium lags also checks that the findings are robust.

Lagging the abortion rate also rules out the possibility that the coefficient *b* measures the impact of capital on abortions rather than the other way around. Greater economic development could well lead women to avoid abortions. That is, the relationship between development and abortions could run in either direction. Since that would make the interpretation of *b* ambiguous, we exclude the possibility of observing how development affects concurrent abortions by using the lag of abortions.

To measure the gender gap, in addition to the average-income ratio in Equation (1), the study uses two proxies: the Human Capital Index (HCI) for women, as reported by the World Bank (2025), and the Human Development Index, as reported by the United Nations. This use of two checks makes robust findings about any connection between abortion and the gender gap. The HCI measures labor productivity in relation to a worker's education and health, compared to a worker with a complete education and perfect health. Higher numbers indicate greater productivity.

The analysis also estimates the correlation between the lagged abortion rate and the broad Human Development Index, as defined by the United Nations Development Programme. The HDI equally weights affluence, education, and health (United Nations Development Programme, 2022). Higher values denote greater human development.

This paper assumes that, consistent with (4), larger HDI values are correlated with smaller gender pay gaps. That is, countries with more human development should have more equal pay for women relative to men. Nevertheless, another possibility stems from the fact that one component of the HDI reflects purchasing power for both sexes. Abortions have offsetting effects on this average real income. On the one hand, they can increase female human capital, thereby raising the average female income relative to that of homemakers. This could raise the average income. On the other hand, abortions also increase labor supply by encouraging female entry into the labor market.

4. RESULTS AND DISCUSSION

This section presents the findings in stages of increasing complexity, making them easier to comprehend. The first findings are for the simple correlation between abortion and the gender gap. Then, moving through ever-more advanced models, each stage of the analysis targets a different econometric concern: Correlation and OLS for transparency, FE and RE for heterogeneity, and 2SLS for endogeneity.

The asterisks in Table 1 denote the years used to calculate the correlations between the HCI and HDI with the five-year lag of abortions in the original dataset, which ended in 2020 and covered Kazakhstan but not Kyrgyzstan. The bottom of Table 1 refers to these correlations as "base-year." The simple correlation between the HCI and lagged abortions is -.55. This is not statistically significant at the 10% level of significance. Neither is their evidence that abortions lead over the medium term to human development

TABLE 1. Correlation of linear HCI, HDI and abortion rate

Year	HCI (W)	HDI (W)	Aborts(t-5)
2010	0.629	0.594	29.1
2011	0.651	0.616	30
2012	0.672	0.639	30.3
2013	0.694	0.661	28.1
2014	0.715	0.683	25.6
2015	0.737	0.705	23
2016	0.758	0.728	20.7
2017	0.78	0.75	20.8
2018	0.808	0.777	18.4
2019	0.73	0.703	18.3
2020	0.652	0.629	17.9
correlation* (base years)	-0.55	-0.59	
correlation (all years)	-.63	-.86	
(i) Years marked with "*" are base years used for comparative correlation analysis. (ii) Compiled by the authors using Stata.			

Note: compiled by the authors based on the Bureau of National Statistics (2024), World Development Indicator (2025)

as measured by the HDI. This correlation is -.59. It is statistically insignificant at the 10% level of significance.

Table 1 also shows that the number of abortions per fertile woman declined rather steadily from 2010 through 2020. This may be due to improvements in other methods of birth control. Westoff (2000, p. vii) writes, "The evidence that the increase in contraceptive practice and the decline in abortion have continued is unmistakable and strong."

The Table 1 analysis of the base years uses a tiny dataset. Thus, the lack of statistical significance in the base-year correlations could be due to the imprecision of the data rather than to the lack of a genuine relationship between abortion and female income or human development.

Nevertheless, with linear interpolation of the HCI and HDI for the missing years, the study can use all annual data for abortions since 2010. The bottom row of Table 1 refers to the correlations across these 11 observations as the all-years correlations.

The analysis obtains a simple correlation of -.63. This is statistically significant at the 5% level of significance (the critical value in absolute terms is .602). Table 1 also gives similar estimates for the HDI. Here, the correlation for the 11 observations is -.86. This is also statistically significant at the 5% level of significance. These correlations contradict the Empowerment Hypothesis and are consistent with the Constraint Hypothesis.

Approximations that increase the degrees of freedom.

In Table 2, a one-year lag of abortions relates negatively and significantly to relative female income.

TABLE 2. OLS Regression Results of Pay Gap on Abortion Rates (One-Year Lagged and First-Differenced)

Variable	(1) AbortLag	(2) DiffAbort	(3) DiffAbLag
Intercept	82.618*** (6.464)	-0.183 (0.937)	0.085 (1.272)
AbortLag	-0.615* (0.304)		
DiffAbort		-0.973 (0.552)	
DiffAbLag			-0.465 (0.736)
R^2	0.291	0.237	0.042

Adj. R^2	0.220	0.161	-0.064
Observations	12	12	11
(i) Dependent variable: Pay Gap. (ii) Model (1) uses abortions per 1,000 live births lagged by one year; (2) uses the first-differenced abortion rate; (3) uses the first-differenced lag of the abortion rate. (iii) Standard errors in parentheses. (iv) * p<0.10, ** p<0.05, *** p<0.01. (iv) Compiled by the authors using Stata.			

Note: compiled by the authors based on the Bureau of National Statistics (2024)

Differentiating the concurrent and one-year lag of Abortions to remove confounding factors does not produce significant results.

For robustness, the second column of Table 2, titled AbortLag, regresses the pay gap on a one-year lag of abortions per 1,000 live births with annual data in Kazakhstan for 2011-2022.

The pay gap is the ratio of the average female income to the average male income, expressed as a percentage point. The coefficient on the pay gap is negative and statistically significant at the 10% level of significance. The impact is also quite significant in a practical sense: An additional abortion per 1,000 live births decreases the pay gap by more than six-tenths of a percentage point. This result contradicts the Empowerment Hypothesis and is consistent with the Constraint Hypothesis. However, the R-squared value is low, at 0.291. This statistic indicates that the model explains only 29.1% of the variation in the pay gap over the dataset. Evidently, the model does not identify the most important determinants of the pay gap. Additionally, the intercept, 82.618, is both statistically and practically significant. This indicates that factors are independent of both abortions and time.

Some factors may correlate with both the pay gap and the abortion rate, obscuring the proper relationship between these two variables. One solution is to take first differences of all variables. The first difference is the change in a variable over a unit of time. Taking first differences removes a linear time trend from the variables. One can then examine the relationship between abortions and female income directly. The third column of Table 2, titled "DiffAbort," regresses the first difference of the pay gap on the first difference of concurrent abortions (DiffAbort) per 1,000 live births, using annual data for Kazakhstan. The abortion coefficient remains negative, albeit slightly less statistically significant at the 11% level of significance, rather than 10%. The impact is significant in a practical sense: A positive change in abortions from one year to the next lowers the pay gap changes over that year by about one percentage point. However, abortion is not the primary factor in the pay gap. According to R-squared, it accounts for less than a fourth of the variation in the annual change of the pay gap over time.

The fourth column of Table 2, titled DiffAbLag, regresses the first difference of the pay gap on the first difference of the one-year lag in abortions (DiffAbLag). The coefficient is negative (-.465) but highly insignificant. The model accounts for only 4% of the variation in the first difference of the pay gap over time. One may discard this model.

In the third and fourth columns of Table 2, the intercept does not differ significantly from zero. This is to be expected. First differencing eliminates the intercept, since it remains constant over time.

Overall, Table 2 suggests that even after controlling for confounding factors in the regression, there is no evidence that abortions, either concurrent or with a one-year lag, affect the pay gap outside of the sample. This contradicts the Empowerment Hypothesis, but it agrees with the Constraint Hypothesis.

In sum, the authors find no evidence so far that abortions increase female human capital or human development. But the small number of observations in Tables 1 and 2 limits the power of the results. The model below expands the dataset to include Kyrgyzstan and Kazakhstan.

A dummy variable (KAZ) controls for the country's permanent characteristics. KAZ

equals 1 for Kazakhstan observations and 0 for Kyrgyzstan observations.

Extending the dataset to Kyrgyzstan.

In Table 3, Pearson's correlations show that abortions relate negatively and insignificantly to female relative income.

TABLE 3. Descriptive statistics and correlations of all variables used in the analysis

Variable	Mean	Std. Dev.	Min	Max	Simple Correlations
Pay Gap	69.766	4.680	62.459	78.4	Abortions = -0.284 (0.115); KAZ = -0.064 (0.727); Year = 0.644* (0.0001)
Abortions	115.329	91.957	15.9	296.11	Pay Gap = -0.284 (0.115); KAZ = -0.865*** (0.000); Year = -0.781*** (0.000)
KAZ	0.406	0.499	0	1	Pay Gap = -0.064 (0.727); Abortions = -0.865*** (0.000); Year = 0.452* (0.009)
Year	2013	5.521	2002	2022	Pay Gap = 0.644* (0.0001); Abortions = -0.781*** (0.000); KAZ = 0.452* (0.009)

(i) There are 32 observations for every variable.
(ii) Correlations are reported with p-values in parentheses.
(iii) An asterisk "*" indicates statistical significance at the 5% level.
(iv) Compiled by the authors using Stata.

Note: compiled by the authors based on the Bureau of National Statistics (2024), World Development Indicator (2025)

This income also exhibits a positive and significant time trend, but it does not correlate significantly with institutions in either Kazakhstan or Kyrgyzstan.

Table 3 presents significant relationships between institutional and temporal variables and the gender pay gap. The *Year* variable shows a positive and significant relationship with *Pay Gap* (r = 0.64), indicating that gender income inequality has decreased over time. However, the Kazakhstan dummy variable *KAZ* has a strongly negative and significant connection with abortion rates (0.72), suggesting that national institutions influence reproductive choices. Compared to Kazakhstan, institutions in Kyrgyzstan are more positively correlated with abortions. This is probably because Kyrgyzstani women are poorer than Kazakhstani women, so they have fewer safe alternatives to abortion. Also, abortion does not increase income equality between genders. The correlation between *Abortions* and *the Pay Gap is negative (-0.284*) and statistically insignificant at the 10% level of significance.

The correlation between *Year* and *Abortions* is negative and highly statistically significant. Abortions in the two-country region are falling over time, perhaps because of improvements in medical technology that provide safe birth control. Finally, the positive correlation between *Year* and *KAZ* means that the unbalanced panel has more observations for Kazakhstan than for Kyrgyzstan.

Comparing the fixed-effects and random-effects models.

In Table 4, the Hausman test finds that the fixed-effects model better suits the analysis of the impact of abortion on relative female income than does the random-effects model. The results showed that Kazakhstan and Kyrgyzstan have distinct institutional structures. The fact that abortion rates are higher in Kyrgyzstan than in Kazakhstan raises the possibility that the two countries have different healthcare institutions. A more general question is: Are two neighboring countries in Central Asia truly different? If they are, then the fixed effects model is better.

TABLE 4. Panel regression of pay gap on abortions using fixed effects and random effects

Variable	(1) Random Effects	(2) Fixed Effects	(3) Hausman Test
Abortions	-0.01447 (0.0089)	-0.068*** (0.014)	Difference = -0.0541 (0.0105)
Constant	71.435*** (1.306)	77.676*** (1.710)	
R^2 (overall)	0.081	0.081	
Observations	32	32	
Groups (KAZ)	2	2	
Hausman χ^2			26.38 (p=0.000)

(i) Dependent variable: Pay Gap.
(ii) Model (1) reports random effects GLS estimates, Model (2) fixed effects estimates, and Model (3) Hausman specification test.
(iii) Coefficients reported with standard errors. (iv) * p<0.10, ** p<0.05, *** p<0.01. (v)
(iv) Compiled by the authors using Stata.

Note: compiled by the authors based on the Bureau of National Statistics (2024); National Statistical Committee of the Kyrgyz Republic (2025)

The FE model would permit permanent characteristics of Kazakhstan to differ from those of Kyrgyzstan by using a different intercept in the model for each country. The intercept reflects the impact of the institutions on relative female income. However, suppose Kazakhstan and Kyrgyzstan do not differ. In that case, the random effects model treats variations in characteristics of both countries as accidental and fleeting, as "noise." Both countries have the same expected intercept, but their actual values differ by a random error. For example, Kazakhstan and Kyrgyzstan could have the same basic health institutions. However, Kazakhstan could have a greater impact on relative female income because of an arbitrary belief that abortions are safer there.

The Hausman test determines whether the random-effects or fixed-effects model is the better one. In the random-effects approach, both countries follow the same model; differences in the characteristics of the two countries are unsystematic and peripheral. In that case, the random and fixed models should produce similar coefficients, because they stem from the same basic model. When the coefficients are sufficiently close, the random-effects model is the appropriate specification. However, if the coefficients of the two countries differ, then they do not follow the same basic model; their permanent institutions are significantly different. For example, the philosophy guiding Kazakhstan's educational system may be more practical than that of Kyrgyzstan. In that case, the fixed-effects model provides a better specification. The null hypothesis of the Hausman test is that the coefficients of the two countries are equal, indicating that the random effects model is suitable.

The abortion coefficients from both the fixed and random effects models (Table 4) are negative but significant only for the fixed-effects model. This is consistent with the recurring conclusion of this paper that abortions do not increase relative female income. Nevertheless, the important point at the moment concerns the bottom right-hand cell in Table 4. The p-value of the Hausman test is effectively zero. Therefore, the authors reject the null hypothesis that the random-effects model is a better fit than the fixed-effects model. Notably, Kazakhstan and Kyrgyzstan differ in their structures. The pay gap is influenced more by country-specific factors than by regional factors.

In principle, the Hausman test may not be consistent because of the endogeneity of Abortions. Because abortions correlate with the error term, their coefficient may measure the impact of the error term as well as the impact of abortions per se. Any difference in the abortion coefficients between the fixed- and random-effects models may mislead the reader,

even when the sample size increases indefinitely. This paper analyzes endogeneity below. However, suppose the fixed-effects model is indeed superior to the random-effects model. In that case, political factors are vital to national institutions, as Kazakhstan and Kyrgyzstan share the same geography and history.

Analyzing endogeneity. The Hausman test in Table 5 suggests that *Abortions* may be endogenous to a fixed-effects model of the impact of abortion on relative female income, so it requires an instrument. However, the dataset does not satisfy the asymptotic restrictions of the Hausman test.

TABLE 5. OLS and IV estimations of the regression of pay gap on abortions

Model / Variable	(1) OLS	(2) 2SLS (IV)	(3) Wu-Hausman Test
Abortions	-0.0081 (0.0254)	-0.088*** (0.016)	
KAZ			
Year	65.285*** (0.238)		
Constant	-1240.355***(482.53)	79.89*** (1.99)	
R^2	0.362	0.081	
Observations	32	32	32
Hausman/Wu Test			$\chi^2(2)$=-16.77

(i) Dependent variable: Gender Pay Gap.
(ii) Model (1) reports OLS estimates with heteroskedasticity test and VIF diagnostics. Model (2) shows 2SLS random-effects IV regression, using KAZ and Year as instruments for abortions. Model (3) reports the Wu-Hausman test for endogeneity of abortions.
(iii) Coefficients reported with standard errors. (iv) * p<0.10, ** p<0.05, *** p<0.01.
(iv) Compiled by the authors using Stata.

Note: compiled by the authors based on the Bureau of National Statistics (2024); National Statistical Committee of the Kyrgyz Republic (2025)

The OLS specification represents the baseline model, which assumes that all independent variables are exogenous and their values do not depend on the model itself. In contrast to OLS is the model in the third column (titled 2SLS (IV)). Here, the abortion rate depends on factors that are part of the error term. Thus, the coefficient on the endogenous variable may reflect not only the variable's impact on the dependent variable but also the impact of the error term. This biases the coefficients.

The justification for the instruments is as follows: The year captures an exogenous temporal decline in abortion rates associated with modernisation. At the same time, the Kazakhstan dummy reflects institutional differences between the two countries. Both instruments correlate with abortion rates but plausibly do not correlate with the error term.

The instrumental approach is implemented by estimating a two-stage least squares model. In the first stage, Abortions are instrumented by *Year*. *Year* affects Abortions negatively, reducing the abortion rate by more than one-third of an abortion per 1,000 live births per year. The Kazakhstan dummy variable *KAZ* increases the *abortion* rate more than sixfold. Both effects are highly significant statistically. The second stage regresses *Pay Gap* on the instrumental variable version of *Abortions*. The results indicate that the impact of the instrumented *Abortions* is large, negative, and highly significant. At an estimated mean abortion rate of 15.5, Abortions reduce the relative female income by more than 40%. The *KAZ* coefficient is large, positive, and highly significant. Kazakhstani institutions raise relative female income by almost a seventh of the mean.

Is the two-stage least squares approach the right choice? If the independent variable was not endogenous to begin with, then two-stage least squares is needlessly complex. To determine whether Abortions are endogenous, the authors use the Wu-Hausman test. It

compares OLS to a model that is accurate regardless of whether Abortions are endogenous. OLS assumes that Abortions are not endogenous. If the OLS model produces coefficients that are like those in the model that is always accurate (IV), then it is not essential to treat *Abortions* as endogenous. The simpler OLS model gives similar results.

The Wu-Hausman test is applied to two random-effects equations, one estimated by IV and the other by OLS. The random-effects model is chosen because it performs better than the fixed-effects model. Usually, for a chi-squared test value of the magnitude obtained, the Hausman test would support that Abortions are endogenous. Moreover, the authors argue that since the fixed-effects model is superior to the random-effects model, institutions in the two countries differ, which would be consistent with the endogeneity of Abortions. How abortions affect female income depends on the constitution, the legal system, and other national institutions that differ between the two countries.

In sum, the Wu-Hausman results reject the Empowerment Hypothesis and align with the Constraint Hypothesis. The findings also suggest that reproductive health decisions are at least partly determined by factors that are difficult to measure and therefore appear in the error term. An abortion policy can have unexpected consequences. Finally, regional institutions and characteristics affect female income. However, abortions have little effect on it; the R-squared value is only 0.08 (Ozili, 2023).

5. CONCLUSIONS

This paper examines whether abortion in Kazakhstan and Kyrgyzstan functions as an instrument of women's economic empowerment or is associated with constraints on relative female income; our evidence is more consistent with the latter. A plausible channel is lower subsequent human-capital accumulation among women with past abortions. For example, women with higher education may be less likely to have abortions due to greater access to effective contraception and safer alternatives; likewise, abortions may be more prevalent among women with stronger preferences for child-rearing over tertiary education or market work, who use abortion primarily to avoid higher parity. While our estimates are robust across specifications, they should be interpreted as associations rather than definitive causal effects.

Policymaking would benefit from closing data gaps: each country should field a nationally representative household survey on reproductive behavior and labor outcomes every two years (renewing instruments analogous to Kyrgyzstan's LiK, discontinued after 2019) and publish annual, gender- and age-disaggregated demographic series by ethnicity and by method of birth control to enable credible monitoring and policy evaluation.

Three more areas are essential:

(1) Expansion of modern contraception, along with sexual education, to decrease unintended pregnancies.

(2) Vocational training, access to colleges, and childcare support to smooth the transition from school to work for young women.

(3) Village health kiosks and national online diagnosis services that can be accessed by phone, to provide accurate information and steer patients to clinics for treatment if needed.

Reproductive freedom is an essential right, but it does not automatically lead to economic equality across genders. Reaching equality requires more statistics and case studies.

Future research needs to focus on three essential directions for expansion. The analysis requires panel datasets that include detailed information about individual and household characteristics to study differences between various age groups, educational backgrounds, ethnicities, and urban and rural areas. The inclusion of sectoral outcomes between formal and informal labor markets and occupational segregation in econometric models would enable researchers to determine how abortion impacts women based on their economic options. Research that compares Kazakhstan and Kyrgyzstan to other transition economies

in Eastern Europe, South Asia, and the Caucasus region will establish whether the findings of this paper represent a unique case or a global pattern. The combination of quantitative analysis with qualitative interview data in mixed-methods studies would enable researchers to understand how social stigma, family expectations, and institutional barriers influence the economic effects of abortion.

Future policy development should support the UN Sustainable Development Goals by aligning reproductive health initiatives with education programs, labor market improvements, and institutional development.

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Gender Influence on Public Administration Quality and Civil Legislation Modernization in Kazakhstan

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ABSTRACT

The purpose of this study was to examine the impact of institutional factors on women's participation in civil law and public administration, and to identify areas for modernizing civil legislation to reduce gender inequality. The analysis covers the period from 2012 to 2023 and is based on official statistical data from the Bureau of National Statistics of Kazakhstan and institutional indicators from the Worldwide Governance Indicators. Correlation analysis, dual comparative assessment, and structural equation modeling (PLS-SEM) were employed to examine the relationships between gender-disaggregated labor market outcomes and institutional quality. The results confirm that democratic indicators are predominantly shaped by male employment and income ($\beta = 0.910$, $p < 0.01$), while the impact of women on democracy remains marginal ($\beta = –0.044$). In contrast, governance indicators demonstrate a strong association with women's participation in the labor market and managerial positions ($\beta = 1.096$, $p < 0.01$), underscoring their role in enhancing transparency and accountability. The persistence of the gender wage gap and unstable female employment reflects structural barriers that are insufficiently addressed by institutional reforms. The findings suggest that modernizing civil legislation requires introducing gender audits, expanding women's access to decision-making, and institutionalizing gender diversity in state structures. This research contributes to the literature on governance and legal modernization by providing empirical evidence of institutional determinants of gender inequality and offering policy recommendations for strengthening equality in public administration.

KEYWORDS: Civil Law, Public Governance, Gender Equality, Rule Of Law, Corruption, Employment, Wage Gap

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1. INTRODUCTION

The protection of civil rights is defined by both legislative guarantees and the real conditions of their implementation. The quality of law and order and civil justice institutions determine the effectiveness of rights protection and the level of social participation, including gender equality. In modern times, the issue of implementing civil rights is particularly acute in the context of gender. Despite formal equality, women are still hindered by institutional and cultural barriers that limit their participation in civil law and governance processes (Mollica et al., 2022).

Globally, the leading positions in levels of judicial independence, corruption, and guaranteed access to fair justice, as measured by the Rule of Law Index, are occupied by Denmark (0.90), Norway (0.89), Finland (0.88), Sweden (0.87), and Germany (0.86) in 2024 (WGI, 2024). Moreover, women are widely represented in government bodies, influence the drafting of legislation, and participate in the development of civil society institutions in Scandinavian countries and Western Europe.

In contrast, Kazakhstan ranked 65th out of 142 countries in the 2024 Rule of Law Index, with a score of 0.24. The level of representation of women in politics, although it meets the 25% quota, does not ensure the proper implementation of the set goals for gender equality.

Women's economic empowerment has a direct impact on global economic growth, as it reduces poverty, increases household incomes, and promotes social protection. Despite this economic potential, normative and cultural constraints limit the opportunities for women: in holding managing positions, lower labor force participation rates, a gender pay gap, and a high burden of unpaid household labor (Bertrand, 2021).

The adoption of international norms and legal equality does not provide actual equality, as discrimination and cultural barriers persisted. Modernization in politics must include expanding the "life chances" of all citizens, and a key part of this is the social inclusion of women.

This study aims to examine the impact of institutional factors on women's participation in civil law and public administration, and to identify areas for modernizing civil legislation to reduce gender inequality.

2. LITERATURE REVIEW

The role and contribution of women in public administration are of particular interest. In particular, the impact of women in government on corruption and liberal democracy. Sung (2012) showed that women's participation in government structures promotes institutional transparency and accountability. Jin (2016) noted that even when controlling for institutional factors (legal structure, press, and economic freedom), women's participation has a significant effect. Women have influence. DiRienzo (2018) noted two types of influence, direct and indirect. Women in government are more likely than men to focus on public and social needs, including healthcare, education, social security, and care for children and the elderly (Carmel, 2019). This reduces social tensions, as the basic needs of society are met (Slyusarevskyy et al., 2021).

At the same time, the likelihood of conflict and social tension decreases, and trust in institutions increases. Therefore, the direct impact is that women politicians bring issues to the agenda that promote long-term stability and social cohesion, which ultimately strengthens peace. Women are less tolerant of corruption and more inclined toward transparency and accountability. When the proportion of women in parliament or government is higher, the level of corruption in a country tends to decrease. Since corruption is recognized as a root cause of instability, it undermines trust, exacerbates inequality, and hinders development. Women influence change by changing the quality of institutions and the level of corruption. Women break traditional chains of corruption. Women's participation in decision-making and consensus-based governance is a necessary

element of sustainable development and governance reform (Dar & Shairgojri, 2022). Women's inclusion is also an additional resource for institutions (Chanda, 2024). Their participation increases attention to social spending, which creates long-term conditions for growth. Furthermore, women's active participation through NGOs serves as a mediator in the dialogue between authorities and society. Therefore, NGOs achieve greater inclusiveness and participation of women in decision-making (Rusfiana & Kurniasih, 2024). Particularly through anti-corruption and human rights advocacy, they contribute to strengthening the rule of law.

Research shows that democratic indices, including liberal and electoral democracy, the rule of law, and constraints on executive power, have historically been shaped predominantly by men's participation in politics and public administration. Men traditionally occupy key positions in parliaments, governments, and executive bodies, and their employment and income have the most significant impact on democratic indicators (Mastracci, 2017; Esarey & Schwindt-Bayer, 2018). Particularly, such practice is characteristic of countries where women are limited by institutional barriers (Mlambo & Kapingura, 2019). Moreover, democratic indices largely reflect men's priorities and attitudes, as men are more associated with the institutional dimensions of democracy. At the same time, women are more likely to focus on inclusiveness and the social dimension (Hansen & Goenaga, 2021). Democracy is significantly correlated with male political participation (Nchofoung et al., 2023; Mechkova et al., 2024).

There is a growing number of studies that state that women are in a disadvantaged position due to cultural norms. First of all, cultural habits often lead to patriarchal practices and the strengthening of positions of religious standards over legal acts. In terms of economic development, the patriarchal system restricts women's access to politics, education, economic resources, and, more importantly, the judicial system for the protection of their rights (Bako & Syed, 2018; Lwamba et al., 2022). Therefore, women's representation in politics is either limited or bears only a formal nature and provides no support for lobbying the interests of minorities, including women. Cultural and religious perceptions of existing international norms and standards for gender equality are stronger, which has led to the implementation of gender quotas of 30% in parliament (Firdaus & Wulandari, 2023; Suryani & Wardana, 2024). Thus, despite receiving global support, women are still excluded from the legal system and often miss opportunities for education (Begum, 2023). The following hypotheses are posed in this work:

H1. Democratic indicators (D) are formed predominantly through men (M), reflecting the dominance of men in public administration and political participation.

H2. Women (W) have a limited impact on democratic indices, confirming women's marginalized participation in the formation of civil rights.

H3. Governance (G) is more strongly associated with the women's bloc (W), indicating that women's inclusion in the labor market and in managerial positions increases the transparency and accountability of government structures.

H4. Men (M) have a moderate impact on Governance (G), but their role in ensuring transparency and oversight is weaker than that of women.

3. METHODOLOGY

The proposed methodology relies on quantitative analysis based on official statistical data and institutional indicators. The Jamovi and SmartPLS software packages were used to process and interpret the results, allowing for a combination of classical descriptive statistics and regression analysis methods with elements of structural modeling. Based on a literature review, indicators reflecting gender inequality in the labor market and institutional characteristics of public administration quality were identified.

The first group includes indicators of wages, employment, unemployment, and the

representation of women and men in management positions.

The second group comprises indices of democracy, rule of law, civil liberties, anti-corruption practices, and public administration effectiveness.

Table 1 presents all variables used in the empirical analysis.

TABLE 1. Indicators for the analysis of gender inequality and institutional quality

Indicator	Code	Measurement
Average monthly wage of women	W1	KZT
Share of women among managers and public servants	W2	%
Employment rate of women	W3	%
Unemployment rate of women	W4	%
Average monthly wage of men	M1	KZT
Share of men among managers and public servants	M2	%
Employment rate of men	M3	%
Unemployment rate of men	M4	%
Liberal democracy index	D1	%
Electoral democracy index	D2	%
Legislative constraints on the executive	D3	%
Judicial constraints on the executive	D4	%
Rule of Law index	D5	%
Private civil liberties index	D6	%
Corruption Perceptions Index (CPI)	G1	%
Voice and Accountability	G2	%
Political Stability and Absence of Violence	G3	%
Government Effectiveness	G4	%
Regulatory Quality	G5	%
Control of Corruption	G6	%

Note: compiled by authors based on the Bureau of National Statistics (2024), Worldwide Governance Indicators (2024)

Based on the identified variables, four hypotheses were formulated to reflect the relationship between the quality of public administration and indicators of gender inequality. To test the hypotheses, the analysis was conducted in stages.

Data standardization. All indicators were z-scored to ensure comparability of disparate variables and eliminate the influence of measurement scales.

Correlation analysis. A matrix correlation was conducted between the gender inequality indicators (W1–W4, M1–M4) and institutional indicators (D1–D6, G1–G6). Primary relationships were identified.

Dual comparative analysis. For greater clarity, two correlation matrices were constructed: (1) a matrix of relationships between women's indicators (W1–W4) and institutional indices (D1–D6, G1–G6); (2) a matrix of relationships between men's indicators (M1–M4) and the same institutional indices.

Based on the dual approach, gender-specific differences were identified, enabling a clearer understanding of the institutional determinants of gender inequality.

Model construction. The next step involved regression and structural modeling analysis (SmartPLS), which tested four hypotheses. The model was constructed according to the formula (1):

$$GAP_{i,t} = \alpha + \beta_1 D_{j,t} + \beta_2 G_{k,t} + \varepsilon_t \quad (1)$$

where:

$GAP_{i,t}$ – the gender inequality index at time t (e.g., the wage gap: W1−M1W1 - M1W1−M1, or the employment gap: W3−M3W3 - M3W3−M3);

$D_{j,t}$ – the institutional indices of democracy and rule of law (D1–D6);

$G_{k,t}$ – the indicators of public administration quality and anti-corruption (G1–G6);

β_1, β_2 – the influence coefficients;

ε_t – the stochastic error.

The next stage of the study involves analyzing the current situation based on the selected indicators in four categories. The analysis will enable the explanation of the results obtained from the PLS-SEM model. Based on the findings, recommendations will be developed to modernize regulatory mechanisms and expand opportunities for women's inclusion in public and legal processes.

4. RESULTS AND DISCUSSION

The main objective of this section is to present and interpret the results obtained. First, the key correlations between women's participation in civil law and institutional indicators will be identified. Next, the results of the regression model and the testing of the hypotheses are presented. Special attention is paid to the analysis of the dynamics of the indicators by gender. Next, based on the results obtained, recommendations are formulated to reduce institutionalized barriers and expand opportunities for women's participation in civil law and public administration. Correlation matrix is presented in Figure 1.

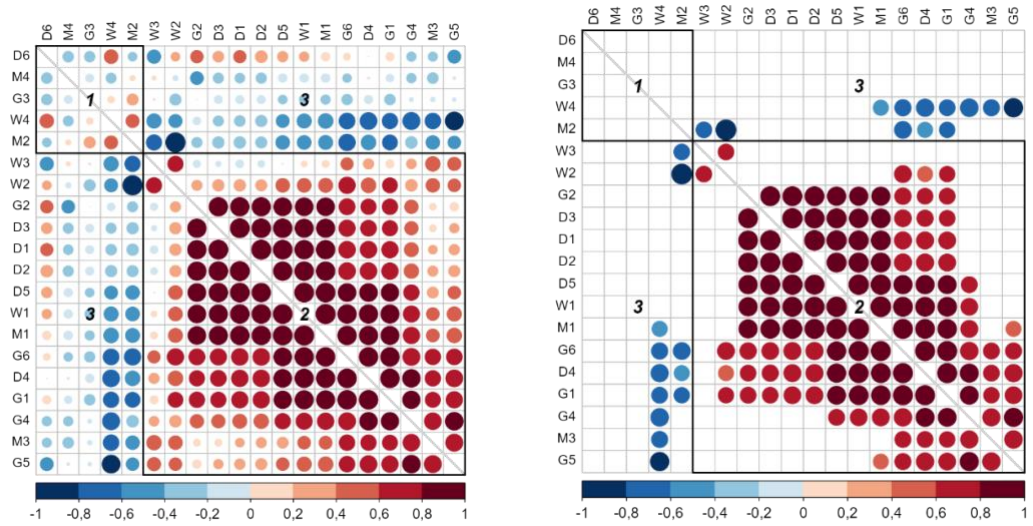


FIGURE 1. Significant correlation patterns

An analysis of the correlation matrix revealed that the institutional indices (D and G) demonstrate a high interrelationship with each other, indicating multicollinearity. In the context of PLS modeling, such a structure poses a risk of model overload; therefore, it is advisable to consider them in an aggregated form through two enlarged latent blocks, Democracy and Governance. The response of the male block of indicators (M) to institutional factors is generally positive: an increase in the indices of democracy and the quality of public administration is accompanied by an increase in men's employment and a rise in their wages. Despite a general rise in institutional indices, the level of female unemployment remains unchanged, and the gender wage gap persists, reflecting the limited effects of modernization.

In the correlation structure, the most obvious and statistically significant relationships are found in several areas. First, the institutional indices grouped into the Governance block (government effectiveness, regulatory quality, control of corruption) have a pronounced positive relationship with male

indicators—an increase in these indicators is accompanied by an increase in male employment and wages. Liberal and electoral democracy are positively correlated with male income and employment levels. Thus, institutional improvements primarily impact men's position in the labor market.

The second relationship illustrates the connection between women's indicators and men's: increases in men's wages and employment are associated with similar changes in women's indicators. However, the effect is weaker and does not eliminate the gender gap. The share of women among managers and civil servants increases more slowly than that of men, despite institutional improvements, and the female unemployment rate remains higher, even with positive trends in institutional indices.

Direct institutional relationships influencing female indicators include the rule of law and civil liberties, which demonstrate a weak and limited relationship with female unemployment. Overall, three significant areas can be identified: the positive impact of institutional indices on male employment and income; the indirect effect of male indicators on female indicators; and the limited and contradictory impact of individual democratic indicators on female employment and unemployment rates.

After analyzing the correlation structure, which allowed us to identify the directions of significant relationships between institutional and gender indicators, the results of testing the proposed hypotheses within the framework of the structural relationships model are presented below (Figure 2).

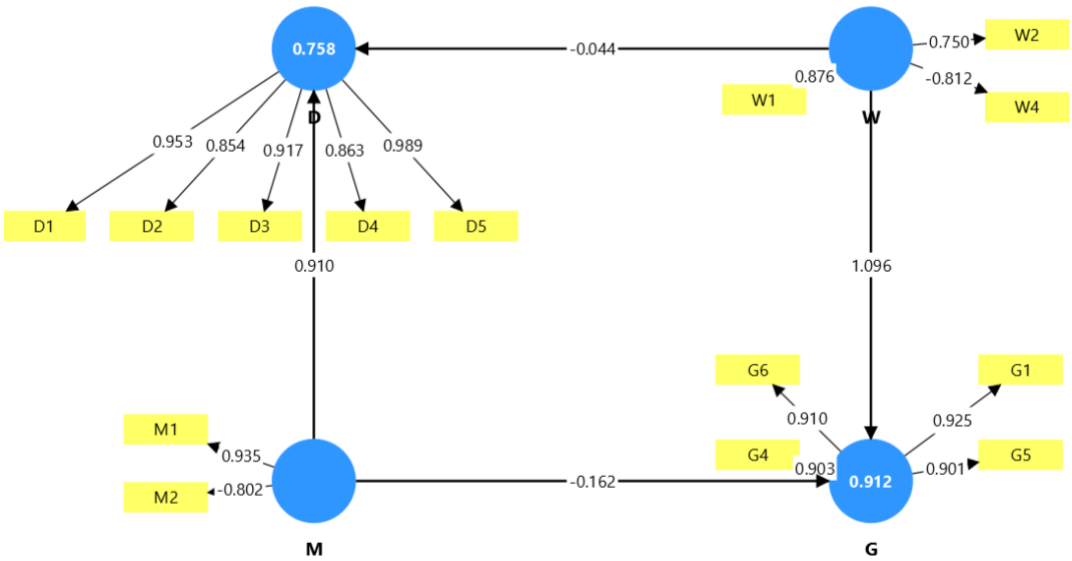


FIGURE 2. Structural model of institutional indicators and gendered labor market outcomes in Kazakhstan

During the model specification, all indicators with factor loadings below 0.7 were excluded as statistically weak and unstable. M3 (male employment rate) and M4 (male unemployment rate) were removed from the male block, W3 (female employment rate) from the female block, and D6 (civil liberties) from the democracy block. Only the variables that demonstrated factor loadings above the threshold were retained in the final model: M1 (0.935), M2 (–0.802), W1 (0.876), W2 (0.750), W4 (–0.812), D1–D5 (0.854–0.989), G1 (0.925), G4 (0.903), G5 (0.901), G6 (0.910).

Hypothesis 1. Democratic indicators are formed predominantly through the male bloc. Confirmed.

The correlation between democracy and male indicators was high (0.910), with the

factor loadings of indicators M1 (0.935) and M2 (-0.802) demonstrating statistically significant effects. The dynamics of democratic indices largely reflect men's employment and wage levels. Democratic processes rely on male participation in the economy. Women's indicators, however, do not form significant relationships.

Hypothesis 2. The women's bloc has a limited impact on democratic indices. Confirmed.

The direct relationship between women's indicators and democratic indices is statistically insignificant (–0.044). Women's participation in public administration and civil law remains marginalized. Legislative and institutional decisions are predominantly concentrated among men.

Hypothesis 3. Governance is more strongly associated with women's participation. Confirmed.

The relationship between women's participation and Governance was high (1.096), and the factor loadings of the W1, W2, and W4 indicators remained stable. This suggests that women's increased inclusion in the labor market and managerial positions is associated with greater transparency and accountability in government structures.

Hypothesis 4. The male bloc has a moderate impact on governance. Not confirmed.

The coefficient for the male bloc's impact on governance is -0.162, reflecting a weak and negative relationship. The impact of men on governance effectiveness, regulatory quality, and corruption control indicators is minimal.

Figure 3 further illustrates the dynamics of women's indicators, highlighting differences in wages, employment, and participation in managerial positions.

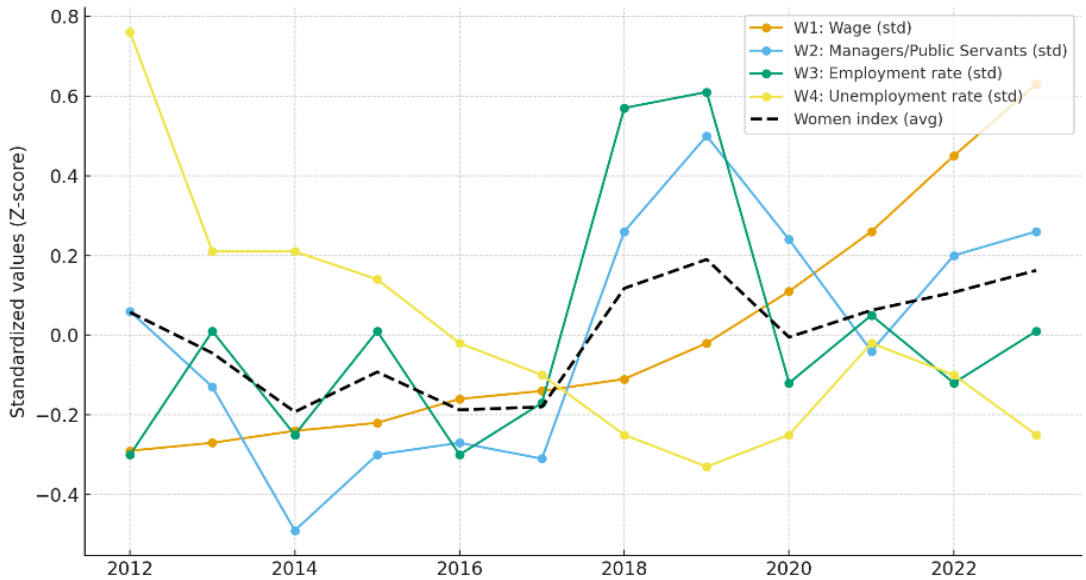


FIGURE 3. Dynamics of women's indicators (standardized, 2012-2023)

The overall trend in women's indicators from 2012 to 2023 showed a positive trend with some exceptions. Women's average wages (W1) showed a steady growth. The share of women among managers and civil servants (W2) increased steadily after a period of decline, reaching a peak in 2016. By 2019–2023, the values for women's indicators recovered. The expansion of women's opportunities in managerial positions was accompanied by rising incomes and the consolidation of their economic contributions.

At the same time, female employment (W3) and unemployment (W4) remained unstable

until 2017. Then, values for the unemployment rate began to decline, while employment values increased. Women had limited access to stable sectors of the economy in the first half of the observed period. Thus, income growth was driven more by specific industries and improvements in skills. Moreover, rising wages and managerial participation have not led to a significant improvement in overall employment.

Figure 4 illustrates the dynamics of men's indicators, which characterize income, employment, and the distribution of managerial positions.

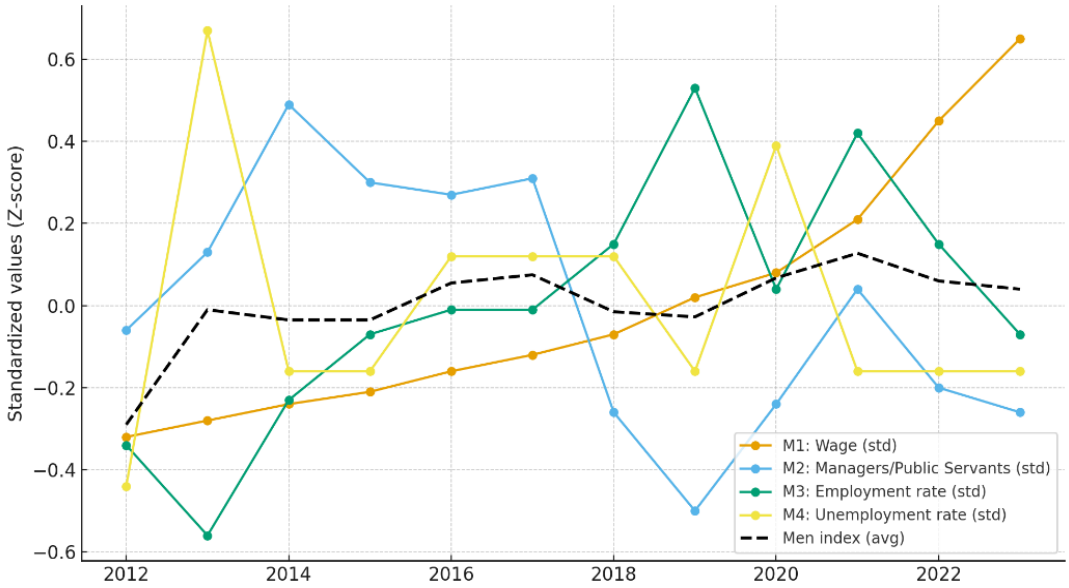


FIGURE 4. Dynamics of men's indicators (standardized, 2012–2023)

For men, the overall trend demonstrated more consistent growth and fewer discrepancies between indicators. Wages (M1) increased steadily and exceeded the female indicator, confirming the gender income gap. The share of men among managers and civil servants (M2) moved in the opposite direction to the female indicator: where female participation increased, the male indicator declined, reflecting a partial rotation of management positions in favor of women.

Employment (M3) and unemployment (M4) indicators were more stable for men than for women: even during periods of decline, they returned to positive values more quickly. Male participation in the economy was more stable. Unlike in the female segment, there is virtually no discrepancy between income and employment levels. Both indicators grew in parallel, which can be explained by the predominance of men in stable sectors of the economy and in structures provided with state funding. Thus, the male block creates a more balanced picture, where income and employment growth are in the same direction.

Figure 5 illustrates the dynamics of various democratic indices, including liberal democracy, electoral democracy, limits on executive power, judicial independence, the rule of law, and civil liberties.

Democratic indices remained low and even recorded negative values until 2017. Then, the dynamics recovered for all indicators. Thus, institutional reforms have strengthened formal democratic mechanisms. Judicial constraints (D4) and the rule of law (D5) have also shown growth, albeit at a more gradual rate.

At the same time, the civil liberties index (D6) does not follow the general trend: its values fluctuated and remained low, suggesting persistent restrictions on the exercise of rights and freedoms at the individual level.

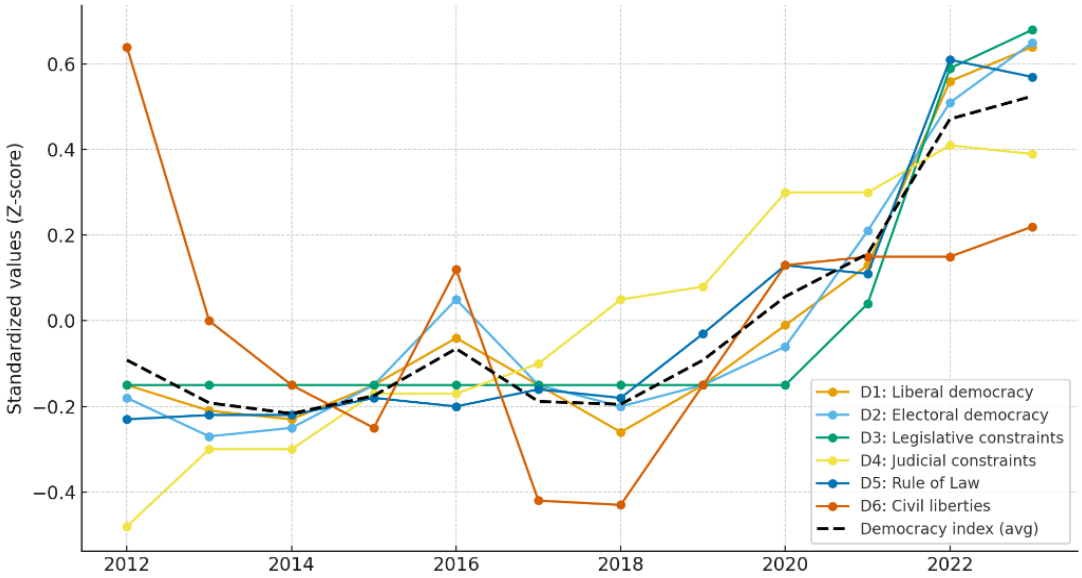


FIGURE 5. Dynamics of democracy indicators (standardized, 2012–2023)

Democratic reforms have had a greater impact on institutional frameworks. Modernization was formal in nature and primarily aimed at strengthening the political and legal framework.

Figure 6 presents the dynamics of governance indicators, covering perceptions of corruption, government accountability, political stability, government effectiveness, regulatory quality, and control of corruption.

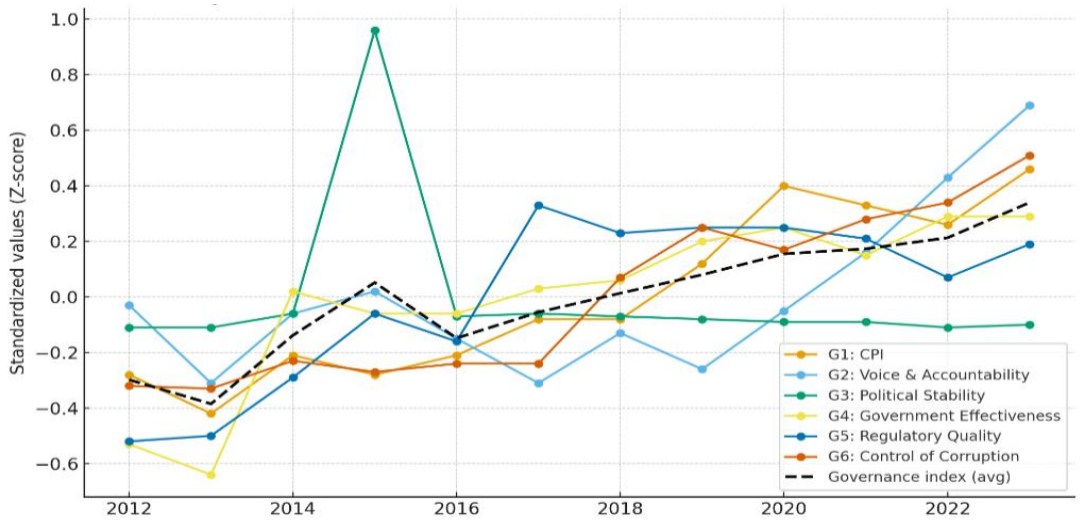


FIGURE 6. Dynamics of governance indicators (standardized, 2012–2023)

Governance indicators have also shown a positive trend, particularly since 2017, but their dynamics are less uniform than those of democracy. The most pronounced increases were recorded for the Control of Corruption (G6), Government Accountability (G2), and Corruption Perceptions (G1) indices. The overlap between these indicators suggests a link to anti-corruption initiatives and international transparency programs.

However, political stability (G3) did not follow the general trajectory: a sharp spike was

observed in 2015, after which the values returned to harmful levels. This suggests instability in the domestic situation, despite overall improvements in governance indicators. The Government Effectiveness (G4) and Regulatory Quality (G5) indices gradually strengthened and became positive at the end of the period, which can be attributed to institutional reforms of the state apparatus. Increased transparency and effectiveness are not always accompanied by sustainable political stability.

To conclude, women's indicators develop more inconsistently and do not demonstrate coherence with the growth of democratic indices. Second, the men's indicators correlate with democratic dynamics, while the women's block correlates more strongly with governance.

TABLE 2. Recommendations for addressing gender differences in institutional policy

Area	Key observation (based on analysis)	Recommendation
Democracy (D)	The dynamics of democratic indices are primarily shaped by male indicators (link 0.910). Female indicators show marginal influence.	Strengthen women's participation in decision-making through legally mandated quotas, gender audits of electoral procedures, and expanded access to judicial protection.
Governance (G)	The link between the female block and governance is stronger (1.096) than that of the male block (–0.162). Women's inclusion correlates with greater transparency and accountability.	Develop programs to promote women into leadership positions in state structures, implement transparency monitoring in personnel policy, and stimulate female leadership in public administration.
Employment and Income (W, M)	Male employment and income remain more stable, while female indicators are fragmented; the gender wage gap persists.	Introduce mandatory gender analysis in labor policy design, enforce equal pay for equal work, and subsidize retraining programs targeted at women.
Civil Law	Institutional reforms in democracy and law show weak connections with female indicators, reflecting women's exclusion from lawmaking processes.	Institutionalize the participation of women's NGOs in advisory councils under ministries, and ensure gender mainstreaming in legal expertise and law-drafting processes.

Note: compiled by the author

Today, the central challenge is that women's participation in governance remains largely formal and unstable rather than substantive and sustained. To address this, governments should: implement long-term programs beginning with girls' education and extending to talent-pipeline; promote women's leadership through targeted initiatives to appoint women to managerial and oversight roles; institutionalize gender diversity across decision-making and supervisory structures so that women's participation is not nominal but embedded, with measurable impact on governance quality.

5. CONCLUSIONS

The purpose of this study was to examine the impact of institutional factors on women's participation in civil law and public administration, and to identify areas for modernizing civil legislation to reduce gender inequality.

Three hypotheses were confirmed (H1, H2, and H3). A stable relationship was revealed between democracy indices and women's employment and wage indicators. Improved law enforcement practices and judicial restrictions were found to be correlated with increased representation of women in managerial positions. It was confirmed that expanding civil liberties has a positive impact on women's institutionalized participation in government.

Hypothesis 4 was not confirmed. The results showed that indices of governance effectiveness and corruption control are

directly related to reduced differences between men and women in civil law.

Recommendations based on the findings include: strengthening the institutional framework of civil legislation, taking into account principles of equality; strengthening rule of law mechanisms to reduce hidden barriers to women's participation; developing systems for monitoring the quality of public administration, taking into account gender indicators; implementing anti-corruption practices as an element of ensuring equal rights and opportunities; developing transparent procedures for appointment and promotion within management structures.

Future research should expand the set of indicators to include indices of gender equality, political participation, and educational factors.

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