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ORIGINAL ARTICLE

EURASIAN JOURNAL OF ECONOMIC & BUSINESS STUDIES UIB

Integrated Economic Dynamics, Business Activity and Income Stability in Urban Kazakhstan

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Abstract
The discrepancy between economic growth and the population's income level is becoming one of the key problems in the development of urban economies, as the expansion of production and business does not lead to an improvement in living standards. The purpose of the study is to identify the causes of uneven income growth across Kazakhstan's cities and to determine the economic conditions that ensure their sustainable dynamics. The research methodology is based on a comprehensive analysis of indicator dynamics using an indicator system, calculation of relative changes, inter-city comparative analysis, and typologization based on thresholds. The empirical basis of the study was official statistical data for 17 cities of Kazakhstan for the period 2016–2024, including indicators of wages, employment, gross regional product, retail turnover, and population. The results showed significant differences in economic dynamics between cities. The highest values of the integral IED index were recorded in Astana (TotalMean = 44.98), Uralsk (23.67) and Shymkent (22.98), while negative values prevail in Karaganda (−11.71), Taraz (−9.77) and Kokshetau (−6.59). It has been established that steady income growth is driven mainly by cities with a developed labor market and an active consumer market, whereas output growth alone does not guarantee an increase in population well-being. The results confirm that the key factor in sustainable income growth is not the scale of economic activity, but the degree of its integration with employment and domestic demand.

KEYWORDS
Economy, Economic Growth, Urban Economy, Business, Business Activity, Employment, Labour Market, Income Stability

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1 | INTRODUCTION

Economic growth does not always lead to higher income for the population. Globally, countries have been facing the discrepancy between economic development and improvement in living standards. The economic value created does not always translate into sustainable wages, employment, or consumption growth. The International Labor Organization, the World Bank, and the OECD have repeatedly raised this issue in analytical reports and policy documents (World Bank, 2019; ILO, 2023; OECD, 2025). Economic growth can be accompanied by wage stagnation, increased precarious employment, and greater inequality due to the poor distribution of development benefits within the labor market and the income system. In particular, ILO reports emphasize the weakening link between labour productivity and wages, while World Bank and OECD reports highlight the growing number of "working poor" and precarious employment patterns, even amid economic recovery.

International experience shows that high rates of economic growth do not guarantee a high standard of living. Urban development is expected to increase incomes, expand employment, and improve living standards. In many cities, economic development is short-lived and is not accompanied by sustainable growth in household incomes. From the 1990s to the 2010s, Chinese cities such as Shanghai, Beijing, Shenzhen, and Guangzhou experienced rapid GDP growth, but income growth for most of the population was weak. This was particularly true for workers and migrants in the service sector and in low-level positions in the private sector, as well as in regions with export-oriented manufacturing (Li, 2016). In the US, industrial agglomerations such as Detroit, Chicago, Los Angeles, and New York experienced growth in productivity and economic activity between 1978 and 2014. However, wages did not grow, particularly in cities with a high concentration of large companies (Wilmers, 2018). In Italy, from 1951 to 2011, accelerated urbanization was observed in Milan, Turin, Bologna, and Naples, driven by certain industries and large companies, while the labor market did not provide sustainable wage growth for many employees (Accetturo et al., 2019). In particular, in cities and regions where the economy was based on agriculture and traditional production, the population's income did not grow, and the economy declined.

Amid accelerated urbanization, the gap between the scale of urban economic activity and the population's actual socioeconomic outcomes is widening. Growth in production, services, and business activity does not always lead to the creation of stable jobs, rising wages, and the development of the consumer market. As a result, the urban economy can exhibit positive dynamics without fulfilling its key function of ensuring a sustainable standard of living and income for the population.

Despite a significant number of studies on the relationship among economic growth, employment, and income, there is no unified approach in modern scientific literature for assessing their consistency at the level of urban economies. Most existing studies either analyze these indicators in isolation or combine them into aggregated indexes without identifying thresholds at which their interaction ensures a steady increase in household incomes. As a result, the question of under what conditions economic growth actually improves the well-being of the population, as well as which structural characteristics of the urban economy ensure this transformation, remains insufficiently studied. The purpose of the study is to identify the causes of uneven income growth across Kazakhstan's cities and to determine the economic conditions that ensure their sustainable dynamics.

2 | LITERATURE REVIEW

Research on urban economic development and sustainability focuses on indicators such as population, labour market conditions, income, and economic output. Some studies note the role of demographic growth, employment, and poverty in the sustainable development of cities. Thus, Drakakis-Smith (1996) used indicators of population growth, employment, and job creation, and the poverty rate to demonstrate that accelerated urbanisation is unable to support the population and leads to chronic imbalances. In particular, the rapid growth of urban populations is not matched by the urban economy, leading to high unemployment or hidden employment, the expansion of the informal sector, concentrated poverty, and a decline in the quality of employment. The sustainability of urban development is undermined, and socioeconomic instability increases. Cities with high rates of economic growth can simultaneously be characterised by low social resilience, such as overburdened infrastructure, uneven access to jobs, and deteriorating living conditions. Liu et al. (2014) concluded that rapid economic growth does not guarantee sustainability unless there are improvements in the employment rate, the city's social capacity, and resource efficiency, which effectively signal the presence of hidden internal imbalances in the urban economy (Kajiita & Kang'ethe, 2024).

Some studies prioritize accelerated growth as a solution to urban growth dilemmas. Increasing output, particularly through accelerated construction or investment expansion, does not generate high-quality employment. While output (e.g., the city's GRP) grows, new jobs are either not created in sufficient numbers or are created in low-productivity sectors with unstable, short-term contracts and low incomes (Wu et al., 2016; Accetturo et al., 2019). Liu et al. (2020) analyzed economic output, employment, and wages simultaneously and found that output growth does not generate income for everyone. That new jobs are concentrated in certain sectors; that wage increases accrue to a narrow group of workers, and that inequality between groups increases. At the macro- and meso-levels, the impact of economic growth on sustainability is conditional. Growth alone does not ensure sustainability if income and production processes are incoherent, deepening inequality and reducing long-term development potential (Cheng & Lin, 2022). Consequently, assessing single indicators does not provide an assessment of the sustainability of urban development, as differences between cities can be determined by the degree of coordination among key components.

The importance of purchasing power reflects the final socioeconomic outcome and the combined significance of income, employment, and economic output, that is, the actual standard of living of the population. Consumer activity is considered a tool for assessing the extent to which income and economic output growth are translated into actual consumption. Thus, strong local consumption supports employment and incomes (Markusen & Schrock, 2009). Khan et al. (2019) considered retail turnover as an indicator of the population's purchasing power, finding that growth in industrial output and population does not guarantee expanded consumption. Thus, with weak purchasing power, economic development is accompanied by rising environmental burdens and the deterioration of the urban environment, without a corresponding improvement in living standards. Growth in per capita output can outpace growth in income and consumption, creating a gap between economic potential and the population's actual wealth (Li, 2016; Zhang & Xie, 2019). Even with increased overall economic output, the weak consumer base limits the development of service industries and the domestic market (Lei et al., 2021).

Other studies consider income, employment, and economic output as key indicators of the urban economy, reflecting the underlying mechanisms of the formation and distribution

of economic results. In the study by Fagiolo et al. (2004), the joint dynamics of output, employment, and wages are analysed within an evolutionary framework, which allows us to demonstrate their simultaneous formation and interdependence during the functioning of the labour market and the production system. The authors emphasised that treating these indicators separately does not adequately describe real economic processes, as changes in output are directly related to employment conditions and income levels. According to Xu et al. (2018) the analysis of the transformation of the urban labor market in China reveals a change in the structure of income determinants in the context of market reforms, indicating the need to simultaneously consider employment, earnings, and economic activity when assessing urban development. In this context, the study by Zhang et al. (2017) demonstrates that economic output and employment, as reflected in productivity indicators, are influenced by the spatial and structural organisation of a city, confirming that these categories constitute basic characteristics of the efficiency of the urban economy. To sum up, income, employment, and economic output are fundamental indicators for urban development analysis, as they capture key structural differences between cities.

In labor market research, one of the key objectives has been to identify the point at which economic changes begin and to determine how the labor market responds to them. To address this, analysis is based not only on the absolute values of employment or wage indicators, but primarily on their changes over time. Therefore, empirical studies often use a change indicator called delta (Δ), which reflects the difference between indicator values across periods and allows the direction of ongoing processes to be identified. Autor et al. (2013) examined the response of local labour markets to external economic shocks. Structural economic factors, including external competition and changes in regional industrial specialisation, were revealed to affect employment, wages, and labour force participation. A similar approach was applied by Blanchard and Katz (1999), who highlighted the adaptation of regional economies to economic shocks through successive changes in employment, wages, and labour migration. The delta (Δ) values captured changes in economic variables and indicated when employment and wages began moving in the same direction. In particular, Faggio and Overman (2014) examined employment dynamics at the local economy level by analyzing changes in indicators over time. In their model, changes in overall employment are expressed as proportional changes between two points and then decomposed into contributions from individual labour market components. The results showed that increases in public sector employment influence the structure of the local labour market and can be accompanied by changes in private sector employment, reflecting the interconnectedness of the regional economy's various segments.

Several studies use aggregate indicators to comprehensively assess urban economic development, combining measures of economic activity, employment, and income (Zhang et al., 2017; Rodrigues & Franco, 2019). Yang et al. (2017) proposed an aggregate index of sustainable urban development for Chinese cities based on economic and social indicators. The authors showed that rapid output growth is often accompanied by imbalances in the employment structure, an uneven income distribution, and an increasing resource burden, despite favourable macroeconomic indicators. Thus, when analysing the indicators separately, the overall result may show growth or moderate dynamics: economic output may grow, employment may formally expand, but income distribution becomes increasingly less consistent with overall economic dynamics. Furthermore, Rodrigues and Franco (2020) noted that income, employment, and economic output are key factors for identifying differences between cities. The authors do not use expert weighting or assign subjective weights to individual indicators. Aggregation is achieved by normalising the original variables and

combining them into a composite index, assuming equal contributions from each indicator. Shutters et al. (2021) emphasised that it is the overall structure of the economy, rather than the dynamics of individual indicators, that determines a city's ability to adapt to external shocks.

A literature review demonstrates that the use of aggregate indices and integrated analytical approaches provides a comprehensive analysis of urban development and its impact on living standards. The studies reviewed consistently identify key categories of socioeconomic indicators reflecting the fundamental mechanisms of the urban economy, including average nominal wages, employment, gross regional product, retail turnover, and population. These indicators are interpreted as interrelated elements of the urban economic system. However, most existing studies either analyse these indicators separately or combine them into composite indices without identifying the point at which the interaction between income, employment, and economic output becomes balanced and contributes to sustainable urban development. Thus, the literature does not provide a clear analytical benchmark that reflects the equilibrium relationship between these indicators.

Existing studies analyse income, employment and economic output either separately or through composite indices, but do not identify the equilibrium range at which their interaction reflects stable urban economic development. This study addresses this gap by introducing the Integrated Economic Dynamics (hereinafter – IED) indicator and identifying the range in which the interaction between income and employment reflects stable economic development and supports improvements in living standards.

3 | METHODOLOGY

The calculations were based on the initial absolute values of the indicators for the period from 2015 to 2024. To conduct the analysis, the annual change in each indicator for each city was calculated. The delta calculation has enabled visual comparison of cities since 2016, as it is the difference between two adjacent years. Therefore, the first year for which a change value could be obtained was 2016. Hence, all calculations were conducted using data from 2016 to 2024.

The indicators used in the analysis are presented in Table 1.

Table 1 Indicators and units of measurement

Indicator	Symbol	Unit of Measurement
Average nominal monthly wage	W	tenge
Employed population	E	persons
Gross Regional Product	GRP	tenge
Retail trade turnover	RT	tenge
Population size	N	persons

Note: compiled by the authors

The analysis comprised five stages to identify overall economic potential, development pressure zones, the relationship between resource growth and activity, and the ability of single-industry towns to maintain an economic base (Table 2).

Table 2 Research stages

Stage	Description	Focus of analysis	Key related indicators
Stage 1	Income and Employment Dynamics	Changes in income levels and employment	Income changes relative to employment changes
Stage 2	Wage and Economic Output Gap	Wage dynamics and economic output dynamics	Wage changes relative to Gross Regional Product
Stage 3	Population Coverage by Economic Output	Economic output per capita	Gross Regional Product relative to population size
Stage 4	Consumer Market Density (CMD)	Retail market activity and population change	Retail trade turnover relative to population change
Stage 5	Threshold-based typology	IED relative to WPG, EPC, and CMD	Identification of income-supporting economic conditions

Note: compiled by the authors

The change in each economic indicator is calculated as the relative growth rate using the following formula (1):

$$\Delta X = \frac{X_t - X_{t-1}}{X_{t-1}} \tag{1}$$

where:

X_t – the value of the indicator in the current period;

X_{t-1} – the value of the indicator in the previous period.

The calculation of delta (Δ) was applied to analyse indicators with different measurement units in comparable dynamic terms. The calculation of Δ was applied to the main variables used in the analysis, including average nominal monthly wage (W), employment (E), gross regional product (GRP), retail trade turnover (RT), and population size (N).

First stage. Analysis of the income–employment dynamics is calculated by the formula (2):

$$IED = \frac{\Delta W}{\Delta E} \tag{2}$$

where:

ΔW – average nominal monthly wage;

ΔE – number of employed persons.

The analysis of income and employment dynamics will allow assessment of the urban economic situation based on changes in income and employment, whether the economy is developing sustainably or changing unevenly. The selected data were chosen because income reflects changes in the overall well-being of the population, and employment reflects changes in participation in the economy, whether the economy is strengthening or weakening. Additionally, it will show the extent to which changes in the labor force support economic changes. The main objective of this analysis is to determine whether economic and employment changes are developing simultaneously or if there is a gap between them.

Second stage. Analysis of the wage and productivity gap is calculated by the formula (3):

$$WPG = \frac{\Delta W}{\Delta GRP} \tag{3}$$

where:

ΔW – average nominal monthly wage;

ΔGRP – gross regional product.

A wage-productivity gap analysis will allow assessing the relationship between changes in income and the value created by the economy. Namely, to what extent changes in wages correspond to changes in regional output. The selected indicators show whether the production base is developing and whether changes in income are supported by real economic impact. Therefore, it will be possible to reveal the equilibrium between economic output and the population's income, or the gap between productivity and wages.

Wages are rising, but the regional economy is failing to keep pace with the individual income increase. As a result, labor is devalued because wage increases are driven by external factors unrelated to local economic development. Consequently, the analysis will reveal if a region is creating sufficient value to support the observed level of income growth.

Third stage. Analysis of the economic power concentration is calculated by the formula (4):

$$EPC = \frac{\Delta GRP}{\Delta N} \tag{4}$$

where:

ΔGRP – gross regional product;

ΔN – number of population.

The analysis of regional economic volume allows assessment of the capacity to sustain regional development and meet residents' basic economic needs. The selected indicators explain the relationship between the scale of production activity and the recipients (number of people). The main objective is to assess whether regions have the capacity to ensure population well-being and the territory's overall ability to support sustainable economic development. High values will indicate a stronger economic base and a higher level of well-being. In comparison, low values will indicate a weaker economic base and insufficient economic resources, especially with a significant influx of population.

Fourth stage. Analysis of the CMD is calculated by formula (5):

$$CMD = \frac{\Delta RT}{\Delta N} \tag{5}$$

where:

ΔRT – retail trade;

ΔN – number of population.

The CMD analysis shows how trade activity changes relative to population growth, to analyze the ability to maintain demand and generate retail sales volume as the population grows. If trade turnover grows faster than population, this indicates increased market activity and sufficient purchasing power. If trade turnover growth lags behind population growth, a weakening consumer environment, and insufficient economic activity, it may be a sign that the economy is in trouble. The main objective is to assess the capacity to cope with increasing population needs and to develop a sustainable market base.

Since the study does not construct a composite index, the indicators are analysed separately. Therefore, equal analytical importance is assigned to each indicator, and no weighting coefficients are applied. Each indicator contributes equally to the interpretation of urban economic dynamics.

The fifth stage of the study revealed the conditions under which urban economic development contributes to household income, per capita economic output, and consumer activity. At this stage, the IED indicator serves as a benchmark against which the wage-to-output gap (WPG), per capita economic output (EPC), and CMD are analyzed. A threshold

classification of cities based on average indicator values was used to determine the levels of economic development that create favourable, neutral, or unfavourable conditions for household income, as well as to identify situations in which comparable increases in earnings and consumption do not accompany economic growth. The novelty of this stage lies in the comprehensive comparison of several economic indicators through a single baseline indicator.

4 | RESULTS AND DISCUSSION

The IED results revealed economic changes in cities and enabled the assessment of sustainable economic growth. An analysis of IED distribution for 2016–2024 revealed differences in economic development across city groups. The IED results showed a decline in economic activity in several cities at the beginning of the period. In 2023–2024, IED values stabilised and were predominantly in the moderately positive range. The weakest cities include Karaganda, Pavlodar, Kokshetau, Petropavlovsk, and Taraz, with negative IED values at the beginning and end of the period. Moreover, despite temporary improvements in Pavlodar, Kokshetau, Petropavlovsk, and Taraz, no sustainable economic development was observed.

Table 3 shows which cities are strengthening their economies and which are experiencing short-term fluctuations without sustained effects.

Table 3 General characteristics of economic dynamics according to the IED for 2016–2024

City	2016	2017	2018	2019	2020	2021	2022	2023	2024	Total Mean
Astana	383.37	0.95	3.17	1.12	4.05	3.82	2.92	2.69	2.75	44.98
Kostanay	3.11	−4.74	3.02	10.33	3.19	6.78	7.66	16.08	−18.30	3.01
Karaganda	−2.28	−1.48	−118.07	−1.94	7.41	−7.47	3.99	10.00	4.49	−11.71
Taraz	−4.15	−48.11	−26.53	2.03	−7.22	13.36	1.06	−13.84	−4.51	−9.77
Ust-Kamenogorsk	11.68	−130.81	29.20	10.21	−14.04	133.80	4.68	3.87	62.34	12.33
Uralsk	5.27	2.57	7.25	19.22	138.36	24.16	1.67	8.88	5.67	23.67
Kokshetau	10.46	11.33	−7.18	−39.63	−3.21	−42.51	1.44	−2.54	12.48	−6.59
Atyrau	−13.73	−0.45	3.81	8.33	−0.23	8.46	6.49	2.35	0.22	1.69
Aktobe	−5.68	3.57	4.43	−51.01	18.48	42.16	3.86	7.15	1.96	2.77
Kyzylorda	−5.03	2.77	4.16	4.11	4.19	23.04	2.61	−44.87	3.23	−0.64
Aktau	−1.57	−0.63	1.65	5.13	−1.43	0.54	1.74	14.16	1.90	2.39
Petropavlovsk	−10.02	−5.99	−10.19	7.34	5.64	0.00	−7.19	−2.24	−4.88	−3.06
Pavlodar	−72.82	−19.33	−15.04	−13.22	238.30	−79.34	75.28	43.47	13.62	18.99
Shymkent	8.01	−6.63	14.41	2.93	145.58	20.57	7.44	10.04	4.50	22.98
Turkestan	1.56	−0.07	−0.29	1.66	13.37	4.20	0.77	2.78	3.10	3.01
Almaty	2.97	2.73	2.10	4.29	4.36	7.91	12.86	4.23	4.23	5.07
Konaev	1.67	−3.00	5.33	−6.82	−4.68	−4.34	1.29	−17.26	3.65	−2.68

Note: compiled by the authors

More favourable economic dynamics are observed in the group of cities of Astana, Ust-Kamenogorsk, Uralsk, Atyrau, Aktobe, Kyzylorda, Kostanay, Shymkent, Turkestan, and Almaty, where positive IED values predominate for most of the period. Economic changes in these cities are generally based on regular sources of output and revenue. The most significant decline in 2024 was in Kostanay (−18.30). Thus, the economy is susceptible to external and internal factors typical of cities with relatively narrow specialisations when

one or more key economic sources temporarily decline, and alternative sectors fail to compensate. As a result, such fluctuations lead to a sharp change in the integrated indicator even within a single year. Therefore, Kostanay lacks sufficient diversification to mitigate abrupt external or internal shocks.

The results of the aggregated IED indicator for 2016–2024 are presented in two characteristics: total mean (TotalMean) and negative mean (NegMean). The most favourable situation was observed in Astana, Uralsk, and Almaty cities, with a consistently positive result and the highest TotalMean values. However, Astana's results showed the maximum total effect and the highest average IED value. The group of cities with predominantly positive dynamics but temporary negative values includes Shymkent, Pavlodar, Uralsk, and Ust-Kamenogorsk. Shymkent has positive results, with minimal negative ones. Pavlodar and Ust-Kamenogorsk have significant negative values and very high positive results. Kostanay, Turkestan, Aktobe, Atyrau, and Aktau occupy an intermediate position, with typically moderate negative values and positive or near-zero results. Economic dynamics here generally remain positive but remain sensitive to individual unfavourable periods, which reduces the average IED values. The weakest overall dynamics are observed in Karaganda, Taraz, Kokshetau, Petropavlovsk, Kyzylorda, and Konaev, where the negative IED values are significant, while the resulting TotalMean indicators remain negative. Astana leads in economic stability and impact scale, followed by Uralsk, Shymkent, and Almaty.

Next, Table 4 presents the results for the wage productivity gap.

Table 4 General characteristics of economic dynamics based on the wage productivity gap for 2016–2024

City	2016	2017	2018	2019	2020	2021	2022	2023	2024	Total Mean
Astana	0.92	0.34	0.40	0.60	4.12	0.96	1.16	0.67	0.68	1.10
Kostanay	1.37	0.33	0.69	0.87	0.97	0.68	1.15	3.48	1.35	1.21
Karaganda	0.45	0.41	1.11	0.37	1.31	−34.89	1.02	3.50	0.71	−2.89
Taraz	0.49	0.44	0.64	1.18	1.67	1.18	1.10	1.82	1.95	1.16
Ust-Kamenogorsk	0.74	0.57	0.80	1.15	1.02	−0.53	0.96	1.33	1.04	0.79
Uralsk	0.70	0.43	0.58	3.19	−1.46	0.58	0.77	1.28	−2.19	0.43
Kokshetau	0.58	0.48	0.82	1.26	0.84	1.14	0.70	4.33	0.67	1.20
Atyrau	0.85	−0.15	0.38	1.10	0.05	0.27	1.14	1.51	−1.01	0.46
Aktobe	0.50	0.61	0.63	1.34	−24.30	0.85	1.04	−4.82	0.98	−2.57
Kyzylorda	0.59	0.59	0.49	1.24	−1.28	1.06	0.99	2.96	0.50	0.79
Aktau	0.45	0.13	0.74	0.86	−0.40	0.44	1.64	1.59	0.97	0.71
Petropavlovsk	1.65	0.81	0.66	1.00	1.20	1.27	0.86	1.26	0.58	1.03
Pavlodar	0.85	0.36	0.46	1.25	4.35	0.71	2.32	12.36	0.79	2.61
Shymkent	1.52	0.15	4.44	13.98	1.35	2.80	0.91	0.73	0.83	2.97
Turkestan	1.96	0.61	0.83	1.21	1.63	0.87	0.61	2.18	0.28	1.13
Almaty	0.63	0.56	2.61	0.99	−16.50	1.69	0.72	0.63	0.63	−0.89
Konaev	1.79	0.37	0.79	0.80	1.81	−1.26	1.15	0.60	0.93	0.78

Note: compiled by the authors

The dynamics of the WPG indicator for 2016–2024 revealed the relationship between

wage growth and economic development across cities. The results showed that WPG remains positive and relatively low in most cities. However, sharp negative and positive deviations are observed. Thus, until 2019, most cities experienced volatility (ranging from approximately 0.4 to 1.3). Since 2020, extreme WPG deviations ranging from −34.9 and −24.3 (Karaganda, 2021, and Aktobe, 2020, respectively) to 13.98 and 12.36 (Shymkent, 2019, and Pavlodar, 2023, respectively) have been observed. The most stable dynamics (positive and moderate values) were observed in Astana. In Kostanay, Petropavlovsk, Taraz, and Kokshetau, uneven income growth was observed. Thus, incomes fluctuate with economic conditions.

Based on the results of the WPG analysis, further consideration focuses on the TotalMean and NegMean indicators, which indicate whether income growth is maintained and generally supported by economic activity, and where incomes often decline and remain volatile. Since 2020, the impact of COVID-19 has been evident across many cities, leading to a worsening correlation between household income and economic performance. Negative WPG values in the post-COVID period indicated that household income is sensitive to external factors.

The first group includes cities where sharp declines in WPG have not been observed in the post-COVID period or have been quickly offset: Pavlodar, Shymkent, Astana, Almaty, Kostanay, Taraz, Kokshetau, Petropavlovsk, Turkestan, and Konaev. The service industry, trade, and administrative functions are crucial for income stability and mitigating the severity of declines. Thus, the COVID crisis has revealed structural differences in urban economies: in less diversified, sector-dependent cities, household incomes are declining more rapidly and severely, while cities with a developed service sector demonstrate more stable dynamics.

Pavlodar and Shymkent form a special subgroup in which high positive WPG values have been recorded since 2020. In these cities, income growth in some years significantly outpaces changes in economic output, reflecting sharp redistribution effects. Moreover, the absence of negative values at the end of the period indicates that the favourable ratio remains. Turkestan demonstrated a weakening in household income growth by 2024. Almaty and Konaev experienced short-term income declines, with sharp declines in 2020 and 2021, respectively.

The second group includes cities characterised by high income sensitivity to deteriorating economic conditions, as reflected in significant negative NegMean values and weak TotalMean results. There are cities with high income sensitivity to deteriorating economic conditions, due to the predominance of extractive and industrial sectors, and that have demonstrated significant declines in WPG since 2020: Aktau, Karaganda, Ust-Kamenogorsk, Uralsk, Atyrau, Aktobe, and Kyzylorda. Under these conditions, a reduction in economic activity directly impacts household income. The exceptions are cities with pronounced isolated declines, primarily Karaganda, Aktobe, and Almaty, where the depth of the negative values requires a separate economic explanation.

Next, Table 5 presents results for per capita economic output dynamics.

Overall, the dynamics of economic output per capita for 2016–2024 are characterised by unevenness and the presence of individual extreme values, as well as sharp changes in the volume of economic output per capita. Between 2016 and 2018, the economy expanded overall, supporting growth in per capita production and services. Post-COVID-19 consequences led to a decline in economic activity, and some cities were unable to withstand the external shock. A partial recovery began at the end of the period, in 2022–2024, with some cities returning to their previous levels of per capita production and services.

Table 5 General characteristics of per capita economic output dynamics for 2016–2024

City	2016	2017	2018	2019	2020	2021	2022	2023	2024	Total Mean
Astana	0.10	3.14	3.47	3.14	0.42	1.27	4.31	3.85	2.34	2.45
Kostanay	7.22	11.67	8.38	8.57	12.00	5.96	15.94	4.36	7.03	9.01
Karaganda	37.29	96.48	−15.05	687.64	21.22	−0.23	26.84	6.41	16.25	97.43
Taraz	−52.42	−8.61	23.96	3016.51	7.60	1.16	17.14	10.08	7.06	335.83
Ust-Kamenogorsk	26.77	8.64	16.50	17.40	18.51	−4.81	41.67	25.80	13.83	18.26
Uralsk	7.57	5.35	10.73	3.33	−5.49	2.87	18.32	8.63	−3.01	5.37
Kokshetau	63.51	−247.84	−30.29	19.91	11.18	1.09	23.58	4.22	10.39	−16.03
Atyrau	5.90	3.30	9.39	4.02	−5.78	5.02	11.38	4.17	−0.58	4.09
Aktobe	6.51	3.97	6.79	3.74	−0.24	10.20	3.35	−1.95	6.82	4.36
Kyzylorda	3.72	3.06	2.54	3.49	−3.83	2.47	12.69	3.59	11.74	4.39
Aktau	−297.44	204.04	8.21	1.91	−2.90	0.63	6.05	2.45	1.85	−8.36
Petropavlovsk	61.42	33.37	20.75	112.29	50.79	13.23	−1033.07	38.65	−22.54	−80.57
Pavlodar	44.99	−717.85	573.37	92.74	7.69	20.60	35.41	5.76	32.86	10.62
Shymkent	3.15	9.18	6.18	0.22	4.58	2.04	2.84	9.27	6.45	4.88
Turkestan	63.78	2.42	6.10	4.91	4.07	0.96	7.27	2.49	5.39	10.82
Almaty	5.81	4.22	0.69	3.48	−0.20	1.90	9.64	10.26	8.46	4.92
Konaev	5.93	5.64	6.30	−11.47	−31.42	−9.86	33.31	14.35	10.97	2.64

Note: compiled by the authors

Astana, Kostanay, Shymkent, Turkestan, Almaty, Atyrau, Aktobe, and Kyzylorda cities with consistently positive production per capita characterised by a predominance of positive per capita economic output throughout the entire period. Karaganda, Taraz, Ust-Kamenogorsk, Uralsk, Kokshetau, Aktau, Petropavlovsk, Pavlodar, and Konaev showed sharp fluctuations in per capita output, including critical declines in some years. The economy is vulnerable and depends on production levels from a limited number of industries or on one-time factors.

Based on the aggregated TotalMean and NegMean results, three stable groups of cities can be identified, differing in their economies' ability to generate output per capita. The first group, comprising cities with leading sustainable output per capita, includes Kostanay, Turkestan, Astana, and Shymkent. TotalMean values range from approximately 4.9 to 10.8, with no negative average values. Thus, it could be assumed that the economy is diversified in terms of production and infrastructure. Therefore, these cities are generally capable of regularly generating significant per-capita levels of production and services. The second group, cities with average positions and limited resilience, includes Atyrau, Aktobe, Kyzylorda, Almaty, Uralsk, Ust-Kamenogorsk, as well as Karaganda and Pavlodar. TotalMean values range from approximately 2.5 to 7, but NegMean values are negative to varying degrees. Although the economy can generate high or moderate output per capita, it relies on a limited set of industries and is highly sensitive to both external and internal shocks. In the case of Pavlodar and Karaganda, high average TotalMean values are due to isolated extreme years and do not reflect the sustainability of economic development. The third group, lagging cities with cumulative adverse effects, includes Taraz, Kokshetau, Aktau, Petropavlovsk, and Konaev, where TotalMean values are negative or close to zero. The population's economic security remains vulnerable and dependent on external sources.

The market is underdeveloped, and the volume of economic activity is insufficient to ensure a sufficient level of per capita economic output.

Next, Table 6 presents results for the CMD dynamics.

Table 6 General characteristics of the CMD dynamics for 2016–2024

City	2016	2017	2018	2019	2020	2021	2022	2023	2024	Total Mean
Astana	2.00	2.41	2.06	2.02	1.90	2.51	6.06	3.61	2.61	2.80
Kostanay	11.91	8.01	10.80	6.40	11.96	6.81	13.41	17.48	5.56	10.26
Karaganda	36.39	82.69	−19.49	743.86	10.73	4.46	25.27	13.73	10.10	100.86
Taraz	−101.93	−7.53	14.37	1897.05	2.41	0.62	11.65	9.33	6.02	203.55
Ust-Kamenogorsk	30.35	8.43	18.52	19.81	8.61	2.53	39.91	45.12	11.77	20.56
Uralsk	8.52	3.03	6.58	16.03	2.06	2.01	13.18	7.36	9.22	7.55
Kokshetau	61.13	−246.60	−89.48	11.76	−10.38	−1.03	26.49	−0.06	6.92	−26.81
Atyrau	9.62	3.02	3.22	2.83	2.01	1.68	5.19	12.34	4.08	4.89
Aktobe	6.54	−0.63	2.37	1.47	4.41	9.23	−1.09	−4.40	1.81	2.19
Kyzylorda	5.33	4.68	1.94	2.96	3.08	1.35	8.69	10.78	7.45	5.14
Aktau	−770.54	−171.49	29.11	5.41	4.76	0.39	7.82	7.91	4.14	−98.05
Petropavlovsk	146.56	27.77	43.35	43.24	−50.67	29.84	−670.07	37.29	0.36	−43.59
Pavlodar	9.85	−364.01	94.21	60.59	19.67	6.77	52.48	75.00	60.48	1.67
Shymkent	6.89	−13.15	1.14	3.38	5.08	5.72	3.25	10.33	9.93	3.62
Turkestan	121.67	13.31	17.05	2.54	1.02	1.52	5.50	5.49	10.83	19.88
Almaty	8.02	4.18	5.48	5.57	0.46	2.96	9.80	6.98	8.39	5.76
Konaev	−33.62	3.90	3.67	0.12	−29.19	−2.40	20.30	−6.10	10.68	−3.63

Note: compiled by the authors

Overall, consumer market density dynamics for 2016–2024 are characterised by high unevenness and sharp fluctuations. In 2018–2019, some cities experienced extremely high values, with short-term growth in the consumer market. In 2020–2021, many cities experienced a decline in consumer market density. In 2022–2024, a general recovery in the consumer market was observed. Also noteworthy are cities with volatile dynamics, such as Karaganda, Taraz, Ust-Kamenogorsk, Pavlodar, Shymkent, and Petropavlovsk, characterised by extreme periods of consumer activity followed by significant contractions. Thus, the consumer market is dependent on specific sources of income and has limited demand stability. Cities with critically unstable dynamics and weak domestic demand stability stand out, such as Aktau, Kokshetau, and Konaev. Moreover, consumer market contractions in some years reach levels that are not offset by subsequent growth.

Based on the aggregated results, three groups of cities can be identified based on the level of consumer market development and stability. The first group includes cities with the highest TotalMean values and the lowest or no negative NegMean, such as Karaganda, Taraz, Ust-Kamenogorsk, Turkestan, and Kostanay, where the consumer market remains large at the end of the period. The second group, with a medium level of consumer market density and with moderate TotalMean and NegMean values, includes Astana, Almaty, Uralsk, Atyrau, Kyzylorda, Shymkent, and Pavlodar. The consumer market remains sensitive to economic shocks and changes in household income. The third group includes lagging

cities with low consumer market density, low or negative TotalMean, and a decline in NegMean, such as Aktau, Kokshetau, Petropavlovsk, and Konaev. The consumer market is underdeveloped, demand is unstable, and the economy is unable to expand consumer consumption sustainably.

Next, diagrams were constructed to determine the values of the IED that generate different values of the wage-productivity gap (WPG), economic output per capita (EPC), and consumer market density (CMD). The vertical axis reflects the IED of the indicators. The scales of the axes differ: for WPG, values are approximately unity (± 1), whereas EPC and CMD have larger magnitudes, as they measure output and consumer activity per capita. The horizontal axis shows the average values of the corresponding indicators, which can be used to assess whether income, output, or consumer market density increases with economic development. The orange line highlights the transition zone between low and positive values on the x-axis. It facilitates visual separation between cities where the IED remains weak or unstable and those with more pronounced economic development.

Figure 1 shows the results for the WPG indicator.

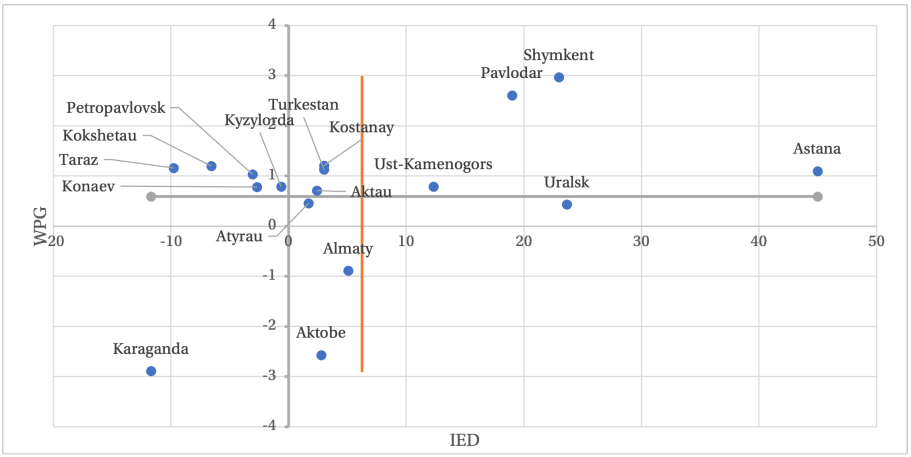


Figure 1 Integrated economic dynamics as a condition for the WPG for 2016–2024

The empirical results demonstrate that the relationship between economic activity and income levels varies significantly across cities, enabling the identification of several distinct development profiles.

1. Cities with high economic activity and income levels (IED above threshold; WPG > 1.0, typically ≈ 1.1˘3.0): Astana, Shymkent, and Pavlodar demonstrate high levels of economic development, reflected in both productivity and the scale of economic activity. The results indicate that IED values are significantly above the average (Astana ≈ 45; Shymkent $\approx$ 23; Pavlodar ≈ 19), while WPG exceeds 1.0, suggesting that wage growth is aligned with economic output. This indicates that expanding production, services, and business activity are effectively transmitted into household income through labour market mechanisms.2. Cities with high economic dynamics and disproportionate incomes (IED $\approx$ 6-7 and above; WPG < 1.0, typically $\approx 0.4 - 0.9$).

2. Cities with high economic dynamics and disproportionate incomes (IED above threshold; WPG < 1.0, typically $\approx$ 0.4–0.9): Uralsk, Almaty, and Aktobe exhibit substantial economic activity; however, income levels lag behind. Despite relatively high IED values

(Uralsk ≈ 24; Almaty ≈ 5–6), WPG remains below 1.0, indicating that economic output grows faster than wages. This suggests that a significant share of generated value is not redistributed to local workers. Possible explanations include income concentration in specific sectors, reliance on external or temporary labour, and the limited availability of stable, high-quality employment.

3. Cities with limited economic growth and relatively stable incomes (IED below threshold; WPG ≥ 1.0, typically $\approx 1.0 - 1.2$): Kostanay, Turkestan, Kokshetau, Petropavlovsk, and Taraz are characterised by moderate economic development and relatively stable income levels. Although economic growth remains constrained, WPG values close to or above 1.0 indicate proportionality between wages and output. Household incomes are supported by stable sources, including public sector employment, local enterprises, and government programmes, which mitigate the effects of weak economic expansion.

4. Cities with low economic activity and low incomes (IED $<\approx 6-7$; WPG < 1.0, negative in some cases): Karaganda and Aktobe exhibit low economic activity and disproportionately low household incomes. WPG values below 1.0 (and negative in some periods) indicate that even the existing economic output does not provide sufficient wages. The economy does not create sufficient stable, well-paid jobs, and household incomes remain sensitive to any deterioration in economic conditions. Structural constraints of the local economy are associated with an outdated production base, narrow specialisation, or a weak labour market. A high level of economic development does not guarantee high income levels. A favourable situation arises only in cities where wages are commensurate with the level of economic activity. Otherwise, economic growth either fails to support incomes or fails to create sustainable conditions for their increase.

Figure 2 shows the results for the EPC indicator.

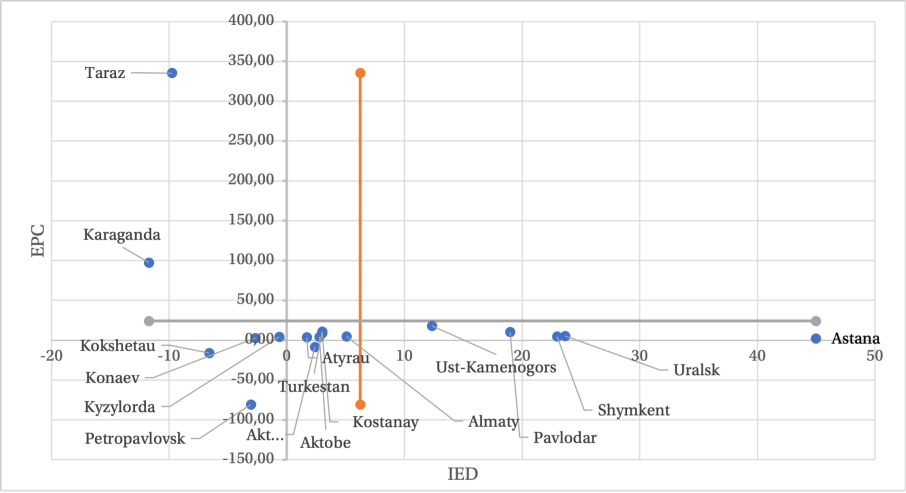


Figure 2 Integrated economic dynamics as a condition for EPC for 2016–2024

Assessing cities through the combined lens of IED and EPC highlights structural differences in how economic activity translates into per capita output and, consequently, potential income levels.

1. Cities with high economic dynamics and high per capita output (IED above the

sample average; EPC significantly above average, $> 20\breve{}30$): Astana, Shymkent, Pavlodar, and Ust-Kamenogorsk are characterised by strong economic dynamics combined with high per capita output. Elevated IED values alongside high EPC indicate that economic activity generates a substantial volume of goods and services relative to population size. This suggests that economic output is not diluted by demographic pressure and is effectively translated into income, employment, and consumption opportunities. High per capita output provides a solid basis for sustainable income growth.

2. Cities with high economic activity and limited per capita output (IED above the sample average; EPC at average or low levels, $\approx 0\breve{}15$): Uralsk and Almaty demonstrate active economic development; however, per capita output remains constrained. Despite relatively high IED values, EPC levels indicate that economic expansion is not sufficient to ensure broad-based improvements in living standards. This imbalance may be associated with rapid population growth and the concentration of production in sectors with limited income spillovers.

3. Cities with limited economic activity and high per capita output (IED below the sample average; EPC above average, >20): Karaganda, Taraz, and Turkestan exhibit weak or unstable economic dynamics despite relatively high per capita output. This pattern reflects structural dependence on capital-intensive industries or isolated large-scale activities that generate output without creating widespread employment. Consequently, high EPC does not necessarily translate into sustainable income or job creation, highlighting the limited inclusiveness of economic growth in these cities.

4. Cities with low economic activity and low per capita output (IED below the sample average; EPC low or negative): Kokshetau, Kyzylorda, Petropavlovsk, Konaev, and Aktau are characterised by weak economic performance and insufficient per capita output. Limited production capacity, underdeveloped labour markets, and strong dependence on external support constrain income generation. As a result, household incomes remain vulnerable to economic shocks and lack stability.

Figure 3 shows the results for the CMD indicator.

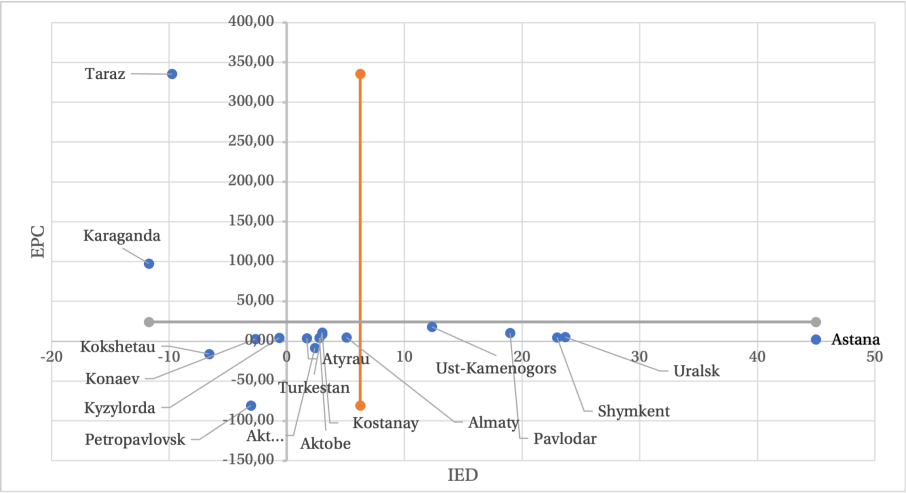


Figure 3 Integrated economic dynamics as a condition for CMD for 2016–2024

To analyze the relationship between economic dynamics and consumer market development, cities were classified into four groups based on the values of the IED and CMD.

1. Cities with High Economic Dynamics and High Consumer Market Density (IED > ≈ 6.5; CMD $> 10\check{}15$): Astana, Shymkent, Pavlodar, Kostanay, and Turkestan demonstrate both strong economic performance and a well-developed consumer market. A high level of economic activity creates conditions for stable and relatively high household incomes, which, in turn, stimulate active consumption. Consumer demand in these cities is intensive and diversified, reflecting both production growth and the everyday purchasing behavior of the population. In this group, economic development effectively translates into domestic demand, making consumption an independent and stabilizing factor of economic sustainability.

2. Cities with High Economic Activity and Limited Consumer Market Density (IED $>\approx 6.5$; CMD $\approx 2\check{}7$): Almaty, Uralsk, and Aktobe are characterized by relatively strong economic activity; however, the consumer market remains underdeveloped compared to expectations. Despite the scale of economic activity, consumer demand remains structurally constrained. This may be explained by income concentration among specific population groups, the outflow of consumption (e.g., online purchases or spending in other regions), or the insufficient development of the retail and service sectors. As a result, economic growth does not fully translate into a sustainable domestic consumer base.

3. Cities with Limited Economic Activity and High Consumer Market Density (IED $<\approx 6.5$; CMD > 10): Karaganda, Taraz, Ust-Kamenogorsk, and Petropavlovsk exhibit moderate or unstable economic dynamics combined with relatively high consumer market density. In these cities, consumption remains active even in the absence of strong economic growth. This is supported by factors such as previously accumulated household income, government transfers, stable employment in large enterprises, and the inertia of consumer behavior. Consequently, consumption creates a temporary perception of stability and partially offsets economic fluctuations; however, it does not generate sustainable conditions for long-term income growth and economic development.

4. Cities with Low Economic Activity and Low Consumer Market Density (IED $<\approx 6.5$; CMD low or negative): Kokshetau, Kyzylorda, Aktau, and Konaev are characterized by weak economic performance and a poorly developed consumer market. In these cities, economic activity does not generate sufficient income, resulting in limited consumer demand. The retail sector remains compressed, business activity is low, and there is a high dependence on external financial support. The analysis shows that sustainable income generation depends not only on economic growth itself but also on the ability of the economy to convert income into domestic consumption. In such conditions, consumer activity remains structurally constrained and highly vulnerable to external shocks.

5 | CONCLUSION

The purpose of this article was to identify why household incomes do not increase with economic growth. The research results showed that growth in production, services, and business activity alone does not guarantee improved living standards unless economic development is accompanied by an expanding labour market and increased consumer activity.

The most favourable situation occurs in cities where jobs are created, and regular household income is generated. Under such conditions, robust consumer demand is rising. In cities with weak labor and consumer markets, economic activity is short-term and does not lead to long-term improvements in the population's well-being.

Even when incomes remain relatively stable despite low economic growth, employment opportunities are limited in the least favourable situations, expansion of production or services does not lead to the creation of sustainable, well-paid jobs, and a significant portion of the economic benefits does not accrue to the local population.

Thus, the study's results demonstrate that, regardless of a city's size or the scale of its economic activity, long-term, high-quality development is based on developed labour and consumer markets. The analysis revealed that when the economic dynamism indicator reaches a threshold of approximately 6–7, economic activity begins to be reflected in household income and well-being. In cities with indicator values in this range or above, economic development was accompanied by growth in household income, as the expansion of production, services, and business activity was supported by a functioning labour market and the generation of regular income. In contrast, in cities with lower indicator values for economic activity, household income did not increase comparably, indicating a weak link between economic development and well-being. Thus, the calculations showed that reaching this threshold reflects the conditions under which economic activity begins to translate into real household income. Further research should consider integrating economic dynamics indicators into a larger group of cities and over longer time periods. It should incorporate additional indicators reflecting the structural characteristics of regional economies.

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Visualization: Maxat K. Shakibayev, Madiyar Khopabayev, Altynay A. Maukenova.
Writing – Review and Editing: Maxat K. Shakibayev, Madiyar Khopabayev, Saule A. Rakhimova.

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Volatility Spillovers in the Economics of Cryptocurrencies and Financial Markets

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Abstract
With the increasing role of cryptocurrencies in the global financial system, the analysis of the mechanisms by which volatility transfers between digital and traditional assets is becoming particularly relevant. The purpose of the study is to assess the degree, directions, and temporal variability of volatility spillovers between Bitcoin, leading cryptocurrencies, and traditional financial instruments. Using daily data and both static and rolling-window estimates, the analysis assesses how shocks to volatility are transmitted between cryptocurrency and macro-financial markets. The results of the study showed that the Total Spillover Index (TSI) in the static model is 28.37%, while in the dynamic model it reaches an average of 35.9%, with peak values up to 45.25% in 2022. It has been established that Bitcoin acts as a net transmitter of volatility: the average level of transmitted effects is 60.31%, received effects are 50.59%, and the net spillover is +9.72%. Moreover, Bitcoin's place in the network is state-dependent to some extent: while it acts as a net transmitter in the average, speculative episodes in alternative cryptocurrencies can cause Bitcoin to act as a receiver of volatility shocks. The results indicate a high degree of internal connectivity in the cryptocurrency market, with limited integration with the traditional financial system, and a pronounced temporary variability in the structure of volatility interactions. These findings have implications for portfolio diversification, risk management, and the ongoing integration of digital assets into the global financial system.

KEYWORDS
Volatility, Volatility Transmission, Bitcoin, Risk, Cryptocurrency, Digital Economy, Financial Economics

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1 | INTRODUCTION

In the last decade, cryptocurrency markets have experienced rapid growth and become a more visible part of the global financial system. Digital assets have transformed from a niche technical experiment into a multi-hundred-billion-dollar asset class, with massive capitalization, growing institutional interest, and frenetic trading since the launch of Bitcoin in 2009. However, this transformation has generated considerable interest among researchers and policymakers who are keen to understand how cryptocurrencies relate to traditional financial markets and whether they pose additional systemic risk.

At the heart of this discussion is volatility. In financial economics, volatility is interpreted as a proxy for uncertainty and the vehicle through which shocks are transmitted between markets. For decades, empirical studies on traditional asset classes have documented the existence of volatility spillovers between equity indices, commodities and cross-currency markets (Guchar et al., 2020), especially so during periods of financial stress. The emergence of cryptocurrencies raises a natural question: do volatility shocks originating in digital asset markets remain largely internal to the crypto ecosystem, or do they propagate more widely to conventional financial assets?

Bitcoin occupies an especially critical place in this debate. The largest and most liquid cryptocurrency, it is often viewed as the benchmark asset in the digital currency market. The empirical literature thus far primarily finds significant contagion across major cryptocurrencies, with Bitcoin often being found to act in transmission of price volatility to other cryptocurrencies. However, the impact of these volatility shocks on other assets in the market remains unknown. Certain studies indicate that cryptocurrencies are merely weakly integrated with conventional financial assets, including gold or foreign exchange rates, whereas others claim that an increasing institutional participation could successively tighten these interrelations across distinct markets.

An additional layer that has garnered growing interest concerns the time-varying nature of market connectedness. Volatility spillovers cannot remain stable over time. Rather, the wave of attention varies between different market regimes. Accordingly, periods of financial stress are commonly associated with increased interdependence among assets; hence, static measures of connectedness may miss structural shifts in volatility transmission.

In this context, the current research investigates volatility spillovers between Bitcoin, leading alternative cryptocurrencies, and some macro-financial drivers. The study employed the connectedness approach, using generalized forecast-error variance decomposition within the context of a Vector Autoregression (VAR) model. To differentiate average spillover relationships from time-varying dynamics, the research perform both static and rolling-window estimations. The use of a rolling analysis highlights periods when volatility transmission increases and whether Bitcoin's role as a shock transmitter or receiver varies with market conditions.

The paper has three key contributions. First, it adds to the existing literature on volatility connectedness by utilizing a much larger dataset that incorporates more recent bouts of turbulence in cryptocurrency markets. Second, the analysis enhances understanding of volatility transmission dynamics over time by applying static and dynamic measures of connectedness. Third, the analysis assesses the structural stability of spillover measures, enabling us to disentangle temporary spikes in connectedness from more permanent structural changes in market ties. Understanding these dynamics has practical implications for investors, portfolio managers, and policymakers. If cryptocurrencies are tightly integrated with the traditional financial markets, shocks to digital asset classes could propagate systemic risk in the wider financial system. On the contrary, weak cross-market spillovers imply

that cryptocurrencies are partially segmented and they may still serve as diversifiers. It adds to the debate about the financial function and systemic importance of these digital assets by investigating both intra-cryptocurrency and cross-market volatility transmission.

2 | LITERATURE REVIEW

The rapid development of cryptocurrency markets has prompted extensive and diverse literature on return behavior, volatility dynamics, and correlations between digital assets and traditional financial markets. As the market capitalization of cryptocurrencies grew and institutional participation in the asset class increased, academics have taken greater notice of whether these new assets remain separate from conventional financial systems or have integrated into broader market structures (Adelopo & Luo, 2025; Polat, 2023). From the standpoint of risk management and financial stability, it is particularly important to understand how volatility transmits across such markets (Wu et al., 2024; Mensi et al., 2025).

Most of the initial empirical work was thus primarily concerned with the statistical properties of cryptocurrency returns. These studies provide a consistent record of characteristics, including volatility clustering, heavy-tailed distributions, and strong persistence; features observed in traditional financial time series data but often to more extreme degrees in cryptocurrency markets. Because of this, many researchers have adopted conditional heteroskedasticity models, such as GARCH-type specifications, over time in the study of cryptocurrency volatility. Katsiampa (2019), for instance, demonstrates that Bitcoin exhibits delayed volatility clusters with significant persistence and responds quickly to information entering the market. Compared with equities, commodities, or foreign exchange rates, the cryptocurrency markets have experienced significantly greater unconditional volatility due to speculative trading, and they are at an earlier stage of market development.

With the maturation of the cryptocurrency market, empirical studies have begun to pay more attention to interconnectedness and contagion effects. The number of studies exploring whether shocks originating in cryptocurrencies could spill over into other financial assets and vice versa began to grow. Previous contributions are typically based on multivariate GARCH-type settings to analyze the transmission of volatility and contagion effects. Though useful, these methods struggle to capture the nonlinearities and intricacies that need to be studied across markets.

Consequently, recent studies have adopted broader methodological approaches. Different approaches like wavelet coherence, cross-quantilogram analysis, and multifractal detrended cross-correlation analysis have been applied to study the nonlinear and time-varying dependence structures between cryptocurrencies versus other asset classes (Kurka, 2019). These techniques enhance researchers' capabilities in investigating spillover dynamics across varying time horizons and market environments, providing a richer understanding of the evolution of volatility interactions during extreme financial conditions (Rehman et al., 2024). With this extensive use of high-frequency data, the literature has also taken a more advanced turn on the empirical side, with new econometric models emerging that allow for time-varying connectedness.

Among the most widely utilized methods in this topic is the connectedness framework proposed by Diebold and Yilmaz (2009, 2012, 2014). This method applies forecast-error variance decomposition based on Vector Autoregression (VAR) models, offering a systematic approach to measuring the size and direction of spillovers between different assets. Overall, applications of the Diebold–Yilmaz framework to cryptocurrency markets find pronounced spillover effects amongst constituents of the digital asset ecosystem. Ji et al. (2019), for instance, document a tendency for Bitcoin to serve as a central transmitter of volatility

shocks across crypto networks and find that spillovers are greater during periods of market stress. Corbet et al. (2018) identify similar dynamic interactions between cryptocurrencies and other (non-crypto) financial assets, but the magnitude of cross-market spillovers is relatively small compared with transmission within the cryptocurrency sector.

A key question that arises from this literature is the level of integration (or lack thereof) between cryptocurrency markets and traditional financial assets. A number of studies point toward cryptocurrencies continuing to act, overall, as a separate asset class. Bouri et al. (2017), for example, assess Bitcoin's potential hedge and safe-haven properties and find limited evidence that it consistently protects investors during periods of financial distress. Other empirical studies find relatively low correlations between cryptocurrencies and traditional assets such as gold, stocks, and foreign exchange rates. However, such correlations may increase temporarily during crisis periods. From a volatility perspective, the overwhelming evidence suggests that although cryptocurrencies exhibit high levels of internal contagion dynamics, their spillovers to traditional financial markets are relatively unamplified.

Another line of research investigates whether Bitcoin consistently leads the cryptocurrency ecosystem or whether leadership positions change over time. Bitcoin has been identified as the main shock transmitter in a number of studies, which implies, however, that its influence varies over time. In episodes of speculative behavior regarding alternative cryptocurrencies, we estimate volatility spills over from outside Bitcoin and then widens across the overall market. Empirical research considers rolling-window or time-varying-parameter VAR models, demonstrating that regime-dependent dynamics come into play in the context of monetary policy (Félix et al., 2020; Kammoun, 2026). These strategies show that the connectivity structures of cryptocurrency markets can change substantially based on market liquidity, investor behavior, and overall macroeconomic conditions. Evidence from the COVID-19 period suggests, for instance, that volatility spillover tends to increase during periods of global financial stress (Goodell & Goutte, 2021).

Building on this literature, the current study investigates volatility spillovers among Bitcoin, major alternative cryptocurrencies, and selected traditional financial assets. Examining spill-over flows both in a time-variation framework, as well as using static connectedness measures by imposing a rolling-window structure on the analysis. The study also measures the stability of the connectedness structure to assess whether recent increases in spillovers result from transient market volatility or more stable structural shifts in the cryptocurrency ecosystem.

3 | METHODOLOGY

This study investigates the time-varying volatility transmission dynamics between Bitcoin and selected financial assets using daily observations from 11 January 2018 to 22 August 2025. The sample includes Bitcoin (BTC), major cryptocurrencies (ETC, BNB, XRP), foreign exchange rates (EUR/USD and TRY/USD), the U.S. Dollar Index (USDX), and gold (XAU/USD).

Let $P_{i,t}$ denote the closing price of asset i at time t. Continuously compounded returns are computed as (1):

$$r_{i,t} = \ln(P_{i,t}) - \ln(P_{i,t-1}) \tag{1}$$

where:

$r_{i,t}$ – the logarithmic return of asset i at time t;

$P_{i,t}$ and $P_{i,t-1}$ – the closing prices of the asset at time t and $t-1$, respectively.

The use of logarithmic returns ensures time-additivity and stabilizes the series' variance. Realized volatility is used as a proxy, computed over a 20-day rolling window, as specified in formula (2):

$$\sigma_{i,t} = \sqrt{252}\sqrt{\frac{1}{19}\sum_{k=0}^{19}\left(r_{i,t-k} - \bar{r}_{i,t}\right)^2} \tag{2}$$

where:

$\bar{r}_{i,t}$ – the mean return within the rolling window;

$r_{i,t-k}$ – the lagged returns within the rolling window. The factor 252 is used to annualize volatility, assuming 252 trading days per year.

Given the strictly positive and skewed nature of volatility, we estimate the model using log-volatility:

$$v_{i,t} = \ln(\sigma_{i,t}) \tag{3}$$

where: $v_{i,t}$ – the logarithm of realized volatility.

This transformation stabilizes variance and mitigates concerns about non-normality. To quantify volatility transmission, we adopt the connectedness framework of Diebold and Yilmaz (2012), which is based on forecast error variance decomposition derived from a Vector Autoregression (VAR). In essence, the VAR framework allows each variable to depend not just on its own past values but also on the values of all other variables in its system. With this feature, it is particularly well-suited for modeling volatility spillovers, since both direct and indirect transmission channels among markets can be captured.

The VAR(p) model is specified as (4):

$$v_t = \sum_{k=1}^{p} A_k v_{t-k} + \epsilon_t \tag{4}$$

where:

A_k – parameter matrices;

$\epsilon_t \sim (0, \Sigma)$ – the vector of error terms.

The lag length is set to $p = 1$ to ensure parameter stability across rolling windows while preserving the dynamic dependence structure.

To quantify volatility spillovers, the study employs the Generalized Forecast Error Variance Decomposition (GFEVD) proposed by Pesaran and Shin (1998), which is invariant to variable ordering. This approach decomposes the forecast error variance of each variable into components attributable to its own shocks and shocks originating from other variables, thereby enabling the identification of volatility transmission across markets. Since the contributions do not necessarily sum to unity, they are normalized to obtain interpretable percentage shares. A forecast horizon of $H = 10$ days is adopted to capture short- to medium-term spillover effects.

The contribution of shocks in variable j to the H-step-ahead forecast error variance of variable i is defined as (5):

$$\theta_{ij}^{(H)} = \frac{\sigma_{jj}^{-1}\sum_{h=0}^{H-1}\left(e_i'\Phi_h\Sigma e_j\right)^2}{\sum_{h=0}^{H-1}\left(e_i'\Phi_h\Sigma\Phi_h' e_i\right)} \tag{5}$$

where:

σ_{jj} – the j-th diagonal element of the covariance matrix

Σ; Φ_h – the impulse response coefficient matrices;

e_i – selection vector with unity in the i-th position and zeros elsewhere.

Since the elements of the variance decomposition do not necessarily sum to one, they are normalized to obtain interpretable percentage shares.

The Total Spillover Index (TSI) measures the overall level of interconnectedness in the system, defined as the proportion of forecast error variance attributable to cross-variable shocks rather than own shocks (6):

$$\text{TSI}^{(H)} = \frac{\sum_{i \neq j} \widetilde{\theta}_{ij}^{(H)}}{N} \times 100 \tag{6}$$

This index reflects the percentage of forecast variance attributable to cross-asset shocks. Higher values of the index indicate stronger interdependence among markets.

Directional spillovers provide additional insights into the transmission mechanism. For each asset, spillovers can be decomposed into those transmitted to other assets ("To") and those received from other assets ("From"). The difference between these measures defines the net spillover, which indicates whether an asset acts as a net transmitter or receiver of volatility. To capture dynamic spillover behavior, a rolling-window estimation approach is applied. A VAR model is estimated using a 252-day moving window with a step size of 20 days. For each window, GFEVD is computed with a forecast horizon of $H = 10$ days, generating time-varying measures of total and directional spillovers.

Stress periods are defined as observations in which Bitcoin's realized volatility exceeds the 90th percentile of its empirical distribution. This data-driven threshold enables the comparison of spillover dynamics under normal and high-volatility regimes.

4 | EMPIRICAL RESULTS

The estimated volatility series exhibits stylized facts commonly observed in financial time series. In particular, volatility clustering is evident: periods of elevated volatility tend to be followed by further high-volatility observations, while tranquil periods are characterized by persistently low volatility. This persistence suggests strong serial dependence in second moments, consistent with well-documented ARCH-type behavior in financial markets. Across asset classes, cryptocurrencies exhibit substantially higher realized volatility than traditional financial assets. Bitcoin and other cryptocurrencies (ETC, BNB, XRP) exhibit markedly larger fluctuations than foreign exchange rates (EUR/USD, TRY/USD), the U.S. Dollar Index, and gold. This differential highlights the comparatively speculative and less mature nature of cryptocurrency markets.

Bitcoin's volatility, in particular, exhibits pronounced spikes during episodes of market stress, most notably throughout the 2020–2022 period. These episodes coincide with global financial uncertainty and heightened turbulence in digital asset markets, resulting in sharp, persistent increases in realized volatility.

To ensure econometric suitability, volatility measures are transformed using the natural logarithm. The log transformation reduces right skewness and stabilizes variance, producing a series that is approximately stationary. Preliminary diagnostic assessments, including inspection of autocorrelation functions and rolling stability checks, indicate that the VAR specification remains stable within rolling estimation windows, thereby supporting the reliability of subsequent spillover analysis.

The unit root and serial correlation diagnostics provide important evidence regarding the statistical properties of the log-volatility series, as shown in Table 1.

Table 1 Stationarity Tests

Series	ADF Stat	ADF p-value	ADF Lags	KPSS Stat	KPSS p-value	LB(10) p-value	LB(20) p-value
BTC/USD	−5.0899	0.0000	21	2.0422	0.0100	0.0000	0.0000
ETC/USD	−4.1784	0.0007	20	2.3665	0.0100	0.0000	0.0000
XRP/USD	−4.4784	0.0002	20	0.9998	0.0100	0.0000	0.0000
BNB/USD	−3.5494	0.0068	21	3.8422	0.0100	0.0000	0.0000
USDX	−3.9418	0.0017	20	0.7972	0.0100	0.0000	0.0000
EUR/USD	−3.5576	0.0066	20	1.1495	0.0100	0.0000	0.0000
TRY/USD	−4.4581	0.0002	24	2.4217	0.0100	0.0000	0.0000
XAU/USD	−5.0914	0.0000	23	0.8418	0.0100	0.0000	0.0000

Note: compiled by the authors using Eviews and R.

First, the Augmented Dickey–Fuller (ADF) test results strongly reject the null hypothesis of a unit root for all series at conventional significance levels. This finding indicates that the log-transformed realized volatility measures are stationary in levels, satisfying a fundamental requirement for VAR-based connectedness analysis. Second, the KPSS test rejects the null hypothesis of stationarity at the 1% significance level for all series. At first glance, this may appear contradictory to the ADF results. However, such outcomes are common in volatility processes. The KPSS rejection reflects the high degree of persistence typically observed in financial volatility, rather than true non-stationarity. When ADF rejects a unit root while KPSS rejects strict stationarity, the evidence is generally interpreted as indicating a highly persistent but mean-reverting process. This behavior is consistent with covariance stationarity exhibiting long memory characteristics. Third, the Ljung–Box statistics are highly significant at lags 10 and 20 across all series. This confirms the presence of substantial serial correlation in the log-volatility measures, consistent with volatility clustering. The rejection of the null hypothesis of no autocorrelation supports the existence of predictable second-moment dynamics.

This subsection presents the static connectedness results derived from the GFEVD with a forecast horizon of $H = 10$ days. The analysis summarizes the average volatility transmission structure across the full sample period, abstracting from time variation. The estimated TSI equals 28.37%, indicating that approximately 28% of the forecast error variance in the system is attributable to cross-asset volatility shocks, while the remaining 72% is explained by own shocks. This magnitude reflects a moderate degree of interconnectedness across the assets considered. The result suggests partial integration between cryptocurrency markets and traditional financial assets. While spillovers are economically meaningful, the system is not dominated by cross-market effects, implying that volatility dynamics remain largely asset-specific.

To assess Bitcoin's systemic importance, its directional spillover measures are examined. On average, Bitcoin transmits 60.31% of volatility to other assets, while receiving 50.59% from them, resulting in a net spillover of +9.72%. The positive net value indicates that Bitcoin acts as a net transmitter of volatility within the system. However, the magnitude of this effect remains moderate, suggesting that Bitcoin's influence, although economically meaningful, does not overwhelmingly dominate the overall system.

This finding is consistent with Bitcoin's role as the largest and most liquid cryptocurrency, often functioning as a benchmark asset within the digital currency ecosystem. A more detailed analysis of pairwise spillovers reveals a pronounced asymmetry between

intra-cryptocurrency transmission and spillovers to traditional financial markets. In particular, volatility originating from Bitcoin exerts a strong influence on other digital assets, accounting for 27.27% of volatility in ETC, 18.54% in BNB, and 13.65% in XRP. These results highlight the central role of Bitcoin within the cryptocurrency network and confirm the presence of strong internal spillover dynamics.

These results indicate pronounced within-sector spillovers, highlighting the central role of Bitcoin in the cryptocurrency network. Shocks originating from Bitcoin account for a substantial share of volatility fluctuations in alternative cryptocurrencies, confirming its dominant position within the digital asset market structure. In contrast, spillovers from Bitcoin to macro-financial variables are negligible. Specifically, the contribution of Bitcoin volatility to the U.S. Dollar Index amounts to only 0.35%, while the corresponding effects on the EUR/USD exchange rate and gold prices are 0.30% and 0.03%, respectively. This limited cross-market transmission suggests that volatility interactions between cryptocurrencies and traditional financial assets remain weak, reinforcing the view that digital assets are only partially integrated into the broader financial system.

The near-zero transmission to currency markets and gold suggests that Bitcoin volatility does not meaningfully propagate to traditional financial assets in the static framework. This finding implies limited direct volatility integration between digital assets and conventional safe-haven or foreign exchange markets during the sample period. Table 2 presents the static spillover matrix (percent).

Table 2 Static Spillover Matrix (Percent)

	BTC	ETC	XRP	BNB	USDX	EUR	TRY	Gold	From
BTC	99.61	0.02	0.06	0.25	0.02	0.04	0.00	0.00	0.39
ETC	54.72	44.96	0.03	0.13	0.00	0.12	0.03	0.00	55.04
XRP	7.41	3.72	87.77	0.04	0.25	0.63	0.13	0.05	12.23
BNB	31.71	7.39	0.14	60.62	0.01	0.04	0.10	0.00	39.38
USDX	0.16	0.07	0.10	0.27	74.67	24.24	0.05	0.44	25.33
EUR	0.27	0.02	0.07	0.08	0.03	99.49	0.02	0.03	0.51
TRY	0.19	0.05	0.02	0.06	0.60	0.71	98.30	0.07	1.70
Gold	0.04	0.11	0.07	0.13	0.39	2.25	0.03	96.99	3.01
To	94.50	11.37	0.48	0.96	1.30	28.02	0.36	0.59	
Net	94.11	−43.66	−11.75	−38.42	−24.03	27.51	−1.34	−2.42	

Note: compiled by the authors using Eviews and R.

The static connectedness analysis demonstrates that volatility transmission is predominantly concentrated within the cryptocurrency sector, with minimal spillover to traditional financial markets. Bitcoin functions as a net transmitter primarily within the digital asset ecosystem rather than as a systemic volatility driver for broader financial markets. These results establish a baseline characterization of the system's average connectedness structure and motivate the subsequent time-varying analysis, which examines whether spillover intensity and Bitcoin's role shift across different market regimes.

To investigate the dynamic evolution of volatility transmission, we estimate a rolling VAR model using a window length of 252 trading days and a step size of 20 trading days. This approach generates a time series of connectedness measures, allowing the identification of

regime shifts and periods of intensified interdependence. For each rolling window, GFEVD are computed with a forecast horizon of $H = 10$ days, from which total and directional spillover indices are derived. The time-varying Total Spillover Index (TSI) averages 35.9%, which is notably higher than the static full-sample estimate of 28.37%. This difference indicates that static measures tend to smooth over episodic spikes in interconnectedness and therefore underestimate the intensity of volatility transmission during turbulent periods.

The dynamic TSI exhibits substantial temporal variation, with pronounced peaks observed in 2022. The highest levels of connectedness are recorded on 9 August 2022 (45.25%), 21 January 2022 (44.68%), and 18 September 2022 (44.61%). These elevated values coincide with periods of heightened market uncertainty and turbulence within cryptocurrency markets. The results suggest that volatility interdependence intensifies during systemic stress episodes, consistent with contagion-type dynamics in which shocks propagate more strongly across assets under adverse market conditions. Overall, the rolling analysis demonstrates that connectedness is not constant but exhibits cyclical amplification during crisis periods.

The rolling directional spillover measures provide further insight into Bitcoin's evolving role within the system. On average, Bitcoin transmits 64.18% of volatility to other assets while receiving 50.07%, resulting in a positive net spillover of +14.12%. This indicates that Bitcoin predominantly acts as a net transmitter of volatility over time, although the magnitude of its influence varies across different market regimes.

On average, Bitcoin remains a net transmitter of volatility, reinforcing its central position within the cryptocurrency ecosystem. However, its net transmission role is clearly time-varying. The rolling estimates reveal the presence of two distinct regimes.

In the first regime, Bitcoin acts as a dominant transmitter of volatility. This pattern is particularly evident during 2019 and parts of 2022, when net spillover values are strongly positive, indicating that Bitcoin serves as a primary source of volatility shocks transmitted to other cryptocurrencies. During these periods, Bitcoin functions as the leading driver of market dynamics within the digital asset space.

In contrast, the second regime is characterized by Bitcoin acting as a net receiver of volatility. This occurs during late 2020 to early 2021, when net spillover values turn negative, implying that Bitcoin absorbs more volatility from other assets than it transmits. For instance, net spillovers reach -30.09% on 26 January 2021 and -23.37% on 15 February 2021. These findings suggest that, during episodes of intensified speculative activity in alternative cryptocurrencies, volatility shocks may originate outside Bitcoin and subsequently propagate toward it.

This episode coincides with substantial capital inflows into alternative cryptocurrencies and heightened speculative activity across the broader crypto market. The results, which are depicted in Table 3, suggest that during this phase, volatility shocks originated primarily in smaller or alternative digital assets and subsequently propagated to Bitcoin.

The time-varying analysis demonstrates that volatility connectedness is regime-dependent. While Bitcoin functions as a net transmitter on average, its systemic role shifts over time in response to changing market conditions. Spillover intensity strengthens markedly during periods of market stress, highlighting the importance of dynamic connectedness frameworks for understanding cryptocurrency market structure. Stress periods are defined as windows where Bitcoin realized volatility exceeds the 90th percentile.

Contrary to conventional expectations, Bitcoin does not become significantly more dominant during its own volatility spikes. Instead, stress periods are characterized by a slight increase in spillovers received, implying greater systemic feedback effects.

Table 3 Comparison of Average Spillovers

Measure	Normal	Stress
Total Spillover	36.19%	33.38%
BTC To	64.18%	61.10%
BTC From	50.07%	51.28%
BTC Net	+14.12%	+9.82%

Note: compiled by the authors using Eviews and R.

The empirical findings reveal key characteristics of how volatility is transmitted through the system under study. Most importantly, much of the spillover dynamics seems to be localized in the cryptocurrency market per se. Bitcoin had a strong influence on the volatility of alternative digital assets and further consolidated its role as a hub within the cryptocurrency network's internal structure. In this way, volatility transmission is not so much cross-asset contagion across the global financial system as it is interactions among cryptocurrencies.

Moreover, the analysis provides little to no evidence of meaningful volatility transmission from cryptocurrencies to traditional financial assets. During the sample period, spillovers from Bitcoin to gold, foreign exchange rates, and the U.S. Dollar Index are economically very small. Such limited transmission implies that crypto markets are still largely decoupled from the volatility patterns of traditional financial assets. The results, therefore, support the second-moment view that cryptocurrencies are still only weakly integrated with traditional markets.

Another interesting aspect of the results concerns Bitcoin and its evolving role in the crypto ecosystem. While Bitcoin is, overall, a net transmitter of volatility, its place in the network is not permanent. At specific intervals, most notably during episodes of sustained speculative excess in altcoins, Bitcoin briefly serves as a sink for volatility spillover from other crypto assets. These episodes suggest that leadership in the cryptocurrency market is dynamic over time and that the internal structure of volatility transmission is sensitive to different market states.

In the end, results suggest a stacked market structure. The volatility spillovers are strong between cryptocurrencies, but they remain relatively contained when interactions with traditional financial markets are taken into account. Although Bitcoin sits at a structurally significant node in the crypto network, its effects on other conventional asset classes are limited over the time frame analyzed.

5 | DISCUSSION

Our empirical findings in this paper are generally consistent with the existing literature concerning volatility connectedness and cryptocurrency market integration. The methodology based on Diebold and Yilmaz (2012) has become one of the most commonly implemented methods for analyzing return and volatility spillovers between financial assets (see e.g. Bouri et al., 2020a; Dias-Filho, 2021); however, in our interpretation here we augment this framework with the logic of condition-relative risk and returns derived from Mikhailov et al. (2022).

A telling aspect of the results is the strong transmission of volatility within cryptocurrency ecosystem. This finding aligns with previous research highlighting Bitcoin as being a primal driver of volatility spillovers across digital asset markets. When applying the Diebold–Yilmaz connectedness framework to cryptocurrencies, empirical evidence often suggests

that Bitcoin is in a dominant position in the digital asset network (Katsiampa, 2019; Corbet et al., 2018). The significant spillovers from Bitcoin to assets such as ETC and BNB documented in this study provide additional evidence reinforcing the hierarchical structure commonly discussed in cryptocurrency literature.

Coinciding with this, the results show little evidence of Bitcoin spillover into traditional financial assets. This result is consistent with earlier evidence demonstrating that cryptocurrencies remain only partially integrated into broader macro-financial markets. Previous studies have found that correlations between cryptocurrencies and traditional assets like gold or foreign exchange rates are low in the normal state but experience short-lived spikes during turbulent condition (Bouri et al., 2017; Ji et al., 2019). The small BTC-to-USDX and BTC-to-gold spillovers found in the current analysis therefore reinforce the perception that cryptocurrencies have remained largely a separate asset class throughout the sample period.

These time-varying results are also consistent with prior work emphasizing the importance of market conditions in determining volatility transmission. Diebold and Yilmaz (2009, 2014) find that spillover intensity is generally greater during periods of financial stress, an observation that highlights contagion-like behavior among asset classes. Similar trends were observed in cryptocurrency markets across major global shocks, including the COVID-19 period (Goodell & Goutte, 2021). The higher spillover peaks observed in 2022 in the current study thus align with this broader body of empirical evidence.

A further contribution of the analysis relates to how these fluctuations in connectedness can be interpreted. Structural break tests indicate that these increases in volatility spillovers may be treated as cyclical amplifications, rather than permanent shifts to a new structural regime. Overall, this finding suggests that the connectedness structure of cryptocurrency markets is neither persistent nor subject to permanent structural change but rather variable and sensitive to changing market conditions.

Results also underscore that Bitcoin's leadership of the cryptocurrency ecosystem is not fully assured. Even though Bitcoin has been shown to be a net transmitter of volatility at the mean, multiple periods are identified in which Bitcoin absorbs volatility shocks coming from other cryptocurrencies, most prominently in late 2020 and early 2021. Such episodes accompany periods of frenetic speculation in alternative digital assets. This shows that who leads the market in terms of volatility can change over time and adjust to the liquidity, sentiment, and trading conditions in place.

Overall, this evidence generally supports the broader conclusion in the literature: that while there are strong volatility spillovers in cryptocurrency markets specifically, these spillovers are muted and less influential when interacting with traditional financial assets. Concurrently, the dynamic patterns identified in this study further support evidence of non-static leadership within the cryptocurrency ecosystem, which is susceptible to change across time-varying market regimes.

6 | CONCLUSION

In our study, we account for volatility transmission using a connectedness framework based on generalized forecast-error variance decomposition within a VAR model among Bitcoin, dominant cryptocurrencies, and some traditional financial assets. The analysis combines static connectedness measures with rolling-window estimation to glean both average spillover patterns and their time-varying characteristics.

The findings suggest that volatility transmission is mainly localized within the cryptocurrency ecosystem. Bitcoin holds a structurally important position in this network, and Bitcoin is, on average, a net-mover of volatility to alternative digital assets. Strong cryptofinancial

spillovers from Bitcoin to other cryptocurrencies means that the digital asset market has a hierarchical internal structure. On the other hand, this analysis offers little suggestive evidence that volatility from Bitcoin significantly spreads to traditional financial assets, like gold, the foreign exchange markets and US Dollar Index in the specified sample period.

The dynamic analysis also suggests heterogeneity in connectedness across market conditions. High-volatility periods, in particular the year 2022, tend to correlate with higher spillover intensity, indicating that interdependence across assets increases during market stress episodes. However, structural break tests suggest that such spikes are a product of cyclical amplification rather than persistent regime shifts. Though Bitcoin usually transmits volatility to other cryptocurrencies, the results also show episodes in which it temporarily absorbs shocks originating from elsewhere in the digital asset market. Those patterns show the state-dependent nature of volatility leadership in the cryptocurrency ecosystem.

Combined, the evidence suggests a multi-layered fabric of financial engagement. While cryptocurrency markets exhibit strong internal volatility spillovers, their linkages appear relatively weaker with traditional financial assets. This segmentation suggests that cryptocurrencies may continue to offer diversification benefits relative to traditional assets, especially when considering volatility.

Such findings have many implications for investors, portfolio managers, and policymakers. For market participants, the findings indicate that diversification benefits can continue so long as spillovers across markets are not too substantial. For regulators and financial stability authorities, the findings suggest that systemic spillover of cryptocurrency volatility to wider financial markets is confined at this stage, at least over the sample period considered. A caveat, however, is that digital asset markets are still maturing and deserve diligent watchfulness as institutions further enter the market.

This analysis can be extended in some directions for future research. Other approaches like frequency-domain connectedness, high-frequency realized volatility measures and time-varying parameter VAR models can help make sense for the short- and long-term channels through which volatility propagates. As cryptocurrency markets mature, how cryptocurrencies fit into the world financial systems will remain a significant topic of academic research and financial discourse.

AUTHOR CONTRIBUTIONS

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Formal analysis and investigation: Saban Celik, Aslı Duman.
Funding acquisition and research administration: Saban Celik.
Development of research methodology: Saban Celik.
Resources: Aslı Duman. Software and supervisions: Saban Celik.
Data collection, analysis and interpretation: Saban Celik, Aslı Duman.
Visualization: Aslı Duman. Writing review and editing research: Saban Celik.

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Tourism Capacity and Green Infrastructure: Evidence from the Eastern part of Lake Alakol

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Abstract
With the growing tourist load and increased anthropogenic pressure on coastal areas, the need to develop sustainable management models for tourist destinations based on the integration of natural and infrastructural solutions is becoming urgent. The aim of this study is to develop a scientifically grounded approach to assessing the capacity of green infrastructure and to propose mechanisms for managing tourist flows to reduce anthropogenic pressure and improve the quality of the destination's tourism environment. The research methods include spatial analysis using geoinformation tools, and the calculation of recreational capacity based on normative, spatial, and temporal approaches, using the methodology for assessing the capacity of territories. The initial data are represented by spatial characteristics of the territory, standards of recreational load, infrastructure parameters (pedestrian and bicycle zones), and time indicators of attendance. The results of the study show that, based on normative spatial modeling, with an area of 40,000 m2 and a standard of 50 m2 per visitor, the simultaneous recreational capacity is 200 people. Considering the turnover rate, the daily throughput reaches 1,200 visits, and during the peak tourist period (60 days), 72,000 visits. The obtained values indicate the possibility of effectively redistributing tourist flows and reducing the burden on coastal ecosystems through the introduction of the AEEB model. The findings indicate the potential to regulate tourist flows and reduce anthropogenic pressure on coastal ecosystems.

KEYWORDS
Tourism Capacity, Tourism Business, Green Infrastructure, Recreational Capacity, Management, Spatial Planning, Regional Economy

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1 | INTRODUCTION

The Alakol resort area, located in the Abay and Zhetysu regions of Kazakhstan, represents one of the country's most significant recreational destinations. This study focuses on the eastern part of Lake Alakol within the Abay region (hereinafter referred to as "the destination"), which is included among the 21 officially designated resort areas. The destination is characterized by a predominance of ecosystem services associated with aquatic environments and is considered to possess therapeutic properties. According to data from the Bureau of National Statistics of the Republic of Kazakhstan (2025), the destination ranks among the top six domestic destinations by visitor numbers, indicating its growing importance within the national tourism system.

Historically, the destination has played a notable role in regional trade and cultural exchange. During the Soviet period, it developed into a center for health and wellness tourism, laying the foundation for its current tourism specialization. Following Kazakhstan's independence in 1991, the destination has experienced steady growth in visitor numbers, attracting both domestic and international tourists. However, the continued expansion of tourism requires a transition toward more sustainable development models, including effective natural resource management, infrastructure modernization, and cross-border cooperation (Kapassova et al., 2025).

At the national policy level, the importance of improving tourism competitiveness has been emphasized in the State of the Nation Address by President Kassym-Jomart Tokayev (2025), where particular attention was given to the condition of tourism infrastructure and the need for systemic improvements. In 2025, the situation in the Alakol resort area further highlighted existing management challenges. Numerous public complaints concerning inadequate sanitary conditions, unregulated trade activities, insufficient infrastructure, and communication issues revealed significant systemic shortcomings in the organization and maintenance of the destination.

In response, government authorities-initiated inspections and introduced measures to improve sanitary and epidemiological conditions, strengthen waste management systems, and enhance infrastructure and communication services (Nigmatullina, 2025). These developments demonstrate that sustainable tourism development requires not only an increase in tourist flows but also the assurance of quality, safety, and resilience of the tourism environment through effective governance mechanisms.

Despite recent progress, the destination's development has largely focused on expanding accommodation facilities and transport accessibility, while the role of green infrastructure remains insufficiently addressed. This imbalance poses risks to environmental sustainability, particularly under conditions of the seasonal concentration of tourist flows along the lake's shoreline. The lack of systematic monitoring of recreational pressure, fragmented infrastructure planning, and limited coordination among stakeholders further exacerbates the destination's vulnerability during peak periods.

Given the above, there is a need to reconsider existing approaches to tourism management by integrating the principles of sustainable development, environmental management, and risk-based planning into territorial governance. In particular, the assessment of carrying capacity and the role of green infrastructure as a regulating mechanism for tourist flows remains insufficiently explored in the context of emerging destinations such as Alakol. The aim of this study is to develop a scientifically grounded approach to assessing the capacity of green infrastructure and to propose mechanisms for managing tourist flows in order to reduce anthropogenic pressure and improve the quality of the tourism environment in the destination.

This study makes three main contributions. First, it advances the understanding of sustainable tourism development by conceptualizing green infrastructure as an integral component of tourism destination systems. Second, it proposes an integrative model that combines the principles of sustainable tourism, nature-based solutions, and culturally sensitive development within the framework of the "Alakol Ethno-Eco Bagshasy" (hereinafter – AEEB) concept. Third, the proposed model offers practical implications for planning and managing sustainable development in emerging tourist destinations.

2 | LITERATURE REVIEW

In recent years, sustainable tourism has been increasingly conceptualized as a multidimensional framework integrating environmental protection, spatial planning, community well-being, and economic development. Within this paradigm, tourism destinations are understood as complex socio-ecological systems in which natural environments, infrastructure, governance mechanisms, and human activities interact dynamically. As a result, the concept of destination resilience has gained prominence, emphasizing the capacity of territories to manage tourist flows, reduce environmental pressure, and maintain the quality and safety of the tourism environment amid growing demand.

For the purposes of this study, the literature review is structured around three interrelated thematic areas: sustainable tourism and destination resilience; green infrastructure, nature-based solutions, and wellbeing; and empirical studies on Lake Alakol. This structure enables a systematic connection between broader theoretical discussions and the destination's specific territorial context.

The literature consistently indicates that sustainable tourism development involves balancing economic growth with environmental protection, cultural preservation, and social inclusion. In this context, tourism destinations are increasingly viewed not merely as sites of consumption, but as integrated systems in which infrastructure, ecosystems, and local communities are closely interconnected. Particular attention has been given to the management of tourist flows and their spatial concentration. In coastal and lake destinations, recreational activities are often concentrated along limited shoreline areas, which may lead to uneven spatial pressure. Under such conditions, insufficient infrastructure planning, limited environmental monitoring, and fragmented governance structures can increase destinations' vulnerability during peak periods.

Recent studies also highlight the importance of integrating hard infrastructure, such as transport networks, accommodation, and service facilities, with environmental infrastructure, including green spaces, ecological corridors, and nature-based systems. This integration is widely regarded as essential for enhancing the resilience and sustainability of tourism destinations. Despite growing recognition of this interdependence, the interaction between built and green infrastructure remains comparatively underexplored, particularly in emerging tourist regions.

Studies on urban park systems demonstrate that the spatial patterns of supply and demand for cultural ecosystem services significantly influence visitor behavior and the intensity of recreational use (Liu et al., 2021). Green infrastructure is increasingly recognized as a multifunctional component of territorial development, contributing to ecological stability, landscape quality, and human wellbeing (Thompson et al., 2023; Beltramo et al., 2024; Thirumarpan & Robinson, 2025). Within tourism studies, green spaces and nature-based solutions are associated not only with environmental conservation but also with improved visitor experience and enhanced destination attractiveness.

Empirical research suggests that exposure to green environments is associated with

reduced stress, improved mood, and enhanced psychological well-being. These effects are particularly relevant in tourism contexts, where environmental quality directly influences visitor satisfaction and the perceived value of the destination. Recent research demonstrates that the relationship between green space and physical health is not uniform across population groups, as gender-specific differences may significantly influence health outcomes and access to environmental benefits (Sillman et al. 2022). Moreover, studies in environmental psychology indicate that the restorative effects of green spaces are observed across different population groups, including adolescents, women, and socially vulnerable communities (Zhang et al., 2020; Rigolon, 2021; Russo et al., 2024; Ijatuyi & Yessoufou, 2025). At the same time, recent research demonstrates that the integration of green and hard infrastructure plays a crucial role in enhancing sustainability and resilience of tourism destinations (Alfehaid, 2025; Trung, 2025).

From a landscape architecture perspective, the effectiveness of green infrastructure depends on spatial composition, accessibility, diversity, and design quality. Well-designed green spaces can facilitate physical activity, promote social interaction, and support psychological resilience. In this regard, green infrastructure may be understood not merely as a passive environmental background, but as an active, experience-shaping component of tourism systems.

In addition to social and health-related benefits, green infrastructure is also associated with economic and governance outcomes. Natural and semi-natural spaces can support economic diversification, local employment, and conservation financing, while contributing to the inclusiveness of tourism development. Consequently, nature-based solutions are increasingly considered as important instruments for achieving a balance between economic development and environmental sustainability.

Research on Lake Alakol provides a diverse, though somewhat fragmented, body of knowledge covering natural, environmental, and tourism-related processes. Existing studies have addressed remote sensing of water bodies, shoreline dynamics, environmental risks, recreational potential, tourist satisfaction, and aspects of carrying capacity.

Early research primarily focused on improving remote sensing techniques and monitoring methods, enabling more accurate delineation of water surfaces and supporting ecological analysis of aquatic systems (Yuyue et al., 2021). Subsequent studies examined geomorphological processes and shoreline vulnerability, identifying high-risk zones and assessing the impact of recreational activities on coastal soils and surface waters (Medeu et al., 2023; Mukayev et al., 2023).

More recent studies have expanded the analytical scope to include recreational capacity, social impacts, tourist satisfaction, and cultural landscape characteristics (Kishkenbayeva & Baisarina, 2024; Valeyev et al., 2024). By 2025, research began to address tourism potential, development barriers, and both physical and social carrying capacity, as well as aspects of landscape planning for recreational areas (Kanatuly et al., 2025; Kishkenbayeva et al., 2025; Valeyev et al., 2025; Kerimbay et al., 2025). The literature emphasizes that sustainable tourism development requires not only the preservation of natural and cultural assets but also their integration into coherent spatial and infrastructure systems (Aldybaev & Zakiryanov, 2021; Tubekova et al., 2024).

Existing research has significantly contributed to understanding individual components of the destination system. However, further work is needed to integrate these elements within a unified spatial and management framework. The analysis indicates a research gap in the integration of green infrastructure into the planning and management of tourism destinations. In particular, the role of green infrastructure as a mechanism for regulating

tourist flows, mitigating anthropogenic pressure, and enhancing the overall quality of the tourism environment remains relatively underexplored.

This gap is especially evident regarding the destination, where the rapid growth of tourism activity is not yet fully supported by a comprehensive, systems-based planning approach. Existing studies provide valuable insights into individual components of the destination; however, an integrated model that links green infrastructure, carrying capacity, spatial organization, and culturally sensitive development remains lacking.

Accordingly, the present study seeks to address this gap by proposing a holistic framework that combines principles of sustainable tourism, nature-based solutions, and destination governance. Within this framework, green infrastructure is conceptualized as a foundational element of a resilient tourism system, enabling a more balanced alignment between economic development, environmental protection, and the well-being of both visitors and local communities.

3 | RESEARCH METHODS

To describe the comprehensive consciousness of destination renaturing, a planning framework grounded in AEEB principles was developed. Within this framework, the concept of a specialized park was elaborated, identifying and structuring key recreational functions - sporting, ethno-cultural, health-related, and educational, while integrating botanical gardens as an independent functional and spatial component.

The developed AEEB model and its description were subsequently examined by experts at the National Institute of Intellectual Property (Qazpatent, 2025), resulting in the registration of copyright for the landscape design work, 'Designed Plan of 'Alakol Ethno–Eco Bagshasy' (January 20, 2025). The research focuses on the proposed AEEB located in the eastern part of Lake Alakol. Its position within the destination's tourism-influenced zone provides the necessary geographical context and supports the selection of the site as a potential instrument for regulating visitor flows within the regional tourism system (Figure 1).

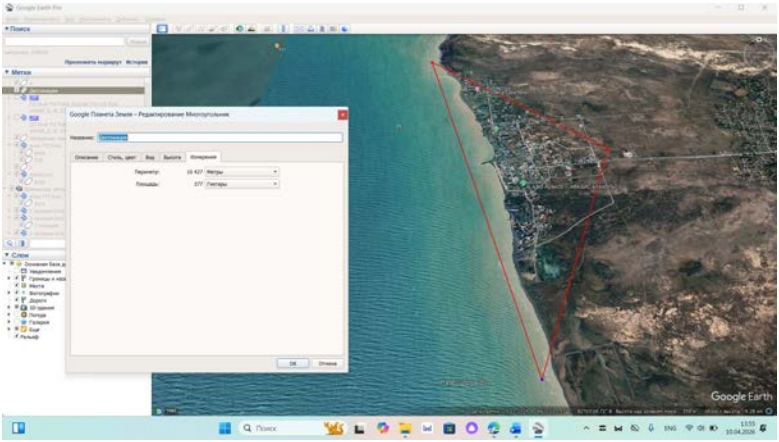


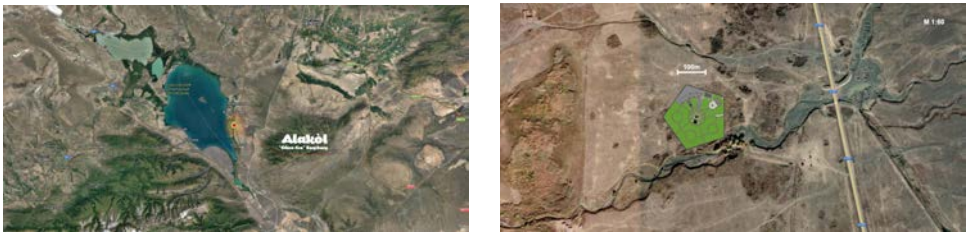
Figure 1 The destination area

The study area was delineated using high-resolution satellite imagery in Google Earth Pro, with polygon-based mapping enabling precise definition of the boundaries of the coastal destination site. The total area of the selected territory is approximately 400 hectares, calculated using built-in geospatial measurement tools. The spatial configuration of the site

is characterized by a predominantly coastal morphology combined with adjacent urbanized and semi-natural landscapes, which is essential for subsequent capacity assessment and planning decisions. The applied geospatial approach provides a reliable foundation for further modeling of the park development concept.

In the first stage of the study, the spatial model of the AEEB was developed in SketchUp (v.21.1.299) at a 1:1 scale to maintain dimensional consistency. Considering the open steppe landscape and the project's conceptual stage, a limited tolerance for positional accuracy was accepted, while the project site itself was georeferenced with sufficient precision.

Figure 2 presents the overall configuration of the AEEB and its relationship with the surrounding landscape.



The eastern part of Lake Alakol Situation map of the AEEB location

Figure 2 Location of the proposed AEEB

The spatial positioning of the proposed AEEB within the eastern part of Lake Alakol highlights its integration into the broader regional landscape. The location serves as a transitional interface among aquatic, riparian, and steppe ecosystems, thereby increasing the ecological and recreational value of the site. At a finer scale, the situation map reveals the internal configuration of the AEEB, including planned functional zones and its proximity to natural water channels and existing transport infrastructure. This spatial context is essential for understanding both the area's environmental sensitivity and its potential for sustainable park development.

In the second stage of the study, the assessment of the AEEB's recreational capacity combines normative, spatial, and temporal components, reflecting a comprehensive approach to evaluating visitor load. In line with this approach, a review of regulatory documents and scientific literature was conducted to justify the selection of a recreational load indicator. Current Kazakhstani legal frameworks recognize the concept of recreational load but do not provide standardized numerical thresholds for visitor density in urban green parks. Therefore, for the purpose of this study, a normative benchmark of 50 persons per hectare was adopted, as recommended in urban landscaping and planning guidelines for open-access natural areas (Andreeva et al., 2020).

In the third stage, the spatial parameters of the AEEB were defined in accordance with the project layout. The total park area is 4 hectares (40,000 m²) and was fully accounted for in the capacity calculations. In addition, the analysis incorporates the spatial characteristics of circulation infrastructure, including 4,804 m² of pedestrian sidewalks and 1,721 m² of cycleway area, as these elements determine the internal distribution and intensity of visitor flows.

The calculations follow the methodological approach proposed by Nikolaeva et al. (2025), which provides a structured framework for estimating recreational capacity using area-based indicators, turnover coefficients, and correction factors. This methodology was selected for its applicability to open-access recreational areas and its ability to explicitly link spatial parameters to visitor-use intensity (Table 1).

Table 1 Source framework and its adaptation for recreational capacity assessment

Component	Source formula	Adapted approach	Applied formula
Turnover coefficient	$Rf = T/Td$	Directly adopted	$Rf = 6$
Base capacity (BCC)	BCC $= (A/Au) \times Rf \times t$	Applied without correction factors	BCC $= (A/Au) \times Rf \times t$
Normative area	$Au = 10000/50$	Converted to an individual space	$Au = 200$ m^2/visitor
Simultaneous capacity	A/Au	Baseline interpretation	$A/Au = 200$
Daily capacity	BCC $\times$ t ($t = 1$)	Throughput interpretation	BCCday $= 1200$ visits/day
Seasonal capacity	BCC $\times$ t	60-day period	BCCseason $= 72000$ visits
Full RCC model	RCC $=$ PCC $\times$ MC	Not applied	–
Correction factors	$Cf = 1 - L/T$	Not applied	–
Management coefficient	MC variable	MC $= 1$	MC $= 1$

Note: compiled by the authors.

The presented model structure and its adaptation provide a transition from the theoretical formulation of the problem to a quantitative assessment of the recreational capacity of the territory. In this context, the basic element of the calculation scheme is the standard area per visitor, reflecting the permissible level of anthropogenic load and ensuring comparability of the results. The corresponding indicator is determined by the following formula (1):

$$A_u = \frac{10{,}000}{50} = 200 \text{ m}^2/\text{person} \tag{1}$$

where:

A_u – the area required per visitor (m^2/person);

10,000 – the area of one hectare (m^2);

50 – the standard of permissible recreational load (people/ha).

The total area of the AEEB is 40,000 m². Based on the defined normative area, the simultaneous recreational capacity of the territory is calculated by formula (2):

$$C_s = \frac{A}{A_u} \tag{2}$$

where:

C_s – the simultaneous recreational capacity (visitors);

A – the total area of the territory (m^2);

A_u – the normative area per visitor (m^2/person).

This value represents the maximum number of visitors that can be accommodated simultaneously without exceeding the accepted recreational load. To incorporate the temporal dimension of visitor use, a turnover coefficient is introduced (3):

$$R_f = \frac{T}{T_d} \tag{3}$$

where:

R_f – the turnover coefficient;

T – the daily operating time (hours);

T_d – the average duration of a visit (hours).

The integrated recreational capacity, combining spatial and temporal parameters, is determined as follows (4):

$$\text{BCC} = \left(\frac{A}{A_u}\right) \times R_f \times t \tag{4}$$

where:

BCC – the recreational capacity (visits over a given period);

A – the total area (m^2);

A_u – the normative area per visitor (m^2/person);

R_f – the turnover coefficient;

t – the duration of the analyzed period (days).

The daily recreational capacity is therefore:

$$\text{BCC}_{day} = 200 \times 6 = 1,200\ visits/day \tag{5}$$

For the peak tourism period of 60 days, the seasonal capacity is estimated as:

$$\text{BCC}_{season} = 1,200 \times 60 = 72,000\ visits \tag{6}$$

The daily value represents visitor throughput rather than simultaneous presence, which aligns with contemporary interpretations of carrying capacity as a dynamic process.

To complement the overall assessment, the adequacy of internal circulation infrastructure is evaluated using area-based indicators. The pedestrian space available per visitor is calculated as (7):

$$S_p = \frac{A_p}{N} \tag{7}$$

where:

S_p – the pedestrian space per visitor (m^2/person);

A_p – the total pedestrian area (m^2);

N – the daily visitor flow (visitors/day).

The performance of cycling infrastructure is evaluated using the following indicators (6):

$$D_c = \frac{N}{A_c}, \quad S_c = \frac{A_c}{N} \tag{8}$$

where:

D_c – the density of users (visitors/m^2);

S_c – the space per cyclist (m^2/person);

A_c – the cycleway area (m^2).

Although the full framework of recreational capacity assessment may include correction coefficients and management factors, this study applies to a simplified model due to limited empirical data on visitor behaviour and environmental conditions. The management coefficient is therefore assumed to be equal to 1, allowing the analysis to focus on directly measurable parameters while maintaining transparency and consistency with more advanced approaches that may be applied in future research.

While the framework for assessing recreational capacity includes a range of correction coefficients and a management factor, this study adopts a simplified approach that focuses on baseline spatial and temporal capacity. The choice is mainly driven by data availability. The calculation of correction coefficients (C_f) requires detailed and consistent empirical

data on environmental conditions, visitor behaviour, safety, and socio-cultural interactions. For the study area, such data are currently limited and not systematically collected, which could introduce a high degree of uncertainty into the results (Table 2).

Table 2 Comparison between the normative model and the simplified approach applied in this study

Component	Full Normative Model	Simplified Model	Rationale
Overall structure	RCC = PCC × MC	Not applied	Focus on baseline capacity
PCC	PCC = BCC × Cf	Not applied	Lack of data
BCC	BCC = $(A/Au) \times Rf \times t$	Fully applied	Core parameter
Normative area	Standard value	Adopted	Comparability
Turnover coefficient	$Rf = T/Td$	Applied	Captures dynamics
Correction factors	$Cf = 1 - L/T$	Not applied	Data uncertainty
Management coefficient	Reflects infrastructure	MC = 1	Low infrastructure
Temporal parameter	Flexible t	Day + season	Tourism seasonality
Output	Adjusted capacity	Baseline capacity	Planning purposes

Note: compiled by the authors.

In addition, the management coefficient (MC) is intended to capture the role of infrastructure and governance in regulating visitor flows. However, given the relatively low level of tourism infrastructure and the park's predominantly natural character, its influence at this stage is minimal. For this reason, it was assumed to be equal to 1.

The simplified model, therefore, focuses on parameters that can be directly measured and interpreted with greater reliability, namely the spatial capacity of the area and the temporal dynamics of its use. This enables more transparent and robust estimation of recreational capacity, particularly in contexts where monitoring data is limited. At the same time, the approach remains compatible with the full normative framework and can be further developed in future studies as more detailed empirical data become available.

4 | RESULTS

The calculated indicators of AEEB recreational capacity are directly derived from the defined normative, spatial, and temporal parameters. Based on the adopted standard of 50 persons per hectare, the individual spatial requirement equals 200 m² per visitor. Given a park area of 40,000 m², the baseline simultaneous capacity is estimated at 200 visitors. Incorporating the turnover coefficient (k = 6), calculated as the ratio of daily operating time to the average visit duration, yields a daily visitor flow of 1,200 visits. For the peak summer period of 60 days, the total seasonal capacity reaches 72, 000 visits.

These findings indicate that the proposed model can accommodate visitor use at a level consistent with the adopted normative threshold. At the same time, the estimated daily value reflects visitor turnover rather than simultaneous presence, allowing recreational capacity to be interpreted as a dynamic process. This interpretation is consistent with current approaches to carrying capacity assessment, which emphasize regulating visitor flows rather than maintaining fixed density limits. In general, the master plan of AEEB is organised through functional zoning, integrating recreational, cultural, and service elements into a coherent system.

Figure 3 presents the zoning structure and the network of interconnected facilities, allowing interpretation of visitor distribution and internal circulation.



№	The main sections of the Park	м²
1	Ethno village (Auyl)	2360
2	Winter garden	8290
3	Spring Garden	8290
4	Autumn garden	8290
5	Administrative Zone	8290
6	Greenhouse complex	
7	Parking area	4410
8	Ticket office	
9	Locker room, bike rentals	972
10	Pond	972
	Total square	4,15 *ha*

Cycleway - 1721 м²
Pedestrian sidewalk - 4804 м²

(a) Master Plan (b) Interconnected tourist facilities

Figure 3 The main sections of the AEEB

To preserve the destination's aquatic ecosystem and reduce anthropogenic pressure from tourist flows, a conceptual model of the AEEB was developed using situational mapping and master planning principles. The model brings together seasonal park zones, an Ethno village (aul), and supporting functional facilities to organize visitor movement and distribute recreational activities more evenly across the site.

As shown in Figure 3, the AEEB master plan includes ten interconnected 10 functional zones: the Ethno village (aul), Winter Garden, Spring Garden, Autumn Garden, Administrative Zone, Greenhouse Complex, Parking Area, Ticket Office, Locker Room and Bike Rental Area, and a Pond. These elements are arranged to form a coherent spatial structure for both domestic and international visitors, while maintaining clear functional differentiation. The plan was developed at a scale of 1:12, where 1 cm on the map corresponds to 12 m in actual distance. In this context, the proposed green infrastructure is intended to support the provision of Alternative Ecosystem Services (AES), particularly during peak tourist seasons. It also reflects ethno-ecological values, linking recreational use with cultural identity and landscape-sensitive planning approaches.

AEEB's concept adopts an integrated tourism planning and sustainability-oriented design approach to develop a conceptual model of an ethno-aul as a cultural tourism destination (Figures 4).

The diagram shows a three-dimensional perspective visualization of an ethno-aul as a key functional element of the AEEB concept integrated into a system of seasonal park spaces. The spatial composition includes traditional yurts grouped around a central public area that performs a cultural and communicative function. Landscaping of the territory is represented by elements of landscape design, including alleys, decorative plantings and buffer green zones, which helps to reduce anthropogenic stress and create a comfortable recreational environment.



Figure 4 Perspective model of the Ethno-aul and seasonal parks

The methodological framework is based on the principles of sustainable tourism development, cultural landscape planning, and visitor experience design, ensuring a balance between cultural preservation, economic viability, and environmental responsibility. The research applies to a functional zoning method combined with a systems approach, where the Ethno-Aul is conceptualized as an interconnected spatial system. Each structural element (yurts, stage, and guest houses) is assigned a specific function contributing to the overall tourism ecosystem. The central performance stage acts as a socio-cultural anchor, supporting the transmission of intangible cultural heritage through performances and public events.

The spatial organization of yurts reflects a thematic clustering strategy aligned with tourism demand and sustainability considerations. A museum yurt is designed to preserve and interpret cultural heritage, contributing to educational tourism. Multiple restaurant yurts, offering both national and international cuisine of Kazakhstan, support gastronomic tourism diversification while distributing visitor flows and reducing spatial congestion. A specialized national cuisine yurt emphasizes local food traditions and promotes the use of regional products, aligning with the principles of sustainable food systems (Figure 5).

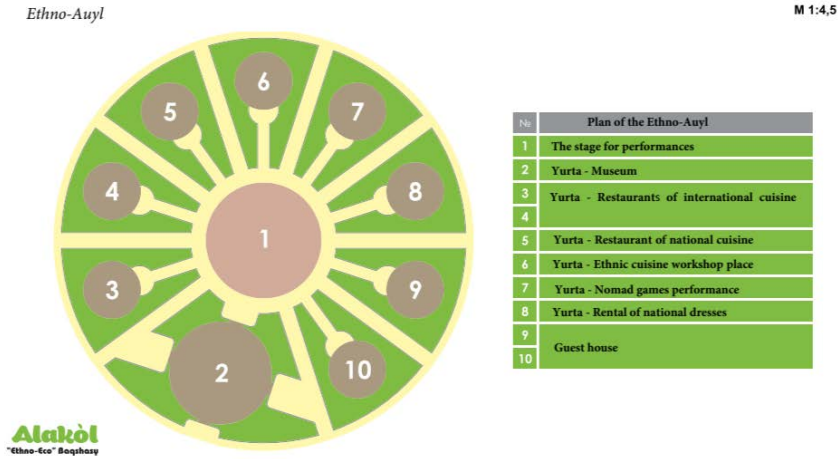


Figure 5 Spatial layout of the ethno-aul with 10 yurts

An ethnic cuisine workshop yurt introduces participatory formats, enabling tourists to engage in hands-on cultural practices, which enhances the experience economy dimension of the destination. The inclusion of a nomadic game's yurt supports the preservation and demonstration of traditional sports, while the national costume rental yurt facilitates immersive and interactive engagement with cultural identity. The accommodation component, represented by guest houses, is integrated into the spatial model to encourage longer visitor stays and increase the economic sustainability of the site. Their placement considers environmental carrying capacity and minimizes potential pressure on core cultural zones.

The overall layout is designed according to principles of sustainable spatial planning, including efficient circulation patterns, balanced distribution of functions, and the reduction of environmental impact. The model incorporates considerations of visitor flow management, resource efficiency, and cultural authenticity, ensuring that both tangible and intangible heritage elements are preserved while maintaining tourism attractiveness (Figure 6).



Figure 6 General view of AEEB

The general view of the park reveals a well-organized spatial structure, the composition emphasizes accessibility and visual coherence, with pathways, greenery, and built features integrated into a unified and balanced environment. All visual materials are used as analytical tools rather than merely descriptive illustrations, supporting the interpretation of spatial organization and functional relationships within the proposed system.

From a spatial perspective, the calculated capacity suggests that the AEEB can function as a regulating element within the tourism system of the destination. The concentration of visitor activity within a planned and functionally organized space creates conditions for the redistribution of tourist flows away from environmentally sensitive shoreline areas. This redistribution reduces the likelihood of uncontrolled anthropogenic pressure on coastal ecosystems, which are particularly vulnerable under conditions of seasonal concentration of tourism. In addition, an important aspect is the compliance of the AEEB with international standards of the Global Sustainable Tourism Standards (GSTC, 2025).

The estimated capacity values also provide a quantitative basis for evaluating the adequacy of internal infrastructure. Given the projected daily flow of 1,200 visits, the relationship between visitor intensity and the provision of pedestrian and cycling space becomes a

critical factor. The alignment between circulation infrastructure and calculated visitor load supports the conclusion that spatial design elements can perform a regulatory function by influencing movement patterns and reducing local congestion within the park area.

The model enhances the multifunctionality of the destination by integrating ecological, cultural, and educational components. This approach supports sustainable tourism development while also generating socio-economic benefits for local communities, including employment opportunities and the promotion of cultural heritage (Figure 7).

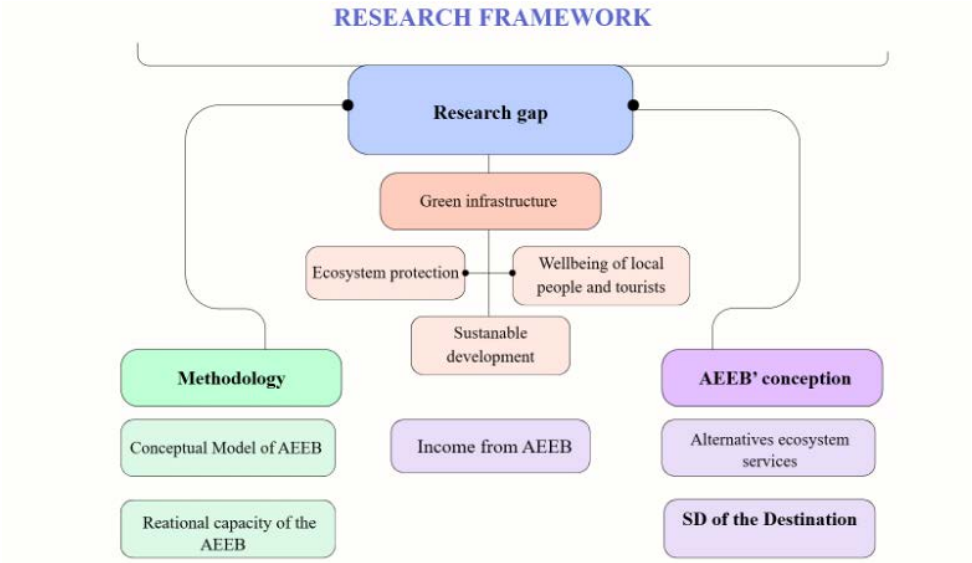


Figure 7 Research framework between the research gap, methodology and AEEB conception

The findings of this study suggest that the AEEB framework can be meaningfully embedded within territorial planning instruments, particularly in the preparation of master plans for the Alakol coastline. Its methodological contribution lies in translating general sustainability principles into spatially defined and functionally differentiated elements. This enables a more nuanced regulation of recreational pressure, supports the preservation of ecosystem integrity, and enhances the overall visitor experience. At the same time, the model treats recreational capacity as a dynamic process shaped by temporal distribution and visitor turnover, rather than as a fixed threshold, which reflects current approaches in destination management.

Furthermore, the results should be interpreted with consideration of methodological limitations. The absence of correction coefficients reflecting environmental conditions, visitor behaviour, and socio-cultural factors introduces a degree of uncertainty into the estimated capacity values. In addition, using a constant turnover coefficient does not account for intra-day variations in visitor intensity during the peak summer period. These factors may lead to a moderate overestimation of actual carrying capacity under real use conditions.

Despite these limitations, the applied approach provides a transparent and internally consistent basis for estimating recreational capacity under conditions of limited empirical data. The results can serve as an initial benchmark for further refinement of the model, including incorporating monitoring data and developing adaptive management mechanisms.

This is particularly relevant for destinations characterized by short and intensive summer tourism periods, where the ability to quantitatively assess and regulate recreational load is a key condition for sustainable territorial development.

5 | CONCLUSION

This study demonstrates that the proposed AEEB concept can be regarded as a viable spatial and managerial framework for sustainable tourism development at the destination level. The results suggest that the model enables the integration of environmental, social, and functional components within a coherent planning approach, contributing to the regulation of recreational pressure, the preservation of ecosystem integrity, and the enhancement of visitor experience.

A key contribution of the study is the understanding of recreational capacity as a dynamic process shaped by temporal distribution and visitor flow, rather than a static spatial constraint. This perspective is consistent with contemporary approaches to destination management and supports a more adaptive understanding of carrying capacity in tourism systems.

The findings also point to several governance-related implications. In particular, the integration of nature-based solutions into planning practices, the prioritization of local community well-being, and the adaptation of the model to specific territorial contexts emerge as critical conditions for sustainable tourism development. In this regard, the AEEB concept can be considered a transferable framework with potential relevance beyond the Alakol region.

The alignment of the proposed model with the Concept for the Development of the Tourism Industry of the Republic of Kazakhstan for 2023–2029 further supports its practical applicability. The framework is consistent with key policy directions, including infrastructure monitoring, capacity building within the tourism sector, the development of sustainable tourist routes, the strengthening of investment mechanisms, and the promotion of environmentally responsible tourism.

Overall, the study contributes to the integration of renaturing, green infrastructure, ecosystem services, recreation, well-being, and rural sustainability within a single analytical framework. While the proposed model demonstrates applicability at the conceptual and planning levels, its implementation in practice requires further empirical validation, particularly regarding long-term environmental and socio-economic outcomes.

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ORIGINAL ARTICLE

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Regional Differences in Social Protection in Kazakhstan: The Role of Payment Levels and Coverage

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Abstract
Regional differentiation of social protection remains one of the key problems of ensuring balanced socio-economic development and reducing inequality. The aim of the study is to assess inter-regional differences in the level of social protection in Kazakhstan and to determine the contribution of the level of payments and coverage of the population to the formation of these differences. The empirical base consists of official data from the Bureau of National Statistics of the Republic of Kazakhstan for the period 2014–2024, covering 17 regions. The research methodology includes the standardization of indicators (Z-score), their time averaging, the construction of an integral index of social protection, cluster analysis with the determination of the optimal number of clusters based on Gap Statistical, as well as multidimensional scaling using Euclidean metrics. The results showed the presence of stable regional differentiation: the values of the integral index range from –0,68 in the North Kazakhstan region to 0,95 in the Turkestan region. High values were also recorded in the East Kazakhstan region (0,72) and Almaty (0,69). Cluster analysis revealed five groups of regions that differ in the combination of payment levels and coverage, which confirms the heterogeneity of the functioning of the social protection system. The results show that an increase in payments has a more significant impact on the level of social protection than an expansion of coverage with a low level of funding, which should be taken into account when shaping regional social policy.

KEYWORDS
Economy, Regional Economy, Regional Differentiation, Economic Efficiency, Social Policy, Public Expenditure, Income Distribution, Cluster Analysis

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1 | INTRODUCTION

Social protection determines the standard of living and reduces the risk of poverty among vulnerable groups by ensuring basic income and reducing social tension. Therefore, social protection is fundamental to societal resilience and helps reduce the gap between different population groups. When sufficiently developed, it creates the conditions for the transition from meeting basic needs to a more sustainable level of well-being.

Social protection creates conditions for people to make economic decisions without the risk of total impoverishment (Norton et al., 2002). The state plays a redistributive role and supports basic living conditions. Social protection ensures a minimum standard of living that the market alone cannot guarantee. People face income loss, illness, and crises, and without a safety net, such shocks lead to a sharp decline in living standards. Most importantly, people maintain access to education and healthcare and remain economically active even during difficult periods.

Cash payments are an important tool of social protection because people often lack a stable income and, without direct financial assistance, cannot cover even basic needs (Slater, 2011). However, questions arise about how to organise payments and who should receive assistance. Paying everyone requires significant expenditure, especially if it is only for those in need; accurately identifying recipients is difficult, leaving some people without support. There is also the issue of conditions: additional requirements can improve outcomes, but they require monitoring resources, which not all countries have. With limited budgets, it is impossible to ensure broad coverage and high accuracy simultaneously.

In many low- and middle-income countries, a significant proportion of people either do not receive support at all or have limited access to it. It is the most vulnerable groups that often fall outside the system. For example, in countries such as Nigeria and Laos, coverage remains extremely low, whereas in Namibia and Botswana it is significantly higher (Schmitt, 2020). Coverage depends directly on the type of program: contributory systems cover only those employed in the formal sector. In contrast, programs without contributory requirements include a much wider range of the population. In settings with high levels of informal employment, this factor becomes crucial, as a significant portion of the population lacks access to insurance mechanisms (Kasteng et al., 2015).

The social protection system in Kazakhstan supports the population and plays a crucial role during economic change and crisis. However, funding in Kazakhstan is lower than in developed countries, and the system is primarily targeted at specific groups of the population who are directly included: pensioners, people with disabilities, large families, the unemployed, and children without parental care. Resources are targeted at those considered the most vulnerable. However, a significant portion of the population with unstable or low incomes may remain outside the system if they do not meet the established criteria. The size of payments is weakly linked to income and wage levels (Tuzubekova et al., 2022). In some cases, social benefits are close to the wages of low-paid workers. In some situations, payments even exceed wages. As a result, the difference between income from work and social support becomes small. At the same time, benefit amounts can vary significantly among individuals with similar labour contributions but different retirement dates or different accrual conditions. Therefore, the level of support is weakly linked to an individual's economic participation. As a result, the social protection system works, but its impact on living standards and income distribution remains limited.

Given the existing differences in the social protection system and the limited impact of payments on living standards, it is important to examine how these differences are formed at the regional level and the role that payment size and population coverage play in this.

The purpose of this study is to assess regional differences in the level of social protection in Kazakhstan and to determine how payment levels and population coverage shape these differences.

2 | LITERATURE REVIEW

The size of social transfers indicates the extent to which government transfers can cover basic household expenses and reduce current vulnerability. Existing studies view transfers as a tool for rapid poverty reduction and consumption growth. According to Fiszbein et al. (2009), cash transfers yield the most significant results when they simultaneously raise households' incomes and encourage them to invest in their children's health and education. Immervoll and Richardson (2011), using OECD countries as an example, showed that even with increased redistribution, market inequality often increases faster than it is reduced. Moreover, social transfers have a stronger impact on reducing inequality than tax instruments. However, Atkinson (2015) showed that the current redistribution system is insufficient and proposed strengthening it through three approaches: increasing child benefits, more progressive taxes, and expanding social support. However, Bastagli et al. (2016) found that low and irregular transfer amounts do not lead to sustainable improvements in living standards. While increased transfers boost consumption, sustainable poverty reduction depends on the size and regularity of transfers, as well as the delivery mechanism. Using African countries as an example, Devereux (2021) showed that during the COVID-19 pandemic, governments most often used two quick fixes: temporarily increasing transfers to existing recipients and expanding the coverage of existing programs. However, a high or increased transfer within an existing program does not guarantee that support will reach everyone who has actually experienced a shock. Thus, in a crisis, even a rapid increase in transfers within existing schemes does not address the problem of new at-risk groups. Therefore, examining the size of social transfers without accounting for who is actually included in the system provides only a partial picture.

Population size determines the proportion of vulnerable groups included in the support system. High payments do not contribute to poverty reduction if the coverage is insufficient. At the same time, expanding coverage without regard to targeting reduces the efficiency of resource allocation. Hanlon (2004) and Barrientos (2016) argued that to combat poverty, a broader population should be included. However, this approach reduces the accuracy of fund distribution, and a significant number of people with more stable incomes are included in the system alongside those experiencing poverty. Therefore, Levy (2009) demonstrated that program targeting can lead to a significant portion of assistance nonetheless reaching target groups. Using the PROGRESA program in Mexico as an example, the author demonstrated that even with precise selection, some people in need remain outside the system because they do not meet the formal criteria. Thus, even with a well-tuned selection system, it is impossible to reach everyone in poverty. Any selection method introduces errors (Devereux et al., 2017). The level of coverage depends on the strictness of the selection criteria. Soft criteria allow more people to be included, but reduce precision. Strict criteria increase precision but reduce the number of beneficiaries. Thus, an increase in the number of beneficiaries does not in itself mean an improvement in the outcome. Even with limited coverage, the system reduces inequality if assistance is targeted to the most vulnerable groups (Niño-Zarazúa, 2019).

The effectiveness of social protection depends on how payment levels and the range of recipients are aligned, as misalignment prevents programs from reducing poverty. Koehler (2011), using transfer programs in South Asian countries as an example, showed that al-

though these programs cover a significant portion of the population, their size remains small (Hanna & Olken, 2018). As a result, households use these funds to cover basic needs and food expenses. However, households are unable to accumulate resources or change their source of income. Consequently, with high coverage, small payments entrench the current situation of recipients and do not change it. However, Barrett and Carter (2013) noted that a household must receive an amount sufficient to move to another level, for example, to invest in production or education. Therefore, the authors argued that it is necessary to establish a payment threshold beyond which income changes. However, the conclusions of Koehler (2011) and Barrett and Carter (2013) that coverage is crucial remain controversial. Gugushvili and Laenen (2021) reached the opposite conclusion: a high level of payments is inefficient, and wider coverage allows for greater redistribution even with moderate payments. Therefore, external factors affect the system, including periods of economic growth or crisis (Wlezien & Soroka, 2021; Busemeyer, 2023).

Social protection is often assessed using composite indices. However, literature lacks a unified approach to constructing such indices. As a result, the same data set can yield different conclusions depending on how the index is constructed. Nardo et al. (2005) view composite indices as the result of a sequential procedure in which each decision alters the final result. The authors noted that a composite index can be a useful tool, but if the design is weak, it produces biased results. An index can be disaggregated by population groups and by individual dimensions (Alkire & Foster, 2011). Decancq and Lugo (2013) emphasised the role of weights, noting that the index's problems begin at the stage of assigning relative importance to dimensions. Each weighting system is based on a specific notion of what is considered more important for well-being. Weights determine the permissible trade-offs between dimensions and indicate how much of one component can compensate for the deficiency of another (Mazziotta & Pareto, 2016). Most of the approaches reviewed construct an index either around multidimensional deprivation in a broad sense or around general rules for aggregation and weighting. However, less developed is the approach that specifically builds an integrated assessment of social protection around the internal structure of the assistance system itself, where a single model must simultaneously reflect the level of support provided and the scale of its distribution. Therefore, further research could fill this gap by developing an index that assesses social protection as a ratio of key parameters of the assistance system itself.

Kazakhstani studies of regional development actively use index-based approaches and territorial grouping methods to identify differences among regions and assess their socioeconomic status. Kuanova et al. (2023) used the index method to assess regional sustainable development. They proposed an aggregate SDI indicator based on GRP per capita, unemployment, poverty, food security, crime rate, education, and environmental pollution. The authors sought to obtain a comparative assessment of the regions and identify leaders and laggards through normalisation, weighting, and ranking. The results showed that regions vary significantly in their levels of sustainability, with poverty being the key differentiating factor. However, this approach does not reveal the contribution of individual factors, nor their relative importance in shaping differences between regions. Uskelenova and Nikiforova (2024) applied a qualitative approach and analysed regional development and the actual state of the economy. However, the quantitative analysis did not identify the significance of individual social and economic policy instruments. Aliyeva et al. (2025) analysed the effectiveness of employment policy, reporting a cluster approach. The analysis was focused on regional employment and showed that the same instruments produce different effects across regions.

Existing studies confirm the presence of pronounced regional differentiation in Kazakhstan and demonstrate the use of index and cluster methods to assess it. However, a general gap remains: an analysis of the significance of individual indicators and instruments, including social policy elements, in shaping these differences is lacking. An assessment of which factors have the greatest impact and how they interact is not provided. This study fills this gap by integrating an index approach with subsequent analytical decomposition of indicators and the use of grouping methods, which allows not only to record differences between regions, but also to determine the contribution of key factors, including social policy parameters, to the formation of the observed structure of regional development.

3 | METHODOLOGY

The choice of indicators is based on a literature review. Fiszbein et al. (2009) and Bastagli et al. (2016) noted that the size of transfers determines households' ability to cover basic expenses and reduce current vulnerability, and that they affect sustainable improvements in well-being. Koehler (2011), Barrett and Carter (2013), Barrientos (2016), and Niño-Zarazúa (2019) noted that the number of recipients reflects the degree of population inclusion in the support system and determines the redistributive effect of social policy. Thus, the choice of indicators is based on identifying two key functions of social policy: the volume of payments and population coverage. Accordingly, the analysis includes indicators reflecting both components: the average size of social payments and the volume of targeted social assistance characterise the level of cash transfers, while the number of pensioners and recipients of targeted assistance reflects the scale of population coverage.

The use of these indicators is motivated by their direct reflection of the parameters used to assess social protection quantitatively. The average size of social payments and the volume of targeted social assistance are used to assess the level of financial support and its sufficiency to cover basic expenses, which is considered a key criterion for the effectiveness of transfers (Immervoll & Richardson, 2011; Atkinson, 2015). The number of pensioners and recipients of targeted assistance is used to assess the degree of population coverage and the scale of inclusion in the system, as it determines the distributional effects and the scope of social policy (Devereux et al., 2017; Levy, 2009). Thus, assess social protection through two measurable parameters, the level of payments and the scale of their distribution, enabling a quantitative analysis of regional differences.

Table 1 presents the initial data for the selected indicators for 2014–2024.

Table 1 Social protection indicators

No.	Code	Indicator	Measurement Unit
1	Z_BEN	Average monthly social benefits	tenge
2	Z_PEN	Number of pension beneficiaries	persons
3	Z_ASP_AMT	Average monthly targeted social assistance	tenge
4	Z_ASP_REC	Number of targeted social assistance beneficiaries	persons

Note: compiled by the authors based on Bureau of National Statistics (2025).

The study aims to identify differences between regions in the level of social protection, evaluate the balance between payment amounts and population coverage, and identify groups of regions with similar characteristics. Additionally, the objective is to present the results visually to identify regional differences. The research design is presented in Figure 1.

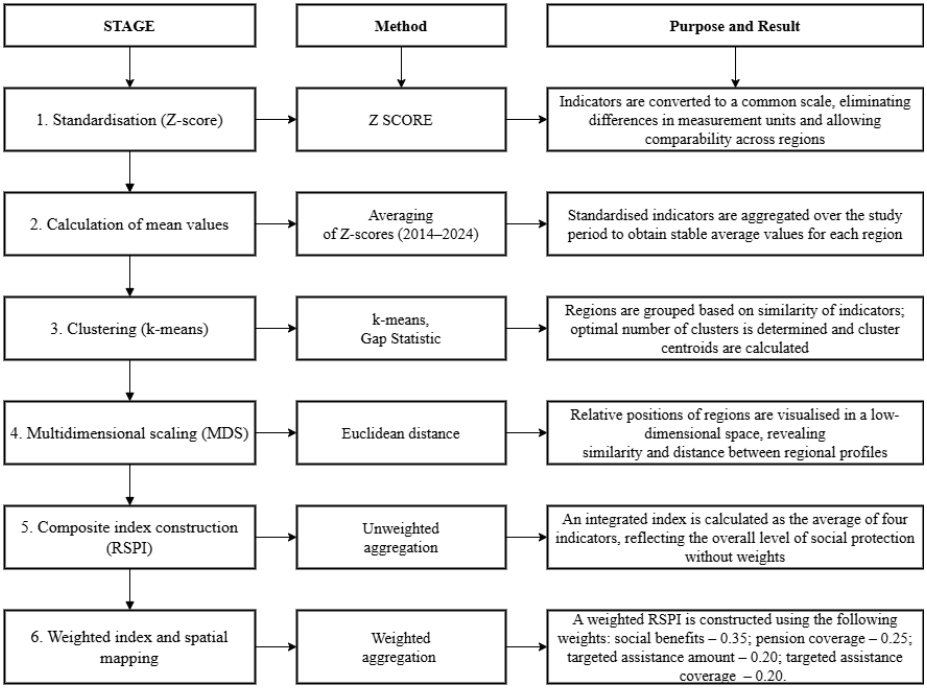


Figure 1 Research design

At the first stage, to achieve the research objectives, the methodology consists of several sequential steps. The initial step involves data preparation through the standardisation of indicators using Z-scores, which ensures comparability by transforming all variables to a common scale. The Z-score is calculated according to formula (1):

$$Z_{it} = \frac{X_{it} - \mu_t}{\sigma_t} \tag{1}$$

where:

X_{it} – the value of one of the social protection indicators for region i in year t, including the amount of social benefits (BEN), the number of pensioners (PEN), the amount of targeted assistance (ASP_AMT), or the number of recipients (ASP_REC);

μ_t – the average value of the corresponding indicator for all year t, calculated separately for each indicator (BEN, PEN, ASP_AMT, ASP_REC);

σ_t – the standard deviation by region in year t for the corresponding indicator, reflecting the degree of variation between regions for each indicator.

At the second stage, the standardised indicators are aggregated over the entire observation period by calculating their average values. This step involves temporal aggregation and the construction of an integrated measure reflecting the overall level of social protection. The calculation is performed according to formula (2):

$$\overline{Z}_i = \frac{1}{T} \sum_{t=1}^{T} Z_{it} \tag{2}$$

where:

$\overline{Z}_i$ – the average standardised value of a given indicator for region i over the entire observation period;

Z_{it} – the standardised value (Z-score) of the indicator for region i in year t;

T – the number of years in the observation period.

At the third stage, a k-means cluster analysis was performed. The optimal number of clusters, k, was determined using the Gap Statistic. The partitioning procedure is based on minimising the within-cluster variance according to formula (3):

$$\sum_{k=1}^{K} \sum_{i \in C_k} \|x_i - \mu_k\|^2 \to \min \tag{3}$$

where:

K – the total number of clusters;

C_k – the set of observations (regions) assigned to cluster k;

x_i – the vector of standardised indicators for region i;

μ_k – the centroid (mean vector) of cluster k.

The centroid is defined as the average value of the indicators within the cluster. At the fourth stage, multidimensional scaling (MDS) was applied to analyse the relative positioning of regions. Distances between regions were calculated using the Euclidean metric according to formula (4):

$$d_{ij} = \sqrt{\sum_{m=1}^{M} (x_{im} - x_{jm})^2} \tag{4}$$

where:

d_{ij} – the Euclidean distance between regions i and j;

x_{im}, x_{jm} – the values of indicator m for regions i and j, respectively;

M – the total number of indicators included in the analysis.

At the fifth stage, an integrated social protection index is constructed. The index values are visualised on a map, enabling the identification of regional differences in social protection levels. The index is calculated as the arithmetic mean of four standardised indicators according to formula (5):

$$\text{RSPI}_i = \frac{Z_{BEN,i} + Z_{PEN,i} + Z_{ASP_AMT,i} + Z_{ASP_REC,i}}{4} \tag{5}$$

where:

RSPI_i – the Regional Social Protection Index for region i;

$Z_{BEN,i}$ – the average standardised value of social benefits for region i;

$Z_{PEN,i}$ – the average standardised value of the number of pensioners for region i;

$Z_{ASP_AMT,i}$ – the average standardised value of targeted social assistance amount for region i;

$Z_{ASP_REC,i}$ – the average standardised value of the number of targeted social assistance recipients for region i.

The results of the RSPI calculation are visualised using a spatial distribution map, allowing for the identification of regional differences in social protection levels. At the sixth stage, in addition to the base model, an alternative map was constructed in which indicators were aggregated according to their respective weights. For this purpose, each indicator was assigned a weight: benefit amount (Z_{BEN}) – 0.35; pension coverage (Z_{PEN}) – 0.25; targeted

assistance amount (Z_{ASP_AMT}) – 0.20; and targeted assistance coverage (Z_{ASP_REC}) – 0.20. The integrated indicator was calculated as a weighted sum of the standardised values (6):

$$\text{RSPI}_i = 0.35 \times Z_{BEN} + 0.25 \times Z_{PEN} + 0.20 \times Z_{ASP_AMT} + 0.20 \times Z_{ASP_REC} \quad (6)$$

This alternative specification allows accounting for the heterogeneous contribution of indicators to the overall assessment and enables testing the robustness of the results with respect to changes in the index structure.

Thus, the proposed methodology is a consistent multi-step approach, including the standardization of indicators, their aggregation, the construction of an integrated index, and the use of cluster analysis and multidimensional scaling methods. The use of Z-normalization ensures comparability across indicators, while time averaging helps offset short-term fluctuations and identify persistent regional differences. The inclusion of spatial visualization complements quantitative analysis and provides visual identification of regional differentiation. Together, the applied methods form a holistic analytical toolkit for assessing the level of social protection and interregional differences.

4 | RESULTS

The results of the Z-score analysis show that some regions have high payment levels, while others have high population coverage, though the two characteristics rarely coincide. The social protection system operates unevenly: either a broad segment of the population receives limited support, or payments are higher, but coverage is lower.

Table 2 presents standardized values of the average monthly amount of state social benefits by region for 2014–2024.

Table 2 Average monthly amount of state social benefits (Z-score)

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Akmola	-1,44	-1,41	-1,45	-1,36	-1,52	-1,48	-1,56	-1,57	-1,47	-1,43	-1,31
Aktobe	-0,49	-0,54	-0,25	-0,26	-0,30	-0,18	-0,12	-0,01	0,25	0,33	0,31
Almaty	0,22	0,15	0,23	0,13	-0,03	-0,08	0,00	0,01	0,16	0,17	0,17
Atyrau	0,15	-1,20	0,18	0,23	-0,08	-0,10	-0,05	0,10	-0,31	-0,71	-0,73
West Kazakhstan	-0,49	0,46	-0,30	-0,22	-0,14	-0,07	-0,09	-0,22	-0,51	-0,43	-0,32
Zhambyl	1,16	1,32	1,14	1,04	0,86	0,74	0,66	0,47	0,44	0,50	0,52
Karaganda	-0,08	0,04	-0,33	-0,55	-0,86	-1,03	-1,09	-1,30	-1,00	-1,12	-1,22
Kostanay	-1,57	-1,03	-1,55	-1,45	-1,70	-1,59	-1,61	-1,55	-1,40	-1,47	-1,47
Kyzylorda	1,21	1,00	1,03	0,83	0,42	0,30	0,28	0,21	-0,06	0,24	0,35
Mangistau	1,95	1,73	1,97	1,99	1,51	1,59	1,50	1,48	1,60	1,51	1,33
Pavlodar	-0,69	-0,73	-0,57	-0,59	-0,59	-0,57	-0,44	-0,47	-0,47	-0,46	-0,45
North Kazakhstan	-1,49	-1,86	-1,64	-1,89	-1,62	-1,65	-1,69	-1,68	-1,51	-1,33	-1,34
Turkestan	0,96	0,83	1,01	1,11	0,88	0,97	0,99	0,96	0,93	1,22	1,19
East Kazakhstan	-0,55	-0,15	-0,64	-0,28	0,96	0,99	0,99	0,88	-0,10	-0,17	-0,25
Astana c.	-0,40	-0,30	-0,39	-0,33	-0,11	-0,08	0,02	0,46	0,69	0,59	0,66
Almaty c.	0,57	0,87	0,55	0,50	0,72	0,64	0,59	0,66	0,67	0,55	0,43
Shymkent c.	0,96	0,83	1,01	1,11	1,59	1,61	1,62	1,59	2,09	2,00	2,14

Note: compiled by the authors based on the Bureau of National Statistics (2025).

The overall trend shows stable regional differences. Differences are observed between regions, with some cases recording year-over-year changes in values. Some regions consis-

tently remain below average. These include the Akmola Region, with values ranging from –1.3 to –1.5, and the North Kazakhstan Region, with values ranging from approximately –1.8 to –1.3. Values remain below average throughout the period. In Mangystau, the values consistently range from 1.5 to 2.0, and in Zhambyl, from 0.4 to 1.3; both regions maintain positive values throughout the period. Values consistently exceed the average. Shymkent stands out, with values exceeding 2.0 since 2018, making it the region with the highest values. Additionally, a group of regions with values close to zero (Almaty, Pavlodar, West Kazakhstan) is distinguished, where fluctuations around the average level are observed without a stable deviation in the positive or negative direction, as well as regions where a change in position occurs over time, moving from negative to positive values.

Table 3 presents standardized values of the number of pension recipients by region for the period under review.

Table 3 Regional distribution of pension recipients (Z-score)

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Akmola	-0,22	-0,24	-0,26	-0,29	-0,28	-0,31	-0,33	-0,35	-0,23	-0,27	-0,31
Aktobe	-0,64	-0,64	-0,63	-0,63	-0,61	-0,62	-0,62	-0,62	-0,55	-0,55	-0,55
Almaty	1,25	1,29	1,33	1,37	1,61	1,65	1,71	1,75	0,68	0,72	0,76
Atyrau	-1,15	-1,15	-1,15	-1,15	-1,18	-1,19	-1,19	-1,19	-1,31	-1,31	-1,30
West Kazakhstan	-0,64	-0,64	-0,65	-0,66	-0,67	-0,68	-0,69	-0,70	-0,67	-0,68	-0,68
Zhambyl	-0,15	-0,14	-0,14	-0,14	-0,07	-0,07	-0,07	-0,08	0,17	0,18	0,18
Karaganda	1,28	1,25	1,21	1,18	1,32	1,29	1,25	1,23	1,23	1,18	1,11
Kostanay	0,16	0,14	0,11	0,08	0,13	0,10	0,08	0,04	0,28	0,24	0,19
Kyzylorda	-0,94	-0,93	-0,93	-0,93	-0,94	-0,94	-0,94	-0,93	-0,97	-0,96	-0,95
Mangistau	-1,30	-1,29	-1,29	-1,28	-1,31	-1,30	-1,29	-1,29	-1,44	-1,41	-1,39
Pavlodar	-0,16	-0,18	-0,19	-0,22	-0,20	-0,21	-0,24	-0,26	-0,11	-0,14	-0,17
North Kazakhstan	-0,35	-0,37	-0,39	-0,42	-0,42	-0,45	-0,47	-0,51	-0,46	-0,51	-0,56
Turkestan	1,51	1,55	1,59	1,65	0,65	0,69	0,71	0,76	1,35	1,40	1,44
East Kazakhstan	1,73	1,69	1,66	1,63	1,81	1,78	1,75	1,71	0,39	0,27	0,20
Astana c.	-0,91	-0,87	-0,82	-0,75	-0,64	-0,56	-0,49	-0,40	-0,12	0,03	0,20
Almaty c.	1,40	1,42	1,43	1,44	1,64	1,66	1,67	1,68	2,55	2,57	2,58
Shymkent c.	-0,88	-0,88	-0,88	-0,87	-0,86	-0,85	-0,84	-0,83	-0,81	-0,78	-0,75

Note: compiled by the authors based on the Bureau of National Statistics (2025).

The trend has been stable over the years, with values for most regions remaining within similar ranges. The highest values are observed in Almaty city, where the indicator exceeds 2.5, and in the East Kazakhstan, where it ranges from approximately 1.6 to 1.8. These regions have maintained positive value throughout the period. The lowest values are recorded in the Mangystau (from –1.3 to –1.4) and the Atyrau (from –1.1 to –1.3), where values remain consistently negative. An additional group of regions with consistently positive values (Almaty, Karaganda, Turkestan, and East Kazakhstan) stands out, in which indicators exceed the average level throughout the period. A group of regions with values close to zero (Kostanay, Zhambyl, and Pavlodar) exhibits minor fluctuations around the average level without sustained deviations. However, in some regions, a transition from negative to positive values has been observed in recent years.

Table 4 presents standardized values of the amount of targeted social assistance by region.

Table 4 Regional distribution of targeted social assistance amount (Z-score)

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Akmola	-0,38	0,21	-0,09	0,13	-1,00	-0,67	-0,91	0,00	0,31	0,11	0,93
Aktobe	0,34	0,33	-0,66	-0,87	-0,73	-0,07	-1,00	-1,07	-0,95	-0,99	-0,23
Almaty	0,74	0,94	1,16	0,82	-0,12	0,13	0,94	0,73	0,58	0,45	-0,53
Atyrau	0,49	0,38	0,28	-0,25	0,17	-1,25	-0,35	-0,79	-1,03	-0,77	0,67
West Kazakhstan	0,41	0,31	0,63	0,95	-0,16	-0,60	-0,61	-0,95	-1,08	-1,50	-1,31
Zhambyl	-0,50	-0,73	-0,33	0,07	-0,86	0,71	-0,96	-1,31	-0,29	-0,15	-0,69
Karaganda	0,11	-0,07	0,07	0,04	-0,14	0,38	-0,39	-0,42	-0,94	-0,68	-0,65
Kostanay	0,43	0,32	0,25	0,37	-0,44	-1,50	-0,41	0,73	0,61	-0,20	0,81
Kyzylorda	-1,14	-1,47	-0,81	0,00	0,08	2,17	-0,25	0,03	-0,12	-0,34	-0,79
Mangistau	0,69	-0,83	0,49	0,56	0,31	0,68	0,47	0,28	0,77	2,02	1,84
Pavlodar	0,46	0,40	0,02	0,24	-0,41	-0,72	-0,27	0,90	1,30	0,87	0,20
North Kazakhstan	-0,40	-0,17	0,17	0,19	-0,70	-1,44	-0,58	-0,48	-0,26	-0,35	0,06
Turkestan	-1,26	0,95	-0,74	-0,31	3,48	-0,43	-1,37	-1,93	-1,49	-1,43	-2,13
East Kazakhstan	1,20	1,16	1,34	1,47	0,21	-0,16	0,67	1,43	1,26	0,78	0,04
Astana c.	-0,50	-0,79	-1,07	-1,27	-0,42	0,99	1,57	1,45	1,73	1,86	1,55
Almaty c.	1,75	1,49	1,76	0,78	0,55	0,62	1,88	1,14	0,75	0,45	0,18
Shymkent c.	-2,41	-2,45	-2,46	-2,92	0,18	1,17	1,58	0,27	-1,16	-0,13	0,06

Note: compiled by the authors based on the Bureau of National Statistics (2025).

Values for targeted social assistance vary significantly year over year and between regions. The highest values are recorded in the Mangistau region (2.0+) and, in some years, up to 2.1 in the Kyzylorda region. In Mangistau, values exceed 2.0 in some years, while in the Kyzylorda region, values increased to 2.17 in 2019. The lowest values are observed in the West Kazakhstan region (from –1.3 to –1.5), while the lowest value is recorded in the Turkestan region (up to –2.13), where values reach minimum levels. There is a significant gap in payment amounts across regions, with differences exceeding 4 standard deviations. Regions with highly variable values (Turkestan, Kyzylorda, Mangistau) are additionally distinguished, while in several regions (Karaganda, Zhambyl), values remain closer to zero without noticeable dynamics.

Table 5 presents standardized values of the number of recipients of targeted assistance.

The overall trend reveals differences between regions; values vary by region and by year. The highest values are observed in the Turkestan region, where the indicator reaches 3.5 and remains above 2.5 for several years. In the Turkestan region, values exceed 3.0 and remain above 2.5 for several years. High values are also recorded in East Kazakhstan region (2.1) at the beginning of the period. In East Kazakhstan region, values reach around 2.0 at the beginning of the period, then decrease. The lowest values are found in the Pavlodar region (from –1.1 to –0.3) and the Akmola region (from –1.1 to –0.6), where values remain negative throughout the period. Regions with changing values (Turkestan, Shymkent) are additionally distinguished, where a transition to positive values is observed. In contrast, in several regions (Akmola, Aktobe, Pavlodar), values remain below average.

Table 5 Regional distribution of targeted social assistance recipients (Z-score)

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Akmola	-0,97	-1,11	-0,96	-0,99	-0,47	-0,58	-0,69	-0,66	-0,60	-0,59	-0,62
Aktobe	-1,41	-1,44	-1,35	-1,28	-0,30	-0,25	-0,36	-0,40	-0,24	-0,26	-0,26
Almaty	0,62	0,99	1,27	1,42	0,55	1,01	0,69	0,83	0,45	0,58	0,59
Atyrau	-0,26	0,40	0,92	0,73	-0,50	-0,61	-0,76	-0,72	-0,72	-0,71	-0,76
West Kazakhstan	0,27	0,43	0,50	0,16	-0,37	-0,48	-0,51	-0,54	-0,50	-0,56	-0,59
Zhambyl	1,28	0,89	0,46	0,24	0,90	0,45	0,25	0,05	0,21	0,30	0,46
Karaganda	1,16	1,28	1,30	1,50	-0,50	-0,46	-0,52	-0,57	-0,60	-0,62	-0,69
Kostanay	-0,07	0,09	0,26	0,22	-0,43	-0,54	-0,54	-0,53	-0,41	-0,41	-0,52
Kyzylorda	-0,27	-0,42	-0,78	-0,91	0,13	0,18	0,23	0,21	0,61	0,49	0,56
Mangistau	0,41	0,00	0,41	0,39	-0,53	-0,51	-0,56	-0,51	-0,40	-0,38	-0,32
Pavlodar	-1,06	-1,13	-1,08	-0,96	-0,59	-0,58	-0,54	-0,52	-0,40	-0,38	-0,32
North Kazakhstan	1,02	0,23	0,21	0,13	-0,55	-0,71	-0,75	-0,69	-0,67	-0,69	-0,75
Turkestan	0,78	1,14	-0,21	-0,31	3,57	3,42	2,88	2,62	3,51	3,52	3,37
East Kazakhstan	1,90	1,89	2,00	2,12	-0,04	-0,21	-0,01	-0,08	-0,51	-0,55	-0,60
Astana c.	-1,00	-0,87	-0,32	-0,06	-0,64	-0,59	-0,51	-0,49	-0,42	-0,39	-0,38
Almaty c.	-1,33	-1,32	-1,28	-1,13	-0,68	-0,45	-0,43	-0,44	-0,30	-0,29	-0,31
Shymkent c.	-1,06	-1,04	-1,34	-1,28	0,44	0,90	2,13	2,44	1,00	0,93	1,12

Note: compiled by the authors based on the Bureau of National Statistics (2025).

Figure 2 presents the results of determining the optimal number of clusters using the Gap Statistic method, where the maximum value indicates the most feasible number of groupings.

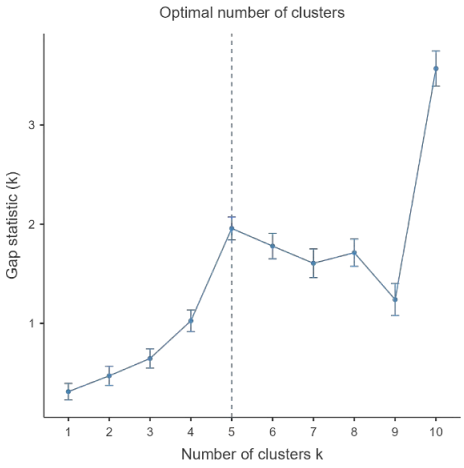


Figure 2 Determining the optimal number of clusters based on Gap Statistic

Based on the K-means analysis, the optimal number of clusters is five. The Gap Statistic

increases, then decreases, as the number of clusters increases. After five clusters, values begin to fluctuate and decline, indicating excessive detail without a significant improvement in clustering quality. Table 6 presents the cluster centroids, reflecting the average indicator values for each group of regions, allowing us to identify differences in payment levels and the scale of social support coverage.

Table 6 Centroids of clusters

No.	Z_BEN_avg	Z_PEN_avg	Z_ASP_AMT_avg	Z_ASP_REC_avg
1	-0.085	37622.000	0.305	-0.300
2	21003.500	-1.070	0.045	0.105
3	1.000	44927.000	-0.970	44228.000
4	-0.425	-0.481	-0.161	-0.317
5	0.125	14429.000	0.580	0.680

Note: compiled by the authors.

Cluster centroids reflect differences between regional groups in terms of payment levels and population coverage, based on standardised indicators. The first cluster is characterised by values close to the average for most indicators, with a slightly positive value of Z_ASP_REC_avg (0.305) and negative values for Z_BEN_avg (–0.085) and Z_ASP_AMT_avg (–0.300), indicating moderate payment levels combined with below-average coverage. The second cluster is characterised by a relatively high value of Z_PEN_avg (–1.070) and values close to zero for other indicators, suggesting average payment levels with limited population coverage. The third cluster demonstrates the highest values across most indicators, with Z_BEN_avg (1.000) and Z_ASP_AMT_avg (–0.970), indicating a combination of high payment levels and relatively strong financial support. The fourth cluster shows negative values for all indicators, reflecting the lowest levels of both payments and coverage. The fifth cluster is characterised by moderately positive values, indicating a balanced combination of relatively higher payments and broader population coverage.

Figure 3 shows the relative positions of regions based on the degree of similarity in social indicator values, with close points indicating similar payment and coverage levels and distant points indicating significant differences.

The multidimensional scaling Plots show the distances between regions based on selected indicators, with proximity indicating similarity in levels of social support and population coverage, and distance indicating differences. Groups located close together are characterised by similar benefit values and recipient numbers, indicating comparable access to social assistance. In such regions, the daily situation for the population appears similar: support levels are predictable, requests for assistance occur regularly, and the burden on the system is evenly distributed. Regions remote from the main group differ in the number of recipients. A significant share of the population depends on social assistance. Due to high volumes, daily issues arise that affect the overall responsiveness of government agencies. There are more requests and longer queues. Moreover, the benefits may not meet demand, and the coverage of basic expenses is limited. In the opposite situation, when population values are low and benefits are higher, assistance is received by a smaller proportion of the population. Still, the amount of support allows for a wider range of needs. There is a more stable standard of living for recipients and less pressure on the system.

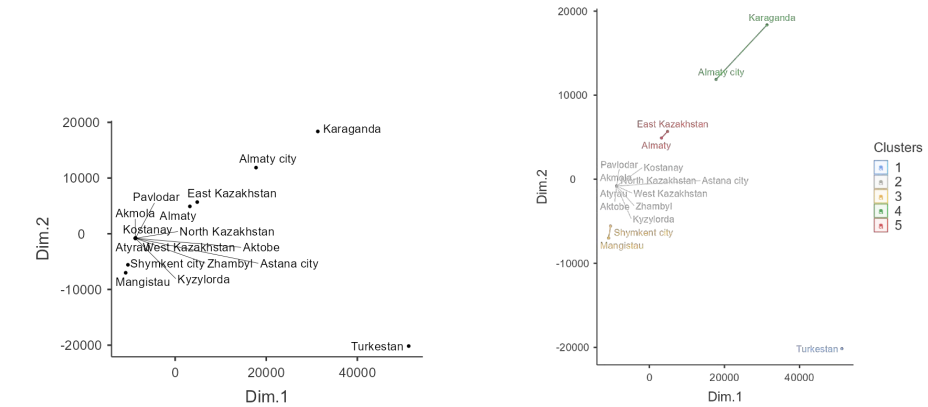


Figure 3 Multidimensional scaling of regions by social protection indicators

Next, a distribution map of social protection levels across regions was constructed from the aggregated index. The results revealed the following. First, regions with higher integrated levels of social support, as indicated by positive index values, were identified. Stable coverage of basic expenses and more accessible access to assistance. Second, areas with lower index levels are observed, with negative values indicating either below-average payments or limited coverage. Some households receive less support or face limited access to programs. Third, the map reveals unevenness between regions. Eligibility for social assistance depends not only on income but also on location, as regions with below-average values may be located nearby.

Figure 4 shows the distribution of the integrated social protection index by region, calculated from the average values of four indicators to assess differences in payment levels and social support coverage.

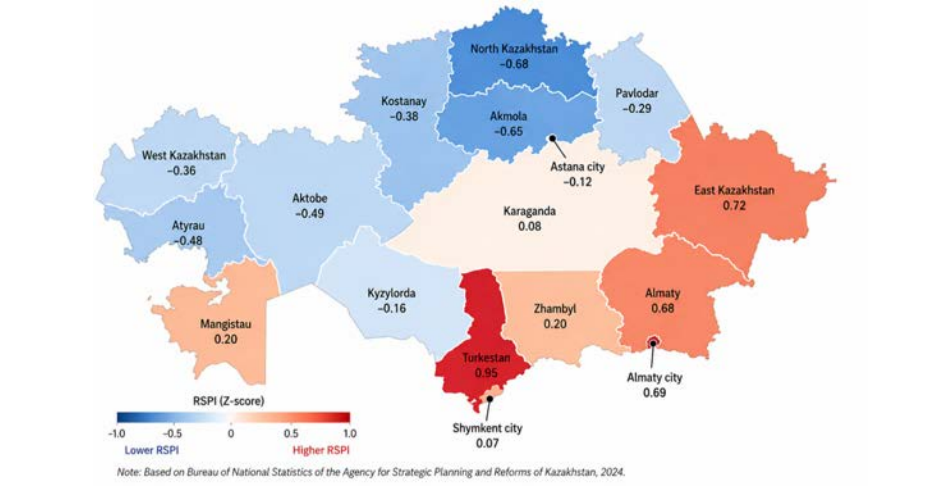


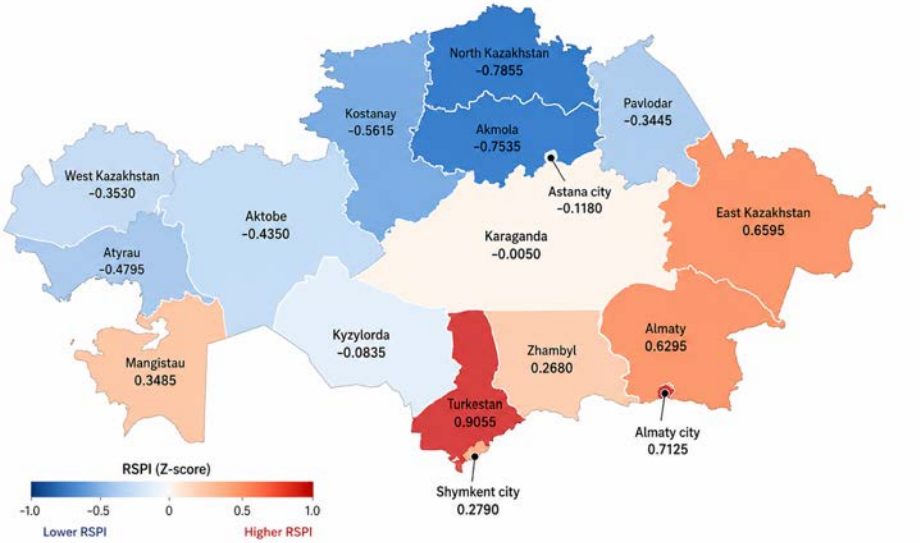
Figure 4 Regional distribution of the RSPI in Kazakhstan (average values, 2014–2024)

The RSPI distribution shows that regions vary significantly in their levels of social support. The highest values are observed in Turkestan (0.95), East Kazakhstan (0.72), Almaty city (0.69), and the Almaty region (0.68). Social assistance covers a significant portion of the population or is accompanied by higher payments. Benefit receipt is more frequent, payments are more stable, and reliance on informal sources of income is lower. Households can cover basic expenses through government transfers.

The next group includes the Zhambyl and Mangystau (0.2 each), Karaganda (0.08) and Shymkent city (0.07). Here, the values are close to each other and remain within the moderate range. In these regions, social assistance is present but does not play a dominant role. For example, payments supplement family income, but do not form its basis.

Negative values are recorded in Kyzylorda (0.16), Astana city (0.12), Pavlodar (0.29), Kostanay (0.38), West Kazakhstan (0.36), Atyrau (0.48), Aktobe (0.49), and Akmola (0.65). The lowest value is observed in North Kazakhstan (0.68). In these regions, payments and coverage are lower. They have a limited number of recipients or lower amounts of assistance. Families often rely on wages or assistance from relatives, with social benefits serving a supporting role.

In the Turkestan region, the high index is due to a significant number of recipients and a lower number of payments. Assistance is distributed among a large number of households, but its volume remains limited. Consequently, regular payments are sufficient to cover basic expenses without creating a reserve. A different situation is observed in the northern regions, including North Kazakhstan, Akmola, and Aktobe Oblasts, where the index values remain negative. Here, coverage is narrower, and payments are lower. Under these circumstances, some members of the population are either not included in the support system or receive minimal support.



Note: Based on Bureau of National Statistics of the Agency for Strategic Planning and Reforms of Kazakhstan, 2024.

Figure 5 Weighted RSPI across regions of Kazakhstan (average values, 2014–2024)

The final score is sensitive to the index structure and the distribution of indicator impor-

tance, as the introduction of weights exacerbated differences between regions. Weighing the indicators revealed that the final index is primarily determined by components related to payment amounts. The Z_BEN indicator, with the highest weight, accounts for the bulk of the result: regions with high payment values experience an increase in the final index even with weak coverage. Z_ASP_AMT has a similar, but less pronounced, effect; the amount of assistance can partially compensate for the limited population coverage.

The coverage indicators (Z_PEN and Z_ASP_REC), despite their significance, have a weaker impact on the final score. Even with high coverage values, their contribution is limited if the payment amount remains low. In such cases, the overall index does not increase, since the contribution of these indicators does not offset the weak values of the more significant components. As a result, an asymmetry of influence is observed: payment indicators act as an amplifying factor, while coverage indicators more often serve a corrective function. There is a compensatory effect: a high level of disbursements can improve the final assessment, whereas high coverage without sufficient funding does not yield a similar result.

The highest values in key indicators that determine the overall score are observed in the Turkestan region (0.9055), Almaty city (0.7125), East Kazakhstan (0.6595), and Almaty region (0.6295). Mangistau (0.3485), Shymkent (0.279), and Zhambyl (0.268) form a middle group in which the indicators are not equally strong.

Weak regions are formed by a combination of negative values for most indicators: North Kazakhstan (–0.7855) and Akmola (–0.7535) have all components below average, resulting in a minimal overall result; Kostanay (–0.5615) also remains in this group, but its position is slightly better due to less pronounced deviations; Atyrau (–0.4795) and Aktobe (–0.435) show moderately low values without sharp dips, making their positions less consistently weak; Karaganda (–0.005) and Kyzylorda (–0.0835) are near zero, as the positive and negative values of the indicators overlap, indicating the presence of individual strong components and the potential for rapid growth if they strengthen.

Thus, the weighting structure indicates that the final assessment is sensitive to the financial aspect of the social protection system, whereas coverage parameters only improve the result when payments are sufficiently high.

5 | CONCLUSION

The results showed that, in some regions, social benefits remain consistently below average, particularly in the north. In terms of the number of pensioners. Higher numbers of pensioners characterise large cities and eastern regions. Therefore, the burden on the payment system in these regions is also higher. The targeted assistance is less stable. The concentration of recipients is particularly pronounced in the Turkestan region, where support accounts for a significant share of the population.

The results also revealed that the social support system varies by region. Thus, a large number of recipients are not associated with higher payments. Conversely, if payments are higher, the coverage is smaller. In some regions, many recipients receive assistance, but the amounts are limited. In some regions, families receive small but regular support; in others, assistance is higher, but access is limited. The Turkestan region stands out for its high coverage at low payments. In northern regions, both coverage and benefits are lower.

The resource distribution system needs to be reviewed. In regions with high burdens, it would be appropriate to strengthen employment measures to reduce dependence on benefits. In regions with low coverage, access conditions need to be reviewed. The government policy should consider developing a mechanism for redistributing resources between

regions to equalise support conditions and reduce disparities. Some financial flows from higher-income regions could be directed to areas with high social burdens.

However, public policy should recognise that strengthening one parameter does not yield sustainable results. Therefore, measures should be developed in a differentiated manner. In regions with systematically low values, it is necessary to increase payment sizes and expand coverage simultaneously. In regions with moderately weak positions, priority should be given to increasing financial support, as this component has a stronger impact on the final assessment. In regions with mixed indicators, it is advisable to selectively strengthen the weakest parameter to allow for faster improvement in the overall situation.

AUTHOR CONTRIBUTION

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Software and Supervision: Saltanat S. Rakymzhanova, Parida B. Issakhova.
Data Collection, Analysis, and Interpretation: Parida B. Issakhova, Nadiya M. Sabitova.
Visualization: Saltanat S. Rakymzhanova, Parida B. Issakhova, Nadiya M. Sabitova.
Writing – Review and Editing: Saltanat S. Rakymzhanova.

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ORIGINAL ARTICLE

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Regional Differentiation of Small and Medium Business Development in Kazakhstan

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Abstract
The development of small and medium-sized businesses is considered one of the key factors for ensuring economic growth, employment, and sustainable regional development. The purpose of the study is to identify the structure of regional development among small and medium-sized businesses in Kazakhstan and to identify groups of regions with different levels of entrepreneurial activity. The methodological basis of the study includes data standardization using the Z-score method, principal component analysis (hereinafter – PCA) and cluster analysis using the Ward method. The study uses data from the Bureau of National Statistics for the period 2018-2024. The results of the study revealed significant interregional differences in the development of small and medium-sized businesses. The highest values of the indicators were recorded in the cities of Almaty and Astana. Thus, in Almaty, the standardized values for gross value added, output, employment, and the number of enterprises were 3.22, 3.11, 3.59, and 2.92, respectively. In Astana, the corresponding figures were 1.76, 1.92, 1.53, and 1.70. Cluster analysis identified two stable clusters of regions, with an intercluster sum of squares of 62.94 and a total sum of squares of 80.71, indicating high interregional differentiation. The results of the study showed that growth in the number of enterprises is not accompanied by proportional increases in output, employment, and value added, indicating structural heterogeneity in the development of small and medium-sized businesses across regions of Kazakhstan.

KEYWORDS
Enterprise, Entrepreneurial Activity, Business Environment, Employment, Economic Activity, Regional Policy

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1 | INTRODUCTION

Modern economic development is accompanied by the strengthening of the role of small and medium-sized businesses as key factors in economic growth, employment, and regional sustainability. Small and medium-sized businesses help create a competitive environment, contribute to economic diversification and the development of local markets, and increase the flexibility of the economic system. In the context of increasing spatial differences, the study of regional features in the development of small and medium-sized businesses is of particular importance, since the level of entrepreneurial activity, the scale of production, employment, and the contribution of businesses to the regional economy vary significantly across territories.

The development of small and medium-sized businesses is considered a key factor in sustainable economic growth. SME development is particularly important in generating employment and increasing the flexibility of national economies. SME development facilitates the redistribution of resources, the development of local markets, and the emergence of new economic trends. However, evidence from Kazakhstan shows that the expansion of SMEs does not always correspond to a proportional increase in their contribution to economic output, indicating structural imbalances within the sector (Zamanbekov et al., 2020).

International organisations, including the World Bank and the OECD, view the development of SMEs as a key element of sustainable economic growth. First, it ensures the diversification of production markets. Second, a significant portion of employment is generated by the SME sector, especially at the regional level. Third, the economy's adaptability to external shocks increases due to enterprise flexibility. Fourth, it promotes the development of territories outside major economic centres. In Kazakhstan, this process is characterised by significant regional disparities, with pronounced differences in economic activity and development levels across regions (Sermagambet et al., 2022).

The experience of various countries shows that a combination of institutional, spatial, and industry factors determines SME development. In Germany, the SME development model is distinguished by its role as the foundation of industrial and export activity, driven by a high proportion of Mittelstand-type enterprises focused on narrow, specialised markets and long-term development. Approximately 99% of companies are classified as SMEs and account for 68% of exports (Parella & Hernández, 2018). Moreover, regions with a higher proportion of SMEs exhibit higher innovation activity (Berlemann & Jahn, 2016). In Brazil, the SME sector makes a strong contribution to local employment, accounting for 98.5% of all companies, approximately 27% of GDP, and 54% of employment (Machado et al., 2018). In South Korea, SME development is strongly supported by the government through financing, concessional lending, and development programs (Kang, 2023).

Despite the growing body of research on SME development, limited attention has been paid to the structural differentiation of SME indicators at the regional level using a unified system of comparable metrics. Existing studies mainly focus on individual indicators without analysing their joint variation across regions. Therefore, it is important to analyse the structure of SME development at the regional level and identify groups of regions with different levels of entrepreneurial activity. The purpose of the study is to identify the structure of regional development among small and medium-sized businesses in Kazakhstan and to identify groups of regions with different levels of entrepreneurial activity.

2 | LITERATURE

Small and medium-sized enterprises are significant in the economies of most countries, forming the foundation of the entrepreneurial environment and accounting for a significant

share of economic activity (Savlovschi & Robu, 2011). In developing economies, SME development is also associated with economic growth dynamics, as the expansion of the entrepreneurial sector is accompanied by an increase in the number of production units and the development of the market structure (Karadag, 2016; Morina & Gashi, 2016). At the regional level, SMEs form production and trade linkages and support economic interactions among market participants (Zafar & Mustafa, 2017). The traditional view of SMEs as the main driver of growth and employment is based on aggregate data that conceals significant heterogeneity among enterprises (Nightingale & Coad, 2014). Most SMEs exhibit low growth rates, limited productivity, and a high risk of market exit. Economic contributions in the form of employment and output growth are generated predominantly by a small group of fast-growing firms. At the same time, the rest of the sector does not produce a comparable effect.

Added value is identified as a key indicator of SME development. Economic output generated during the production process allows assessing the business sector's contribution to overall production volume. Integrating enterprises into production networks increases added value through specialisation and the distribution of production functions (Brazinskas & Beinoravičius, 2014). In Asian countries, SME participation in global value chains is associated with the expansion of production capabilities and increased economic performance (Abe & Proksch, 2017). For example, a small enterprise can produce components for a large international company, provide services (such as logistics or IT), or supply raw materials. Thus, the created value chain assumes that each company adds its share of value to the final product. In the context of technological change, the participation of small businesses in production networks is also associated with the adoption of new technologies and production modernisation, which contributes to increased added value creation (Chen, 2019). Empirical studies show that integrating businesses into international production networks can be associated with improved economic performance through access to new markets and technologies (Deyshappriya & Maduwanthi, 2021). Thus, the value-added indicator allows us to assess the SME sector's contribution to economic output.

SME production activity is measured by output volume as an indicator of added-value creation and changes in the sector's economic dynamics. However, the economic content of this indicator varies. The meaning of the SME output indicator changes depending on how the analysis is conducted and the data used. When individual enterprises are considered, output reflects their efficiency and competitiveness. When analysed at the industry or regional level, output reflects the overall scale of production activity. The choice of model determines which is considered the source of growth: the firm's internal productivity, inter-enterprise interactions, or the macroeconomic environment. In the production environment model, output volume depends on the concentration of SMEs within the cluster (Capello, 1999). Output volume increases when SMEs are located close to one another, facilitating the exchange of knowledge, technologies, and practices, reducing costs, and speeding up solution implementation. As a result, productivity increases. In microeconomic models, output dynamics are determined by the reallocation of resources among enterprises with different levels of productivity. The growth is regarded as aggregate output, achieved by crowding out less efficient and concentrating resources in more productive organisations (Aw, 2002). In this case, production activity reflects a change in the qualitative composition of enterprises, with output becoming an indicator of selective efficiency. Analysis of SME output in developing economies reveals a quantitative expansion of economic activity, accompanied by employment growth. However, limited capital and technology reduce their contribution to aggregate productivity (Li & Rama, 2015). In other words, a combination

of SME numbers and productivity does not ensure rapid efficiency. However, when SMEs produce more, this increases GDP over time, demonstrating the sector's contribution to the country's economy (Syzdykova & Azretbergenova, 2025).

The number of SMEs is considered an indicator of entrepreneurial activity and the spatial distribution of businesses. However, its economic content is also determined by the conditions under which the firms develop, form, sustain, and survive. The distribution of enterprises is linked to territorial and institutional conditions that determine the density and structure of the entrepreneurial environment (Yeung, 2009). There are also regional differences in firm concentration and access to resources, which influence the formation of entrepreneurial systems and the dynamics of their development (Plummer & Pe'er, 2010). The spatial development of entrepreneurial activity is also linked to processes of economic growth and regional transformation, in which an increase in the number of enterprises reflects a changing economic structure (Ferreira et al., 2018). However, quantitative growth of enterprises does not necessarily lead to an increase in economic performance. During crisis shocks, the dynamics of enterprise numbers reflect the entry and exit of firms from the market, with some enterprises ceasing operations and new firms emerging in response to changing economic conditions (Kuckertz et al., 2020). The number of SMEs reflects the instability of entrepreneurial activity, while firm density reflects the overall density of firms. Thus, a significant share of enterprise closures and short life cycles reflects firm density. In the European context, the number of enterprises is considered an element of a broader system of business demography, in which the relationships among firm creation, survival, and liquidation are important, determining the stability of the entrepreneurial environment (Andrei et al., 2021).

Employment in the SME sector is considered a key indicator of labour market performance. However, there is no unified interpretation of the mechanisms of job creation. SMEs have high labour intensity and flexible organisational structures, which enable faster adaptation to changes in demand and job creation during periods of economic growth (Kongolo, 2010; Nasr & Rostom, 2013). In developing economies, the SME sector generates a significant share of employment and drives private-sector expansion. Smaller firms exhibit higher net job creation rates, while this indicator decreases with increasing enterprise size (De Wit & De Kok, 2014). At the same time, there is no universal relationship between enterprise size and employment. The number of jobs depends on the enterprise's financial capacity. Thus, if an enterprise has access to credit and stable income, it can hire employees. Thus, access to finance, liquidity, enterprise size, and age significantly impact job creation (Yazdanfar & Öhman, 2015). Limited financial resources reduce the ability to expand employment. Reduced demand, lower revenues, and limited financial reserves, especially during periods of crisis, lead to job losses, especially among small firms (Engidaw, 2022). At the same time, some enterprises adapt to changing conditions. Outside of a crisis, an increase in the number of active enterprises and their expansion of activities leads to increased employment (Bekzhanova et al., 2023). However, job creation depends on the availability of financial resources as well as on support measures and institutional conditions that affect business sustainability (Kazbekova et al., 2024). In a favourable environment, enterprises expand their operations and increase employment, whereas restrictions hinder this process.

The share of SMEs in the economy reflects the distribution of value added, employment, and entrepreneurial activity among different types of enterprises (Woźniak et al., 2019). It is determined by a set of interrelated indicators, including SME participation in employment, their value-added share, and enterprise density per capita. This specification allows for assessing the degree of the sector's inclusion in the economic system and differences in its

functioning across territories. In developed economies, the share of SMEs in employment exceeds half of total employment, and their contribution to value added remains consistently high (Woźniak et al., 2019). At the same time, differences between countries and regions are associated with the distribution of value created and the sectoral structure, as the concentration of SMEs in certain activities limits their contribution to economic growth. A significant portion of value added is generated in trade and manufacturing, indicating the sector's dependence on industries with varying levels of productivity (Woźniak et al., 2019). As a result, the share of SMEs allows recording not only the quantitative presence of enterprises but also their real contribution to the economy, which requires comparison with indicators of output, employment, and the number of enterprises to assess the consistency of the business sector's development.

The choice of time frame for analysing entrepreneurial activity and the development of small and medium-sized businesses is examined through the lens of the stability of institutional and economic processes. Analysis of spatial differences in entrepreneurial activity requires a medium-term perspective, as institutional conditions, infrastructure, and the entrepreneurial environment change gradually. An analysis of the SMEs development in European cities is based on Eurostat and Urban Audit statistics for the period 2004–2010, which allows for the identification of persistent differences in entrepreneurial activity between regions and the assessment of the influence of institutional and infrastructural factors on the formation of regional entrepreneurial systems (Audretsch & Belitski, 2017).

At the same time, entrepreneurship development is increasingly analysed through integrated indicators that combine several characteristics of entrepreneurial activity into a single aggregated indicator. The index approach implemented in the Global Entrepreneurship Index aggregates institutional and economic characteristics across territories to rank countries and regions by the level of entrepreneurial system development (Acs et al., 2017). The OECD SME activity analysis is based on SMEs. dynamics of small and medium-sized businesses and are examined through comparison and analysis of key stages of the economic cycle, including periods of economic stability, crisis shocks, and subsequent economic recovery (OECD, 2018). At the same time, modern research on entrepreneurship development shows that analysing small business dynamics should account for the impact of external economic shocks, which can significantly alter the trajectory of enterprises. The COVID-19 pandemic has become one of the most significant factors impacting small firms. Thus, when analysing the entrepreneurial sector, it is necessary to consider periods of structural economic shocks that can alter the dynamics of employment, income, and firm resilience (Belitski et al., 2021). Analysing the development of small and medium-sized businesses requires a set of indicators reflecting various aspects of entrepreneurial activity, which justifies the use of integrated indicators and multivariate analytical methods when studying regional differences in the development of the entrepreneurial sector.

3 | METHODOLOGY

The methodological approach is based on the analysis of regional differences in small and medium-sized business development using a system of quantitative indicators and multivariate statistical methods. The study focuses on identifying structural differences between regions through comparable indicators reflecting production activity, employment, and the economic contribution of small and medium-sized businesses. To ensure comparability and eliminate scale effects, the analysis includes data standardisation followed by cluster analysis to identify groups of regions with similar characteristics of small and medium-sized business development.

The analysis of regional differences in small and medium-sized business development was conducted at the regional level using the following indicators:

(1) Gross value added of small and medium-sized businesses (Z_GVA);

(2) Output volume of small and medium-sized businesses (Z_OUT);

(3) Number of active small and medium-sized enterprises (Z_ENT);

(4) Number of people employed in small and medium-sized businesses (Z_EMP);

(5) Share of small and medium-sized businesses in gross regional product (Z_GDP_SH).

The selected variables reflect the scale of activity, labor force involvement, and SMEs' contribution to the regional economy. The data were collected from official sources, the Bureau of Statistics of the Republic of Kazakhstan, across regions for the period 2018–2024. The period represents a complete administrative-territorial structure comprising 17 regions, including the cities of national significance (Almaty, Astana, and Shymkent). The regional structure remains unchanged throughout the entire observation period, eliminating gaps and data incomparability. There are no gaps in the data, as the complete official indicator series for each year of the observation period was used. The panel data is balanced without the need to reconstruct or interpolate values.

The selection of the five indicators (Z_GVA, Z_OUT, Z_ENT, Z_EMP, and Z_GDP_SH) is based on empirical studies that identify value added, output, number of enterprises, employment, and the share of the sector in the economy as key characteristics of entrepreneurial activity and the contribution of small and medium-sized businesses to economic development. The value added indicator is used to assess the economic contribution of small and medium-sized businesses and their participation in production chains (Brazinskas & Beinoravičius, 2014; Abe & Proksch, 2017; Chen, 2019). Output reflects the scale of production activity and the reallocation of resources among enterprises with different levels of efficiency (Capello, 1999; Aw, 2002; Li & Rama, 2015). The number of enterprises is considered an indicator of entrepreneurial activity and spatial business density associated with institutional and territorial conditions (Yeung, 2009; Plummer & Pe'er, 2010; Ferreira et al., 2018). Employment in the small and medium-sized business sector reflects labour market dynamics through job creation patterns and is influenced by access to finance, firm-level resources, and institutional conditions (De Wit & De Kok, 2014; Yazdanfar & Öhman, 2015; Kazbekova et al., 2024). The integration of small and medium-sized businesses into the regional economy and their contribution to economic activity are assessed through the share of small and medium-sized businesses in gross regional product (Woźniak et al., 2019).

Since the original indicators are measured in different units (tenge, number of people, and percentages) and differ substantially in scale, data standardisation was performed prior to the cluster analysis. For each indicator and each year, the following statistical measures were calculated: the mean value across regions, sample variance (divided by N–1), standard deviation, and Z-score based on formula (1):

$$Z_{\text{it}} = \frac{X_{\text{it}} - \mu_t}{\sigma_t} \tag{1}$$

where:

X_{it} – the indicator value in region i in year t;

μ_t – the average value across regions in year t;

σ_t – standard deviation across regions in year t.

After standardisation, the data are converted to a comparable scale for each year. Moreover, this eliminated differences in units of measurement and shows the relative positions of regions at a specific point in time. At this stage, Z-scores reflect interregional differentiation within each year. Further averaging of Z-scores for the period 2018–2024 is used

to obtain an integrated regional profile that accounts for its position over time. These averaged values help smooth short-term fluctuations in indicators and highlight persistent differences between regions. This results in a generalised score used for clustering. The use of a medium-term horizon to identify stable regional differences aligns with approaches used in the analysis of entrepreneurial ecosystems (Audretsch & Belitski, 2017).

The aggregation of indicators into an integrated measure is also consistent with index-based approaches, including the Global Entrepreneurship Index (Acs et al., 2017), as well as OECD approaches to the analysis of small and medium-sized businesses based on the aggregation of indicators across different economic periods (OECD, 2018). The Z-score values were averaged over the period 2018–2024 using formula (2):

$$Z_i^{\text{avg}} = \frac{1}{7} \sum_{t=2018}^{2024} Z_{\text{it}} \tag{2}$$

where:

Z_i^{avg} – the average standardised value of the indicator for region i over the analysed period;

Z_{it} – the standardised value of the indicator for region i in year t.

Thus, for each region, one integrated value was obtained for each indicator, reflecting the region's average position relative to other regions over the analysed period.

To identify regional typologies, hierarchical cluster analysis using Ward's method and Euclidean distance was applied. Based on the dendrogram and the ratio of intra- to inter-cluster variances obtained in Jamovi, two clusters were identified. The partition into two clusters corresponds to maximum inter-cluster differentiation with low intra-cluster variance. The inter-cluster sum of squares exceeds the intra-cluster sum of squares, reflecting a stable separation of regions. A two-cluster structure is used in the analysis. Ward's method minimises intracluster variance and ensures the formation of compact and statistically stable clusters. Principal component analysis (hereinafter – PCA) shows that the first component accounts for most of the variance among the selected indicators. The results show that the first principal component explains the majority of the total variance, indicating a high degree of consistency among the indicators included in the clustering procedure.

4 | RESULTS

The use of standardized values makes it possible to compare regions with each other, regardless of differences in the scale of the initial indicators, and to determine the relative position of each region according to key characteristics of the development of small and medium-sized businesses over the analyzed period. To assess inter-regional differences in the development of small and medium-sized businesses, an analysis of standardized indicators reflecting production activity, employment and the sector's contribution to the regional economy was carried out. Table 1 shows the average standardized values of the indicators (Z-score) for the regions of Kazakhstan for 2018-2024 for five variables.

Table 1 Average standardised indicators of small and medium-sized business development for 2018-2024

Region	Z_GVA	Z_OUT	Z_ENT	Z_EMP	Z_GDP_SH
Akmola	-0.45	-0.46	-0.45	-0.53	-0.13
Aktobe	-0.39	-0.38	-0.12	-0.37	-0.43
Almaty	-0.07	-0.06	0.94	0.29	0.75
Atyrau	0.29	0.32	-0.36	-0.48	-0.76
West Kazakhstan	-0.21	-0.23	-0.50	-0.66	0.40
Zhambyl	-0.55	-0.57	0.08	-0.53	-0.45
Karaganda	-0.21	-0.17	0.33	0.20	-0.98
Kostanay	-0.33	-0.33	-0.33	-0.36	0.05
Kyzylorda	-0.62	-0.66	-0.38	-0.74	-0.99
Mangistau	-0.31	-0.34	-0.24	-0.54	-0.28
Pavlodar	-0.48	-0.46	-0.47	-0.53	-0.97
North Kazakhstan	-0.55	-0.55	-0.78	-0.74	0.00
Turkestan	-0.45	-0.46	1.53	0.15	-0.28
East Kazakhstan	-0.37	-0.35	0.15	-0.05	-0.82
Astana c.	1.76	1.92	1.70	1,53	2.43
Almaty c.	3.22	3.11	2.92	3.59	1.78
Shymkent c.	-0.30	-0.33	0.20	-0.21	0.66

Note: compiled by the authors.

The results presented demonstrate significant regional differences in SME development. The highest values for most indicators were observed in Almaty c. and Astana c. In particular, Almaty c. revealed the highest values for all key indicators (Z_GVA = 3.22, Z_OUT = 3.11, Z_ENT = 2.92, Z_EMP = 3.59). Thus, the results indicated a high concentration of SME economic activity, significant production volumes, and high employment in this sector. Astana c. is also characterised by high values for all variables, showing the significant role of SMEs in the capital's economy.

Several regions occupy an intermediate position. Almaty region demonstrated positive values for entrepreneurial activity indicators (Z_ENT = 0.94, Z_EMP = 0.29, Z_GDP_SH = 0.75), indicating a relatively high level of SME development compared to the average. Similarly, Turkestan stands out for a high number of SMEs (Z_ENT = 1.53), reflecting active entrepreneurship development, although production indicators remain below average. Negative Z-score values characterise most regions for production indicators. For example, Kyzylorda, Pavlodar, and North Kazakhstan demonstrated low values for several variables simultaneously, including output and employment, indicating relatively weaker SME economic activity. At the same time, differences between structural and production characteristics were observed in certain regions. For example, West Kazakhstan showed negative values for both output and employment indicators. Nevertheless, the share of SMEs in the regional product remained above average (Z_GDP_SH = 0.40), as the more significant role of entrepreneurship in the regional economic structure.

After assessing standardised indicator values for each region, the next stage of the study involved cluster analysis to identify groups of regions with similar patterns of SMEs devel-

opment. The analysis included average Z-score values for five indicators (Z_GVA, Z_OUT, Z_ENT, Z_EMP, Z_GDP_SH), ensuring data comparability and enabling the simultaneous consideration of multiple aspects of the SME sector. The results of the initial stage of cluster analysis are presented in Table 2.

Table 2 Summary of within-cluster and between-cluster sums of squares

Cluster component	Sum of squares	Interpretation
Cluster 1	4.85	Low intra-cluster variance
Cluster 2	12.93	Moderate intra-cluster variance
Between clusters	62.94	High inter-cluster differentiation
Total	80.71	Total variance

Note: compiled by the authors.

The total sum of squares is 80.71, of which 62.94 is accounted for by intercluster variation, while the intracluster variation is significantly lower, at 4.85 for the first cluster and 12.93 for the second. This distribution indicates that most of the total variation is explained by differences between the resulting clusters, demonstrating a fairly clear division of regions into groups with distinct characteristics of small- and medium-sized enterprise development. Thus, the selected variables enable us to effectively differentiate regions by the level of SME development.

The results of the cluster analysis determine characteristic indicator values for each formed group of regions. For this purpose, cluster centroids are calculated, which reflect the average values of standardised variables within each cluster. The clustering results indicate a strong differentiation in SME development across regions rather than a balanced multi-group typology. The first cluster unites regions with a high concentration of SME economic activity and a significant sectoral contribution to the economy. In contrast, the second cluster includes regions with lower production and structural characteristics of entrepreneurship development. The resulting values are presented in Table 3.

Table 3 The centroids of the clusters

Cluster component	Z_GVA	Z_OUT	Z_ENT	Z_EMP	Z_GDP_SH
Cluster 1	2.490	2.515	2.310	2.560	2.105
Cluster 2	-0.333	-0.335	-0.027	-0.340	-0.282

Note: compiled by the authors.

The first cluster is characterised by high positive centroid values across all analysed indicators: gross value added (2.490), output volume (2.515), number of enterprises (2.310), employment (2.560), and the share of SMEs in gross regional product (2.105). These values indicate that the regions included in this cluster significantly exceed the national average in terms of entrepreneurial activity, production performance, employment, and the economic contribution of the SME sector. The highest centroid value is observed for employment (2.560), while the lowest is recorded for the share of SMEs in gross regional product (2.105). Nevertheless, all indicators remain substantially above average, reflecting a high concentration of SME economic activity within this group of regions. The results indicate that

these territories are characterised by stronger business activity, higher production capacity, and a more significant role of SMEs in the regional economy. Overall, the cluster reflects the concentration of SME development in the largest urban and economically developed regions of Kazakhstan.

The second cluster exhibits centroid values close to zero, but predominantly negative: Z_GVA (−0.333), Z_OUT (−0.335), Z_EMP (−0.340), Z_GDP_SH (−0.282), and Z_ENT (−0.027). Regions in the second cluster generally perform below average in terms of production activity and SME employment. In terms of the number of small and medium-sized businesses, the regions of the second cluster are approximately average compared to other regions included in the analysis. Still, their economic performance and contribution to the regional economy remain lower. These regions exhibit moderate entrepreneurial activity, but with a weaker production base and a smaller contribution to the country's gross regional product. This indicates that the number of enterprises alone does not translate into higher output, employment, or value added across regions.

Figure 1 shows a dendrogram generated by Ward's hierarchical clustering.

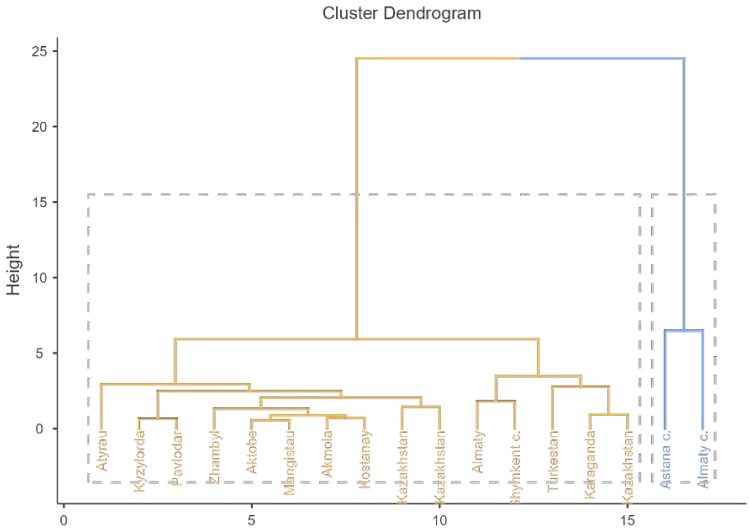


Figure 1 Ward's hierarchical cluster dendrogram of regional small and medium-sized business development in Kazakhstan

The dendrogram was constructed using Ward's hierarchical clustering method, which minimises intra-cluster variance and ensures the formation of relatively homogeneous regional groups. Euclidean distance based on standardised indicator values was used as the distance measure. The dendrogram illustrates the sequence of regional grouping during the clustering process. The vertical axis (Height) represents the linkage distance and reflects the degree of dissimilarity between the grouped regions. Higher linkage levels indicate greater differences between regional groups.

Analysis of the dendrogram structure reveals two main clusters, as confirmed by the results presented in the sums of squares and cluster centroid tables. The first cluster is formed at the top level and includes regions with significantly higher values of the indicators under

consideration. The second cluster includes the majority of regions and is characterized by lower values of the standardized indicators. The clustering structure is characterised by a high level of polarization: a small group of regions with exceptionally high values is separated from a large group of regions with relatively homogeneous and lower indicator levels.

The first cluster includes the cities of Almaty and Astana, which differ significantly from other regions across all the analysed indicators of small and medium enterprise development. The second cluster includes the remaining regions of the country, characterized by lower values of the standardized indicators. Thus, the dendrogram confirms a pronounced spatial concentration of SME economic activity in the country's largest cities. Thus, the results reflect a spatial pattern of SME development, with economic activity disproportionately concentrated in the largest cities rather than distributed across regions.

Figure 2 shows the distribution of variables and regions in the principal component space obtained using PCA.

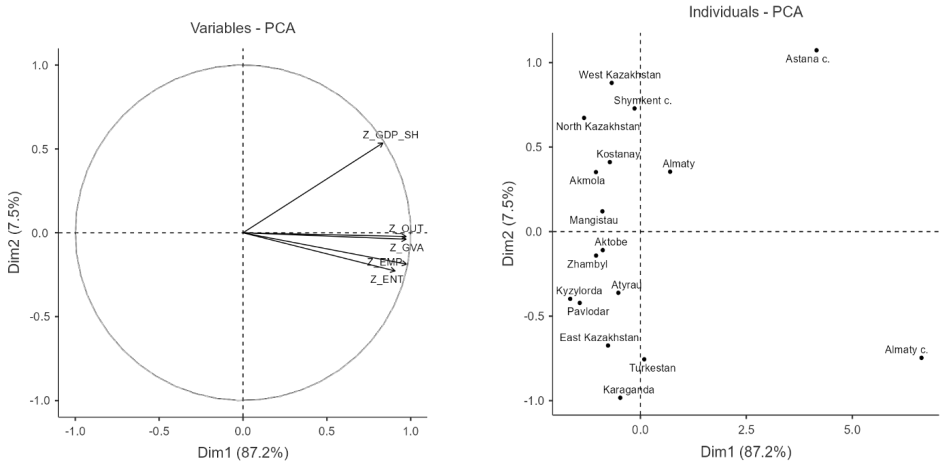


Figure 2 PCA distribution of regions and variable contributions

This method represents the structure of differences between regions in a two-dimensional coordinate system. The first principal component (Dim1) explains 87.2% of the total variance, while the second component (Dim2) explains 7.5%. The majority of differences between regions are formed along the first component. The distribution of variables on the graph shows that Z_GVA, Z_OUT, Z_ENT, Z_EMP, and Z_GDP_SH move in similar directions in the component space. These indicators change consistently and reflect the overall economic characteristics of small and medium-sized business development in the regions. As a result, the first principal component effectively aggregates the influence of these indicators and summarises their joint variation.

The distribution of regions in the component space demonstrates differences in the level of entrepreneurial activity development. Regions with higher values for these indicators shift toward the positive side of the first component. Regions with more moderate values are located closer to the negative side of the axis. The first principal component primarily captures differences between regions.

In Kazakhstan, regions differ in their overall level of entrepreneurship development. The highest indicators are observed in Almaty and Astana cities. These cities simultaneously exhibit higher SME added value, output volume, number of enterprises, and employment in the entrepreneurial sector. Moreover, higher values of one indicator correspond to higher values of other indicators.

The concentration of SME activity in Almaty and Astana is consistent with the economic role of major cities. Higher values of added value, output, employment, and the number of enterprises are observed in these cities. In most regions, including Akmola, Kostanay, Pavlodar, Zhambyl, Mangistau, Kyzylorda, North Kazakhstan, and West Kazakhstan, SME development indicators remain more moderate. The number of enterprises, output volume, and employment in the entrepreneurial sector remain at lower levels than in the largest cities.

The Almaty region, Karaganda, Atyrau, Turkestan, and East Kazakhstan regions occupy an intermediate position, with several SME indicators higher than in many other regions of the country. These regions show higher values for selected SME indicators compared to other regions, but remain below the levels observed in the largest cities. However, overall economic activity and SME indicator values in these regions are lower than in the largest cities, Almaty and Astana.

The integral analysis identified the overall distribution of regions according to the level of small and medium-sized business development. To further examine the dynamics of SME indicators, the analysis of individual indicators is presented below, taking into account the main stages of economic dynamics: the period of relatively stable business development before the pandemic (2018–2019), the period of the COVID-19 crisis shock in 2020, and the subsequent stage of recovery and adaptation of the business sector during 2021–2024 (Figure 3).

The period 2018–2019, before COVID-19, is characterised by a relatively stable structure of regional development of small and medium-sized businesses. The analysis of individual indicators confirmed the previously identified regional distribution. The share of gross value added of SMEs (Z_GVA), output volumes (Z_OUT), and employment (Z_EMP) form a similar spatial structure, where the first principal component explains the majority of the variation in the indicators (54.5% for value added, 57.9% for employment, and 51.5% for output). The concentration of economic activity in the business sector is found in economically developed regions, where the share of SMEs in regional economic output is higher (Z_GDP_SH). The indicator for the number of enterprises (Z_ENT) demonstrates a more even distribution of regions; however, differences in the scale of entrepreneurial activity persist. Overall, the analysis of individual factors reproduces the same regional structure identified in the integrated assessment of SME development, confirming the stability of the existing structure of regional differentiation.

The 2020 period, marked by the COVID-19 pandemic, is characterised by a change in the regional distribution of entrepreneurial activity. Changes in SME output (Z_OUT) and employment (Z_EMP) are reflected in shifts in the positions of regions in the principal component space. The most noticeable changes are observed in employment and production indicators, where differences between regions become more pronounced. At the same time, the number of enterprises (Z_ENT) indicator shows a more moderate response to the crisis, indicating a more stable distribution compared to other indicators. Despite temporary shifts in individual regions, the overall distribution in factor space retains the same basic structure identified in the integrated analysis.

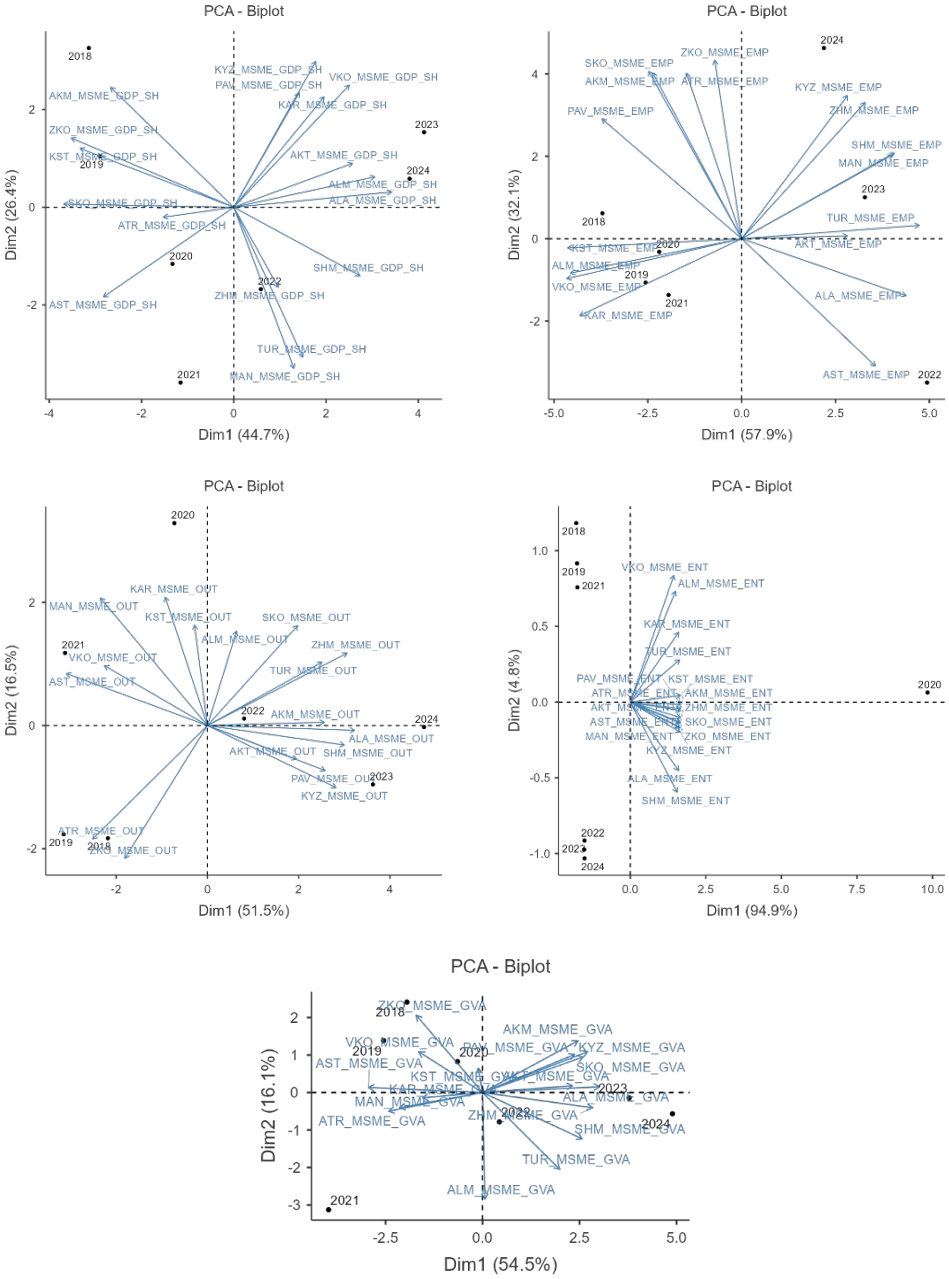


Figure 3 PCA biplot of regional small and medium-sized business development in Kazakhstan

In the period 2021–2024, characterised by a gradual recovery in economic activity, changes in SME indicators are observed. Partial changes in SME indicators, including employment (Z_EMP), output (Z_OUT), and value added (Z_GVA), are reflected in the component space. In the principal component space, regions are still divided into two groups: territories with a higher concentration of entrepreneurial activity and regions where SMEs' contribution to the economy remains more limited (Z_GDP_SH). The number of enterprises (Z_ENT) indicator also shows differences in dynamics across regions.

The results generally confirm several consistent findings presented in the academic literature, both at the regional level and across individual indicators. Factor analysis reveals that the first principal component explains over 50% of the variance in key indicators (54.5% for Z_GVA, 51.5% for Z_OUT, and 57.9% for Z_EMP), indicating that SME indicators are concentrated in a limited group of regions. Consistency with previous studies is evident in the structural heterogeneity of SMEs. The identified division of regions into groups with high and low entrepreneurial activity is consistent with the findings of Nightingale and Coad (2014), that a limited number of enterprises account for higher values of output and value added, while the rest of the sector demonstrates weaker performance, as evidenced by the formation of two stable groups of regions with different concentrations of value added and output. The employment results support findings of De Wit and De Kok (2014) and Ayyagari et al. (2014) that employment levels vary with enterprise structure and economic conditions. In 2020, Z_EMP declined, and regions' relative positions in employment levels changed. Between 2021 and 2024, regions show different dynamics in indicator values, and employment does not fully follow the patterns observed for the number of enterprises and output. The Z_ENT indicator shows a more stable structure, with the first component explaining 94.9% of the variation.

In terms of production activity and value added, the results align with findings of Abe and Proksch (2017) and Chen (2019), that sector indicators (Z_OUT, Z_GVA) differ depending on their position in the economic structure. Thus, the Z_OUT and Z_GVA indicators form a more concentrated structure than Z_ENT. At the same time, they reveal discrepancies with some studies that suggest a more direct relationship between enterprise growth and economic development (Savlovschi & Robu, 2011; Karadag, 2016). In the conducted analysis, the increase in the number of enterprises (Z_ENT) is not accompanied by proportional changes in Z_OUT and Z_GVA, as differences between regions in Z_OUT and Z_GVA remain. Thus, the results confirm the existing provisions on the heterogeneity and structural differentiation of the SME sector, indicating that the number of enterprises (Z_ENT) does not correspond in a proportional manner to Z_OUT, Z_EMP, and Z_GVA. At the same time, the identified structure is maintained both in the pre-crisis and post-crisis periods, indicating the stability of the regional distribution of SME activity.

The results of the cluster analysis categorized Kazakhstan's regions by the level of SME development. To visualise the identified structure of regional SME distribution and the differences in key economic indicators, a diagram was constructed that groups regions by level of entrepreneurial activity. The diagram shows a division of regions into two clusters with different levels of SME indicators (Figure 4).

The diagram clearly distinguishes Kazakhstan's regions by the level of development of small- and medium-sized enterprises. The results of the cluster analysis revealed a distinct division of regions into two clusters with different levels of SME indicators. The most prominent group is one with lower values for most of the analysed indicators, including SME added value, output volume, employment in the entrepreneurial sector, and the share of SMEs in the regional product. These regions are characterised by lower values of SME

indicators across the analysed variables.

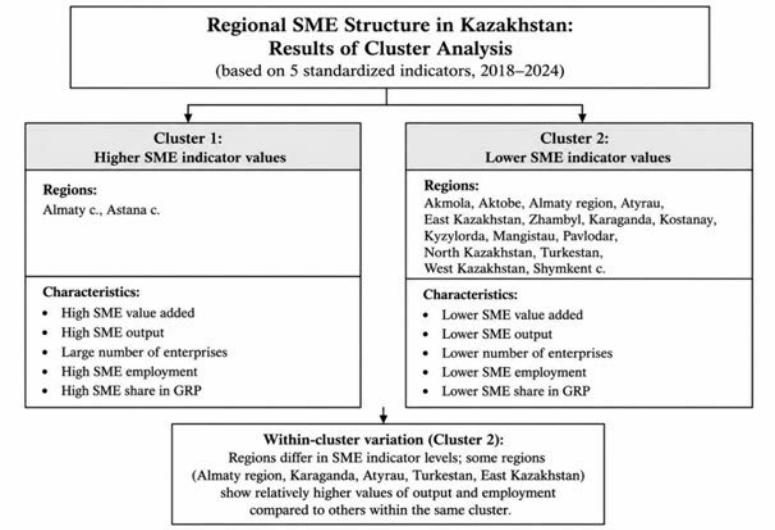


Figure 4 Regional SME Structure in Kazakhstan

Within the second cluster, regions differ in SME indicator levels. Regions such as Almaty, Karaganda, Atyrau, Turkestan, and East Kazakhstan show higher values for individual entrepreneurial activity indicators than most other regions. These regions show relatively higher values of SME indicators, including the number of enterprises, employment, and output, compared to other regions within the same cluster.

5 | CONCLUSION

The analysis revealed significant regional differences in the development of small- and medium-sized businesses in Kazakhstan. The results of the cluster analysis revealed two clusters.

The first cluster comprises territories with the highest values of entrepreneurial activity indicators (Almaty and Astana), where the highest values are observed for SME added value, output volume, number of enterprises, employment in the entrepreneurial sector, and the share of SMEs in the regional product. These cities show the highest values across the analysed SME indicators. The second cluster comprises regions with lower values of SME indicators across the analysed variables, including Akmola, Kostanay, Pavlodar, Zhambyl, Mangistau, Kyzylorda, North Kazakhstan, and West Kazakhstan. In addition, several regions (Almaty, Karaganda, Atyrau, Turkestan, and East Kazakhstan) occupy intermediate positions between the two clusters, with SME indicator values that fall between them.

Given the identified differences across regional groups, public policy measures for SME development should be tailored accordingly. For the largest cities, characterised by high SME indicators, the priority is to support improvements in the efficiency and quality of entrepreneurial activity, including the development of innovation and increased productivity. For regions with comparatively low SME indicators, it is advisable to focus on expanding the scale of entrepreneurial activity, including employment support, infrastructure devel-

opment, and improved access to finance. For regions in between, the priority is to level the SME indicator structure, specifically increasing output and added value for the existing number of enterprises. This approach allows for consideration of differences in the level of SME development and the development of more targeted regional policy measures.

As a recommendation, a more detailed analysis of the structure of entrepreneurship by economic sector is recommended for future studies. In particular, it seems appropriate to examine the differences in the development of small and medium-sized businesses in agriculture, industry, and services. Attention could be given to the analysis of entrepreneurship in the agro-industrial complex, as it is an important source of economic activity and employment in many regions of Kazakhstan.

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Structural Changes in Russia–Kazakhstan Economic Cooperation: Evidence from Trade and Business Entities

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Abstract
Economic cooperation between Russia and Kazakhstan has been undergoing significant changes in recent years under the influence of external economic constraints and the transformation of regional economic ties. The aim of this article is to assess how Russia–Kazakhstan economic cooperation has evolved under sanctions by examining changes in bilateral trade, organizational embeddedness, and relative structural position between 2018 and 2025. The analysis uses Kazakhstan as a focused empirical setting and traces developments from 2018 to 2025, with the earlier years serving as a pre-shock benchmark. The results indicate that bilateral trade rose sharply after 2022, then remained elevated without further expansion. The results showed that a structural asymmetry of trade flows was revealed: Kazakhstan's exports to Russia decreased from 9.55–9.56 billion US dollars in 2024 to 8.14 billion US dollars in 2025, while imports from Russia increased from 18.24 billion US dollars to 19.26 billion US dollars. Russian-linked firms also retained the largest foreign business presence in Kazakhstan. At the same time, the growing weight of China altered Russia's relative standing rather than removing its importance. The study shows that cooperation under sanctions is better understood as differentiated restructuring than as simple expansion and contraction. Thus, the economic cooperation between Russia and Kazakhstan does not show signs of either steady expansion or consistent reduction, but is developing in the form of structural adjustment at a high level of interaction.

KEYWORDS
Economy, Economic Cooperation, Economic Sanction, Bilateral Trade, Foreign Trade, Trading Structure, International Business

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1 | INTRODUCTION

Since 2022, economic relations between Russia and its neighboring partners have received growing attention in studies examining the implications of economic sanctions (Morgan et al., 2023). Existing scholarship has largely converged on two competing positions. One holds that financial restrictions, export controls, and threats of secondary sanctions progressively raise transaction costs, thereby weakening trade, investment, and organizational ties between the sanctioned state and its partners (Hufbauer et al., 2007). The other contends that, where geographic proximity, institutional interfaces, and logistics corridors remain intact, ally networks may serve as critical conduits through which sanctioned states reorganize supply chains, relocate corporate entities, and sustain external connectivity (Drezner, 2003; Early, 2015).

Kazakhstan offers a critical case for adjudicating between these positions. The country maintains deep and long-standing economic ties with Russia while simultaneously being embedded in Chinese, European Union, and broader global markets (Myrzakhmetova et al., 2019; Hudson, 2022). This structural position means that Russia–Kazakhstan cooperation could either intensify under sanctions pressure or contract under rising compliance constraints (Libman & Obydenkova, 2022; Arapova, 2023). Empirical evidence from the early post-conflict period documents a measurable expansion in bilateral trade and investment linkages, which challenges the linear expectation that sanctions necessarily compress cooperation among allied states. Expansion during the initial shock period, however, does not constitute a medium-term trend. As of 2025, the more pressing analytical question is not whether Russia–Kazakhstan cooperation persists, but why it remains at elevated levels, why further expansion has not continued, and whether Russia's structural position within Kazakhstan's economy has undergone reconfiguration. The aim of this article is to assess how Russia–Kazakhstan economic cooperation has evolved under sanctions by examining changes in bilateral trade, organizational embeddedness, and relative structural position between 2018 and 2025.

Against this backdrop, this article advances one central research question and three interrelated sub-questions. The central question asks: under conditions of sustained sanctions, what dynamics characterize Russia–Kazakhstan economic cooperation between 2022 and 2025, and do existing binary expectations of compression versus expansion adequately account for these dynamics? Three subquestions follow in sequence. The first concerns trade flows: how have the overall scale and directional composition of bilateral cooperation, disaggregated by export and import flows, evolved over this period? The second concerns organizational stocks: as trade flows adjusted, did institutional presence manifest as exit or as sedimentation? The third concerns structural position: in the face of rising Chinese market share and tightening compliance pressure, has Russia's relative standing within Kazakhstan's external economic structure shifted, and if so, in what form?

This article makes three contributions. First, the observation window extends through the full year 2025 and into early 2026, which guards against treating short-

run shock dynamics as proxies for medium-term trends. Second, bilateral trade volume is not treated as the sole object of analysis; trade directionality, firm-level embeddedness, and relative structural position are examined concurrently, which improves the capacity to identify how the bilateral relationship is being reorganized rather than merely whether it persists. Third, this article argues that Russia–Kazakhstan economic cooperation after 2022 is more accurately characterized as structural rebalancing at an elevated baseline rather than as either continued intensification or progressive contraction.

2 | LITERATURE REVIEW

A central tradition in sanctions theory emphasizes the compressive effects of economic coercion. The foundational literature argues that when a sanctioning coalition is sufficiently broad and consistently enforced, sanctions raise the policy costs of the target state by restricting access to trade, finance, and technology (Hufbauer et al., 2007). More recent reviews similarly find that comprehensive and coordinated sanctions reshape the target's external transaction networks through multiple simultaneous channels (Morgan et al., 2023). From this perspective, Kazakhstan's economic ties with Russia should contract continuously as external constraints intensify.

A second tradition is skeptical of this linear expectation. Pape (1997) observed that the coercive effectiveness of sanctions is routinely overstated, with alternative markets, third-party channels, and political tolerance eroding their policy impact. Drezner (2003) further argued that the outcomes of economic coercion depend on anticipated conflict, political relationships, and third-party choices rather than on the magnitude of economic harm alone. Early (2015) demonstrated from a sanctions-busting perspective that non-participating third states can substantially undermine sanctions through trade, financial, and material support, and subsequent work identified the expansion of informal economic channels as a key mechanism (Early & Peksen, 2019). On this reading, Kazakhstan would not distance itself from Russia under sanctions pressure but might capture new intermediary rents.

By 2025, neither expectation fits the available evidence. Kazakh official data point to a configuration in which bilateral ties remain at elevated levels, expansion has ceased, and the shock-phase growth trajectory has not continued. The relevant question is therefore not whether sanctions are effective but through what mechanisms they alter the form, function, and boundaries of allied economic linkages.

A second line of debate centers on regional institutions. Research supporting a buffering function argues that regional integration arrangements reduce transaction friction, stabilize internal logistics, and preserve payment and regulatory interfaces during external shocks. Scholars have found that the Eurasian Economic Union's institutional framework helps sustain goods flows and regional supply chains among member states (Pomerlyan & Belitski, 2024) and that the Union functions less as a strictly standardized common market than as a pragmatic

coordination mechanism during external crises (Braun et al., 2024). Historical, linguistic, and institutional linkages also provide a durable foundation for Kazakhstan to maintain cooperative ties with Russia (Hudson, 2022).

Critical scholarship argues the opposite. Studies following the 2014 sanctions document significant economic interdependence among Russia, Belarus, and Kazakhstan, implying that sanctions shocks spill over through trade, investment, and remittance channels (Makhmutova, 2019). Related work points out that the Union can function simultaneously as a transit and substitution corridor while exposing new fault lines as member states face differentiated compliance pressures (Libman & Obydenkova, 2022). On this view, cooperation under intensified sanctions should reflect institutional fragility rather than buffering.

The difficulty in accounting for conditions after 2025 stems from treating institutional effects as a single entity. Institutions have neither failed entirely nor succeeded entirely but have diverged across functional dimensions: the Eurasian Economic Union has continued to stabilize goods trade through tariff and customs rules while proving unable to prevent structural contraction at the level of payment clearing and compliance coordination. Explaining this requires disaggregating regional institutions into distinct functional layers and examining each separately.

A third line of debate derives from the trade deflection literature. Classical work establishes that restrictive trade policies cause affected exports to deflect toward third markets (Bown & Crowley, 2007). Research on Iran found that export sanctions induce measurable export deflection toward non-participating countries (Haidar, 2017). Gravity model studies further show that economic actors engage in inventory adjustment and channel repositioning before policy measures formally take effect (Afesorgbor, 2019). Work on the 2014 Russia sanctions documents how sanctions and countersanctions significantly altered export directions and transaction risk (Crozet & Hinz, 2020). A contrasting body of literature emphasizes that deflection is not boundless: the trade effects of sanctions vary substantially across sectors, targets, and time periods, and short-run redirection during the shock phase cannot be extrapolated as the stable outcome of a rebalancing phase (Felbermayr et al., 2020; Morgan et al., 2023). Spillover effects on transition economies are similarly inconsistent across third-party states, with trade and investment sometimes moving in opposite directions (Sedrakyan, 2022).

This literature has focused predominantly on flow-level dynamics and devoted less attention to organizational sedimentation and functional reallocation. For Russia–Kazakhstan relations, the critical phenomenon observable by 2025 is precisely that expansion in trade flows has ceased while import supply structures, corporate entities, and institutional interfaces have not contracted in parallel. Explaining this configuration requires extending the unit of analysis from trade flows to three jointly operating levels: import supply, organizational sedimentation, and institutional interfaces.

The three lines of debate share an underlying premise: that sanctions operate on allied ties in a uniform direction across all dimensions, leaving contraction versus expansion as the only question. This article argues instead that sanctions

simultaneously release two categories of forces operating in opposite directions, with their relative intensity varying systematically across economic levels. Sustaining forces derive from the structural inertia of existing networks, including border supply chains, regional institutional interfaces, and long-standing organizational relationships. Constraining forces derive from sanctions enforcement pressure, including compliance scrutiny, entity designation management, payment friction, and third-party transit oversight. These two sets of forces operate concurrently rather than sequentially.

The contribution lies in specifying that sustaining forces are stronger at the level of organizational stocks than at the level of trade flows, while constraining forces exhibit the reverse pattern. Legal registration and long-standing contractual arrangements carry high exit costs and adjust slowly, whereas compliance thresholds for individual transactions are lower and marginal adjustment is more flexible. If compression logic holds, all levels should contract in the same direction. If adaptive expansion logic holds, all levels should expand in the same direction. If the framework advanced here holds, the same relationship at the same point in time should simultaneously display flow-level plateauing, stock-level continuity, and positional reordering.

3 | METHODOLOGY

This article employs a single-case longitudinal design, combining descriptive statistics with cross-period comparative analysis to systematically trace the evolution of Russia–Kazakhstan bilateral economic cooperation under the conditions of the Russia–Ukraine conflict and comprehensive sanctions. The selection of Kazakhstan as the case rests on three methodological considerations. First, Kazakhstan shares one of the longest land borders in the world with Russia and is a member of the Eurasian Economic Union, a combination of geographic and institutional conditions not replicated in other allied-state cases. Second, Kazakhstan maintains high-intensity economic ties with China while pursuing a balancing posture between cooperation with Russia and compliance with Western expectations, making it a well-situated vantage point for observing how nodes in allied networks actively adapt under sanctions pressure (Hudson, 2022). Third, the Bureau of National Statistics of Kazakhstan publishes complete annual trade bulletins and partner-share data, providing two mutually independent official data sources that support the estimation approach used in this article and satisfy the minimum conditions for robustness verification.

This article does not adopt econometric identification or index construction, for three reasons. First, publicly available high-frequency Russia–Kazakhstan data remain incomplete with respect to services trade, cross-border payment costs, firm-level exports, and bilateral quarterly investment flows disaggregated by partner. Second, the external shocks following 2022 are highly heterogeneous, with policy shifts, price movements, and wartime developments intertwined in ways that make strong identification designs difficult to satisfy. Third, the primary objective of this article is to characterize a new empirical configuration and delimit its explanatory

boundaries, rather than to estimate the precise magnitude of a single causal effect.

Figure 1 summarizes the research design by linking the research questions, the analytical framework, the level-specific empirical effects, and the core interpretation of high-level rebalancing.

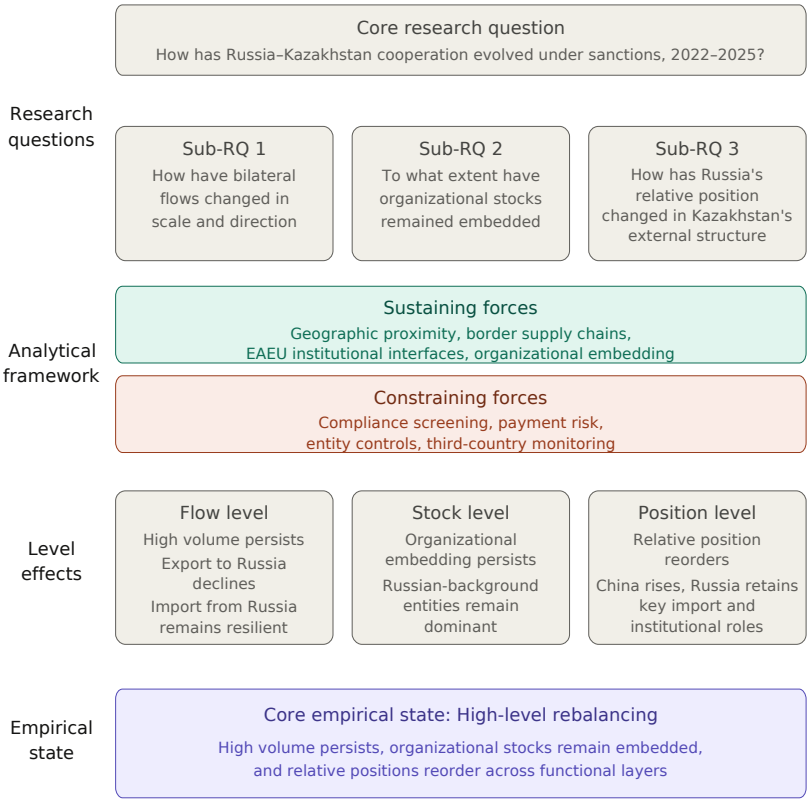


Figure 1. Research framework

Three key concepts require explicit definition. "Elevated rebalancing" refers to an intermediate state in which the scale of bilateral ties and the organizational presence of both parties remain substantial, while marginal expansion has ceased, export and import directions have diverged, and partner rankings and functional positions have shifted. "Organizational embeddedness" refers to institutional presence established through legal registration, joint-venture arrangements, and ongoing operations, as distinct from discrete short-term transactions (Granovetter, 1985). "Relative structural position" refers to a partner's composite standing within the host country's external economic architecture, encompassing share, rank, and functional non-substitutability simultaneously.

Two boundaries on scope apply. First, the investment component does not bear the primary identificatory burden of this article, as the publicly available bilateral flow data are less consistent than the trade and enterprise data. Second, this article examines Kazakhstan's external economic function as a node in an allied network, not the microeconomic performance of individual firms. Accordingly, the findings are more appropriate for explaining relational reorganization under sanctions than for drawing direct inferences about the profitability of specific enterprises.

This article draws on three categories of source material. The first consists of annual foreign trade bulletins published by the Bureau of National Statistics of Kazakhstan covering the period from 2018 to 2025. These sources provide data on total trade turnover, aggregate exports and imports, intra-Eurasian Economic Union (EAEU) trade volumes, Russia's share in Kazakhstan's trade within the Union, and the shares of major trading partners in Kazakhstan's exports and imports. The second category consists of enterprise entity census data published by the Bureau of National Statistics of Kazakhstan as of January 1, 2026, used to identify the registration and operational status of Russia-affiliated entities and Russia–Kazakhstan joint ventures operating in Kazakhstan (Bureau of National Statistics, 2026). The third category includes direct investment position data published by the National Bank of Kazakhstan as of October 1, 2025, which are used as supplementary evidence of capital linkages (National Bank, 2026).

As shown in Table 1, this article treats 2022 as the reference year for post-sanctions adjustment, designates 2018–2021 as the pre-2022 period and 2022–2025 as the post-2022 adjustment period, and constructs continuous annual inputs for the dual-path estimation accordingly.

Table 1. Dual-path estimates of Russia–Kazakhstan trade for 2018–2025

Period	Year	Path A Estimate, USD bn	Path B Estimate, USD bn	Absolute Gap, USD bn
Pre-war period	2018	18.48	18.51	0.03
Pre-war period	2019	19.99	19.99	< 0.01
Pre-war period	2020	18.77	18.77	< 0.01
Pre-war period	2021	24.60	24.62	0.02
Post-war adjustment period	2022	26.76	26.98	0.22
Post-war adjustment period	2023	25.96	26.00	0.04
High-level rebalancing period	2024	27.78	27.80	0.02
High-level rebalancing period	2025	27.40	27.37	0.03

* Path A is based on Kazakhstan's exports, imports, and Russia's trade shares; Path B is based on Kazakhstan's EAEU trade turnover and Russia's share within it. Values reported as < 0.01 indicate non-zero differences below reporting precision.

Note: compiled by the authors.

To reduce dependence on a single measurement route, the study estimates the scale of bilateral Russia–Kazakhstan merchandise trade through two independent paths, both based entirely on official Kazakh statistics. The first is a global-share path, which estimates bilateral trade using Kazakhstan's total merchandise exports and imports together with Russia's official shares among Kazakhstan's export destinations and import sources, as shown in Equation (1):

$$T_t^A = X_t \times s_{R,t}^X + M_t \times s_{R,t}^M \tag{1}$$

where:

T_t^A – the estimated value of bilateral Russia–Kazakhstan merchandise trade in year t;
X_t – the total value of Kazakhstan's exports in that year;
M_t – represents the total value of Kazakhstan's imports in that year;
$s_{R,t}^X$ – Russia's share of Kazakhstan's export destinations;
$s_{R,t}^M$ – Russia's share of Kazakhstan's import sources.

This path essentially estimates "Kazakhstan's exports to Russia" and "Kazakhstan's imports from Russia" separately and then sums them up.

The second path is an alliance-structure path, which estimates bilateral trade using Kazakhstan's total trade turnover with member states of the Eurasian Economic Union (EAEU) together with Russia's official share within that trade, as shown in Equation (2):

$$T_t^B = EAEU_t \times s_{R,t}^{EAEU} \tag{2}$$

where:

T_t^B – the estimated bilateral trade volume between Russia and Kazakhstan in year t;
$EAEU_t$ – Kazakhstan's total trade turnover with EAEU member states;
$s_{R,t}^{EAEU}$ – Russia's share in the Union's trade.

This path uses the trade structure within the Union to cross-validate the estimates obtained from Path A. Table 2 presents the dual-path estimates across the full observation period alongside robustness notes for each year.

The largest absolute gap appears in 2022 (0.22 billion USD), likely to reflect higher partner-share volatility during the adjustment period rather than a systematic estimation bias. For the remaining years, the absolute gap does not exceed 0.04 billion USD. The consistency between the two paths supports the reliability of this article's characterization of bilateral trade dynamics.

4 | RESULTS

According to data published by Kazakhstan's Bureau of National Statistics, total foreign trade followed an overall upward trajectory between 2018 and 2025, increasing from approximately 93.5 billion USD to approximately 143.9 billion USD, with a decline in 2020 due to the pandemic. Trade with EAEU member states rose

as well, from approximately 19.3 billion USD in 2018 to approximately 30.9 billion USD in 2025, indicating that the regional trade framework remained functional throughout the period (Bureau of National Statistics, 2026).

Table 2. Robustness check of Russia–Kazakhstan trade estimates for 2018–2025

Period	Year	Path A, USD bn	Path B, USD bn	Gap, USD bn	Robustness Note
Pre-2022 period	2018	18.48	18.51	0.03	The two paths converge closely, indicating a stable baseline.
Pre-2022 period	2019	19.99	19.99	< 0.01	The negligible gap suggests a highly consistent estimate.
Pre-2022 period	2020	18.77	18.77	< 0.01	The pandemic-related contraction is captured consistently by both paths.
Pre-2022 period	2021	24.60	24.62	0.02	Trade recovery is reflected similarly across both estimation paths.
Shock-reorgan. period	2022	26.76	26.98	0.22	The largest gap in the series likely reflects higher partner-share volatility during the adjustment year.
Shock-reorgan. period	2023	25.96	26.00	0.04	Bilateral trade remains elevated, while the gap returns to a low level.
High-level rebal. period	2024	27.78	27.80	0.02	The two paths remain highly consistent and support the interpretation of stable high-level trade.
High-level rebal. period	2025	27.40	27.37	0.03	The small gap supports the interpretation of high-level plateauing rather than continued expansion.

* Path A uses Kazakhstan's exports, imports, and Russia's trade shares; Path B uses EAEU trade turnover and Russia's share within it. Values < 0.01 indicate non-zero differences below reporting precision. January 2026 is excluded due to data incomparability.

Note: compiled by the authors.

The drivers of growth differed across periods. The dynamics observed between 2018 and 2021 largely reflected post-pandemic recovery, whereas the period after 2022 was shaped by the restructuring of external economic relations under sanctions conditions. Between 2022 and 2023, intra-EAEU trade rose steeply from approximately 27.2 billion USD to approximately 30.6 billion USD. Russia's share in Kazakhstan's intra-EAEU trade, while still dominant, experienced minor reductions in certain years, suggesting that although Russia remains Kazakhstan's primary partner within the Union, the trade concentration is evolving.

At the regional level, Kazakhstan's trade with Eurasian Economic Union member states remained high over the most recent two years. According to the Bureau of National Statistics, Kazakhstan's total EAEU trade turnover reached approximately 30.4 billion USD in 2024 and increased modestly to approximately 30.9 billion USD in 2025. Of these totals, trade with Russia accounted for the predominant share (Table 3).

An important asymmetry emerges beneath the aggregate trade figures. Russia's share contracted on both sides between 2024 and 2025, but the decline on the

export side (from 11.7% to 10.3%) was steeper than on the import side (from 30.5% to 29.7%). This pattern suggests that Kazakhstan's export diversification away from Russia is proceeding faster than import substitution.

Combined with Kazakhstan's aggregate export decline of 3.2 percent and import growth of 7.4 percent, this asymmetry points to directional divergence at the bilateral level. Kazakhstan's export composition is shifting away from Russia more rapidly, while its reliance on Russian imports remains structurally sticky.

On an annual basis, Russia–Kazakhstan bilateral goods trade after 2022 remained broadly within the range of approximately 26.0–27.8 billion USD. The estimate for 2024 is approximately 27.8 billion USD, and for 2025, approximately 27.4 billion USD. The two estimation pathways yield closely aligned figures across all years, confirming that this article's characterization of bilateral trade dynamics does not depend on a single measurement approach and is robust to alternative estimation methods. Disaggregating by direction, Kazakhstan's exports to Russia declined from approximately 9.55–9.56 billion USD in 2024 to approximately 8.14 billion USD in 2025, while imports from Russia rose from approximately 18.24 billion USD to approximately 19.26 billion USD over the same interval. This indicates that while overall bilateral trade remained elevated, its internal composition shifted: the export side contracted, while the import side remained resilient. Russia–Kazakhstan goods trade after 2025 is therefore more accurately characterized as structural rebalancing at an elevated baseline than as continued expansion.

Table 3. Kazakhstan's external trade and Russia-related indicators for 2024–2025

Indicator	2024	2025	Change
Kazakhstan's total merchandise trade, USD bn	141.406	143.888	+1.3%
Kazakhstan's exports, USD bn	81.618	79.041	–3.2%
Kazakhstan's imports, USD bn	59.787	64.847	+7.4%
Kazakhstan's trade turnover with the EAEU, USD bn	30.448	30.893	+1.5%
Russia's share among Kazakhstan's export destinations	11.7%	10.3%	–1.4 p.p.
Russia's share among Kazakhstan's import sources	30.5%	29.7%	–0.8 p.p.

Note: compiled by the authors based on Bureau of National Statistics (2026).

The reordering of partner shares displays two distinct patterns rather than a single trend. Russia's export-side share contracted markedly faster than its import-side share, while China gained on both sides but with a notably steeper rise in import-source share than in export-destination share (Table 4).

Table 4. Russia and China shares in Kazakhstan's trade, 2024–2025

Partner	2024 Export share	2025 Export share	2024 Import share	2025 Import share
Russia	11.7%	10.3%	30.5%	29.7%
China	18.3%	19.2%	25.3%	29.2%

Note: compiled by the authors based on Bureau of National Statistics (2026).

Russia's relative position changed unevenly across trade dimensions. Russia's share among Kazakhstan's export destinations declined from 11.7% in 2024 to 10.3% in 2025, while its share among import sources decreased more moderately from 30.5% to 29.7%. At the same time, China strengthened its position in Kazakhstan's trade structure, with its export share increasing from 18.3% to 19.2% and its import share rising from 25.3% to 29.2%, indicating a gradual reordering of external trade relations. The organizational footprint presents a different pattern from trade flows. Russian-affiliated entities substantially outnumber those from other major source countries, while the operational-to-registered ratio of approximately three-quarters suggests that this presence reflects sustained economic activity rather than residual legal registration (Table 5).

Table 5. Business entities in Kazakhstan by major source country, as of January 1, 2026

Country	Foreign-Funded Entities Registered	Foreign-Funded Entities Operating	Joint Ventures Registered	Joint Ventures Operating
Russia	22,821	17,348	4,798	3,719
Uzbekistan	8,209	6,528	631	465
China	8,081	6,356	1,171	940
Turkey	5,051	3,272	736	473
Kyrgyzstan	2,849	2,017	382	282

*Business-entity statistics reflect organizational presence and do not directly measure industrial upgrading.

Note: compiled by the authors based on Bureau of National Statistics (2026).

Chinese-affiliated entities accounted for 8,081 registered and 6,356 operating firms, while Uzbek-affiliated entities accounted for 8,209 registered and 6,528 operating firms. These differences across source countries suggest that Russia maintains a particularly strong organizational presence within Kazakhstan's enterprise structure. Previous research indicates that the institutionalization of the EAEU contributed to bilateral foreign direct investment and capital integration prior to the sanctions period (Kemme et al., 2021). Building on this structural foundation, available investment data, although less directly comparable than trade statistics, suggest that capital linkages between Russia and Kazakhstan remain substantial.

Investment data are less directly comparable than trade and business-entity statistics. Nevertheless, direct investment position data published by the National

Bank of Kazakhstan as of October 1, 2025, suggest that Russia continues to represent an important source of capital linkages for Kazakhstan (National Bank, 2026). Because publicly available summaries do not provide a fully consistent bilateral investment flow series, investment is not used here as the principal basis for identifying the direction of change but rather as supplementary evidence. At minimum, the available investment data do not support the conclusion that bilateral capital ties have been severed.

5 | DISCUSSION

The results indicate that Russia–Kazakhstan relations have not evolved along a single path of "continuous expansion" or "rapid contraction" but have instead entered a state of high-level rebalancing. If one were to strictly adhere to the logic of sanctions-induced contraction, Russia–Kazakhstan trade and business activity should have declined in tandem as sanctions intensified. Contractionist explanations in sanctions research typically support this expectation (Hufbauer et al., 2007; Morgan et al., 2023). However, the findings of this paper show that Russia's share of Kazakhstan's import sources remained at nearly 30 percent between 2024 and early 2026, whilst the number of Russian-affiliated business entities continued to hold a significant advantage. This indicates that existing ties have not contracted linearly. Conversely, if one were to strictly adhere to the logic of adaptive restructuring, circumvention dividends and alternative channels should continue to drive the expansion of bilateral ties (Early, 2015). However, the estimates in this paper indicate that by 2025, bilateral goods trade between Russia and Kazakhstan had shifted from expansion during the shock period to a plateau at a high level, with Kazakhstan's exports to Russia showing a marked decline. This implies that the assessment of continued strengthening, formed based on observations during the early stages of the shock, needs to be revised over a longer time horizon.

A more accurate explanation is that sanctions have simultaneously unleashed two opposing forces. The first is a stabilising force, stemming primarily from geographical proximity, cross-border supply chains, institutional interfaces within the EAEU, and existing organisational networks; these factors reduce the likelihood of a sudden rupture in relations (Hudson, 2022; Pomerlyan & Belitski, 2024). The second category comprises restraining forces stemming primarily from compliance audits, corporate entity lists, payment risks, and third-party transshipment regulations. These factors have compressed new arbitrage opportunities and raised the marginal cost of continued expansion (Felbermayr et al., 2020; Morgan et al., 2023). Between 2022 and 2023, sustaining forces temporarily dominated, resulting in an anomalous expansion of bilateral relations. From 2025 onwards, constraining forces rose significantly; whilst bilateral trade remained at a high level, it no longer increased at the same rate as during the shock period. The so-called "rebalancing at a high level" is essentially the result of the coexistence of these two types of forces: existing ties, institutional channels and organisational embeddedness prevent the relationship from being severed, whilst compliance pressures and intensified competition significantly weaken its expansionary momentum.

The findings of this paper indicate that, after 2025, the key mechanism sustaining Russian–Kazakh ties is no longer the shock-driven amplification on the export side but rather three mechanisms with greater stickiness. First, the stickiness of import supply chains. Although Russia's share of Kazakhstan's import sources has declined marginally, it remained at a high level of around 30 percent in 2024 and 2025. Second, institutional interface stickiness. Russia–Kazakhstan relations are embedded within the common trading system of the EAEU; internal Union statistics show that Russia's share of Kazakhstan's trade with the EAEU remains very high. Third, organisational embedding stickiness. The number of Russian-affiliated enterprises operating in Kazakhstan is significantly higher than in other countries, indicating that many links have evolved into legal entities with long-term operations rather than one-off trade transactions (Bureau of National Statistics, 2026). Furthermore, this embeddedness is reinforced by underlying structural complementarities within their national innovation systems, which create operational and technological interdependencies that are difficult to untangle in the short term (Yakovenko et al., 2026).

Based on the aforementioned mechanisms, this paper adopts "functional stratification" as a key concept for understanding Russia–Kazakhstan relations. This refers to the fact that different partners fulfill distinct functions within Kazakhstan's external economic structure. Russia is more focused on import supply, the Union interface, and organizational networks. China is more concentrated on export absorption, equipment supply, and a larger share of foreign trade. Functional stratification implies that changes in the partnership should not be judged solely on the basis of total figures but should be assessed separately across functional dimensions.

The results indicate that Russia's relative position within Kazakhstan's external economic structure has not disappeared, but has indeed shifted. In this paper, relative position is understood as a partner's overall standing in terms of ranking, market share and functional importance. In terms of total trade volume and import sources, Russia remains significant. However, in terms of export destinations, Russia's relative position is declining when compared with China. In other words, the shift in Russia's position does not represent an absolute loss of standing, but rather a transition from "dual expansion in both volume and direction" to "maintaining critical importance in certain dimensions whilst facing competitive pressure in others."

This shift offers two insights for existing theory. First, research on sanctions should not interpret the relationship between the target country and its allies as simply contracting or expanding continuously, but should allow for the existence of an intermediate state characterised by a realignment of relative positions (Morgan et al., 2023; Sedrakyan, 2022). Second, regional institutions do not exert a uniform influence on all economic functions. Institutions may simultaneously sustain import supply and organisational embeddedness, yet they may not necessarily continue to support exceptional expansion on the export side (Libman & Obydenkova, 2022).

Naturally, this paper does not claim that all changes are caused solely by sanctions. Global commodity prices, the expansion of domestic demand in Kazakhstan, and the restructuring of global shipping and land-based logistics may all influence total import and export volumes and partner shares. Precisely for this reason, this paper refrains from elevating descriptive comparisons to strict causal identification, instead limiting its conclusions to empirical explanations supported by continuous official statistics.

From a measurement perspective, this paper mitigates the risk that bilateral total volumes rely on a single summary metric through dual-path estimation and bases its core arguments on total volumes, market shares, and the number of enterprises directly published by the National Statistics Bureau. Even without relying on a single point estimate of the bilateral total, the paper's five conclusions—namely, that "the scale remains large, exports have declined, imports remain high, enterprise integration persists, and relative positioning is adjusting"—remain valid (Bureau of National Statistics, 2026).

From a research perspective, future studies on sanctions can be advanced in at least three areas. First, by shifting the temporal focus forward to identify the rebalancing phase, rather than concentrating solely on the shock period. Second, by integrating flow and stock dimensions to examine not only trade but also business entities and institutional arrangements. Third, introducing the agency of small states into research on alliance networks to analyze how middle powers proactively set the boundaries of cooperation between the pursuit of benefits and compliance constraints (Early, 2015; Libman & Obydenkova, 2022; Ibrayeva et al., 2023).

6 | CONCLUSION

This paper provides a systematic analysis of the evolution of economic cooperation between Russia and Kazakhstan against the backdrop of sanctions. The findings suggest that economic relations between the two countries since 2022 cannot be simply characterised as either continuous expansion or continuous contraction, but rather exhibit a more complex process of structural rebalancing. This process reflects the adaptability of alliance networks and regional institutional interfaces in the face of sanctions shocks, while also revealing how compliance pressures, shifts in the competitive landscape, and functional restructuring have reshaped bilateral relations. External sanctions have not disrupted economic cooperation between Russia and Kazakhstan, but its operational logic, supporting mechanisms, and structural positioning have undergone significant changes.

The main findings can be summarised as follows. First, Russia–Kazakhstan economic cooperation remains at a relatively high level in absolute terms, but the expansion phase has ended. Both the global-path estimates based on total export and import shares and the EAEU-path estimates based on the intra-EAEU trade structure indicate that bilateral goods trade remained at a high level after 2025 but no longer expanded at the rate seen during the shock period. Second, the direction of bilateral economic ties has diverged significantly: Kazakhstan's exports to Russia have declined while imports from Russia have remained resilient,

indicating that the dominant forces underpinning the relationship have shifted from export-driven expansion to more persistent import supply and institutional interfaces. Third, bilateral ties have evolved from short-term trade flows into institutionalized organizational embedding. Although Kazakhstan's exports to Russia declined markedly in 2025, Russian-affiliated enterprises in Kazakhstan numbered 22,821 registered and 17,348 in operation, ranking first among all foreign sources. The coexistence of cooling trade flows and consolidation at the organisational level indicates that cooperation has evolved from ad hoc trade opportunities into a structural network underpinned by legal entities and sustainable operations. Fourth, Russia's importance within Kazakhstan's economic structure remains, but its relative position has shifted. The continued rise in China's share, particularly its convergence with, and eventual overtaking of, Russia as both an export destination and an import source, signals that Russia's role is transitioning from comprehensive dominance to a functional niche. Fifth, the key impact of sanctions lies not in whether existing ties are severed, but in how they alter the functional boundaries, distribution patterns, and adjustment pathways of those ties.

The theoretical significance of this paper lies in advancing the analytical framework for research on sanctions and allied cooperation. Existing studies typically debate between "sanctions lead to contraction" and "sanctions induce adaptive expansion," yet neither explanation accounts for the "high-level but no longer expanding" state observed after 2025. This paper demonstrates that allied cooperation under sanctions does not necessarily evolve in a single direction but towards a state of jointly constituted structural rebalancing. Future research should not rely solely on changes in total trade volume to judge an alliance relationship, but should simultaneously examine functional levels, organisational forms, and structural positioning.

The practical significance is reflected at three levels. For policymakers, middle powers are not passive recipients in sanctions games between major powers but continuously adjust the boundaries of their cooperation between profit-seeking, risk management, and compliance constraints. For businesses and market participants, the prospects for Russia–Kazakhstan cooperation should be assessed by the stability of import supply chains, the sustained expansion of corporate networks, and the effectiveness of institutional interfaces, rather than by aggregate trade volume alone. For researchers, sanctions research needs to shift from the impact phase to the rebalancing phase, identifying the phased differences in sanctions spillovers across the temporal dimension.

This paper has several limitations. It employs a single-case longitudinal descriptive design, which supports pattern identification but not strict causal inference. Investment data are less comparable than trade and enterprise statistics and are treated only as supplementary evidence. The analysis focuses on Kazakhstan as a node in an alliance network rather than firm-level performance heterogeneity. Future research could extend the observation period to test whether high-level rebalancing consolidates into a new stable structure, integrate sectoral and product-level data to identify heterogeneous adjustments across commodities,

and conduct cross-national comparisons with other middle-income economies affected by sanctions spillovers.

The core conclusion of this paper is not whether Russia–Kazakhstan relations have strengthened or weakened, but that the nature of their dynamics has changed. Sanctions have not severed existing ties, but they have constrained further expansion and driven the bilateral relationship from a phase of expansion during the shock period towards a phase of restructuring during the rebalancing period. What truly warrants attention in the future is no longer merely whether bilateral cooperation will continue, but the functional form in which it will persist and the boundaries within which it will be reorganised.

AUTHOR CONTRIBUTIONS

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ESG Transformation in Logistics and Supply Chain Management: Bibliometric Evidence from Central Asia

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Abstract
In the context of digital transformation, climate risks and geo-economic instability, ESG approaches are becoming an important direction for the modernization of logistics, distribution systems and supply chain management. The purpose of the study is to conduct a bibliometric analysis of scientific publications to identify the dynamics, thematic structure, and role of Central Asian countries in the development of ESG-oriented research in logistics and supply chain management. The methodological basis of the study was made up of bibliometric analysis, the PRISMA approach, co-authorship analysis, co-word analysis and network visualization using the VOSviewer program. The initial empirical base was formed from publications indexed in the Web of Science Core Collection for 2021–2025. The results demonstrate a more than threefold increase in publication activity, from 70 publications in 2021 to 226 publications in 2025, reflecting the growing scientific interest in sustainable logistics systems and ESG-oriented supply chain management. The results of the network analysis revealed the key thematic areas of ESG research: digital ESG ecosystems, artificial intelligence, machine learning, blockchain technologies, supply chain sustainability, circular economy, green logistics, and ESG-oriented risk management. Kazakhstan and Uzbekistan are increasingly serving as connecting nodes between European and Asian research clusters, reflecting the growing importance of Central Asia in Eurasian transport corridors and in the transformation of sustainable logistics within an ESG-oriented economy. The results indicate that ESG is increasingly functioning as an integrated governance framework for adaptive, digitally connected, and sustainable supply chain systems amid climate risks, geo-economic instability, and global disruptions.

KEYWORDS
Logistics, Sustainable Logistics, Logistics Economics, Supply Chain Management, Green Economy, Supply Chain Resilience, Central Asia

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1 | INTRODUCTION

ESG is becoming a crucial component in transforming supply chain management and logistics amid growing global instability, digital transformation, and demands for sustainable development. Approaches to supply chain management have changed dramatically due to increased regulatory pressure, the growth of sustainable finance, the adoption of net-zero pledges, and the fallout from global disruptions such as the COVID-19 pandemic. Resilience-oriented and sustainability-driven supply chain strategies are increasingly replacing the conventional emphasis on cost efficiency.

Early research on ESG, logistics, and supply chain management primarily focused on green supply chain management, logistics efficiency, and companies' environmental sustainability. At the initial stage, ESG was interpreted mainly through environmental sustainability, reputational benefits, and compliance-oriented practices, while issues of resilience, digitalisation, and strategic adaptability in supply chains were not yet central to the research agenda (Kim et al., 2021; Chouaibi & Chouaibi, 2021).

After the COVID-19 pandemic, the research focus increasingly shifted to supply chain resilience, ESG-oriented risk management, and digital transformation. Song et al. (2022) emphasise the importance of flexibility, collaboration, and adaptive logistics capabilities for the sustainability of supply chains, while Dai and Tang (2022) consider ESG as part of strategic supply chain management in the post-pandemic economy. At the same time, interest in digital ESG ecosystems is growing, including blockchain technologies, IoT, big data analytics and smart logistics systems.

Central Asian regional studies are mainly focused on modernising logistics infrastructure, digitalising supply chains, and enhancing transportation connectivity. Arynova et al. (2024) analyse the role of distribution centres in the development of logistics infrastructure in Kazakhstan, while Tazhibekova et al. (2023) emphasise the importance of digital tools and information systems for the sustainability of supply chains during COVID-19 disruptions. Li et al. (2025) consider reverse supply chains and circular economy approaches in Kazakhstan's mining industry. However, the issues of ESG governance, supply chain resilience and digital sustainability remain insufficiently integrated into the regional research agenda. The existing research gaps highlight the need for further analysis of the interrelationships among ESG integration, digital transformation, logistics efficiency, and supply chain resilience in the context of emerging economies and the sustainable transformation of global supply chains.

The research aims to conduct a comprehensive bibliometric analysis of scientific publications to identify new trends in the development of sustainable logistics systems, key research areas and the structure of international scientific cooperation, as well as to determine the role of Central Asian countries in shaping the modern ESG agenda and developing research on sustainable supply chains in the context of digitalisation and geo-economic transformation.

Based on the aim, the following research questions arise:

RQ1: How has the scientific agenda of ESG research in the field of distribution,

logistics and supply chain management changed in the period 2021–2025?

RQ2: Which thematic, intellectual and interdisciplinary clusters form the modern structure of ESG research in logistics and supply chain management?

RQ3: Which countries, authors and scientific journals are central to the development of ESG research in the field of logistics and supply chain management, and what is the structure of international scientific cooperation?

RQ4: What role do the Central Asian countries play in shaping the modern ESG agenda and developing research on sustainable logistics systems in the global scientific space?

RQ5: What new trends, technological directions and research gaps determine the further development of ESG-oriented logistics and supply chain management?

2 | LITERATURE REVIEW

Early ESG research on logistics and supply chain management was predominantly shaped around green supply chain management, logistics, and the basic integration of environmental criteria into corporate practice. First of all, he focused on environmental sustainability, reputational advantages, and regulatory-compliance-oriented practices such as supply chain sustainability, digitalisation, and strategic adaptability, thereby paying little attention to strategic development. Zhang (2021) showed that the practice of "green" supply chains can significantly improve the effectiveness of legislation and a company's environmental performance. Kim et al. (2021) analysed ESG logistics as a competitor for e-commerce companies, linking it with stable legal operations and respect for readers. Such studies have focused mainly on operational and environmental efficiency, rather than comprehensive supply chain transformation.

ESG management and corporate value creation developed in parallel. Chouaibi and Chouaibi (2021) identified a link between social and ethical practices and firm value, while Signori et al. (2021) examined value creation for stakeholders, showing that ESG indicators increasingly complement traditional metrics. The literature of this period remained somewhat fragmented: ESG was considered either as a tool to increase the company's value or as an element of environmental responsibility, but rarely as an integrated mechanism for strategic supply chain management.

Researchers have concentrated on resilience building, risk management, local environmental activities, and the transformation of the ESG-focused supply chain since the COVID-19 pandemic. Amidst global upheavals, the shortcomings of early systems that prioritised environmental efficiency have become especially apparent. In this regard, Song et al. (2022) conceptualised supply chain sustainability through flexibility, redundancy, collaboration, and adaptive logistics capabilities. Dai and Tang (2022) also highlighted the shift from traditional cost-effectiveness to sustainable, ESG-driven supply chains, indicating a more dynamic approach to strategic sustainability.

Buallay (2022) showed a link between sustainability reporting and retail sector performance, while Garsaa and Paulet (2022) showed that ESG disclosure can help reduce staff turnover. Consideration of issues related to the assessment of

consumer demand, long-term profitability, mechanisms of causation, and industry heterogeneity, which, of course, are significant mainly in emerging markets.

ESG is increasingly focused on digital transformation, intelligent management and innovative capabilities. Barykin et al. (2023) analyse smart city logistics as a tool for achieving ESG goals, while Qian et al. (2023) propose a platform based on blockchain and the Internet of Things to support a closed-loop economy and green supply chains. Long et al. (2023) show that the effectiveness of ESG is related to "green" innovations, as it can be implemented under conditions of increased competition and innovation.

The methodological evolution of research is also becoming more pronounced. Early research was based on conceptual analysis, case studies, and ESG correlational approaches. Regression, behavioural measurement models, digital management systems, blockchain/IoT modelling, and data-driven ESG analytics are used widely. Galletta et al. (2022), for example, use a bibliometric approach to analyse the effectiveness of ESG in the banking industry, Long et al. (2023) use quantile regression, and Barbosa et al. (2024) analyse the integration of ESG with the perception of workers and the theory of responding to them. De la Fuente and Velasco (2024) analyse inequality in the field of sustainable development as a possible symptom of symbolic practices of sustainable development, and Zhao et al. (2024) indicate that inconsistencies in executive power can lead to the "greening" of the economy. Such a transformation of research logic indicates a shift in attention from studying the information disclosure to analysing reliability, managerial depth, and behavioural integration in the field of ESG principles.

Research conducted in Central Asia and Kazakhstan focuses on the modernisation of logistics infrastructure, digital transformation of supply chains, and closed-loop economics approaches. While Tazhibekova et al. (2023) examine digital tools and information systems to support supply chains during COVID-19 interruptions, Arynova et al. (2024) examine the function of distribution centres in the growth of Kazakhstan's logistics connectivity. Azimov et al. (2024) analyse the application of blockchain technologies in business, and Li et al. (2025) introduce reverse supply chains, approaches to a closed-loop economy, and the mining industry in Kazakhstan.

Despite a significant increase in ESG studies in logistics and supply chain management, several important gaps remain in the literature. Most early research focused on environmental aspects of sustainability and green logistics, while the strategic integration of ESG into supply chain management was considered fragmentary. Modern works increasingly analyse the relationship between ESG and digital transformation, supply chain sustainability, and risk management, but these areas are developing mainly in isolation from one another.

In addition, existing ESG bibliometric studies are primarily focused on corporate finance, sustainable investment, and non-financial reporting, while the development of the ESG agenda in distribution, logistics, and supply chain management remains poorly understood. Central Asia, which is becoming increasingly important in international transport corridors and global supply chains, requires

special attention, but its contribution to shaping the scientific ESG agenda has been studied to a limited extent. Thus, the scientific gap lies in the absence of a comprehensive bibliometric analysis that simultaneously assesses the dynamics of research, the structure of international cooperation, the thematic evolution and new directions of ESG development in the field of distribution, logistics and supply chain management, taking into account the increasing role of Central Asian countries.

3 | RESEARCH METHODS

This article uses a bibliometric analysis of scientific publications indexed in the Web of Science Core Collection database for the period 2021–2025. The empirical research base is based on a search query on ESG, distribution systems, logistics, and supply chain management. The study used the PRISMA (PRISMA flow diagram) approach adapted for bibliometric analysis to systematise and select scientific publications. The PRISMA approach enabled transparency and reproducibility of the sampling procedure in scientific publications (Figure 1).

At the first stage (identification), publications were searched in the Web of Science Core Collection database on the topics of ESG, distribution, logistics and supply chain management using the search query: TS=('ESG' AND ('distribution' OR 'logistics' OR 'supply chain')). At the second stage (Screening), sequential filters for the selection of publications were applied: restrictions on the publication period (2021–2025), the type of document (articles), as well as the affiliation of the country of the authors (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan). At the final stage (included), the final sample included publications that met all the selection criteria and were used for subsequent bibliometric analysis. The use of PRISMA ensured a logical sequence of data selection and minimised the inclusion of irrelevant publications in the study dataset.

The study used quantitative bibliometric methods, including analyses of publication activity, the dynamics of scientific publications, the structure of international cooperation, the most-cited works, and the frequency of keyword use. The methods of co-word analysis and network visualisation were used to identify the main thematic clusters and research areas.

Bibliometric data were processed and visualised using VOSviewer, a software tool that enables the analysis of collaborations, thematic clusters, and bibliographic coupling. The results obtained were used to identify the main trends in the development of ESG research in logistics, distribution systems, and supply chain management.

To assess trends in scientific research development, an analysis of the dynamics of publication activity on ESG topics in distribution, logistics, and supply chain management was conducted. The study's results demonstrate a significant increase in publication activity on ESG topics across distribution, logistics, and supply chain management during 2021–2025. The number of publications increased from 70 in 2021 to 226 in 2025, indicating a more than threefold increase in research interest during the analysed period (Figure 2).

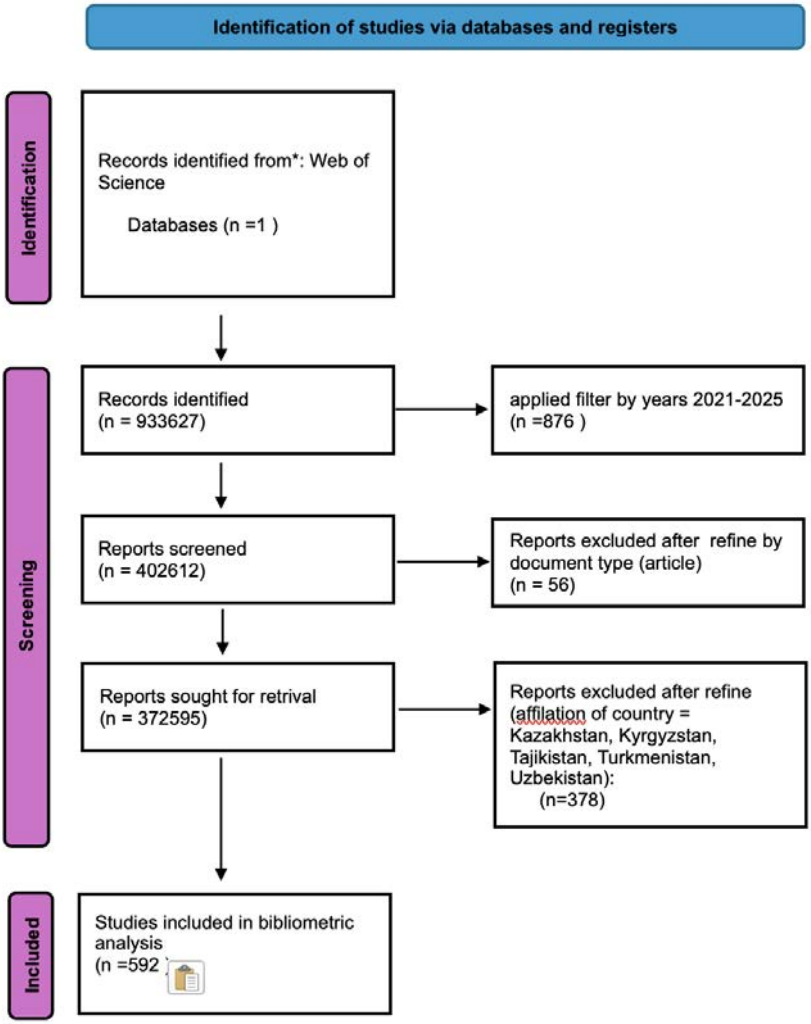


Figure 1. PRISMA-based flow diagram of publication selection for bibliometric analysis

4 | RESULTS

The dynamics of publications are characterised by steady growth, which intensified after 2023. The results obtained reflect the growing attention of the scientific community to integrating ESG principles into logistics systems, sustainable supply chain management, and distribution management processes. A significant increase in publications in 2024–2025 also indicates the growing importance of sustainable development, green logistics, and responsible supply chain management in the modern scientific agenda.

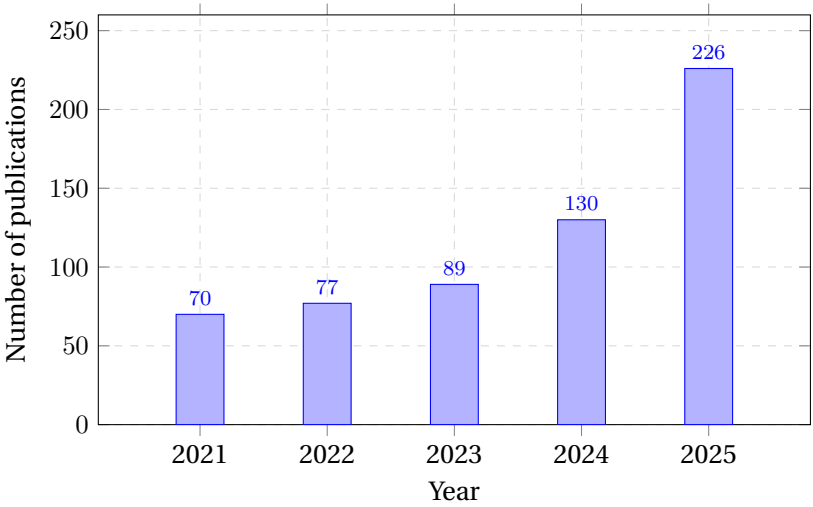


Figure 2. Dynamics of publication activity for 2021–2025

Note: compiled by the authors based on Web of Science database

To identify the structure of international scientific cooperation, an analysis of countries' co-authorship networks was conducted, revealing the most active countries, the intensity of international cooperation, and key research clusters. The results of the analysis are shown in Figure 3.

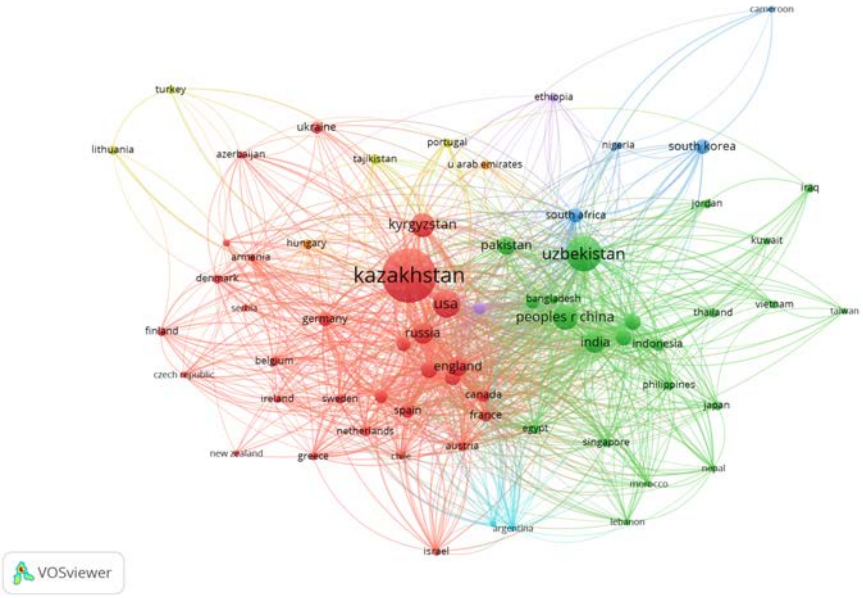


Figure 3. Map of international scientific cooperation between the countries

The network card demonstrates a high level of international cooperation between countries in ESG research and sustainable supply chains. However, the identified central positions of Kazakhstan, Uzbekistan, the People's Republic of China, the USA and England are determined not only by quantitative indicators of publication activity, but also by the specifics of modern global logistics development and ESG transformations. The dominant positions of China, the USA and England are explained by their leading roles in shaping the global ESG agenda, developing sustainable supply chain systems, and concentrating large international research centres in logistics, sustainability and digital transformation. For China, the key factors are the large-scale integration of ESG principles into the Belt and Road Initiative and the development of green logistics and digital supply chain management platforms. The United States and Great Britain retain their central positions due to the high concentration of publications in highly rated journals, the developed research infrastructure and active international scientific cooperation.

Strengthening the positions of Kazakhstan and Uzbekistan as new regional ESG research centres in Central Asia is associated with the active integration of countries into international transport and logistics corridors, including the Middle Corridor and Belt and Road Initiative, the increasing role of the region in ensuring the sustainability of Eurasian supply chains, and increased attention to ESG transformation of raw materials and transit economies. An additional factor is the expansion of international research projects, academic mobility and publication cooperation with universities in Europe and Asia, which contributes to increasing the international scientific visibility of Central Asian countries in the field of sustainable logistics and supply chain management.

The study shows that Kazakhstan and Uzbekistan are emerging as connecting nodes between European and Asian research clusters, forming a new Eurasian segment of scientific cooperation in sustainable supply chain management. Additionally, the results demonstrate a shift in research focus from traditional ESG analysis in corporate and financial contexts to the use of ESG as a tool to enhance the sustainability of international logistics systems, transport corridors, and supply chain resilience amid geo-economic transformation and global crises.

Further analysis aims to identify the quantitative characteristics of publication activity and the structure of international scientific cooperation. For a more detailed presentation of the results of the bibliometric analysis, the main indicators of publication activity, citations and international interaction of researchers were systematised. The corresponding results are presented in Table 1.

The results indicate a high degree of internationalisation of ESG research in Central Asia, particularly in logistics and supply chain management. The greatest publication activity is observed among countries that actively integrate ESG principles into national strategies for sustainable development and digital transformation of logistics systems. The analysis also shows that international co-authorship is a key factor in increasing scientific visibility and publication citations. The most active research networks are formed across Asia, Europe, and North America, reflecting the global nature of the ESG agenda in supply chain management. In

addition, the results demonstrate a gradual increase in Central Asian countries' participation in international ESG research, indicating their expanding integration into the global scientific community and growing interest in sustainable logistics and responsible supply chain management.

Table 1. Distribution of publication activity, citation and strength of international scientific relations by country

No.	Country	Document	Citation	Total link strength
1	Kazakhstan	354	2192	613
2	Uzbekistan	154	1498	494
3	USA	92	910	350
4	China	74	929	352
5	Kyrgyzstan	72	606	200
6	India	55	1091	345
7	Russian Federation	53	519	323
8	England	45	578	370
9	Pakistan	42	481	210
10	Italy	33	450	333

Note: compiled by the authors based on VOSviewer

To determine the most widespread scientific research areas, an analysis of publication subject categories was conducted. The results of the distribution of publications by scientific categories are presented in Table 2.

Table 2. Top 10 scientific journals by number of publications and citation rate

No.	Source title	Quantity of articles	Quantity of citations	H-index
1	Sustainability	21	202	7
2	PLOS ONE	13	88	5
3	Economic annals XXI	11	4	1
4	Scientific reports	9	46	4
5	Industrial engineering and management systems	8	14	3
6	Frontiers in public health	7	12	2
7	Sensors	7	52	3
8	Applied Sciences Basel	6	30	3
9	BMC Public Health	6	127	4
10	Diagnostics	6	19	3

Note: compiled by the authors based on Web of Science database

The analysis shows that ESG research in logistics and supply chain management has a pronounced interdisciplinary character. High publication activity is

observed across journals in various scientific fields, including Sustainability, PLOS ONE, Economic Annals XXI, Scientific Reports, Industrial Engineering and Management Systems, Frontiers in Public Health, Sensors, Applied Sciences Basel, BMC Public Health, and Diagnostics. The dominant position of Sustainability magazine stems from the modern ESG agenda in logistics and supply chain management, which is increasingly focused on sustainable development, green logistics, carbon neutrality, and ESG governance. A significant part of the publications is devoted to decarbonising transport systems, the sustainability of supply chain networks, and integrating sustainability principles into corporate governance.

The high representation of the journals Industrial Engineering and Management Systems and Applied Sciences Basel reflects the strengthening of engineering and technology areas of ESG research. The publications of these journals focus on optimisation of logistics systems, digital transformation, automation, and the use of intelligent technologies in supply chain management. This structure of publication activity indicates the transition of ESG research from primarily normative analysis to the development of applied mechanisms to improve the efficiency and sustainability of logistics systems.

The presence of the journals PLOS ONE, Frontiers in Public Health, BMC Public Health and Diagnostics demonstrates the expansion of the ESG agenda in the field of public health and the sustainability of socio-economic systems. This trend has strengthened since the COVID-19 pandemic, when supply chain sustainability, food security, environmental safety, and public health began to be considered interrelated elements of ESG risk management. The high impact of the journals Economic Annals XXI and Scientific Reports reflect the growing interest in the economic aspects of ESG-oriented logistics systems, including evaluating the effectiveness of ESG practices, reducing transaction costs, assessing the sustainability of international supply chains, and examining the impact of ESG factors on the competitiveness of logistics networks.

The analysis shows that modern ESG research in logistics and supply chain management is developing a new interdisciplinary model that integrates sustainable development, engineering solutions, digital technologies, public health, and the economics of sustainable logistics systems. Accordingly, ESG serves as a comprehensive mechanism for transforming international supply chain systems amid digitalisation, climate risks, and global geo-economic instability.

To assess the scientific impact and quality of publication activity, an analysis of bibliometric indicators for leading scientific journals was conducted and is presented in Table 3.

The results of the analysis show that a significant part of the publications is concentrated in high-quartile journals (Q1–Q2), which indicates a high level of scientific interest in the issues of sustainable supply chain management, green logistics and ESG-oriented business models. Publications in highly rated journals reflect the increasing importance of research on the decarbonization of transport systems, the sustainability of global supply chains, the digitalisation of logistics, and ESG governance. The high values of the Journal Impact Factor and the Journal

Citation Indicator confirm that ESG research is increasingly recognised as a priority in modern interdisciplinary science.

Table 3. Bibliometric indicators of scientific journals

No.	Source	Journal Impact Factor	Journal Citation Indicator	Highest Quartile
1	Sustainability	3.3	0.67	Q2
2	PLOS ONE	2.6	0.85	Q2
3	Economic annals XXI	0.3	0.12	Q4
4	Scientific reports	3.9	1.07	Q1
5	Industrial engineering and management systems	0.5	0.1	Q4
6	Frontiers in public health	3.4	1.06	Q1
7	Sensors	3.5	0.84	Q2
8	Applied Sciences Basel	2.5	0.53	Q2
9	BMC Public Health	3.6	1.18	Q1
10	Diagnostics	3.3	0.92	Q1

Note: compiled by the authors based on Web of Science database

The analysis also shows that the modern ESG agenda is developing at the intersection of management, environmental sciences, engineering, economics and digital technologies. This interdisciplinarity helps expand international scientific cooperation and increase the citation of research in logistics and supply chain management. The conducted analysis allows us to conclude that ESG research in logistics is gradually moving from local applied tasks to the formation of an independent global scientific direction focused on the sustainability of international logistics systems, the digital transformation of supply chains, and business adaptation to climatic and geo-economic challenges.

To identify the structure of scientific cooperation and the most active research groups, an analysis of the authors' co-authorship network was conducted, revealing key researchers, the intensity of scientific interaction, and the research groups formed. The results of the analysis are shown in Figure 4.

The results of the network analysis demonstrate the existence of several stable clusters of scientific cooperation united around the most active researchers. However, the identified structures of co-authorship reflect not only the formal ties between authors, but also the formation of international research centres and thematic scientific schools in the fields of ESG, logistics, and supply chain management. The central positions of the authors Sarria-Santamera Antonio, Issanov Alpamys and Aimagambetova Gulzhanat are due to the high intensity of international publication cooperation, the interdisciplinary nature of research, and the integration of ESG topics with issues of sustainable development, public health, logistics, and the digitalisation of supply chain systems. At the same time, the scientific significance of these nodes is determined not only by the number

of publications but also by their role as connecting elements between various international research groups.

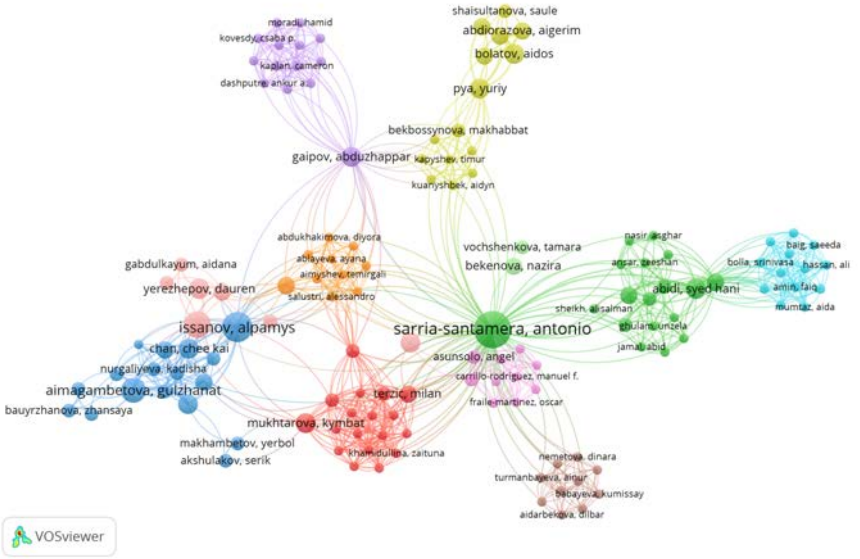


Figure 4. Network visualisation of researchers' co-authorship

The green cluster forming around Sarria-Santamera Antonio reflects the high degree of internationalisation of ESG research and sustainable development. Modern ESG research is increasingly developing at the intersection of public health, sustainability management and risk governance.

The blue cluster, which unites Issanov Alpamys, Aimagambetova Gulzhanat, and related researchers, reflects the emergence of the Central Asian direction in ESG research. The increase in researchers' publication activity in Kazakhstan is associated with the region's growing role in Eurasian transport corridors, the development of the Middle Corridor, and the integration of ESG principles into transport and logistics infrastructure. A significant part of the publications in this area focuses on regional sustainability, logistics resilience, and digital transformation.

The red cluster focuses on research related to ESG performance, management mechanisms, and sustainability assessment of supply chain systems. This cluster reflects the development of quantitative ESG analysis and managerial approaches to the sustainable management of logistics networks. Its formation is associated with growing interest in ESG metrics, performance assessment, and business sustainability models amid global uncertainty.

The purple cluster reflects the development of specialised research related to quantitative analysis methods, digital management models, and international scientific cooperation. The economic interpretation of this cluster is to strengthen the role of data-driven approaches, econometric modelling, and analytics-based

sustainability assessment in ESG research. This cluster demonstrates the transition from traditional descriptive studies to the use of intelligent analytical tools for assessing the sustainability of supply chains.

The yellow cluster unites researchers working in the field of innovative development and the educational and institutional aspects of ESG. Its formation reflects the growing importance of human capital, knowledge transfer and ESG-oriented institutional modernisation in the development of sustainable logistics systems. The analysis shows the strengthening of Central Asia's role as an emerging research hub in sustainable supply chain research and demonstrates a shift in the global ESG agenda towards integrating logistics sustainability, digitalisation, and regional transport security.

To identify key research areas and the most frequently used thematic concepts, an analysis of the type 1 keyword network was carried out. The results of the analysis are shown in Figure 5.

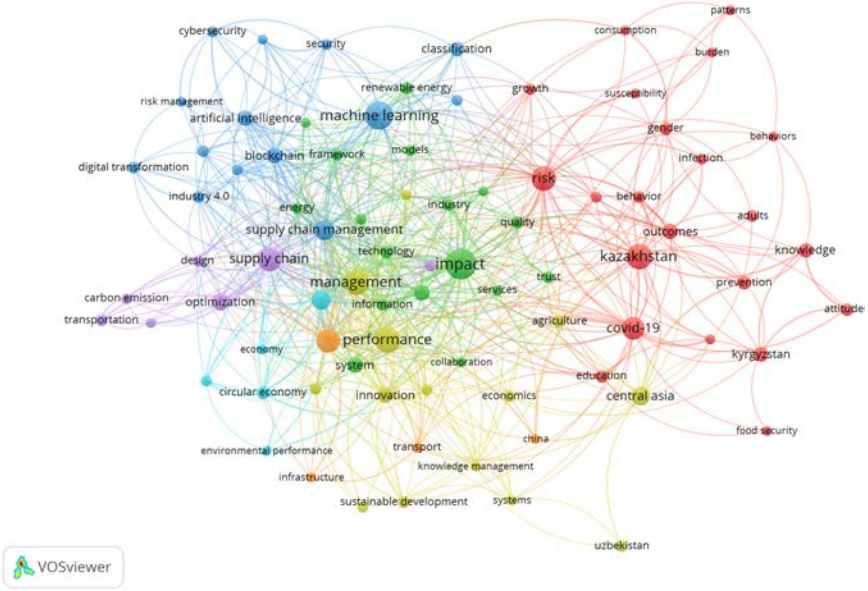


Figure 5. Network visualisation of type 1 keywords

The analysis demonstrates a high level of thematic interconnectedness between ESG research and sustainable supply chain management. However, the allocation of six main clusters reflects the structural transformation of the modern ESG research agenda in the context of digitalisation, geo-economic instability and increasing requirements for the sustainability of global supply chain systems. The centrality of the impact, management, performance, supply chain and risk categories shows that the modern ESG agenda is increasingly focused not only on corporate reporting issues, but also on improving the sustainability and efficiency

of global logistics systems.

The blue cluster, which unites artificial intelligence, machine learning, blockchain, cybersecurity, and Industry 4.0, reflects the emerging digital direction of ESG research. Modern supply chains increasingly depend on intelligent forecasting systems, digital monitoring of ESG risks, and automation of logistics processes. This topic is particularly active in Chinese and South Korean research focused on smart logistics, digital supply chains, and AI-driven sustainability management.

The green cluster, which includes impact, management, industry, quality, and services, reflects the managerial and organisational direction of ESG transformation. This cluster shows that ESG is increasingly seen as a tool for improving operational efficiency, management quality, and long-term business sustainability. The economic essence of the cluster lies in integrating ESG metrics into corporate governance and performance management systems.

The yellow cluster, which unites innovation, sustainable development, knowledge management, systems and economics, demonstrates the innovation and economic research area. Its formation is due to the fact that the sustainability of supply chain systems increasingly depends on innovative adaptability, digital competencies and the ability of companies to integrate ESG principles into strategic development processes. This cluster reflects the transition from traditional logistics to the concept of sustainable innovation ecosystems.

The red cluster, which includes risk, COVID-19, Kazakhstan, Central Asia, food security, and prevention, reflects the regional crisis focus of ESG research. The economic interpretation of this cluster is that the COVID-19 pandemic, geopolitical risks, and disruptions to global supply chains have significantly increased interest in resilience logistics and the sustainability of food systems. The presence of Kazakhstan and Central Asia in the cluster's centre underscores the region's growing importance in research on transport corridors, food security, and the sustainability of Eurasian supply chains.

The purple cluster, associated with transportation, carbon emission, optimisation, and design, reflects the environmental and transportation research area. Its economic essence lies in the search for models to reduce carbon emissions, optimise traffic flows and increase energy efficiency of logistics systems. This cluster is directly related to the development of green transportation policies and carbon-neutral supply chains, which are being actively researched in the European Union.

The blue cluster, which unites circular economy, environmental performance, economy and infrastructure, demonstrates the development of a circular model of sustainable logistics. This cluster reflects the transition from linear supply chain management models to circular supply chains based on resource recycling, reduced waste generation, and ESG-oriented infrastructure development. The analysis shows that the modern ESG agenda is developing into an integration system that combines digitalisation, sustainable development, risk management, transport sustainability, and the innovative transformation of global supply chains.

To deepen understanding of the research agenda's structure, an analysis of the

thematic relationships among type 2 keywords was conducted. The results of the analysis are shown in Figure 6.

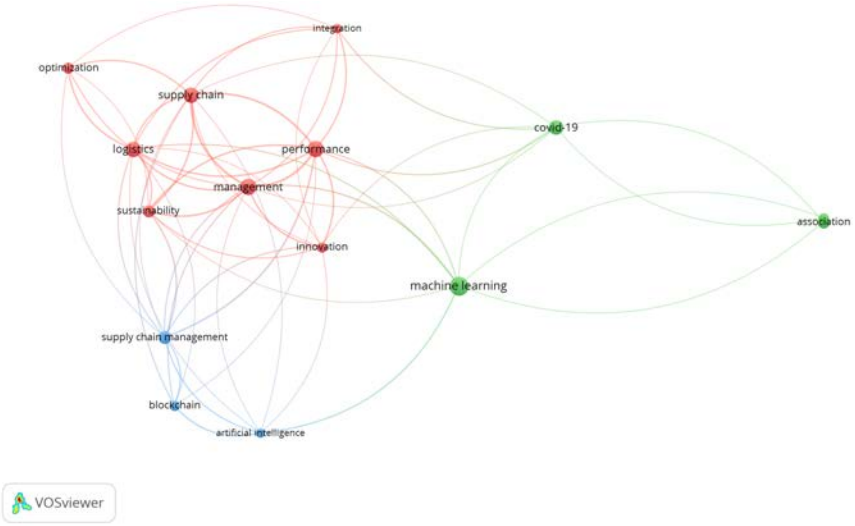


Figure 6. Network visualisation of type 2 keywords

The results of the analysis demonstrate that the central place in the research network is occupied by the categories logistics, supply chain, performance and management, which form the basis of modern research on ESG-oriented supply chain management.

The red cluster, which unites performance, innovation, integration, optimisation, sustainability, logistics and supply chain, reflects the management and operational direction of research. ESG is increasingly seen as a tool for improving the efficiency of supply chain systems, optimising logistics processes, and integrating sustainability metrics into corporate management. The high density of connections between performance and sustainability suggests that modern research is increasingly focused on balancing economic efficiency and environmental sustainability.

The blue cluster, which includes blockchain, artificial intelligence, and supply chain management, reflects the digital transformation of ESG-oriented logistics systems. Digital technologies are increasingly used to increase supply chain transparency, monitor ESG risks, and automate logistics operations. The use of blockchain technologies enables traceability of supply chains and ESG compliance, while artificial intelligence supports predictive analytics, demand forecasting, and the optimisation of logistics networks.

The green cluster associated with machine learning and COVID-19 reflects the crisis-analytical direction of research. The COVID-19 pandemic has demonstrated the high vulnerability of global supply chain systems and increased the need for intelligent forecasting models and risk analytics. The economic interpretation of this

cluster is the transition from traditional supply chain management to resilience-oriented logistics systems based on machine learning algorithms and adaptive risk management. In recent years, ESG has increasingly been seen as a tool for ensuring the sustainability of logistics networks amid global shocks, disruptions, and geopolitical instability.

The results obtained confirm that the modern ESG research agenda in logistics and supply chain management is developing towards the integration of sustainable development, digitalisation, and intelligent logistics system management technologies. ESG acts not only as a non-financial reporting system but also as a tool to enhance the sustainability, adaptability, and technological modernisation of international logistics systems.

5 | DISCUSSION

The results of the study demonstrate a significant transformation of the ESG scientific agenda in the fields of distribution, logistics, and supply chain management during the period 2021–2025. The number of publications increased from 70 in 2021 to 226 in 2025, indicating a more than threefold increase in research interest.

Early research mainly focused on green logistics, environmental sustainability, and compliance-oriented ESG practices. The ESG was mainly interpreted through environmental performance, reputational benefits, and sustainability reporting. Similar findings are reported in studies by Zhang (2021) and Kim et al. (2021), in which ESG was mainly associated with logistics efficiency and competitiveness. After the COVID-19 pandemic, the scientific agenda is increasingly shifting towards supply chain resilience, adaptive logistics systems, ESG-oriented risk management and digital transformation. This transformation is consistent with the findings of Song et al. (2022) and Dai and Tang (2022), who emphasise the growing importance of resilient, flexible, and adaptive supply chains for governance in a post-pandemic economy.

An integrated governance paradigm that integrates sustainability, digitalisation, resilience, and strategic supply chain coordination is gradually replacing fragmented environmental analysis in modern ESG research. Blockchain, AI, machine learning, and digital monitoring systems are becoming increasingly important. This suggests that ESG is seen not just as a non-financial reporting tool but also as a means of modernising technology and managing logistics in an adaptable manner.

The bibliometric analysis revealed several key thematic and intellectual clusters that form the modern structure of ESG research. The most significant areas are green logistics and environmental performance; supply chain resilience and risk management; ESG governance and performance assessment; digital supply chain transformation; circular economy and reverse logistics; and intelligent logistics systems based on blockchain and artificial intelligence technologies.

The analysis of keyword networks demonstrates the high level of interdisciplinarity of ESG research. Dedicated clusters combine logistics management, sustainability science, digital governance, public health, engineering systems, in-

novation studies, and economics. This interdisciplinarity reflects the formation of an integrated framework for sustainable and adaptive management of logistics systems.

The study demonstrates the high level of internationalisation of ESG research in logistics and supply chain management. Kazakhstan and Uzbekistan increasingly act as connecting nodes between European and Asian research clusters. The region's increased publication activity is related to the growing strategic importance of Eurasian transport corridors, including the Middle Corridor, as well as the digitalisation of logistics systems and ESG transformation of transit economies.

The analysis of co-authorship networks shows the formation of stable international research clusters. The identified author networks reflect not only formal ties among researchers but also the emergence of new interdisciplinary scientific schools in ESG governance, sustainable logistics, digital supply chains, and resilience management. Analysis of scientific journals confirms the pronounced interdisciplinary nature of ESG research. The concentration of publications in Q1–Q2 journals indicates the growing scientific significance of ESG-oriented logistics and supply chain management research.

The Central Asian countries are gradually strengthening their presence in the global ESG research landscape. Regional research is mainly focused on logistics infrastructure modernisation, digital transformation of supply chains, transportation connectivity, blockchain technologies and reverse logistics systems. However, compared to global ESG literature, regional research largely remains operationally oriented and focuses primarily on infrastructure efficiency and digitalisation rather than integrated ESG governance frameworks, stakeholder accountability, and sustainability-oriented institutional coordination.

At the same time, a new Eurasian segment of international scientific cooperation on ESG is emerging. Central Asia is increasingly serving as a regional research hub, connecting European and Asian scientific networks in sustainable logistics and supply chain resilience. Further development of ESG-oriented logistics research will increasingly involve digital ESG ecosystems, artificial intelligence, blockchain-based traceability systems, machine learning, circular supply chains, and adaptive resilience-oriented governance models. The identified keyword clusters show that the modern ESG agenda is increasingly associated with intelligent logistics systems, predictive analytics, cybersecurity, digital monitoring of ESG risks and automated supply chain management. The strengthening of blockchain and AI technologies reflects the transition from traditional logistics management to data-driven, fully traceable supply chain ecosystems.

Most existing studies continue to analyse ESG, digitalisation, resilience, and logistics performance in isolation from each other, rather than within integrated analytical frameworks. Limited attention has been paid to the interrelationships among ESG governance, digital transformation, the circular economy, and adaptive supply chain resilience, especially in emerging and transit-oriented economies.

The modern ESG agenda increasingly functions not only as a non-financial reporting system, but also as a strategic governance architecture for sustainable lo-

gistics systems in the context of climate risks, geo-economic instability and global disruptions. In this regard, future research should shift from descriptive sustainability analysis to integrated models that combine resilience, digital governance, intelligent logistics systems, and ESG-oriented strategic coordination.

6 | CONCLUSION

The study showed that over the period 2021–2025, there has been a steady increase in scientific interest in ESG issues across distribution, logistics, and supply chain management. The results of the bibliometric analysis indicate a shift in the research agenda from traditional issues of environmental efficiency and green logistics to more complex topics related to supply chain sustainability, digital transformation, risk management, and the introduction of artificial intelligence and blockchain technologies.

The analysis of international scientific cooperation revealed a high level of internationalisation of research and the strengthening of Central Asian countries' role in shaping the modern ESG agenda. Kazakhstan and Uzbekistan are becoming important participants in global research networks, reflecting the region's growing importance in the development of Eurasian transport corridors and sustainable logistics systems. The identified thematic clusters confirm the interdisciplinary nature of ESG research, combining approaches from sustainable development, management, economics, digital technologies, and logistics. The results obtained allow us to conclude that further research will involve integrating ESG principles, digitalisation, and supply chain resilience, as well as expanding research on the role of developing regions in the transformation of global supply chains.

Promising areas of future research include assessing the impact of ESG practices on the efficiency and sustainability of logistics systems, exploring the role of artificial intelligence, blockchain, and big data technologies in ESG-oriented supply chain management, and conducting comparative studies between developed and developing countries. It is advisable to pay special attention to the countries of Central Asia, including the analysis of the ESG transformation of transport and logistics infrastructure, the sustainability of international transport corridors and the region's integration into global supply chains in the context of digitalisation and geo-economic changes.

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ORIGINAL ARTICLE

Digital Financial Transactions and Household Economic Behaviour in Kazakhstan

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Abstract
The acceleration of digitalization of financial services and the expansion of non-cash and online transactions is transforming the economic behavior of households, changing the structure of consumption, borrowing and saving, as well as strengthening the relationship between retail business activity and banking financial instruments. The study aims to assess the impact of digital financial transactions on household behaviour in Kazakhstan, focusing on consumption, borrowing, savings, retail activity, household lending, and deposit accumulation within the banking system. The study's methodological basis is a quantitative approach using a system of indicators reflecting households' financial behaviour, including consumption, credit activity, savings, and digital transactions. The study covers the period 2014–2024 and is based on macroeconomic and financial indicators characterising the dynamics of consumption, lending, savings, and digital payments. The results showed that in 2014-2024, household deposits increased from 4.3 to 23.0 trillion tenge, household loans from 3.7 to 20.3 trillion tenge, the number of online transactions increased almost 190-fold, and the volume of digital payments almost 500-fold. Regression models confirmed a significant association of digital transactions with consumption, lending, deposits, and retail turnover; R2 values were 0.973, 0.958, 0.979, and 0.940, respectively. The findings show that the digitalization of financial transactions enhances not only household financial activity but also the development of the retail business environment, as online payments and digital services increase consumption intensity and support the growth of Kazakhstan's consumer market.

KEYWORDS
Finance, Digital Finance, Digital Economy, Household Behaviour, Household Economy, Consumer Lending, Business Activity, Consumption

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1 | INTRODUCTION

The digitalisation of financial services and payment systems changes banking activity, retail markets, and consumer finance by accelerating the circulation of financial resources and expanding the use of digital transactions (Ure, 2021). The integration of online banking, FinTech platforms, cashless payments, and digital lending instruments increases retail turnover, household borrowing, and consumer spending. As digital financial services become integrated into everyday economic activity, financial transactions are performed more frequently and at lower transaction costs, thereby increasing the macroeconomic significance of household financial behaviour. However, even in developed financial markets, unresolved issues remain regarding systematic inefficiency in households' decision-making: overborrowing, misallocation of funds, and the loss of available financial resources through product use. Households incur high costs for account and credit card services, with a substantial share attributable to peculiarities in decision-making. A significant portion of interest payments and fees can be eliminated through simple changes in everyday financial behaviour (Stango & Zinman, 2009).

Households spend money immediately after receiving income. Moreover, even when income is known in advance and should be distributed equally, households tend to spend 50–75% of it. At the same time, the level of liquid savings remains low, and debt obligations and the accumulation of illiquid assets continue (Beshears et al., 2018). These behavioural patterns influence not only household financial stability but also broader economic processes through their impact on retail consumption, banking sector liquidity, and consumer lending activity.

Digital platforms enhance the influence of financial instruments on consumer behaviour by integrating payments and lending into a single digital space (Frost et al., 2019). The expansion of FinTech infrastructure and digital payment systems is changing retail trade and financial services by combining purchasing, lending, and payment operations on digital platforms. Financial transactions are conducted within a single environment and become part of everyday economic activity. Online payment platforms in China expand the use of digital financial services and increase transaction activity by simplifying payments and access to credit instruments (Zhao et al., 2024). In Europe, online banking services reinforce existing differences in the use of financial instruments. In the Czech Republic, some customer groups remain cost-conscious and use a limited set of transactions, while others utilise a wider range of electronic payments and digital banking services (Soukal & Draessler, 2019).

Research by the Bank for International Settlements also shows that digital payments and FinTech infrastructure are transforming the savings mechanism. The shift from cash to digital forms of storing funds changes household liquidity preferences: the share of funds held in accounts increases, the role of cash savings declines, and integration with investment and credit products expands. Thus, digital transactions are not simply a payment tool but a factor transforming economic behaviour. Under these conditions, the structure of financial decisions becomes more accelerated and less reflective.

An analysis of international experience shows that changes in household financial activity accompany the spread of digital and online payment services. However, the nature of these changes varies across countries and institutional settings. This creates a need to examine how the expansion of digital transactions affects household behaviour, banking activity, retail turnover, and consumer finance dynamics in Kazakhstan. Thus, the study aims to assess the impact of digital financial transactions on household behavior in Kazakhstan, focusing on consumption, borrowing, savings, retail activity, household lending, and deposit accumulation within the banking system.

2 | LITERATURE REVIEW

The development of digital finance, FinTech, and online payments has changed the structure of financial services, consumer payments, and household lending. Shahrokhi (2008) demonstrated that the development of e-finance has expanded the use of electronic financial transactions and changed the mechanism for providing financial services. Digital finance and FinTech have strengthened the role of digital technologies in banking operations and the provision of financial services (Gomber et al., 2017), including access to credit and payment instruments (Agarwal & Zhang, 2020). Agur et al. (2020) and Alwahidin et al. (2023) showed that the development of digital financial services has increased the use of online payments, mobile banking, and electronic payments, and has affected household consumption and the structure of financial transactions.

Human behaviour in financial decisions depends on when the decision is made. The closer financial decisions are to current consumption, the less attention is given to future financial outcomes (Friedman, 1957; Feldstein, 1964; Frederick et al., 2002). Therefore, the decision to save some part of the income is overwhelmed by current expenses. As a result, households save less, or not at all, because many decisions are made without further evaluation of long-term consequences. Kahneman (2003) demonstrated that decision-making occurs either quickly and automatically or through more controlled, deliberate decisions. Therefore, Adams et al. (2014) concluded that current desires are stronger than plans, leading to a consistent deviation from plans in favour of current decisions. Within households, differences between spending and saving priorities further affect financial decision-making.

Behavioural economics explains how people make financial decisions about purchases, spending, and saving. Zeller and Sharma (2000) stated that for households with limited income, loans and savings help to cope with income instability. Simple and accessible options are driven by time constraints, which influence spending patterns and increase the propensity to borrow (Bertrand et al., 2006). Financial decisions also depend on how credit conditions are presented. People often focus on simplified indicators, such as the monthly payment amount, instead of the total loan cost (Altman, 2012). More importantly, individuals focus on the immediate payment. Therefore, instalments and deferred payments play a significant role in avoiding upfront payment (Reisch & Zhao, 2017). Credit product terms,

such as payment breakdowns, terms, and the format of information presentation, determine how easy it is to make a borrowing decision and how the debt burden is structured (Fömötör et al., 2017). These characteristics are taken into account when designing consumer protection mechanisms, as simply disclosing information does not change behaviour if it is not perceived and used in decision-making (Lefevre & Chapman, 2017).

One of the key ways digital technologies have impacted consumer behaviour is the reduction in search and selection time when shopping online. First, access to information and reduced search costs expand the opportunities for comparison and intensify competition (Smith et al., 2001). Second, the digital environment develops new decision-making models through the speed, accessibility, and constant availability of online services (Goldfarb et al., 2015). As a result, purchases are increasingly made at the moment of need, as access to products become continuous, and Automated payments and stored data simplify the purchasing process (Lim et al., 2023). Ultimately, the need to postpone a purchase disappears. Specifics of product presentation also affect the purchasing behaviour. The absence of physical contact with a product reduces the likelihood of impulse decisions based on visual perception (Huyghe et al., 2017). At the same time, the convenience of digital channels and constant access to products increases overall consumption. The digital environment creates a constant flow of information that influences choices, as consumers rely on other users' opinions (Alghizzawi, 2019).

People often behave irrationally, spend more now, fail to save, and continue to pay for things they do not use simply because they have already paid for them (Thaler, 2016). Companies often offer terms that seem convenient but are ultimately less beneficial. That is, prices may deviate from actual values not because of objective factors but because of human behaviour. Such a person is inclined to spend more and save less than a rational person because, at any given moment, a "current" person prefers to consume now rather than think about the future, creating an internal conflict between current and future decisions (Liu et al., 2020). As a result, if a person has money, they spend it faster rather than distributing it evenly, and their behaviour becomes highly dependent on current income. If they have money, they spend it. Constraints also play a stronger role, such as the inability to borrow money, because a person does not save for the future. People undervalue future payments and overvalue current decisions. Cheng and Huo (2025) showed that present bias causes a person to perceive a future payment as less significant than it actually is. A person is more likely to agree to purchase a product if the payment is deferred because they mentally underestimate future expenses. Buyer behaviour changes not because the product is better or worse, but because the time of payment and the perception of future money are distorted.

People make spending and borrowing decisions not based on their current income but on their expected future income. Therefore, if income is lower today but expected to increase in the future, people take out a loan and “postpone” consumption. Vandone (2009) found that borrowing behaviour is linked to household consumption patterns and their expectations of future income. Families borrow

when current expenses exceed available income. As a result, spending often increases faster than income. In particular, such expenses are incurred for housing, education, childcare, and durable goods. Under these conditions, loans are used to finance current consumption and large household expenses before income increases. Also, with lower average incomes, people are more likely to borrow as they consume more, whereas with higher incomes, they can manage without borrowing. Income is not the only important factor; its stability is also important: if income is unstable, people borrow less and save more. However, increasing credit card debt reduces the rate of spending growth (Ekici & Dunn, 2010). Subsequently, accumulated debt requires interest payments, and part of the income is spent not on new purchases but on paying off old obligations. Zinman (2015) showed that the bulk of household borrowing is not related to everyday (food) consumption but to expenses in large non-food categories such as housing, cars, and education. Credit initially increases consumption, then begins to constrain it. A temporary economic recovery occurs when credit supply expands (Mian & Sufi, 2018). Friedman (2018) also argued that current consumption decisions depend on expected future income rather than only on current earnings. After gaining access to loans to maintain their living standards, families rely on loans (Kizyma, 2019; Garber et al., 2024). Thus, credit drives a surge in current spending and a decline in future consumption.

Differences in savings between men and women arise from differences in income and risk tolerance (Fisher, 2010). For example, with lower incomes, women have less left over after expenses, so even if they want to save, their ability to save is limited. Kamas and Preston (2015) showed that women tend to make more cautious decisions and are risk-averse, so with limited income, they exercise greater control over their spending and are less likely to engage in active savings. Moreover, they show that, with limited resources and a high share of mandatory expenses, households save less and rely on simple forms of savings, as they are unable to reallocate funds to higher-yielding instruments (Suppakitjarak & Krishnamra, 2015). After covering current expenses, many households have limited opportunities to accumulate savings (Barrafrem et al., 2024). Lower female-to-male wage ratios increase the share of income spent on mandatory expenses, reducing the amount of funds available for savings.

Existing research in household and digital finance primarily examines individual aspects of household financial behaviour. Some studies focus on the impact of digital payments and online services on consumption and retail trade. In contrast, others analyse consumer lending, savings behaviour, and the influence of income on household financial decisions. Gender income differences and their impact on consumption and savings are also considered separately. At the same time, the literature contains few studies that integrate digital transactions, consumption, lending, deposits, and the gender wage ratio within a single model of household financial behaviour. This article comprehensively examines the relationships among digital payments, consumption, consumer lending, household deposits, and the gender wage ratio in Kazakhstan using macroeconomic and banking indicators for

2014–2024.

3 | METHODOLOGY

According to the literature review, the methodology used quantitative methods. Fisher (2010) used empirical analysis of household data, employing statistical methods to identify differences in savings behaviour (regression). Ekici and Dunn (2010) used regression analysis to estimate the impact of credit card debt on consumption growth (regression analysis). Suppakitjarak and Krishnamra (2015) and Garber et al. (2024) used econometric analysis to identify factors influencing savings patterns (descriptive statistics and regression analysis) and to estimate the impact of credit expansion on consumption using aggregate data (regression analysis). Thus, the regression approach and the analysis of variable dependencies, including correlation analysis, form the basis of the methodological framework underlying the current study.

Firstly, a set of indicators was developed for the analysis presented in the article. In the analysis, annual macroeconomic and financial indicators for Kazakhstan for the period 2014–2024 were used, obtained from official sources, the Bureau of National Statistics of the Republic of Kazakhstan, and the National Bank of the Republic of Kazakhstan. The sample included indicators reflecting deposits, household lending, consumer spending, retail turnover, non-cash and online transactions, and cash withdrawals (Table 1).

Table 1. Variable definitions and coding of indicators

Code	Variable	Interpretation	Unit
DEP	Total Deposits	Overall deposit base of the banking system	billion tenge
DEP_HH	Household Deposits	Household saving behaviour	billion tenge
WAGE_RATIO	Female-to-Male Wage Ratio	Gender disparity in earnings	ratio
LOAN_HH	Household Loans	Household borrowing behaviour	billion tenge
NPL	Non-Performing Loans	General level of credit risk	billion tenge
NPL_AMT	NPL Amount	Total volume of overdue debt	billion tenge
CONS_FOOD	Food Expenditure	Essential household consumption	tenge per household
CONS_NONFOOD	Non-Food Expenditure	Discretionary household consumption	tenge per household
POS_TRX	POS Transactions (Volume)	Frequency of cashless payment transactions	million transactions
POS_AMT	POS Transactions (Value)	Value of cashless payment transactions	billion tenge
WEB_TRX	Online Transactions (Volume)	Frequency of online payment transactions	million transactions
WEB_AMT	Online Transactions (Value)	Value of online payment transactions	billion tenge
CASH_TRX	Cash Withdrawals (Volume)	Cash withdrawal activity	million transactions
CASH_AMT	Cash Withdrawals (Value)	Value of cash withdrawals	billion tenge
RETAIL_PC	Retail Turnover per Capita	Consumer market activity	tenge per capita

Note: compiled by the authors based on Bureau of National Statistics and National Bank of Kazakhstan

The selected variables are grouped according to the key dimensions of household financial behaviour. The first group includes variables reflecting savings behaviour and financial resources (DEP, DEP_HH), which characterise the accumulation of funds within the banking system and the role of households in deposit formation. The second group includes variables related to borrowing behaviour and financial risk (LOAN_HH, NPL, NPL_AMT), enabling the analysis of credit activity and the quality of debt servicing. These indicators reflect both the scale of household borrowing and the associated level of credit risk. The third group consists of variables describing consumption behaviour and consumer market activity (CONS_FOOD, CONS_NONFOOD, RETAIL_PC). Food expenditure reflects essential consumption, non-food expenditure captures discretionary spending, and retail turnover per capita represents overall consumer market activity. The fourth group includes variables related to digital and cash payment behaviour (POS_TRX, POS_AMT, WEB_TRX, WEB_AMT, CASH_TRX, CASH_AMT), reflecting the frequency and value of cashless, online, and cash transactions. In addition, WAGE_RATIO is included as a structural factor capturing income differences and

their potential influence on household financial decisions.

To test the proposed hypotheses, correlation analysis was conducted to identify statistically significant relationships between the variables. The hypotheses are presented in Table 2. Based on the identified relationships, regression models were constructed to assess the influence of selected independent variables on household behaviour.

Table 2. Research hypotheses and model specification

No.	Hypothesis
H1	The growth of digital transactions (POS_AMT) increases household food consumption (CONS_FOOD), while gender wage inequality (WAGE_RATIO) reduces it.
H2	Household borrowing (LOAN_HH) is driven by non-food consumption expenditures (CONS_NONFOOD).
H3	Expansion of digital payments (WEB_AMT) contributes to the accumulation of household deposits (DEP_HH), while the female-to-male wage ratio has a negative effect (WAGE_RATIO).
H4	Growth in online transaction activity (WEB_TRX) increases retail turnover per capita (RETAIL_PC).

Note: compiled by the authors based on the literature review

The proposed hypotheses are based on the findings of the conducted literature review, which identifies stable relationships between digital financial instruments and household behaviour.

The first hypothesis builds on studies showing that digital payments simplify purchasing and increase consumption frequency (Goldfarb et al., 2015; Lim et al., 2023). At the same time, behavioural research indicates that limited income constrains consumption and leads to more controlled spending patterns (Fisher, 2010; Kamas & Preston, 2015).

The second hypothesis is supported by research demonstrating that borrowing is closely linked to non-food consumption. Credit is primarily used to finance discretionary expenditures (Zinman, 2015; Vandone, 2009). Behavioural studies also showed that instalment payments reduce the perceived cost of purchases and stimulate borrowing (Reisch & Zhao, 2017; Cheng & Huo, 2025).

The third hypothesis follows from studies indicating that digital payments change the mechanism of savings formation. The transition from cash to digital transactions increases the share of funds held in accounts and supports deposit accumulation (Frost et al., 2019). At the same time, income differences limit the ability to save and affect savings behaviour (Suppakitjarak & Krishnamra, 2015).

The fourth hypothesis is based on evidence that digital platforms increase consumer activity through easier access to goods and their constant availability (Smith et al., 2001; Alghizzawi, 2019).

4 | RESULTS

The first stage of the analysis examines the dynamics of key indicators characterising household financial behaviour. This analysis allows us to identify general trends in savings, credit use, expenditure distribution, and the transition to digital payment methods, which form the basis for subsequent verification of statistical

relationships. Figure 1 further shows the dynamics of household deposits and savings for the period 2014–2024.

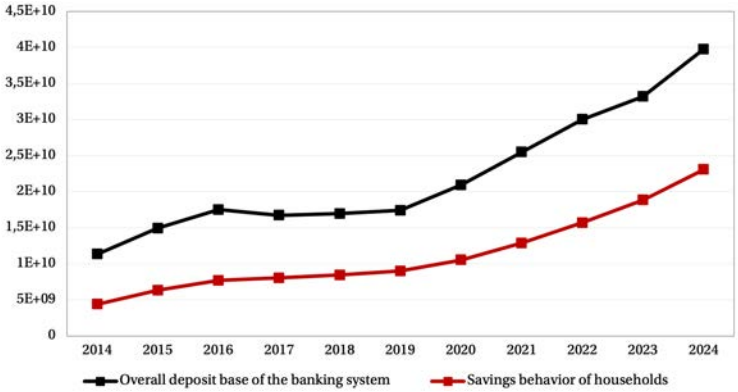


Figure 1. Dynamics of total deposits and household deposits in Kazakhstan, trillion tenge

More and more financial transactions are being conducted through the banking system, resulting in some funds remaining in accounts and deposits. Total deposits increased from 11.3 trillion to 39.8 trillion tenge, while household deposits grew from 4.3 trillion to 23.0 trillion tenge. The banking system's deposit base grew unevenly. After increasing in 2014–2016, deposit growth slowed between 2017 and 2019 and reached its lowest level before the pandemic. In 2020, deposits began to increase again and continued to grow in subsequent years. Household deposits increased steadily throughout the period, from 4.3 trillion tenge in 2014 to 23.0 trillion tenge in 2024. Household savings increased more than fivefold. Household funds are increasingly being stored in the banking system and used to accumulate and safeguard financial resources.

Figure 2 further shows household borrowing indicators and credit risk levels.

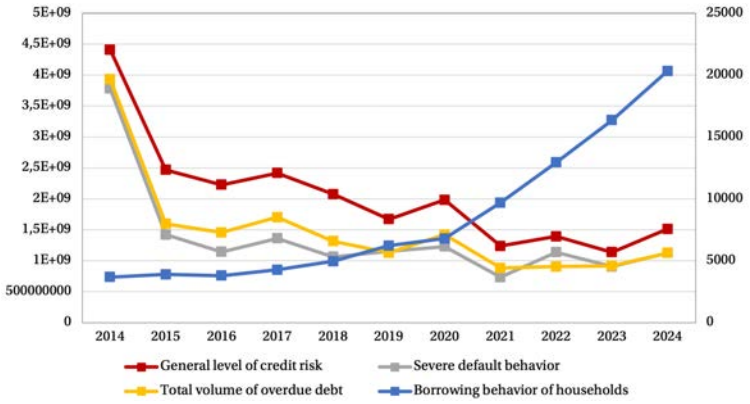


Figure 2. Dynamics of household loans and credit risk indicators in Kazakhstan, trillion tenge

Household loans increased from 3.7 trillion tenge in 2014 to 20.3 trillion tenge in 2024. The highest growth was observed after 2020. Credit risk indicators generally declined. The overall credit risk level decreased from 4.4 trillion to 1.5 trillion tenge, and the volume of overdue loans decreased from 3.9 trillion to 1.1 trillion tenge. Some indicators increased slightly in 2017, 2020, and 2024, but their values remained below 2014 levels. The growth in consumer lending did not lead to a corresponding increase in problem loans in the banking system.

People have increasingly used borrowed funds to purchase goods and pay for current expenses, rather than relying solely on their own income and savings. The growth in lending demonstrates that consumer loans are increasingly used to purchase goods, pay for services, and cover other everyday expenses. As a result, some consumption has come to be supported by bank lending. The volume of loans grew significantly faster than the volume of bad debt. People began taking out more loans, but overdue debt and credit risks did not increase at the same rate. The expansion of consumer lending did not lead to a sharp deterioration in the quality of the loan portfolio.

Figure 3 further shows the structure of household consumption.

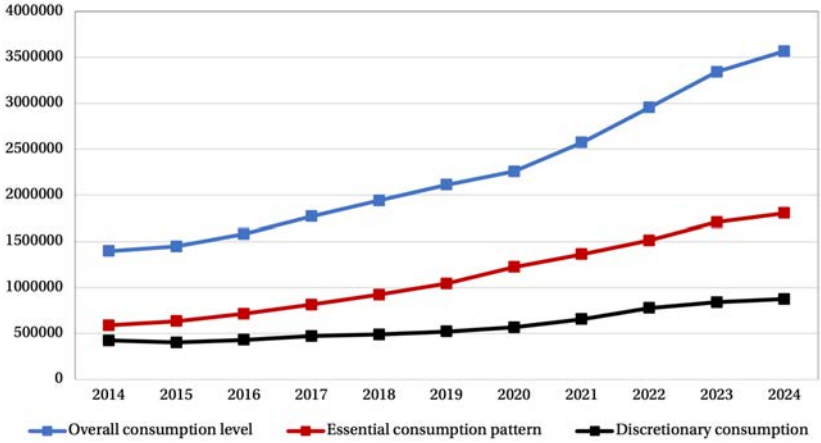


Figure 3. Dynamics of household consumption expenditures and retail turnover in Kazakhstan, tenge

Household spending increased throughout the period. Food expenditures increased faster than non-food expenditures. Moreover, non-food consumption grew at almost half the rate. Overall consumption increased from 1.39 million tenge in 2014 to 3.56 million tenge in 2024. Food expenditures increased from 589 thousand tenge to 1.8 million tenge, while non-food expenditures doubled, from 424 thousand tenge to 875 thousand tenge. The highest growth in food expenditures was observed after 2020. Most of the household budgets during the observed period were spent on essential daily expenses. As a result, funds for additional expenditures remained limited. Consequently, non-food consumption increased more slowly.

Figure 4 further shows the dynamics of non-cash and digital payments.

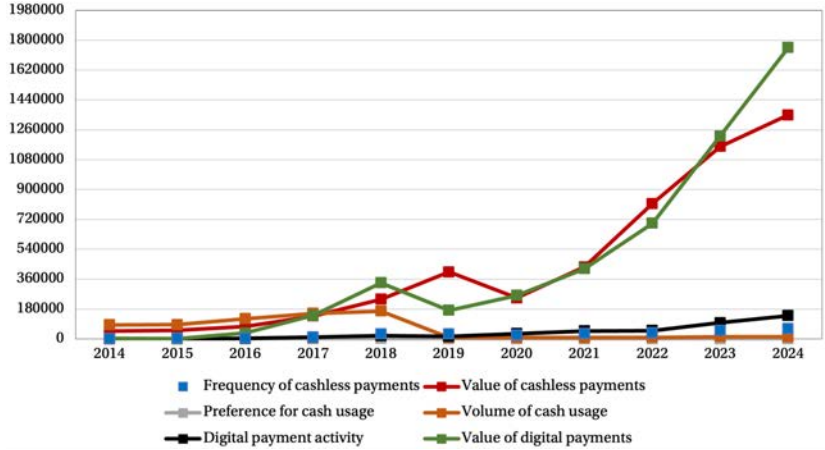


Figure 4. Dynamics of cashless and online payment transaction values in Kazakhstan, billion tenge

Online payments grew faster than traditional non-cash transactions. Financial transactions, particularly mobile banking, banking apps, and online payments for goods and services, were increasing. The volume of non-cash payments during the period under review increased more than 28-fold, reaching 1.3 million tenge in 2024. The number of non-cash transactions increased almost 24-fold, reaching 62.3 thousand. The growth in digital payments was even more dramatic. The number of online transactions increased almost 190-fold, reaching 140.5 thousand transactions, while the volume of digital payments increased almost 500-fold, reaching 1.7 million tenge. The most rapid growth was observed after 2020. The number of cash transactions has decreased by almost 77 times since 2018, falling to 22.6 million transactions in 2019. The volume of cash transactions has decreased by more than 20-fold, falling to 8.2 thousand tenge. From 2020 to 2024, cash transaction figures remained significantly below 2018 levels.

Kazakhstan's financial system increasingly relied on banking and digital transactions. The growth of deposits, lending, and digital payments indicates an increase in the volume of financial transactions within the banking system. At the same time, the share of mandatory expenses, primarily food products, increased. Consumer lending grew faster than non-performing debt, and digital payments gradually replaced cash transactions. Banking apps, online payments, and digital financial services have become widely used in retail financial transactions and consumer payments.

After examining the dynamics of the indicators, it is necessary to determine which indicators are related to each other and how these relationships manifest. To do this, a correlation analysis is conducted, which allows us to identify the presence and direction of relationships between household financial behaviour

indicators.

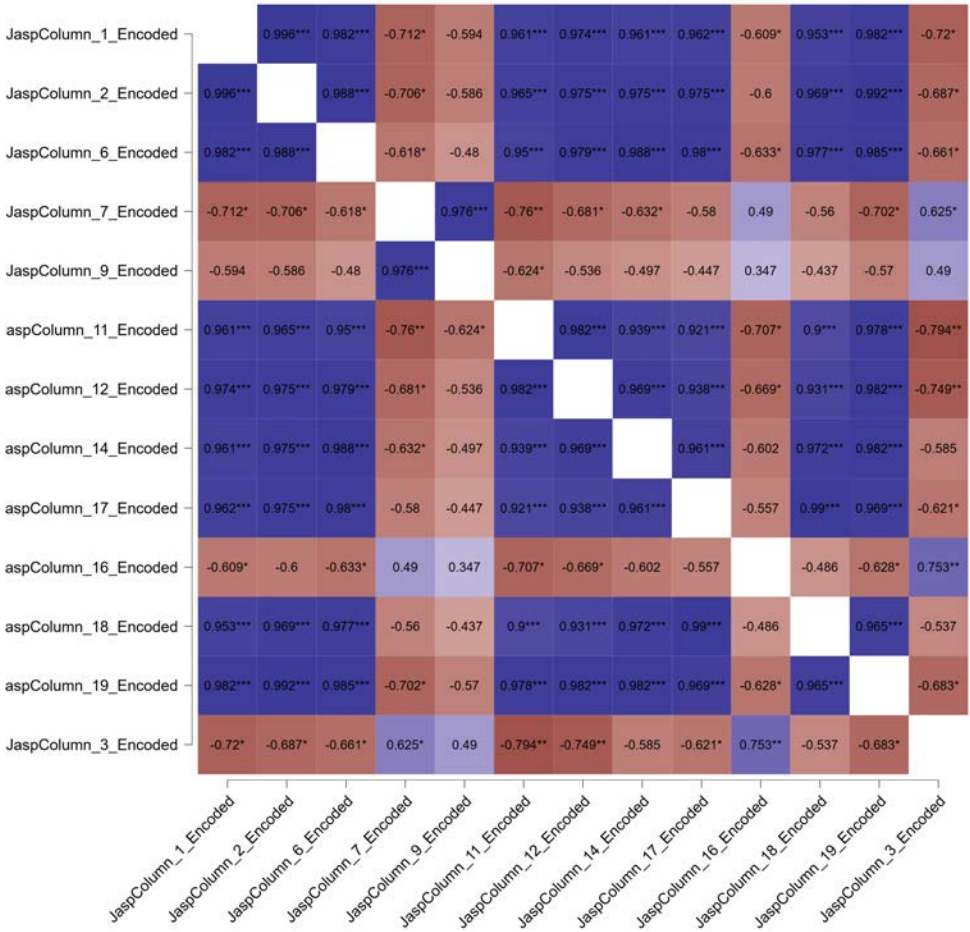


Figure 5. Correlation matrix for models' specifications

Correlation analysis revealed statistically significant relationships between financial resources, consumption, and digital transactions. The highest correlation coefficients were observed for household spending, non-cash transaction volumes, and credit activity (0.93–0.99). There is growth in digital payments, accompanied by expansion in consumer spending and lending, indicating the growing role of digital financial services in the consumer market. Negative coefficients between non-performing loans (NPL) and consumption (ranging from -0.6 to -0.76) indicated a decrease in current spending as the debt burden increased. This relationship indicates a limitation in consumer activity, as evidenced by an increase in non-performing loans and greater financial risks in the consumer lending system.

The ratio of female to male wages demonstrated a negative correlation with indicators of consumption and digital transactions (up to -0.79). These results indicate that women's lower incomes limit consumption and the use of digital payment instruments. High correlation coefficients (above 0.93) between non-food spending, digital transactions, and retail turnover indicate that growth in non-food consumption is accompanied by increased digital payment activity and expansion of the retail market.

Based on the identified relationships, a regression analysis is conducted to assess which factors influence household behaviour and to what extent. The results of the regression analysis for the selected models are presented below (Table 3).

Table 3. Model summary of regression results

Dep. Var.	Model	R	R^2	Adj. R^2	RMSE
CONS_FOOD	M_0	0.000	0.000	0.000	431041.972
CONS_FOOD	M_1	0.986	0.973	0.966	79708.435
LOAN_HH	M_0	0.000	0.000	0.000	5724.597
LOAN_HH	M_1	0.979	0.958	0.953	1243.372
DEP_HH	M_0	0.000	0.000	0.000	5.724×10^9
DEP_HH	M_1	0.989	0.979	0.973	9.371×10^8
RETAIL_PC	M_0	0.000	0.000	0.000	259600.856
RETAIL_PC	M_1	0.989	0.940	0.933	67082.930

Note: compiled by the authors

The coefficient of determination (R^2) values indicate that a high proportion of the variation in the dependent variables is explained. For the first model (CONS_FOOD), an R^2 of 0.973 indicated that the included factors explain 97.3% of the variation in food expenditures. Similarly, for the second model (LOAN_HH), $R^2 = 0.958$ indicated that the included factors accounted for 95.8% of the variation in household borrowing. For the third model (DEP_HH), the highest explanatory power ($R^2 = 0.979$) indicated that the selected factors explain 97.9% of the variation in household deposits. For the fourth model (RETAIL_PC), R^2 indicated that 94.0% of the variation in per capita retail sales is explained by the included variables.

To assess the overall significance of the models, an analysis of variance is performed (Table 4).

The F-statistics indicate that all regression models are statistically significant: 142.218 for CONS_FOOD, 202.977 for LOAN_HH, 182.574 for DEP_HH, and 140.757 for RETAIL_PC. In all models, the explained variance substantially exceeds the residual variance, confirming the high explanatory power of the selected variables. Thus, in the CONS_FOOD model, the explained variation equals 1.807×10^{12}, compared with the residual variation of 5.083×10^{10}. Similar patterns are observed in the other models, where the explained variance exceeds the residual variance by approximately 20 times for LOAN_HH, 45 times for DEP_HH, and 15 times for

RETAIL_PC. These results indicate that the selected variables explain a substantial share of variation in household consumption, borrowing, deposits, and retail turnover. At the same time, given the limited number of annual observations and the presence of common upward trends in macroeconomic and financial indicators, the results should be interpreted as evidence of strong statistical associations rather than direct causal effects.

Table 4. ANOVA results of regression models

Dep. Var.	Component	Sum of Squares	df	Mean Square	F	p
CONS_FOOD	Regression	1.807×10^{12}	2	9.036×10^{11}	142.218	$< .001$
	Residual	5.083×10^{10}	8	6.353×10^{9}		
	Total	1.858×10^{12}	10			
LOAN_HH	Regression	3.138×10^{8}	1	3.138×10^{8}	202.977	$< .001$
	Residual	1.391×10^{7}	9	1.546×10^{6}		
	Total	3.277×10^{8}	10			
DEP_HH	Regression	3.207×10^{20}	2	1.603×10^{20}	182.574	$< .001$
	Residual	7.025×10^{18}	8	8.781×10^{17}		
	Total	3.277×10^{20}	10			
RETAIL_PC	Regression	6.334×10^{11}	1	6.334×10^{11}	140.757	$< .001$
	Residual	4.050×10^{10}	9	4.500×10^{9}		
	Total	6.739×10^{11}	10			

Note: compiled by the authors

To determine the influence of individual factors on dependent variables, regression coefficients are considered (Table 5).

In the first model (CONS_FOOD), the coefficient for POS_AMT was positive ($\beta = 0.721$). Therefore, the results confirmed an increase in consumption and in non-cash transactions. The coefficient for WAGE_RATIO was negative ($\beta = -0.373$). The results revealed that consumption dynamics decrease as the female-to-male wage ratio declines, indicating lower consumption levels with increasing wage gaps between males and females. In the LOAN_HH model, the coefficient for CONS_NONFOOD was positive and extremely high ($\beta = 0.979$). In the DEP_HH model, WEB_AMT has a positive coefficient, indicating that deposits grow as digital transactions increase. WAGE_RATIO has a negative coefficient, indicating lower savings levels under lower female-to-male wage ratios. In the RETAIL_PC model, WEB_TRX has a strong positive coefficient, indicating that higher online activity is associated with higher retail trade.

Multicollinearity indicators are within acceptable limits (VIF < 2), indicating a lack of strong correlation between the independent variables and the robustness of the obtained estimates. In Table 6, the summarised results of the regression analysis are presented.

Table 5. Regression coefficients and model parameters

Model	Sub.	Predictor	Unstd.	Std. Err.	Std.	t	p	Toler.	VIF
CONS_FOOD	M_0	(Intercept)	1.121×10^6	129964.044		8.626	$< .001$		
	M_1	(Intercept)	1.876×10^6	225625.664		8.317	$< .001$		
		POS_AMT	0.679	0.068	0.721	9.996	$< .001$	0.658	1.519
		WAGE_RATIO	−36349.916	7022.657	−0.373	−5.176	$< .001$	0.658	1.519
LOAN_HH	M_0	(Intercept)	8448.745	1726.031		4.895	$< .001$		
	M_1	(Intercept)	−10512.974	1382.720		−7.603	$< .001$		
		CONS_NONFOOD	0.032	0.002	0.979	14.247	$< .001$	1.000	1.000
DEP_HH	M_0	(Intercept)	1.136×10^{10}	1.726×10^9		6.582	$< .001$		
	M_1	(Intercept)	1.624×10^{10}	2.502×10^9		6.494	$< .001$		
		WEB_AMT	8595.043	625.337	0.844	13.745	$< .001$	0.711	1.406
		WAGE_RATIO	-3.025×10^8	7.943×10^7	−0.234	−3.808	0.005	0.711	1.406
RETAIL_PC	M_0	(Intercept)	655826.862	78272.603		8.379	$< .001$		
	M_1	(Intercept)	444301.106	26962.493		16.478	$< .001$		
		WEB_TRX	5.615	0.473	0.969	11.864	$< .001$	1.000	1.000

Note: compiled by the authors

The growth of transactions related to food consumption, according to the existing studies, is contingent on the quality of service industry. Grocery purchases are increasingly moving to online platforms and delivery services, driving greater use of digital payment instruments in everyday consumption. The results on the negative relationship with WAGE_RATIO confirmed that consumption opportunities differ across men and women due to unequal wage distributions. Lower female-to-male wage ratios are associated with more restrained consumption patterns and stronger expenditure rationalisation. Under higher female-to-male wage ratios, consumption activity becomes more intensive, including more frequent purchases and wider use of online shopping services. Differences in male and female wages, therefore, affect both the overall level and the structure of household consumption.

Table 6. Hypotheses results

Hypothesis	Confirmed	Explanation
H1: Digital transactions and female-to-male wage ratio influence food consumption (CONS_FOOD).	Confirmed	POS_AMT positive and significant, WAGE_RATIO negative and significant, indicating lower consumption levels under larger differences between male and female wages, model $R^2 = 0.973$
H2: Non-food consumption drives household borrowing (LOAN_HH).	Confirmed	CONS_NONFOOD strong positive effect ($\beta = 0.979$), high explanatory power $R^2 = 0.958$
H3: Digital payments and female-to-male wage ratio affect household deposits (DEP_HH).	Confirmed	WEB_AMT positive, WAGE_RATIO negative, indicating lower savings levels under larger differences between male and female wages, both significant, $R^2 = 0.979$
H4: Online transaction activity increases retail trade (RETAIL_PC).	Confirmed	WEB_TRX strong positive effect ($\beta = 0.969$), $R^2 = 0.940$

Note: compiled by the authors

The results for H1 are consistent with those of Goldfarb et al. (2015) and Lim et al. (2023), who found that the development of digital payments and online services increases the frequency of purchases and consumer activity. In the study on Kazakhstan, the growth of non-cash transactions was associated with increased grocery spending. Fisher (2010) and Kamas and Preston (2015) found that income differences influence consumption patterns and limit spending at lower income levels. In the study on Kazakhstan, a lower female-to-male wage ratio is associated with lower consumption levels and more limited consumer spending.

The results for H2 are consistent with those of Vandone (2009), Zinman (2015), and Cheng and Huo (2025), who found a relationship among consumer credit, non-food expenditures, and the use of installment plans. In the study on Kazakhstan, non-food consumption showed a strong positive relationship with household credit volume. The results show that consumer loans were used primarily to finance non-food expenses and current consumption.

The results for H3 are consistent with those of Frost et al. (2019), who found that digital payments increase the amount of funds retained within the banking system. In the Kazakhstan study, the rise in online transactions was accompanied by higher household deposits, as funds were withdrawn less frequently in cash and more often from bank accounts. The lower wage ratio between women and men simultaneously limited both savings opportunities and deposit volumes.

The results of H4 are consistent with those of Smith et al. (2001), Goldfarb et al. (2015), and Alghizzawi (2019), who found that digital platforms and online services increase retail trade and consumer activity. In the Kazakhstan study, the increase in online transactions was accompanied by higher per capita retail turnover and the expansion of digital payments in consumer transactions.

5 | CONCLUSION

The study aimed to analyse how the expansion of digital transactions influences household behavioural patterns in consumption, borrowing, and savings in Kazakhstan, including their effects on retail turnover, household lending, and deposit accumulation within the banking system.

The analysis revealed consistent relationships between digital transactions and key elements of household behaviour. The growth of online transactions affects consumption behaviour by enabling easier access to online shopping, reducing time constraints on purchasing, and increasing spending frequency. At the same time, digital tools increase financial engagement, as reflected in higher account balances.

The development of credit instruments is fueling growth in spending on non-food items and in consumer lending. Online commerce and installment plans have combined the processes of purchasing, payment, and lending in digital consumer markets. The expansion of digital platforms has increased transaction volumes, increased the use of cashless payments, and integrated credit services into retail.

A lower wage ratio between women and men reduces savings and limits consumption. Moreover, the majority of expenditure goes toward essential consumer

spending. Therefore, opportunities for savings are reduced.

Digitalisation simplifies financial transactions and changes household behaviour, strengthening the link between consumption, borrowing, and savings. Linear models confirm the robustness of the identified relationships and allow us to view them as reflecting ongoing changes in economic behaviour. Thus, digitalization of financial services is becoming an important mechanism for transforming household consumption, savings, and credit behavior. For Kazakhstan, this means the need to further develop digital payment services, increase the transparency of credit products, and form a balanced policy aimed at supporting both the financial stability of the population and the development of the retail business environment.

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Software and Supervision: Galiya A. Bekzhanova, Serik K. Serikbayev.
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Visualization: Sharbat A. Igenbayeva, Farida M. Tuleyeva.
Writing – Review and Editing: Galiya A. Bekzhanova, Tolendi A. Ashimbayev, Serik K. Serikbayev.

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Institutional Frictions and Supply Chain Resilience: Evidence from the Sino-Kazakhstan Agri-Food Corridor

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Abstract
Cross-border agri-food supply chains are increasingly facing institutional uncertainty, logistical constraints, and geopolitical disruptions, which increases the importance of supply chain sustainability for the stable development of international trade. This study aims to assess how perceived institutional and spatial frictions influence supply chain resilience in the Sino-Kazakhstan agri-food corridor, with particular attention to the mediating roles of relational governance and trust, and flexible strategies. The study uses a quantitative approach based on partial least squares (PLS-SEM) structural equation modeling. The empirical basis was based on data from a survey of 100 specialists involved in cross-border agri-food trade between China and Kazakhstan. The results showed that perceived institutional and spatial barriers have a strong positive impact on relational governance and trust (β = 0.502; t = 6.223; p < 0.001), while their direct impact on flexible strategies is not statistically significant at the 5% level (β = 0.197; t = 1.782; p = 0.075). Mediation analysis confirmed that relational governance and trust significantly mediate the relationship between institutional barriers and supply chain sustainability (β = 0.207; t = 3.978; p < 0.001), whereas the mediating effect of flexible strategies was not confirmed (β = 0.111; t = 1.705; p = 0.088). The findings show that, in the context of cross-border institutional barriers, relational governance is a key mechanism for ensuring sustainability, especially for resource-constrained companies operating in transition economies.

KEYWORDS
Cross-Border Economy, Agri-Food Trade, Supply Chain Resilience, Agribusiness, Logistics, Transport Corridor, Middle Corridor, China, Kazakhstan

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1 | INTRODUCTION

The global agri-food supply chain has faced unprecedented disruptions in recent years, characterized by compounding geopolitical tensions, climate-induced shocks, and institutional volatilities. Within this macro-environmental turbulence, the cross-border trade corridor between China and Kazakhstan has emerged as a critical node in the Belt and Road Initiative (hereinafter – BRI). As Kazakhstan remains China's largest trading partner in Central Asia, the agricultural sector, encompassing grains, oilseeds, and meat, has become a cornerstone of bilateral economic cooperation (Yerniyazova, 2024). However, the narrative of "hard connectivity" driven by massive physical infrastructure investments often masks the pervasive "soft frictions" inherent in cross-border logistics. Agri-food products are inherently time-sensitive and perishable, making them exceptionally vulnerable to transit delays and coordination failures.

Practitioners operating in this corridor frequently encounter a dual challenge conceptualized as Perceived Institutional and Spatial Frictions (hereinafter – PIF). Spatial frictions manifest physically, most notably through the railway gauge differences at key border gateways such as Dostyk-Alashankou and Altynkol-Khorgos. This technical incompatibility necessitates time-consuming cargo transshipment, creating structural bottlenecks (Tjia, 2022). Concurrently, institutional frictions exacerbate these physical delays. Kazakhstan, as a transition economy, is often characterized by "institutional voids" instances where formal regulatory frameworks are either absent or inefficiently implemented (Tjia, 2022). Beyond the historical railway gauge break, practitioners in 2026 now face evolving frictions, including tightening Sanitary and Phytosanitary (SPS) protocols and the geopolitical complexities of the Middle Corridor's development. While physical transshipment times at Khorgos have been reduced through dual-gauge automation, the administrative hurdles, especially opaque certification requirements for meat and dairy, remain a dominant source of institutional friction (Yerniyazova, 2024; ADB, 2023).

Despite the growing body of literature on Supply Chain Resilience (hereinafter – SCR), traditional supply chain risk management paradigms predominantly focus on mature market economies equipped with robust legal frameworks. There remains a profound theoretical gap regarding how enterprises, particularly small and medium-sized enterprises (hereinafter – SMEs), navigate profound institutional voids in transition economies. Under high-friction conditions, formal contractual governance often proves inadequate; contracts are costly to draft, rigid to adapt, and exceedingly difficult to enforce across cross-border jurisdictions (Eckerd et al., 2021). Consequently, firms are compelled to rely on alternative, informal mechanisms. Drawing upon social exchange theory and new institutional economics, this study emphasizes the role of "soft governance" specifically Relational Governance and Trust (hereinafter – RGT). In environments where legal enforceability is weak, trust and relational norms serve as vital lubricants, enabling flexible renegotiations and collaborative problem-solving during sudden border disruptions (Chen & Lewis, 2024; Zhang et al., 2024).

In parallel with relational mechanisms, the literature emphasizes "hard" flexible

strategies, such as maintaining pre-positioned inventory in overseas warehouses or securing multimodal transport options, as buffers against spatial delays (Lücker et al., 2024). However, deploying such asset-heavy forms of structural flexibility requires substantial capital investment and predictable policy horizons. It remains empirically unclear whether cross-border frictions alone are sufficient to induce firms to adopt these costly FS, or whether resource constraints lead practitioners to rely more heavily on relational capital.

Despite the growing body of research on supply chain resilience, three specific gaps remain inadequately addressed in the extant literature. First, many SCR studies are anchored in mature market economies equipped with robust legal and institutional frameworks, leaving the governance dynamics of transition economies, particularly in Central Asia, largely underexplored. Second, the theoretical debate on whether relational governance and FS function as substitutes or complements remains empirically unresolved, especially under conditions of severe institutional and spatial friction. Third, the boundary conditions governing the deployment of FS, particularly the constraining role of firm-level resource capabilities among SMEs, have not been empirically validated in the context of high-friction cross-border corridors. The present study is designed to address these three interrelated gaps.

This study aims to assess how perceived institutional and spatial frictions influence supply chain resilience in the Sino-Kazakhstan agri-food corridor, with particular attention to the mediating roles of relational governance and trust, and flexible strategies (hereinafter – FS). To achieve this aim, the study develops a conceptual model that examines the interplay among institutional and spatial frictions, governance choices, and supply chain resilience. Using Partial Least Squares Structural Equation Modeling (PLS-SEM) on a sample of 100 cross-border trade practitioners, this research offers three distinct contributions. First, it empirically validates the substitution effect of soft governance in the presence of formal institutional voids within the Central Asian context. Second, it uncovers the boundary conditions of FS, highlighting the resource-capability gap that hinders their immediate deployment. Finally, it provides actionable managerial insights for agribusinesses striving to build robust supply chains across high-friction geopolitical corridors.

2 | LITERATURE REVIEW

The theoretical foundation of this study rests on Transaction Cost Economics (hereinafter – TCE), which posits that high asset specificity coupled with environmental uncertainty compels firms to deploy structural safeguards to minimize exchange hazards (Williamson, 1985). In cross-border agri-food trade, the inherent perishability of agricultural products constitutes a form of high asset specificity, making supply chains particularly vulnerable to institutional and spatial frictions. Building on TCE, the concept of "institutional voids" characterized by the absence of specialized intermediaries, regulatory uncertainties, and weak legal enforcement, has emerged as a critical framework for understanding how formal institutional fail-

ures amplify transaction costs in emerging economies (Eckerd et al., 2021). Recent studies also emphasize the importance of resilience in global food value chains under systemic disruptions (Ali et al., 2022). These foundational perspectives establish the theoretical basis for examining how firms respond to compounding frictions in transition economies such as Kazakhstan.

As institutional void theory evolved, scholars increasingly recognized that traditional TCE prescriptions relating to formal contracts and structural safeguards are insufficient in the face of severe institutional instability. FS is closely related to the broader concept of supply chain agility, which reflects a firm's ability to rapidly adjust its logistics and operational processes (Swafford et al., 2006). For many SMEs, establishing asset-heavy FS such as redundant inventory, pre-positioned overseas warehousing, or multi-modal transport options requires substantial, often irreversible capital investments (Wissuwa et al., 2022; Niu et al., 2025). This recognition gave rise to the concept of SCR, defined as a firm's capacity to absorb disruptions and restore operational performance (Ambulkar et al., 2015). In parallel, scholars developed the notion of RGT as an alternative governance mechanism: non-contractual mechanisms rooted in social norms, solidarity, and inter-organizational trust that enable firms to navigate institutional voids without costly formal enforcement (Wu et al., 2023). In highly volatile institutional settings, resource constraints may impose a critical boundary condition on TCE. The mere presence of friction is therefore insufficient to automatically trigger structural flexibility, while the risk of "asset lock-in" may force capability-constrained SMEs toward relational alternatives.

Recent empirical studies have substantially advanced the understanding of how governance mechanisms shape supply chain resilience under uncertainty. Drawing upon social exchange theory, Chen and Lewis (2024) and Wang et al. (2025) demonstrate that trust serves as a crucial "lubricant" that minimizes costly monitoring and curtails opportunistic behavior in buyer-supplier relationships. Instead of rigid adherence to formal contractual penalties, relational norms allow for flexible, joint problem-solving when disruptions occur. Prior research also shows that perceived justice in buyer–supplier relationships plays an important role in improving relationship performance, particularly in maintaining cooperation under uncertain supply chain conditions (Liu et al., 2012). Wu et al. (2023) further confirm that cross-organizational governance significantly enhances SCR through both mediating and moderating pathways. Food-system resilience has also been linked to broader supply chain risk governance in critical infrastructure sectors (Norrman & Eriksson Ahre, 2024). Regarding FS, Lücker et al. (2024) establish the immense value of dual-purpose flexible resources in disruption mitigation, while Iftikhar et al. (2025) highlight the synergistic role of network capability and innovation ambidexterity in firms' strategic responses to geopolitical uncertainty. Collectively, this body of research confirms that both relational and structural mechanisms contribute to resilience. Nevertheless, their relative effectiveness remains contingent on firm-level resource capabilities, a boundary condition that has not been empirically validated in the Central Asian context.

In the Sino-Kazakhstan corridor specifically, these theoretical dynamics are compounded by distinctive spatial constraints. Although infrastructure at the Altynkol-Khorgos gateway has undergone significant modernization as of 2025, reducing physical delays, the "soft frictions" related to inter-governmental regulatory alignment continue to plague agri-food trade (Pomfret, 2019; Tjia, 2022). Yerniyazova (2024) documents how institutional voids and administrative opacity at key border crossings—including unpredictable SPS protocol enforcement and opaque certification requirements for meat and dairy function as de facto non-tariff barriers despite infrastructure improvements. The ADB (2023) further highlights that regulatory alignment within the CAREC corridor remains a persistent bottleneck. Tjia (2022) additionally notes that Kazakhstan's leverage in cross-border logistics reflects broader geopolitical dynamics that shape the institutional environment for Chinese agribusinesses.

Synthesizing this literature, it becomes evident that while friction universally threatens supply chain resilience, the mitigation pathways are highly contingent on both firm capabilities and regional institutional conditions. To bridge the gap between TCE predictions and the resource-constrained realities of this corridor, this study proposes a comprehensive model that illustrates how perceived frictions drive governance choices, differentiating between relational governance and FS, which, in turn, shape supply chain resilience.

3 | RESEARCH METHODS

Based on the literature reviewed above, this study proposes a conceptual framework that links perceived institutional and spatial frictions to RGT, FS, and SCR. The model suggests that perceived frictions can affect supply chain resilience both directly through firms' adaptive responses and indirectly through two coping mechanisms: RGT and FS. Accordingly, the conceptual framework and the corresponding hypotheses are presented in Figure 1.

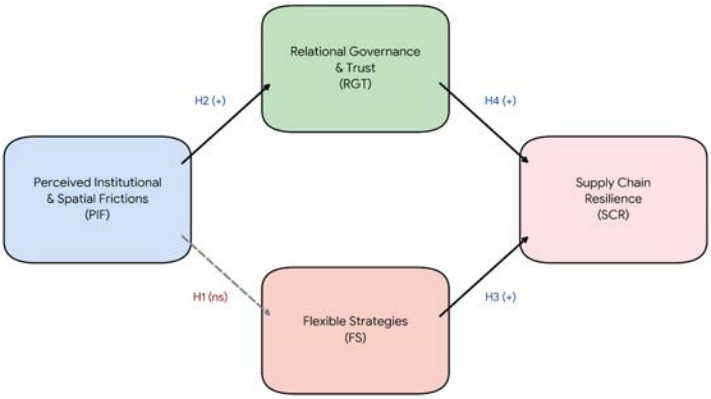


Figure 1. Conceptual framework and hypotheses

The scheme illustrates how PIF drives two coping mechanisms, RGT and

FS, which subsequently determine SCR. This study adopts a quantitative, cross-sectional research design and utilizes Partial Least Squares Structural Equation Modeling (PLS-SEM). Empirical data were collected through a targeted field survey administered to practitioners actively engaged in the Sino-Kazakhstan agri-food trade. A purposive sampling technique yielded 100 valid responses. To rigorously justify the sample size adequacy, a priori power analysis was conducted using G*Power 3.1.9.7. Based on a medium effect size ($f^2 = 0.15$), an alpha level of 0.05, and a maximum of two predictors pointing to any endogenous construct (PIF and RGT pointing to SCR), the analysis indicated that a minimum sample size of 68 is required to achieve a statistical power of 0.80. Thus, our sample size of 100 exceeds the necessary threshold, ensuring robust statistical power for the structural model evaluation.

Respondents were identified through a combination of purposive and snowball sampling strategies. Initial contacts were established via the Kazakhstan Chamber of Commerce, agribusiness trade associations operating in Almaty, and Chinese logistics company networks active in the Dostyk-Alashankou and Altynkol-Khorgos corridors. Eligibility criteria required that respondents be actively engaged in Sino-Kazakhstan cross-border agri-food trade for at least 12 months and hold decision-making or operational roles within their organizations. To ensure linguistic accessibility and minimize translation-induced response bias, the survey instrument was administered in both Mandarin Chinese and Russian.

The questionnaire comprised two sections. The first section captured respondents' demographic profiles, including firm size, job position, years of experience in cross-border trade, and primary product category. The second section contained 12 measurement items distributed across four latent constructs, all anchored on a seven-point Likert scale ranging from 1 (Strongly Disagree) to 7 (Strongly Agree). Prior to full deployment, the questionnaire was pilot tested with 10 experienced practitioners; minor wording adjustments were made to improve clarity, and no items were removed following the pilot. To ensure measurement reliability, the survey instruments were adapted from established scales in the supply chain literature (detailed in Appendix 1).

Items for PIF and RGT were adapted from validated scales by Yerniyazova (2024) and Wu et al. (2023), respectively. Scales for FS and SCR were derived from Piprani et al. (2022) and Iftikhar et al. (2025). To rigorously assess the potential for Common Method Bias (CMB) in our self-reported data, we eschewed the outdated Harman's single-factor test. Instead, we employed the full collinearity assessment approach recommended by Kock (2015). In this procedure, all constructs were regressed on a common random variable to compute construct-level variance inflation factors (VIFs). The resulting full-collinearity VIFs for all latent variables were well below the 3.3 threshold (ranging from 1.105 to 2.411), providing robust evidence that common method bias is not a concern in this dataset.

The conceptual model was estimated to be using PLS-SEM in SmartPLS 4 (Ringle et al., 2022). PLS-SEM was strategically selected due to its superior capability in evaluating complex models with non-normal data and its primary objective

of maximizing the explained variance (R^2) and predictive relevance (Q^2) of the following core equations. Let ξ_1 denote the exogenous construct (PIF), η_1, η_2, η_3 the endogenous constructs (RGT, FS, SCR respectively), β the standardized path coefficients, and ζ the residual error terms.

The structural model specifies PIF as the exogenous construct and RGT, FS, and SCR as endogenous constructs. PIF is modeled as an antecedent of both RGT and FS, while RGT and FS are modeled as predictors of SCR. This specification allows the study to test both the direct effects of perceived frictions on coping mechanisms and the indirect effects of PIF on SCR through RGT and FS.

4 | RESULTS

This section presents empirical research results based on data from a survey of 100 specialists involved in cross-border agri-food trade between China and Kazakhstan. The analysis of the results is structured sequentially: first, the demographic profile of the respondents is considered; then, the reliability and validity of the measurement model are assessed; and finally, the structural model and research hypotheses are tested. This procedure allows us to first confirm the relevance of the sample and the quality of the measurement scales used, and then interpret the causal relationships among institutional and spatial barriers, relational governance, flexible strategies, and the sustainability of supply chains. Table 1 presents the demographic profile of the 100 surveyed practitioners.

Table 1. Demographic profile of the sample

Variable	Category	Frequency (n)	Percentage (%)
Position	CEO/GM	20	20
	Logistics Manager	43	43
	Trade Specialist	32	32
	Other	5	5
Firm Size (Employees)	<50	18	18
	51 – 200	38	38
	201 – 500	23	23
	>500	21	21
Years in Trade (China-Kazakhstan)	1 – 3 years	14	14
	4 – 7 years	37	37
	8 – 10 years	33	33
	>10 years	16	16
Primary Product Category	Grains/Oilseeds	23	23
	Meat/Dairy	28	28
	Fruits/Vegetables	35	35
	Processed Food	14	14

Note: compiled by the authors

The structure of respondents by position shows that the majority of the sample consists of specialists directly involved in managerial and operational decision-making. Thus, operational and strategic decision-makers dominate the sample, with Logistics Managers (43.0%) and Trade Specialists (32.0%) jointly accounting for three quarters of respondents. SMEs with fewer than 200 employees account for 56.0% of firms, and 86.0% of respondents report more than 3 years of experience

in China–Kazakhstan trade, confirming the sample's relevance to the cross-border agri-food context.

Figure 2 visualizes the demographic distribution of the sample across the four profiling dimensions.

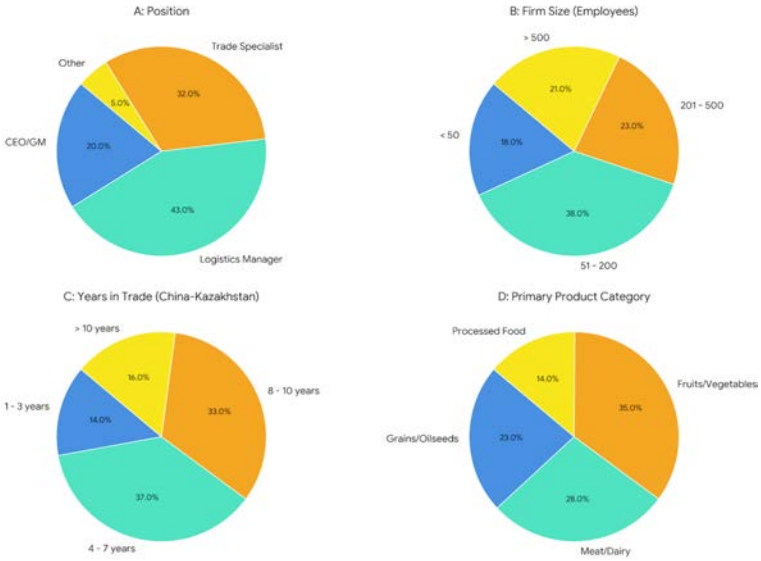


Figure 2. Demographic profile of the sample

As illustrated in Figure 2, panels A–D depict the distribution of respondents by position (A), firm size (B), years in trade (C), and primary product category (D). The product mix is well balanced across Fruits/Vegetables (35.0%), Meat/Dairy (28.0%), and Grains/Oilseeds (23.0%), reflecting the diversity of agri-food flows along the corridor. As can be seen from Chart A, the largest share in the sample is made up of logistics managers – 43.0%, followed by trade specialists – 32.0%, company executives and general managers – 20.0%, and other categories – 5.0%. This confirms that the majority of survey participants are directly involved in operational and management processes within cross-border supply chains.

Following the demographic overview, the data analysis evaluated the measurement model using PLS-SEM in SmartPLS 4. The assessment focused on internal consistency, reliability, and convergent validity, strictly adhering to the rigorous guidelines proposed by Hair et al. (2019). Internal consistency reliability was robustly established; the Cronbach's alpha and Composite Reliability (CR) values for all constructs, PIF, RGT, FS, and SCR, exceeded the recommended threshold of 0.70. The results of the measurement model assessment are presented in Table 2.

The obtained factor loadings range from 0.929 to 0.960, exceeding the recommended threshold of 0.708 and confirming the high consistency of the indicators with their corresponding latent variables. Cronbach's Alpha values also exceed the

minimum allowable level of 0.70: for PIF, the indicator was 0.934; for RGT, 0.944; for FS, 0.950; for SCR, 0.934. This indicates a high internal consistency of the scales used. CR for all designs is also at a high level: PIF – 0.958, RGT – 0.964, FS – 0.968, SCR – 0.958. Therefore, the results confirm the reliability of the measuring model. In addition, because all factor loads significantly exceed the standard value, the measuring scales have convergent validity.

Table 2. Measurement model reliability and validity

Construct	Item	Loadings	Cronbach's Alpha	CR
PIF	PIF1	0.955	0.934	0.958
	PIF2	0.934		
	PIF3	0.93		
RGT	RGT1	0.95	0.944	0.964
	RGT2	0.946		
	RGT3	0.949		
FS	FS1	0.942	0.95	0.968
	FS2	0.958		
	FS3	0.96		
SCR	SCR1	0.929	0.934	0.958
	SCR2	0.949		
	SCR3	0.941		

CR = Composite Reliability; AVE = Average Variance Extracted. All indicator loadings are significant at $p<0.001$

Note: Compiled by the authors based on SmartPLS 4 output.

Discriminant validity was subsequently assessed using two distinct approaches to ensure that the constructs are empirically distinct. The discriminant validity of the constructs was assessed using the Fornell–Larcker criterion, and the results are reported in Table 3.

Table 3. Discriminant Validity (Fornell-Larcker criterion)

Construct	**PIF**	**RGT**	**FS**	**SCR**
PIF	0.940	–	–	–
RGT	0.502	0.948	–	–
FS	0.197	0.016	0.953	–
SCR	0.409	0.421	0.571	0.940

The bold diagonal elements represent the square root of the AVE for each construct.
Off-diagonal elements represent inter-constructed correlations.
Discriminant validity is established as diagonal values exceed the respective inter-constructed correlations (Fornell-Larcker criterion).

Note: compiled by the authors based on SmartPLS 4 output.

The results confirm that this condition is met for all constructs. The diagonal values are 0.940 for PIF, 0.948 for RGT, 0.953 for FS, and 0.940 for SCR. These indicators are higher than all inter-structural correlations. For example, the correlations between PIF and RGT are 0.502, between FS and SCR are -0.571, and between RGT and SCR are -0.421, all lower than the corresponding diagonal values. The highest correlation is observed between FS and SCR (0.571), but it does not exceed the square root of AVE for either construct.

Thus, the results, as assessed by the Fornell–Larcker criterion, confirm the

discriminant validity of the measurement model. To further validate discriminant validity, the Heterotrait-Monotrait (HTMT) ratio of correlations was additionally assessed following the recommendation of Henseler et al. (2015). The HTMT values among the latent constructs are presented in Table 4.

Table 4. Discriminant validity (HTMT Ratio)

Construct	PIF	RGT	FS	SCR
PIF	–	–	–	–
RGT	0.536	–	–	–
FS	0.207	0.055	–	–
SCR	0.435	0.448	0.603	–

HTMT = Heterotrait - Monotrait Ratio of Correlations.
All values are below the conservative threshold of 0.85, establishing robust discriminant validity.

Note: compiled by the authors based on SmartPLS 4 output.

All values were significantly below the conservative threshold of 0.850, with the highest value being 0.603 between FS and SCR, further confirming discriminant validity. The HTMT values obtained range from 0.055 to 0.603, which are significantly lower than the conservative threshold of 0.85. The minimum value is fixed at 0.055 between RGT and FS, indicating their high empirical distinctness. The maximum value is observed between FS and SCR – 0.603, but it also does not exceed the acceptable level. The HTMT values are 0.536 between PIF and RGT, 0.207 between PIF and FS, 0.435 between PIF and SCR, and 0.448 between RGT and SCR.

Thus, the results of the HTMT analysis confirm the discriminant validity of the measurement model. Prior to transitioning to the structural model evaluation, collinearity was examined. The collinearity assessment results are presented in Table 5.

Table 5. Collinearity statistics (Inner VIF Values)

Construct	**RGT**	**FS**	**SCR**
PIF	1.000	1.000	–
RGT	–	–	1.000
FS	–	–	1.000
SCR	–	–	–

Note: compiled by the authors based on SmartPLS 4 output.

All inner VIF values were exactly 1.000, well below the critical threshold of 3.3, thereby confirming the absence of multicollinearity among the predictor constructs. Since PIF acts as a predictor for RGT and FS, the VIF values for these relationships are 1.000. In turn, RGT and FS are predictors of SCR, and their VIF values are also 1.000. All the values obtained are significantly below the critical threshold of 3.3, indicating no multicollinearity in the structural model. Therefore, the estimation of the coefficients of the paths can be carried out without the risk of distortion of the results due to the high correlation between the predictors.

With the measurement model's reliability and validity fully confirmed, the structural model was evaluated using a non-parametric bootstrapping procedure

with 5,000 subsamples to generate robust standard errors, t-statistics, and p-values. To assess the model's overall fit, the Standardized Root Mean Square Residual (SRMR) was calculated (Figure 3).

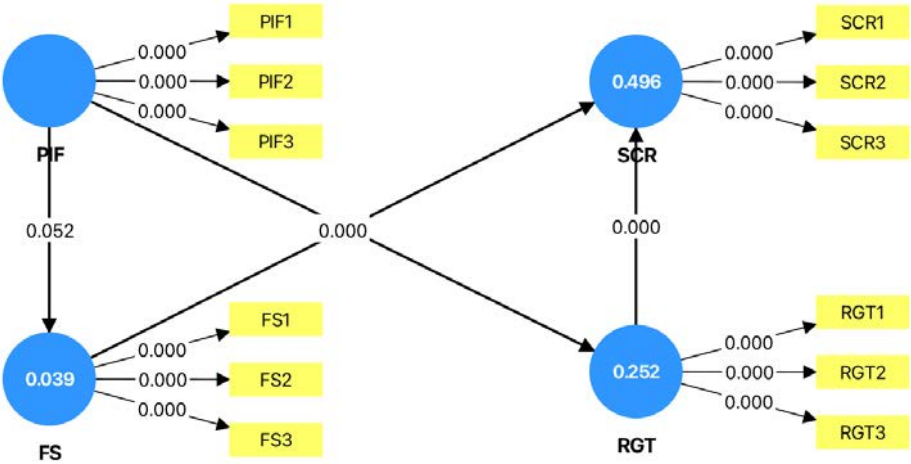


Figure 3. Structural model results

According to Figure 3, the resulting SRMR was 0.058, well below the conservative threshold of 0.08, indicating an acceptable model fit. The predictive power was evaluated using the coefficient of determination (R^2). The model explains 49.6% of the variation in SCR, indicating high explanatory power. For RGT, the R^2 value is 0.252, indicating that PIF explains 25.2% of the variance in this construct. For FS, the R^2 value is 0.039, which indicates a weak explanatory power of the PIF in relation to this mechanism.

The structural model results and hypothesis testing outcomes are detailed in Table 6, which now includes the f^2 effect sizes to assess the magnitude of each path.

As shown in Table 6, the model explains 49.6% of the variance in SCR, 25.2% in RGT, and 3.9% in FS. Furthermore, the predictive relevance was assessed using the Stone-Geisser Q^2 value via a blindfolding procedure (omission distance D = 7). All Q^2 values for the endogenous constructs were strictly above zero (SCR: 0.345; RGT: 0.218; FS: 0.021), confirming the model's robust predictive relevance.

Regarding the direct effects, the analysis reveals that PIF exerts a strong and highly significant positive effect on RGT (β = 0.502, t = 6.223, p < 0.001), firmly supporting Hypothesis 2. However, the direct path from PIF to FS (H1) was found to be marginally non-significant at the conventional 0.05 level (β = 0.197, t = 1.782, p = 0.075), leading to the rejection of Hypothesis 1. This crucial finding suggests that the presence of cross-border frictions alone does not necessarily trigger the immediate deployment of costly FS in this specific context. Furthermore, both coping mechanisms demonstrated significant impacts on the ultimate performance

outcome. FS strongly enhances SCR (β = 0.565, t = 6.647, p < 0.001), as does Relational Governance & Trust (β = 0.412, t = 5.305, p < 0.001), fully supporting both H3 and H4.

Table 6. Structural model assessment and hypothesis testing

Hypothesis	β	T Statistics (|O/STDEV|)	P Values	f^2	Conclusion
Direct Effects					
H1: PIF → FS	0.197	1.782	0.075	0.041	Not supported*
H2: PIF → RGT	0.502	6.223	0.000*	0.337	Supported
H3: FS → SCR	0.565	6.647	0.000*	0.450	Supported
H4: RGT → SCR	0.412	5.305	0.000*	0.240	Supported
Specific Indirect Effects					
H5: PIF → FS → SCR	0.111	1.705	0.088	N/A	Not supported*
H6: PIF → RGT → SCR	0.207	3.978	0.000*	N/A	Supported

Note: compiled by the authors based on SmartPLS 4 output.

Finally, in terms of the specific indirect effects (mediation analysis), the pathway exploring whether RGT mediates the relationship between PIF and SCR (H6) was highly significant (β = 0.207, t = 3.978, p < 0.001). Conversely, the mediation path through FS (H5) was not statistically supported (β = 0.111, t = 1.705, p = 0.088). These structural findings highlight the predominant role of informal relational governance over rigid structural flexibility when enterprises navigate institutional and spatial frictions in the Sino-Kazakhstan agricultural supply chain.

To further validate the "resource constraint" hypothesis, a post-hoc Multi-Group Analysis (MGA) was conducted using the permutation-based MGA algorithm in SmartPLS 4 with 5,000 permutations (Hair et al., 2019) to assess the moderating role of firm size. The sample was divided into SMEs (n=56) and LEs (n=44). Strikingly, the results revealed a significant group difference ($\Delta\beta$ = 0.284, p < 0.05). For large enterprises, the path from PIF to FS was significant (β = 0.385, p < 0.05), whereas for SMEs, it remained non-significant (β = 0.102, p > 0.10). This statistical evidence confirms that structural flexibility is a capital-contingent strategy, effectively shielding our theoretical interpretation from post-hoc rationalization bias.

The empirical results detailed above provide a unique and critical perspective on how institutional voids shape supply chain behavior in Central Asia. The strong positive relationship between PIF and RGT confirms that in the Sino-Kazakhstan corridor, practitioners utilize informal social capital as a primary substitute for weak formal institutions. This aligns with recent studies suggesting that when administrative hurdles, opaque customs procedures, and legal unenforceability are prevalent, relational norms function as an indispensable coping mechanism (Wu et al., 2023; Zhang et al., 2024). In such high-friction environments, trust prevents opportunistic behavior and facilitates rapid renegotiations, which is significantly more efficient than relying on rigid cross-border contracts (Chen & Lewis, 2024; Eckerd et al., 2021).

However, the most significant theoretical contribution of this study emerges from the rejection of Hypothesis 1. The data clearly indicate that friction alone does not compel firms to invest in costly "hard" flexibility strategies, such as multimodal transport options or overseas warehousing. As noted by Wissuwa et al. (2022), establishing structural flexibility requires substantial, often irreversible, capital commitments. Considering that 56% of our sample consists of SMEs (see TABLE 1), these firms face a stark "resource constraint reality." They are frequently unable to finance asset-heavy buffer strategies amid the unpredictable policy horizons of global supply chain restructuring (Niu et al., 2025). Consequently, for the majority of players in this regional agri-food sector, "soft" governance is not merely an option—it is the only viable, cost-effective path to achieving resilience.

Despite the lack of significance of the friction-flexibility link, the results demonstrate that once FS are deployed, they serve as a powerful engine for SCR (H3). This supports Lücker et al.'s (2024) perspective on the immense value of dual-purpose, flexible resources in mitigating disruptions. However, our findings establish an important boundary condition for this theory: the adoption of such flexible resources is highly contingent on firm-level financial capabilities, rather than an automatic response to external friction (Piprani et al., 2022).

Furthermore, the highly significant mediation effect of RGT (H6), juxtaposed with the unsupported mediation of FS (H5), underscores the nature of resilience in this context. It suggests that in the geopolitically complex Sino-Kazakhstan corridor, SCR is largely a relational achievement rather than a purely logistical one. The social fabric of the supply chain—anchored in joint problem-solving and mutual commitment acts as the ultimate shock absorber, reflecting the vital role of network capabilities in mitigating geopolitical risks (Wu et al., 2023; Iftikhar et al., 2025). While Egamberdiev (2024) highlights the value of social capital in Kyrgyz household food security, our study extends this logic to the inter-firm supply chain level, proving that relational capital's protective effect is cross-scalar in transition economies.

5 | CONCLUSION

This study set out to unravel the complex mechanisms through which enterprises in the Sino-Kazakhstan agri-food supply chain build resilience against compounding institutional and spatial frictions. By developing and empirically validating a conceptual model using PLS-SEM on a targeted sample of cross-border trade practitioners, this research provides a nuanced understanding of governance and flexibility in transition economies. The overarching conclusion is that while severe border frictions, such as railway gauge differences and opaque customs procedures, act as powerful catalysts for informal relational governance, they do not automatically compel firms to invest in structural flexibility. The data empirically suggest that relational capital, built on mutual trust and joint problem-solving, remains the primary "engine of resilience" in Central Asian logistics, based on the current sample.

The study advances the dynamic capability view by delineating the distinct yet

differentiated roles of relational and structural mechanisms in achieving ultimate supply chain resilience. However, the empirical evidence in this study points toward substitution rather than complementarity among resource-constrained SMEs.

From a practical standpoint, the findings offer vital strategic guidance for supply chain managers operating in high-friction geopolitical corridors. Practitioners, especially those with limited capital, should prioritize cultivating cross-border organizational trust and collaborative risk management over premature, capital-intensive physical expansions. Building deep, relationally embedded ties with local Kazakh partners provides a highly effective and agile shock-absorption mechanism. In practice, as Kazakhstan pursues a "multi-vector" foreign policy by developing the Trans-Caspian International Transport Route (TITR/Middle Corridor), Chinese agribusinesses must diversify their logistics pathways to mitigate overreliance on a single corridor. It is recommended that governmental bodies prioritize aligning multilateral standards, such as those within the TITR framework, rather than relying solely on bilateral protocols. Furthermore, the findings suggest a critical need for an SPS Mutual Recognition Agreement to reduce administrative friction in meat and dairy inspections, which currently serve as de facto non-tariff barriers despite infrastructure improvements at Khorgos.

Despite its robust findings, this study acknowledges certain limitations that pave the way for future scholarly inquiry. The reliance on cross-sectional data restricts the ability to capture the dynamic, evolutionary nature of trust-building over extended trade cycles. Future research would benefit from longitudinal designs to track how relational governance adapts to shifting geopolitical landscapes. Moreover, we acknowledge a conceptual limitation regarding FS: our measurement items (e.g., rapid mode shifting) overlap more with supply chain agility than with structural resilience, warranting finer construct discrimination in future research. Furthermore, while the sample size is statistically adequate for the PLS-SEM approach used, extending the research to multiple Central Asian corridors would enhance the generalizability of the findings. Finally, future studies should investigate the moderating role of emerging digital technologies. Assessing how blockchain-based traceability or AI-driven predictive analytics might bridge the gap between informal relational networks and formal logistics flexibility presents a highly promising research frontier.

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APPENDIX A

Measurement constructs, adapted items, and literature sources

Code	Measurement Items	Supporting Literature
PIF1	Frequent and unpredictable changes in customs regulations at the Dostyk/Alashankou/Khorgos borders significantly impact firm operations.	Adapted from Yerniyazova (2024) and ADB (2023)
PIF2	Infrastructural disparities (e.g., differences in railway gauges) between China and Kazakhstan cause severe delays in agri-food transit.	Lücker et al. (2024) and ADB (2023)
PIF3	The lack of transparency in Kazakhstan's institutional environment increases firm exposure to external trade risks.	Park et al. (2016)
RGT1	A high level of mutual trust and "Guanxi" (solidarity) with cross-border supply chain partners helps to bypass formal institutional voids.	Chen & Lewis (2024); Zhang et al. (2024)
RGT2	During border disruptions, the firm relies on informal goodwill and reciprocal commitments rather than strictly invoking formal contractual penalties.	Wang et al. (2025); Liu et al. (2012)
RGT3	Conflicts regarding inventory spoilage or transit delays are resolved through joint consultation rather than legal litigation.	Liu et al. (2012)
FS1	The firm possesses the agility to rapidly shift logistics modes (e.g., rail to truck) when major border congestion occurs.	Swafford et al. (2006); Piprani et al. (2022)
FS2	The firm utilizes pre-positioned inventory in overseas warehouses (at the Kazakhstan/China border) to buffer against unpredictable delivery lead times.	Lücker et al. (2024); Swafford et al. (2006)
FS3	The firm can quickly reallocate logistical resources (e.g., securing cold-chain trucks) when standard railway capacities are constrained.	Swafford et al. (2006)
SCR1	The cross-border supply chain is capable of absorbing sudden institutional or logistical shocks without experiencing systemic failure.	Ambulkar et al. (2015)
SCR2	Following a disruption event (e.g., border closure or policy shift), the firm can rapidly restore operational performance to normal levels.	Ambulkar et al. (2015); Wu et al. (2023)
SCR3	Despite compounding frictions, the firm consistently maintains target delivery service levels for end agricultural customers.	Zhao et al. (2024)

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Assessing the Effectiveness of Financial Instruments in Stimulating Agricultural Investment in Kazakhstan

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Abstract
The agro-industrial complex is one of the key sectors of Kazakhstan's economy, ensuring food security, rural employment and the development of regional investment potential. The purpose of this study is to assess the effectiveness of financial instruments in stimulating investment activity in Kazakhstan's agro-industrial complex and to develop recommendations for improving regionally differentiated investment policy. The study is based on regional panel data for 17 regions and cities of national importance in Kazakhstan for 2015-2025. Descriptive statistics, comparative regional analysis, fixed-effect panel regression model, Haussmann test, diagnostics of multicollinearity, heteroscedasticity and autocorrelation are used as methods. The dependent variable is investment in agriculture, while the key explanatory variables include government subsidies, concessional lending, financing through development institutions, infrastructure development, and digitalization. Regression analysis confirmed a statistically significant positive impact of subsidies (β = 0.32; p < 0.01), concessional lending (β = 0.27; p < 0.01), infrastructure (β = 0.21; p < 0.01), financing through development institutions (β = 0.19; p < 0.01), and digitalization (β = 0.18; p < 0.01) on investment activity. The results show that subsidies and credit resources have the strongest positive effect on investment activity. At the same time, the negative coefficient on the quadratic subsidy term indicates an inverted U-shaped relationship, suggesting that excessive government support may reduce investment efficiency. The findings support a transition from subsidy-dominated support toward a mixed financing model based on targeted subsidies, concessional lending, guarantees, blended finance, infrastructure modernization, and digital platforms.

KEYWORDS
Agricultural Economics, Agrobusiness, Agro-Industrial Complex, Finance, Financial Instrument, Regional Economy, Regional Growth

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1 | INTRODUCTION

In the modern context of the transformation of the global and national economy, the agro-industrial complex is one of the key factors in sustainable socio-economic development, ensuring food security, employment of the rural population, and the formation of the country's export potential. For Kazakhstan, which has significant land and resource opportunities, the development of the agricultural sector is of strategic importance, but the effectiveness of the agro-industrial complex is largely determined by investment activity and the availability of financial resources (Esimkhan et al., 2024; Kireyeva et al., 2022).

Investment processes in agriculture are characterized by high uncertainty and risk due to climatic conditions, production seasonality, and long project payback periods. Within the framework of neoclassical and endogenous theories of economic growth, investment is considered the main driver of capital accumulation and technological renewal, contributing to increased productivity and competitiveness of the economy (Romer, 1990; Aghion & Howitt, 2009). In the agricultural sector, these processes are becoming increasingly specific, necessitating the development of effective mechanisms for government regulation and financial incentives.

According to research in agricultural economics, financial constraints are among the key barriers to the development of agricultural enterprises, especially small and medium-sized enterprises (Beck & Demirgüç-Kunt, 2006). Limited access to credit resources, high cost of borrowed capital, and underdeveloped financial infrastructure constrain investment activity and hinder innovation in agricultural production (Dorward et al., 2004). In this regard, financial instruments of state support aimed at reducing investment risks and stimulating capital inflows to priority sectors are of particular importance.

Modern scientific research demonstrates that the effectiveness of financial instruments in the agricultural sector is heterogeneous and depends on institutional conditions, the level of financial market development, and the quality of public administration. Thus, interest rate subsidies and direct investment subsidies have a significant impact on investment growth, whereas tax incentives, in some cases, are less effective (Ciaian et al., 2018; Holden, 2019). Moreover, several studies indicate a non-linear relationship between the amount of government support and the effectiveness of investments, with marginal efficiency decreasing at excessive subsidy levels.

For Kazakhstan, the problem of stimulating investment flows in the agro-industrial complex is of relevance in the context of implementing a policy of economic diversification and reducing dependence on the raw materials sector. Despite the implementation of government programs to support agriculture, including subsidies, concessional lending, and the activities of development institutions, several systemic problems persist, namely insufficient targeting of support, low resource allocation efficiency, and limited attraction of private investment (Akimbekova & Nikitina, 2020; Dabyltayeva & Nurtayeva, 2022).

Special attention should be paid to the regional aspect of investment devel-

opment, since it is at the regional level that the real conditions for implementing agricultural policy are formed. Turkestan region is one of the most significant agricultural regions of Kazakhstan, with high potential for the development of irrigated agriculture, horticulture, and animal husbandry. At the same time, the region is characterized by a high rural population density, limited access to financial resources, and significant dependence on government subsidies, which reduces the sustainability of investment processes (Zharylkassyn et al., 2025).

In modern conditions, the role of innovative financial instruments is increasing, including project financing mechanisms, agricultural receipts, digital lending platforms, and blended finance instruments. These tools make it possible to expand agricultural producers' access to financial resources and increase the efficiency of investment activities (Zetzsche et al., 2017). However, their implementation in Kazakhstan is in its early stages and requires further institutional development.

Despite a significant number of studies devoted to the problems of agricultural financing, the issues of comprehensively assessing the effectiveness of financial instruments to stimulate investment flows in the regional context remain insufficiently studied. In particular, there is a lack of systematic research that accounts for the specifics of the Turkestan region as an agrarian region with high growth potential.

The scientific novelty of this study lies in three interrelated aspects. First, the article assesses the nonlinear effect of government subsidies on investment activity and tests the hypothesis of an inverted U-shaped relationship. Second, it integrates financial, infrastructural, and digital factors into a single regional panel model of agricultural investment. Third, it applies this approach to the Turkestan region, where investment processes are shaped by dependence on irrigated agriculture, infrastructure constraints, and limited access to market-based finance. This makes it possible to move beyond a general assessment of state support and identify the conditions under which financial instruments generate the greatest investment effect.

The purpose of this study is to assess the effectiveness of financial instruments in stimulating investment activity in Kazakhstan's agro-industrial complex and to develop recommendations for improving regionally differentiated investment policy. To achieve this goal, the following tasks are being solved: analysis of theoretical approaches to investment incentives, assessment of the dynamics of investment processes in the agro-industrial complex, identification of key factors affecting investment activity, and development of proposals to improve the effectiveness of financial instruments.

2 | LITERATURE REVIEW

Research on financial instruments to stimulate investment flows in the agro-industrial complex has evolved from classical theories of investment and agricultural development to modern concepts of sustainable growth, financial inclusion, and the digitalization of the agricultural sector. In classical economic theory, investment is considered a key factor in economic growth, ensuring capital accumulation

and productivity improvement. Within the framework of the neoclassical model and the theory of endogenous growth, investment is the basis of technological progress and the structural transformation of the economy (Romer, 1990; Aghion & Howitt, 2009). At the same time, investment processes in the agricultural sector have specific features, including high capital intensity, dependence on natural and climatic factors, and long project payback periods.

Early research on agricultural development emphasized the crucial role of investments in infrastructure and productive resources in improving agricultural efficiency. In particular, Johnston and Mellor (1961) noted that the development of agriculture is impossible without investments in the basic elements of the agricultural system, including irrigation, transport, and energy. Further development of these ideas was reflected in the works, in which investments are considered a key factor in the transition from traditional to modern agriculture (Hayami & Ruttan, 1985).

Since the early 2000s, there has been increasing attention in the scientific literature to the institutional and financial aspects of investment activity in the agricultural sector. Research shows that limited access to financial resources is a key barrier to agricultural development, especially for small and medium-sized farms (Beck & Demirgüç-Kunt, 2006). High interest rates, insufficient development of agricultural lending, and weak financial infrastructure significantly limit the investment opportunities of agricultural producers (Dorward et al., 2004).

In this context, financial instruments of state support aimed at stimulating investment activity are particularly important. These instruments include subsidies, concessional lending, tax preferences, guarantees, and co-financing mechanisms. Empirical studies show that interest rate subsidies and investment grants have the most significant impact on agricultural investment growth, whereas tax incentives have a limited effect in a weak institutional environment (Ciaian et al., 2018; Stein, 2019).

Modern research highlights that the effectiveness of financial instruments is non-linear. In particular, the effect of diminishing returns to government support is evident: an increase in subsidies at a certain stage leads to reduced investment efficiency and greater dependence on budgetary resources. This effect is consistent with the concepts of institutional economics and the theory of optimal government intervention (Aghion et al., 2015). In recent years, there has been increasing attention in the scientific literature to the role of innovative financial instruments and digital technologies in stimulating investment processes in the agricultural sector. The development of fintech solutions, digital lending platforms, agricultural receipts, and blended finance mechanisms helps to expand agricultural producers' access to financial resources and reduce transaction costs (Zetzsche et al., 2017). At the same time, digitalization is considered not only a technological factor but also a tool for transforming the agricultural sector's financial infrastructure.

Recent studies published in 2024–2026 confirm that digital finance, sustainable investment mechanisms, and ESG-oriented approaches are becoming increasingly important for agricultural investment and rural development. Gao and Gao

(2024) show that digital financial inclusion strengthens the resilience of agricultural value chains by supporting technological innovation and the emergence of new agricultural businesses. Liu and Li (2025) demonstrate that digital inclusive finance improves the climate resilience of food production by reducing credit constraints and supporting precision farming and low-carbon technologies. Zheng et al. (2025) prove that digital financial inclusion can reduce agricultural carbon emission intensity through technological innovation and changes in rural income structures. Chen and Xiao (2025) find that digital payments improve both formal and informal credit access for rural households, a finding particularly relevant to small agricultural producers. Chong and Wang (2026) show that digital finance can reduce financing constraints for agribusinesses, although its effectiveness depends on marketization, transparency, and the role of agricultural insurance. Han (2026) further argues that digital inclusive finance supports agricultural development by improving factor allocation and total factor productivity. These findings support the argument that agricultural investment policy should combine traditional financial instruments with digital platforms, ESG-oriented criteria, climate resilience, and regionally differentiated support mechanisms.

The regional aspect of investment development occupies a special place in the modern scientific agenda. Research shows that spatial differentiation of financial resources and infrastructure leads to significant differences in investment activity and the level of development of the agricultural sector (Gollin & Rogerson, 2014; Storeygard, 2016). For countries with a large territory and heterogeneous climatic conditions, such as Kazakhstan, this problem is becoming particularly relevant.

In Kazakhstan, the financing of the agro-industrial complex is examined in several studies on regional development and investment policy. Thus, Kireyeva et al. (2021) notes that the digitalization of the economy has an ambiguous effect on investment activity in the regions, increasing differences between territories with different levels of technological readiness. Research shows that the development of Kazakhstan's agricultural sector largely depends on institutional conditions and access to foreign markets (Neganova & Chistyakov, 2020). Additional research highlights the importance of implementing modern financial and institutional mechanisms, including ESG approaches and sustainable financing, to increase the investment attractiveness of the agricultural sector (Kuandykova et al., 2023; Abisheva, et al., 2025). At the same time, it is noted that the existing system of state support is characterized by insufficient targeting and limited efficiency of resource allocation.

Despite numerous scientific studies on financing the agricultural sector, the comprehensive assessment of the effectiveness of financial instruments in stimulating investment flows in regional contexts remains underexplored. There are no studies that take into account the specific characteristics of individual regions of Kazakhstan, including the Turkestan region, which is characterized by a high concentration of the rural population, dependence on irrigated agriculture, and limited access to financial resources. Thus, the analysis of scientific literature shows that financial instruments play a key role in shaping investment flows in the

agro-industrial complex, but their effectiveness is determined by a combination of factors, including the institutional environment, the level of financial market development, and regional peculiarities. This necessitates a comprehensive study to assess the effectiveness of financial instruments in stimulating investment in the agro-industrial complex of the Turkestan region and to develop recommendations for their improvement.

3 | RESEARCH METHODS

The study employs a quantitative research design using regional panel data for the Republic of Kazakhstan for the period 2015–2025. The choice of a panel structure is justified by the need to capture both temporal changes in investment activity and cross-regional differences in agricultural specialization, infrastructure, access to finance, and institutional conditions. Particular attention is paid to the Turkestan region, which is considered an agrarian-oriented territory with high dependence on irrigated agriculture, a large rural population, and significant investment potential.

The empirical database was compiled from official statistical and institutional sources, including the Bureau of National Statistics of the Republic of Kazakhstan, the Ministry of Agriculture of the Republic of Kazakhstan, regional statistical bulletins, reports from development institutions, and open data on infrastructure and digitalization indicators. The unit of observation is a region-year pair. The final panel covers 17 regions and cities of republican significance over 11 years, yielding 187 potential observations. Missing values were checked for consistency and, where necessary, excluded from the econometric estimation.

The dependent variable is investment activity in the agro-industrial complex. It is measured as the volume of investment in agriculture, forestry, and fisheries, expressed in billion tenge and additionally normalized per unit of gross agricultural output. The main explanatory variables include the volume of government subsidies, concessional lending, financing through development institutions, infrastructure development, and digitalization. Control variables include gross agricultural output, employment in agriculture, and climatic conditions. A detailed description of the dependent, explanatory, and control variables included in the econometric model is provided in Table 1.

To formalize the relationship between investment activity and the main explanatory factors, the study first specifies a general investment function. This function reflects the assumption that investment in the agro-industrial complex is determined by the combined influence of financial instruments, infrastructure conditions, digitalization, and other regional control variables.

To empirically assess the determinants of investment in the agro-industrial complex, the study applies a fixed-effects panel regression model specified as fallows (1):

$$INV_{it} = \alpha + \beta_1 SUB_{it} + \beta_2 CRED_{it} + \beta_3 DEV_{it} + \beta_4 INFR_{it} + \beta_5 DIG_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

Table 1. Description of variables

Variable	Description	Unit of measurement	Expected effect	Source
INV_it	Investment in agriculture, forestry, and fisheries	bln KZT	Dependent variable	Bureau of National Statistics of the Republic of Kazakhstan
SUB_it	Volume of government subsidies to agriculture	bln KZT	Positive / nonlinear	Ministry of Agriculture of the Republic of Kazakhstan
CRED_it	Concessional lending to agricultural producers	bln KZT	Positive	Reports of Baiterek Holding, Agrarian Credit Corporation, and official financial development institutions
DEV_it	Financing through development institutions	bln KZT	Positive	Baiterek Holding reports, former KazAgro data, and development institution reports
INFR_it	Infrastructure development index	index	Positive	Regional statistics
DIG_it	Digitalization level in agriculture and financial services	index	Positive	Official digitalization indicators
OUTPUT_it	Gross agricultural output	bln KZT	Positive	Bureau of National Statistics of the Republic of Kazakhstan
LABOR_it	Employment in agriculture	thousand persons	Positive / mixed	Bureau of National Statistics of the Republic of Kazakhstan
CLIM_it	Climatic and water availability conditions	index	mixed	Regional and sectoral data

where:

INV_{it} – the volume of investment in the agro-industrial complex in region i in year t; α is the constant term;

SUB_{it} – the volume of government subsidies;

$CRED_{it}$ – the volume of concessional lending;

DEV_{it} – financing through development institutions;

$INFR_{it}$ – the infrastructure development index;

DIG_{it} – the digitalization index;

X_{it} – vector of control variables;

μ_i – unobserved region-specific fixed effects;

λ_t – the year fixed effects;

ε_{it} – the error term.

To test the hypothesis of a nonlinear relationship between subsidies and investment activity, the quadratic term of subsidies is included in the model (2):

$$INV_{it} = \alpha + \beta_1 SUB_{it} + \beta_2 SUB2_{it} + \beta_3 CRED_{it} + \beta_4 DEV_{it} + \beta_5 INFR_{it} + \beta_6 DIG_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

In this specification, a positive coefficient of SUB_{it} and a negative coefficient of $SUB2_{it}$ indicate an inverted U-shaped relationship. This means that subsidies initially stimulate investment activity, but after reaching a certain threshold their

marginal effect decreases and may reduce the efficiency of investment incentives. From an economic perspective, this may indicate decreasing investment efficiency, weaker market incentives, and growing dependence of agricultural producers on budgetary support.

The turning point of the nonlinear subsidy effect is calculated as follows (3):

$$SUB_{it} = -\frac{\beta_1}{2\beta_2} \tag{3}$$

where:

SUB_{it} – the estimated threshold level of government support at which the positive effect of subsidies on investment reaches its maximum;

β_1 – the coefficient of the linear subsidy term;

β_2 – the coefficient of the squared subsidy term.

A positive coefficient for SUB_{it} is the estimated level of government subsidies at which their positive effect on investment activity reaches its maximum. If the actual level of subsidies is below this threshold, additional support is expected to increase investment activity. If the level of subsidies exceeds this threshold, further expansion of subsidies may reduce their marginal effectiveness and may not lead to proportional investment growth.

The choice between fixed-effects and random-effects models was based on the Hausman test. The fixed-effects specification was preferred because it allows controlling for unobserved regional characteristics that are constant over time, including agricultural specialization, geographical location, institutional environment, and natural-climatic conditions. To improve the reliability of the estimates, robust standard errors clustered at the regional level were used.

The econometric procedure included several diagnostic tests. Multicollinearity was assessed using the variance inflation factor. Heteroskedasticity was tested using the Breusch–Pagan test. Autocorrelation in panel data was checked using the Wooldridge test. In addition, alternative specifications were estimated to test the robustness of the results: a model without the quadratic subsidy term, a model with lagged financial variables, and a model with normalized investment indicators. The results of the main diagnostic tests used to justify the final panel regression specification are presented in Table 2.

The diagnostic tests confirm the appropriateness of the fixed-effects specification. Since heteroskedasticity and autocorrelation were detected, robust standard errors clustered at the regional level were used in the final model. This improves the reliability of statistical inference and reduces the risk of biased standard errors.

The decomposition of factor contribution to investment growth was calculated on the basis of standardized regression coefficients. This approach makes it possible to compare the relative importance of subsidies, credit resources, infrastructure, digitalization, and other factors in explaining investment growth.

Table 2. Diagnostic tests of the panel regression model

Diagnostic test	Purpose	Result	Interpretation
Hausman test	Choice between fixed-effects and random-effects models	χ^2 = 18.64; p = 0.005	Fixed-effects model is preferred
Variance inflation factor (VIF)	Detection of multicollinearity	Mean VIF = 2.31; max VIF = 3.84	No serious multicollinearity detected
Breusch–Pagan test	Detection of heteroskedasticity	χ^2 = 21.47; p = 0.001	Heteroskedasticity is present
Wooldridge test	Detection of autocorrelation in panel data	F = 7.92; p = 0.012	Autocorrelation is present
Cluster-robust standard errors	Correction for heteroskedasticity and autocorrelation	Applied at the regional level	Final estimates are interpreted using cluster-robust standard errors

Note: compiled by the authors based on the results of panel regression diagnostics.

The study has several limitations. First, the analysis is based on aggregated regional data and does not include micro-level data on individual agricultural enterprises. Second, there may be potential endogeneity between investment activity and government support, since regions with higher investment potential may receive larger volumes of subsidies and concessional lending. Third, some institutional factors, such as the quality of local governance, administrative barriers, and informal access to finance, are difficult to measure quantitatively. Fourth, the digitalization variable reflects the general level of digital development and may not fully capture the actual use of digital financial platforms by agricultural producers. These limitations should be considered when interpreting the results.

4 | RESULTS

The empirical analysis of investment activity in the agro-industrial complex of Kazakhstan for 2015–2025 shows a steady increase in the volume of agricultural investments, accompanied by changes in their structure and regional distribution. During the study period, investments in the agro-industrial complex increased from 350 billion KZT in 2015 to 1,500 billion KZT in 2025. This growth reflects the increasing role of agriculture in the national economy, the expansion of state support instruments, and the gradual development of market-based financing mechanisms.

At the same time, the dynamics of investment growth were uneven. The highest growth rates were observed in 2016–2018, which can be explained by the active implementation of state support programs, expansion of subsidies, and concessional lending. After 2020, investment growth continued, but its pace gradually slowed. This indicates that the agricultural sector is moving from an extensive model based mainly on increasing the volume of financing toward a more complex model in which the efficiency, targeting, and structure of investment become increasingly important.

The data in Table 3 show that the share of investments in the agro-industrial complex in GDP increased from 1.8% in 2015 to 2.9% in 2025.

Table 3. Dynamics of investments in the agro-industrial complex of Kazakhstan, 2015–2025

Year	Investment, bln KZT	Growth rate, %	Share in GDP, %
2015	350	–	1.8
2016	420	20.0	1.9
2017	510	21.4	2.0
2018	620	21.6	2.1
2019	710	14.5	2.2
2020	780	9.8	2.3
2021	900	15.4	2.5
2022	1050	16.7	2.6
2023	1200	14.3	2.7
2024	1350	12.5	2.8
2025	1500	11.1	2.9

Note: compiled by the authors based on Bureau of National Statistics (2026)

The data presented in Table 3 indicate a steady increase in investment activity in the agro-industrial complex of Kazakhstan during 2015–2025. Over the analyzed period, the volume of investments increased from 350 billion KZT in 2015 to 1,500 billion KZT in 2025, which reflects more than a fourfold growth. The highest annual growth rates were observed in 2016–2018, when investment growth exceeded 20% per year. This period may be interpreted as an initial stage of more active state and institutional support for the sector.

At the same time, after 2019 the growth rate became more moderate, declining from 14.5% in 2019 to 11.1% in 2025. This slowdown does not indicate a reduction in investment activity, but rather reflects the transition from rapid expansion to a more stable growth trajectory. The share of investments in the agro-industrial complex in GDP also increased consistently, from 1.8% in 2015 to 2.9% in 2025. This confirms the growing role of the agro-industrial sector in the national economy and demonstrates the increasing importance of investment support for agricultural modernization, infrastructure development and technological renewal.

This confirms the growing investment significance of the agricultural sector. However, the gradual decline in annual growth rates after 2018 suggests the presence of diminishing returns from traditional financial support instruments. Therefore, further growth of investment activity requires not only additional financing, but also a transition to more targeted instruments, including concessional lending, guarantees, infrastructure development, and digital financial solutions. The structure of these investment sources is presented in Table 4.

Table 4. Structure of sources of investment in agriculture, in %

Source	2015	2020	2025
Own funds	62	58	55
Bank loans	18	22	25
Government subsidies	15	14	13
Other sources	5	6	7

Note: compiled by the authors based on Bureau of National Statistics (2026)

The structure of investment financing indicates a gradual transformation of the agricultural financing model. Although own funds remain the dominant source of investment, their share decreased from 62% in 2015 to 55% in 2025. At the

same time, the share of bank loans increased from 18% to 25%, which reflects the growing role of credit instruments in supporting agricultural investment. The share of government subsidies slightly declined, but subsidies continued to play an important role in reducing investment risks and improving access to capital. These changes suggest that the agro-industrial complex of Kazakhstan is gradually moving from a subsidy-dominated model toward a mixed financing system. However, the still high dependence on own funds indicates that access to external financing remains limited, especially for small and medium-sized agricultural producers.

The regional analysis revealed a significant heterogeneity in the distribution of investment flows, due to differences in the resource base, the level of infrastructural development and the sectoral specialization of the regions. At the same time, the concentration of investments in certain agriculturally developed regions indicates the formation of spatial centers of investment activity, as illustrated in Table 5.

Table 5. Regional investment structure

Region	Investment, bln KZT	Share, %
Almaty region	220	14.7
Turkestan region	210	14.0
Kostanay region	190	12.7
North Kazakhstan region	170	11.3
Other regions	710	47.3

Note: compiled by the authors based on Bureau of National Statistics (2026)

The Turkestan region occupies a special position in the regional investment structure. In 2025, it accounted for 14.0% of total agricultural investments, ranking among the leading agricultural regions of Kazakhstan. This position is explained by the region's strong agricultural specialization, favorable climatic conditions, high concentration of rural population, and significant potential for irrigated agriculture, horticulture, greenhouse production, and livestock development.

At the same time, the investment development of the Turkestan region is constrained by several structural factors. First, the region remains highly dependent on water availability and irrigation infrastructure, which increases the sensitivity of investment projects to climatic and resource risks. Second, a significant part of agricultural production is concentrated in traditional sectors with relatively low added value. Third, access to long-term financial resources remains limited for small and medium-sized agricultural producers. Fourth, processing, logistics, storage infrastructure, and digital solutions are still developing more slowly than primary agricultural production. Therefore, the Turkestan region requires a differentiated investment policy. Priority should be given not only to increasing the volume of financial support, but also to developing irrigation systems, agricultural processing, logistics infrastructure, digital lending platforms, and cluster-based projects in high-value agricultural segments.

Compared with other agricultural regions, the Turkestan region has a different investment profile. Kostanay and North Kazakhstan regions are more strongly associated with large-scale grain production and relatively extensive land use, while the Turkestan region is more dependent on irrigated agriculture, labor-intensive

production, horticulture, greenhouse farming, and small and medium-sized producers. This makes the region more sensitive to water availability, irrigation infrastructure, logistics costs, and access to affordable finance. Therefore, investment policy for the Turkestan region should not simply reproduce national support mechanisms, but should be adapted to its water, infrastructure, and sectoral specialization.

To assess the impact of financial instruments and related development factors on investment activity, a fixed-effects panel regression model was estimated. The model includes subsidies, concessional lending, financing through development institutions, infrastructure development, and digitalization as key explanatory variables. The results are presented in Table 6.

Table 6. Regression analysis results

Variable	β	Standard error	Robust SE	t-stat	p-value
Subsidy	0.32	0.050	0.054	6.40	0.000
Subsidy^2	−0.11	0.030	0.032	−3.67	0.001
Credit	0.27	0.060	0.064	4.50	0.000
Dev	0.19	0.040	0.043	4.75	0.000
Infra	0.21	0.050	0.052	4.20	0.000
Digital	0.18	0.040	0.042	4.50	0.000

N = 187. Fixed-effects model. Robust standard errors clustered at the regional level. $R^2 = 0.84$.

Note: compiled by the authors

The regression results confirm that financial instruments and development conditions have a statistically significant effect on investment activity in the agro-industrial complex. Government subsidies have the strongest positive effect on investment activity ($\beta = 0.32$; $p < 0.01$), which confirms their role as the main instrument for reducing investment risks in agriculture. Concessional lending also has a strong positive effect (($\beta = 0.27$; $p < 0.01$), indicating that access to affordable credit resources remains a key condition for expanding agricultural investment.

Financing through development institutions has a positive and statistically significant effect (($\beta = 0.19$; $p < 0.01$). This result shows that institutional mechanisms of long-term financing support investment projects that cannot be fully financed through commercial lending. Infrastructure development also has a significant effect (($\beta = 0.21$; $p < 0.01$), confirming that transport, irrigation, energy, storage, and logistics infrastructure reduce transaction costs and increase the attractiveness of agricultural projects.

Digitalization has a positive effect on investment activity (($\beta = 0.18$; $p < 0.01$). Although its coefficient is lower than those of subsidies and credit, digitalization should be considered a strategic factor because it improves access to information, reduces administrative barriers, increases transparency in the allocation of support measures, and facilitates the development of digital financial services for agricultural producers. Since the baseline model identifies statistically significant effects for the main financial and institutional variables, the robustness of these results was further tested using alternative model specifications. The results of the robustness check are reported in Table 7.

Table 7. Robustness check results

Variable	Baseline FE model	FE model with Subsidy^2	FE model with lagged financial variables
Subsidy	0.29***	0.32***	0.27***
Subsidy^2	–	−0.11***	−0.09**
Credit	0.25***	0.27***	0.24***
Dev	0.17***	0.19***	0.18***
Infra	0.20***	0.21***	0.19***
Digital	0.16***	0.18***	0.17***
R^2	0.79	0.84	0.81
Number of observations	187	187	170

***, ** indicate statistical significance at the 1% and 5% levels, respectively

Note: compiled by the authors

The robustness checks show that the direction and statistical significance of the main coefficients remain stable across alternative model specifications. In particular, subsidies and concessional lending retain a positive effect on investment activity, while the quadratic subsidy term remains negative and statistically significant. This confirms that the nonlinear effect of government support is not the result of a single model specification.

The negative coefficient of the quadratic subsidy term confirms the presence of a nonlinear relationship between government support and investment activity. This means that subsidies stimulate investment only up to a certain threshold. At low and medium levels of support, subsidies reduce financial barriers and encourage agricultural producers to invest. However, when the volume of subsidies becomes excessive, their marginal effect declines. This may be explained by the weakening of market incentives, growing dependence on budgetary resources, and the risk that investment decisions are made primarily to obtain state support rather than to improve productivity and competitiveness.

The estimated nonlinear relationship between government subsidies and investment activity is illustrated in Figure 1.

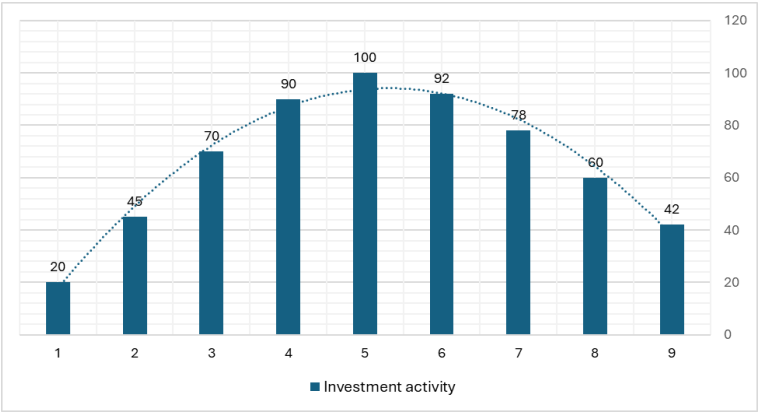


Figure 1. Nonlinear effect of subsidies on investment activity

The nonlinear relationship between subsidies and investment activity can be

interpreted as an inverted U-shaped curve. At the initial stage, an increase in subsidies reduces financial barriers and stimulates investment growth. At the middle level of support, the investment effect reaches its maximum. However, after the threshold point, the marginal effect of subsidies declines, which indicates the risk of dependence on state support and weakening of market incentives. This confirms that subsidy policy should be optimized not by increasing the total volume of support, but by improving its targeting and linking it to productivity, technological modernization, processing depth, and sustainability indicators. Based on the estimated model coefficients, Table 8 presents the contribution of key financial and institutional factors to investment growth in the agro-industrial complex.

Table 8. Contribution of factors to investment growth

Factor	Contribution, %
Subsidies	32
Credit resources	27
Infrastructure	21
Digitalization	18
Other factors	2

Note: compiled by the authors

The decomposition was calculated using standardized regression coefficients. This approach makes it possible to compare the relative importance of variables measured in different units. The results show that subsidies account for the largest share of explained investment growth, followed by credit resources, infrastructure, and digitalization. The interpretation of this decomposition should be treated as an analytical approximation rather than as a direct causal allocation of investment growth.

Overall, the empirical results show that investment activity in Kazakhstan's agro-industrial complex is shaped by the combined influence of financial, infrastructural, digital, and regional factors. Subsidies and concessional lending remain the most important instruments, but their effectiveness depends on the quality of allocation and the development of complementary conditions. For the Turkestan region, the results indicate the need to combine financial support with infrastructure modernization, irrigation development, agricultural processing, and digital financial instruments. This confirms the need to move from a predominantly subsidy-based model to a mixed, regionally differentiated system of investment stimulation.

DISCUSSION

The results of the study confirm that investment activity in the agro-industrial complex is shaped by the interaction of financial instruments, infrastructure conditions, digitalization, and regional characteristics. This conclusion is consistent with the logic of neoclassical and endogenous growth theories, according to which investment serves as a key mechanism of capital accumulation, technological renewal, and productivity growth (Romer, 1990; Aghion & Howitt, 2009).

The strong positive effect of subsidies and concessional lending is consistent with previous studies showing that financial constraints remain one of the main barriers to agricultural development, especially for small and medium-sized producers (Beck & Demirgüç-Kunt, 2006; Dorward et al., 2004). In Kazakhstan, this effect is particularly important because agricultural producers often face limited access to long-term credit, high collateral requirements, and significant production risks.

At the same time, the results show that subsidies are not effective indefinitely. The negative coefficient of the quadratic subsidy term confirms the presence of an inverted U-shaped relationship. This finding is consistent with studies emphasizing that excessive state support may distort market incentives and reduce the efficiency of resource allocation (Ciaian et al., 2018; Stein, 2019). Therefore, the practical question is not whether subsidies should be maintained, but how they should be targeted and linked to measurable outcomes.

The identified role of infrastructure supports the argument that agricultural investment depends not only on access to finance, but also on the quality of the investment environment. Transport, irrigation, storage, energy, and logistics infrastructure reduce transaction costs and increase the predictability of agricultural projects. This is especially relevant for the Turkestan region, where dependence on irrigated agriculture makes water infrastructure a key condition for investment efficiency.

Digitalization also has an important explanatory role. Although its coefficient is lower than that of subsidies and credit, digitalization should be interpreted as a long-term institutional and financial driver. Digital platforms can reduce information asymmetry, improve transparency in subsidy distribution, simplify access to lending, and support risk assessment for agricultural projects (Zetzsche et al., 2017). This finding strengthens the argument that digital transformation should be integrated into agricultural finance policy.

Compared with other regions of Kazakhstan, the Turkestan region demonstrates a specific investment profile. Its potential lies in irrigated agriculture, horticulture, greenhouse production, livestock development, and agricultural processing. However, these advantages are constrained by dependence on water, insufficient logistics and storage infrastructure, and limited access to market-based finance. Therefore, national financial instruments should be adapted to the regional structure of production rather than applied uniformly across all territories.

Overall, the findings suggest that Kazakhstan's agricultural investment model is moving from a subsidy-dominated system toward a mixed financing model. This model should combine targeted subsidies, concessional lending, guarantee instruments, development institution financing, infrastructure modernization, and digital financial platforms. The theoretical implication of the study is that the effectiveness of agricultural investment policy depends not only on the volume of public support, but also on the quality of financial architecture and the institutional capacity of regions to transform investment into productivity and added value.

5 | CONCLUSION

The conducted research made it possible to identify key patterns in the formation of investment flows in the agro-industrial complex of Kazakhstan and to assess the role of financial instruments in stimulating investment activity at the regional level. The results show that investments in agriculture demonstrate steady positive dynamics, but their growth is accompanied by structural constraints, high dependence on government support mechanisms and insufficient diversification of financing sources.

The econometric analysis confirmed the significant positive impact of subsidies, preferential loans, development institutions, infrastructure and digitalization on investment activity. Government support in the form of subsidies makes the greatest contribution to investment growth, reflecting its strategic role in conditions of limited access to market capital for agricultural producers. At the same time, the revealed negative coefficient for the quadratic term of subsidies confirms the existence of a nonlinear effect: excessive subsidies reduce investment efficiency and form the dependence of business entities on budgetary resources.

The scientific contribution of the study lies in the fact that investment processes in agriculture are considered not only as a result of an increase in financial resources, but also as an effect of the interaction of financial, institutional, infrastructural and digital factors. This makes it possible to clarify the theoretical provisions of the endogenous theory of growth in relation to the agricultural sector of Kazakhstan: sustainable investment growth is ensured not by a simple expansion of government support, but by the quality of the financial architecture, the targeting of instruments and the ability of the regional system to transform investments into productivity, technological renewal and added value.

The practical significance of the study is to substantiate the need to move from an extensive subsidy model to a more complex and effective investment incentive system. For Kazakhstan, this means that agricultural policy should be focused not on a mechanical increase in budget support, but on increasing its effectiveness, transparency and connection with the final results. It is advisable to link subsidies to indicators of productivity, export potential, technology adoption, processing depth and sustainability of agricultural production.

For the Turkestan region, which has a high agricultural potential, the key policy direction should be the formation of a specialized regional model of investment incentives. Priority should be given to sectors with high added value: irrigated agriculture, horticulture, greenhouse production, animal husbandry, agricultural processing and agrotechnological solutions. This will make it possible to move from a raw-material model of agricultural growth to a model based on processing, innovation and cluster development.

Of particular importance is the development of concessional lending and risk-sharing mechanisms. Government support should gradually shift from direct subsidies to guarantee instruments, project financing, agricultural receipts, mixed financing and digital lending platforms. This approach will expand the participation of banks, microfinance institutions, development institutions and private

investors in financing agricultural projects.

Infrastructure modernization is an equally important area. Investments in agriculture will have limited effect without the development of irrigation systems, logistics, warehouse infrastructure, energy, transport accessibility and digital communications. This is especially important for the Turkestan region, since the effectiveness of agricultural investments directly depends on the availability of water, sales markets and modern technological solutions. Digitalization should be considered not as an auxiliary element, but as an independent financial and institutional tool. The development of digital platforms for accounting subsidies, monitoring investment projects, agricultural loans and risk assessment will reduce information asymmetry, increase transparency in resource allocation and strengthen the trust of private investors.

Thus, the results of the study show that the further development of investment policy in the agro-industrial complex of Kazakhstan requires a transition to an integrated model combining targeted subsidies, affordable lending, infrastructure modernization, digital financial solutions and regional specialization. This model will improve the efficiency of public resource use, boost private investment, reduce regional disparities, and strengthen the competitiveness of Kazakhstan's agro-industrial complex in the long term.

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Financial Distress Prediction Using MARS and Logistic Regression: Evidence from Indonesia

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Abstract
The increasing uncertainty in the business environment has intensified the need for reliable financial distress prediction models, particularly within the manufacturing sector, which plays a strategic role in economic development. The study aims to compare the effectiveness of logistic regression and multivariate adaptive regression splines (hereinafter – MARS) in predicting financial distress among manufacturing companies listed on the Indonesian stock exchange. The study employs a quantitative research design with purposive sampling, using data from 70 manufacturing firms and 210 firm-year observations over the 2022–2025 period. Financial distress is examined using four key financial indicators, namely current ratio, total liabilities to total assets, return on assets, and sales to total assets. The findings reveal that both models are statistically valid; however, MARS outperforms logistic regression in terms of predictive accuracy, achieving an overall classification rate of 82.4% compared to 65.7%. Logistic regression revealed a statistically significant effect of return on assets only on financial distress ($p = 0.003$; $Exp(B) = 0.006$), whereas MARS showed that all financial indicators under consideration contributed to the predictive model. These findings highlight the importance of profitability as a primary determinant of financial distress and suggest that MARS provides a more robust framework for developing early warning systems and supporting financial decision-making. The practical significance of the study lies in the potential for businesses, investors, creditors, and regulatory authorities to use the results to identify financial risks early, which is important for the economy's stable development.

KEYWORDS
Finance, Corporate Finance, Financial Distress, Business Performance, Manufacturing Company, Economic Sustainability, Indonesia

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1 | INTRODUCTION

The manufacturing sector plays a crucial role in supporting economic growth, employment creation, and industrial development, particularly in emerging economies. In Indonesia, manufacturing activities contribute significantly to national economic performance and are among the primary drivers of sustainable development. However, rising global economic uncertainty, intensifying market competition, and commodity price fluctuations have intensified financial pressures on firms, thereby increasing the likelihood of financial distress. Financial distress is a condition in which a company has difficulty meeting its financial obligations and may eventually face bankruptcy if corrective actions are not taken (Altman, 1968; Sun et al., 2014). Consequently, the ability to predict financial distress has become increasingly important for managers, investors, creditors, and policymakers seeking to reduce risk and improve strategic decision-making.

Research on financial distress prediction has evolved substantially since the pioneering work of Altman (1968), who introduced the Z-Score model as an early warning system for corporate failure. Subsequent studies have demonstrated that financial ratios provide valuable information regarding a firm's financial condition and can effectively distinguish distressed firms from healthy firms (Beaver, 1966; Ohlson, 1980). Among the most frequently employed indicators are liquidity ratios, solvency ratios, profitability ratios, and activity ratios. Specifically, the Current Ratio (hereinafter – CR), Total Liabilities to Total Assets (hereinafter – TLTA), Return on Assets (hereinafter – ROA), and Sales to Total Assets (hereinafter – STA) are widely used to assess a firm's ability to meet short-term obligations, manage debt, generate profits, and utilize assets efficiently (Platt & Platt, 2002; Sun et al., 2014). These financial indicators have consistently been identified as important determinants of financial distress risk across various industrial and geographical contexts.

From a methodological perspective, Logistic Regression has become one of the most widely used techniques for financial distress prediction because it is relatively easy to interpret and well-suited to binary classification problems (Ohlson, 1980; Martin, 1977). Nevertheless, previous studies have highlighted several limitations of Logistic Regression, particularly its inability to capture nonlinear relationships and complex interactions among financial variables fully (Jones et al., 2017). To address these limitations, researchers have increasingly adopted machine-learning and nonparametric approaches capable of modeling more sophisticated data structures. One promising technique is multivariate adaptive regression splines, introduced by Friedman (1991), which is designed to identify nonlinear relationships and interaction effects without imposing strict statistical assumptions. Previous studies have shown that multivariate adaptive regression splines can provide competitive and, in some cases, superior predictive performance compared with conventional statistical approaches in bankruptcy and financial distress prediction (De Andrés et al., 2011; Barboza et al., 2017).

Despite the growing literature on financial distress prediction, empirical studies comparing logistic regression and multivariate adaptive regression splines remain relatively limited, particularly in emerging-market environments such as Indonesia.

Moreover, prior findings regarding the effects of liquidity, leverage, profitability, and activity ratios on financial distress have often been inconsistent, suggesting that the underlying relationships may be more complex than those captured by traditional linear models (Sun et al., 2014; Tian et al., 2015). Therefore, further investigation is required to evaluate whether more flexible analytical methods can improve prediction accuracy and provide deeper insights into the determinants of financial distress.

Accordingly, the study aims to compare the effectiveness of logistic regression and Multivariate Adaptive Regression Splines (hereinafter – MARS) in predicting financial distress among manufacturing companies listed on the Indonesian stock exchange. The study focuses on four financial ratios, CR, TLTA, ROA, and STA, and evaluates their ability to explain financial distress under both methodological approaches. By comparing model accuracy and identifying the most influential predictors, this research contributes to the financial distress literature and offers practical implications for developing more effective early warning systems and financial risk management strategies (Barboza et al., 2017; Jones et al., 2017). The results of the study are of practical importance for business, as they enable managers, investors, and creditors to promptly identify financially vulnerable companies and reduce corporate risks. In a broader economic context, the application of such models can help strengthen the financial sustainability of Indonesia's manufacturing sector and support its sustainable development.

2 | LITERATURE REVIEW

Signaling theory provides a fundamental explanation of how firms communicate information to external stakeholders in situations characterized by information asymmetry. Originally introduced by Michael Spence, the theory argues that managers possess superior information regarding a firm's financial condition, operational performance, and future prospects compared to investors and creditors. Consequently, stakeholders rely on observable signals to evaluate organizational quality and assess investment risk. In corporate finance, financial statements and financial ratios serve as important signaling mechanisms, providing objective information on profitability, liquidity, efficiency, and financial stability. Strong financial performance generally conveys positive signals concerning management effectiveness and future growth potential, whereas deteriorating financial indicators may signal increased uncertainty and financial vulnerability. Recent studies emphasize that accounting information remains one of the most influential sources of signals for investors when assessing firm value and financial sustainability (Connelly et al., 2011; Alareeni & Hamdan, 2020). Within the context of financial distress prediction, declining profitability, weakening liquidity, and increasing leverage serve as negative signals that may indicate future financial difficulties. Stakeholders interpret these signals to adjust investment and lending decisions accordingly. Therefore, Signaling Theory provides an appropriate theoretical foundation for explaining why financial ratios are frequently used as predictors of financial distress, as they convey valuable information about a firm's capacity to maintain

operational continuity and long-term financial stability.

Trade-off theory explains corporate financing decisions by emphasizing the balance between the benefits and costs of debt financing. Developed from modern capital structure theory, this framework posits that firms seek an optimal level of leverage that maximizes firm value by balancing the tax advantages of debt against the costs of financial distress and bankruptcy risk (Kraus & Litzenberger, 1973). Debt financing offers benefits because interest payments are tax-deductible, thereby reducing the effective cost of capital and increasing shareholder value. However, excessive reliance on debt increases fixed financial obligations and exposes firms to greater risks during periods of declining earnings or economic uncertainty. Manufacturing firms are particularly relevant to this theory because their operations typically require substantial investments in fixed assets, inventories, and production facilities, often financed through external debt. According to Trade-Off Theory, firms with stable profitability can sustain moderate leverage while maintaining financial flexibility, whereas excessive debt may increase vulnerability to financial distress (Frank & Goyal, 2009). Empirical evidence indicates that leverage remains one of the most important determinants of corporate financial stability, particularly when profitability and liquidity weaken simultaneously (Vo et al., 2022). Therefore, Trade-Off Theory provides a useful framework for understanding how financing decisions influence the probability of financial distress and why leverage-related indicators are frequently incorporated into bankruptcy prediction models.

Financial distress refers to a condition in which a firm experiences a deterioration in financial performance that impairs its ability to meet contractual obligations and sustain normal business operations. It is generally considered a transitional stage between financial stability and formal bankruptcy, during which firms encounter increasing financial pressure resulting from declining profitability, weakening liquidity, and excessive leverage. Early identification of financial distress is essential because timely intervention may prevent business failure and preserve organizational value. Contemporary literature recognizes financial distress as a multidimensional phenomenon influenced by both internal and external factors, including operational inefficiency, ineffective financial management, economic downturns, market competition, and unfavorable macroeconomic conditions (Sun et al., 2014). Advances in predictive analytics have significantly improved the ability to identify distress risk through accounting information and financial indicators. Recent studies demonstrate that profitability, liquidity, leverage, and activity ratios consistently provide valuable information for distinguishing financially healthy firms from distressed firms (Barboza et al., 2017; Hosaka, 2019; du Jardin, 2021). Furthermore, machine learning and data-driven approaches have enhanced predictive accuracy compared with traditional statistical techniques by capturing nonlinear relationships among financial variables. Consequently, financial distress remains a major topic in corporate finance research because of its significant implications for investors, creditors, managers, regulators, and policymakers seeking to reduce financial risk and improve organizational sustainability.

ROA is a profitability ratio that measures a firm's ability to generate net income relative to the total assets employed in its operations. The ratio reflects managerial effectiveness in utilizing available resources to create sustainable earnings and is widely regarded as one of the most important indicators of corporate financial performance. For manufacturing firms, ROA is particularly relevant because substantial investments in fixed assets, production facilities, and working capital require efficient use of resources to maintain profitability. A high ROA indicates effective asset management and strong operational performance, whereas a declining ROA suggests inefficiencies in asset utilization and weakening earning capacity. According to Signaling Theory, profitability serves as a positive signal regarding firm quality because profitable firms are generally perceived as more capable of sustaining operations and fulfilling financial obligations. Recent empirical studies consistently identify profitability as one of the strongest predictors of financial distress, with firms exhibiting higher ROA levels demonstrating significantly lower probabilities of bankruptcy and financial failure (Hosaka, 2019; Liang et al., 2015). Strong profitability enhances internal cash flow generation, reduces dependence on external financing, and increases financial flexibility during periods of economic uncertainty. Consequently, ROA is widely incorporated into financial distress prediction models because it captures both operational efficiency and a firm's ability to maintain long-term financial sustainability.

TLTA is a leverage ratio that measures the proportion of a firm's assets financed by debt. This ratio provides important information about capital structure decisions and financial risk exposure, as it reflects the extent to which a company depends on external financing to support its operations and investments. A higher TLTA ratio indicates greater reliance on debt financing, which may increase financial flexibility during periods of growth but simultaneously elevates the risk of financial distress when business performance deteriorates. According to Trade-Off Theory, firms attempt to balance the benefits of debt, such as tax advantages, against the potential costs associated with financial distress and bankruptcy. However, excessive leverage can significantly increase fixed financial obligations and reduce a firm's ability to withstand adverse economic conditions (Frank & Goyal, 2009). Manufacturing firms are particularly vulnerable to leverage-related risks because they generally require substantial investments in production facilities, machinery, and inventories, often financed through debt. Recent empirical studies consistently demonstrate that leverage is positively associated with the probability of financial distress and corporate failure (Barboza et al., 2017; Hosaka, 2019). Firms with high debt burdens frequently encounter difficulties in meeting interest and principal payments during periods of declining profitability or economic uncertainty. Consequently, TLTA is widely recognized as one of the most important indicators in financial distress prediction models because it captures the relationship between financing decisions, financial risk, and long-term corporate sustainability.

CR is one of the most widely used liquidity indicators for assessing a firm's ability to meet short-term financial obligations using current assets. Calculated as current

assets divided by current liabilities, the ratio reflects the adequacy of working capital to support daily operations and meet maturing liabilities. For manufacturing companies, liquidity management is particularly important because production activities require substantial investments in inventories, accounts receivable, and operational expenditures. A higher Current Ratio generally indicates stronger liquidity and greater capacity to absorb temporary financial shocks, thereby reducing the likelihood of financial distress. Conversely, insufficient liquidity may limit a firm's ability to fulfill short-term obligations and increase dependence on external financing, potentially leading to financial difficulties. Nevertheless, contemporary literature suggests that the relationship between liquidity and financial distress is more complex than traditionally assumed. While low liquidity is often associated with elevated distress risk, excessively high liquidity may indicate inefficient resource allocation and underutilization of productive assets (Alaka et al., 2018). Recent studies emphasize that liquidity should be evaluated alongside profitability and leverage indicators because financial distress is typically driven by multiple interconnected factors rather than a single financial metric (Mai et al., 2019; du Jardin, 2021). Therefore, CR remains an important variable in financial distress prediction models as it provides valuable information regarding short-term financial resilience and operational continuity.

STA, commonly referred to as total asset turnover, measures the efficiency with which a firm utilizes its assets to generate revenue. The ratio is calculated by dividing total sales by total assets, reflecting management's effectiveness in converting invested resources into productive business output. In manufacturing industries, where firms typically make large investments in fixed assets and production facilities, efficient asset utilization is critical to profitability and competitiveness. A higher STA ratio indicates that a company generates greater revenue from its asset base, suggesting effective operational management and productive resource allocation. Conversely, a lower STA ratio may indicate underutilized assets, operational inefficiencies, weak market demand, or declining competitiveness, all of which may contribute to financial difficulties over time. From the perspective of Signaling Theory, efficient asset utilization signals to investors and creditors that management can maximize organizational resources and sustain business performance. Empirical evidence suggests that activity ratios, including STA, contribute significantly to financial distress prediction because firms experiencing declining asset efficiency often exhibit deteriorating financial performance and increased financial vulnerability (Barboza et al., 2017; Hosaka, 2019). Furthermore, efficient asset utilization supports revenue growth, enhances cash flow generation, and strengthens profitability, thereby reducing the likelihood of financial distress (Liang et al., 2015). Therefore, STA is considered an important operational indicator in financial distress prediction models because it captures the relationship between resource efficiency, revenue generation, and long-term financial sustainability.

Logistic regression is widely used in financial distress prediction because it is well-suited to binary classification problems, in which firms are classified as either financially distressed or non-distressed. This method allows researchers to

estimate the probability of financial distress based on a set of explanatory variables and to interpret the influence of each predictor through regression coefficients and odds ratios. Its main advantage is interpretability, which makes it useful for explaining how liquidity, leverage, profitability, and activity ratios affect the likelihood of financial distress (Hosmer et al., 2013; Menard, 2002; Agresti, 2018). However, logistic regression has certain limitations because it mainly captures linear relationships between predictors and the log-odds of the outcome. As a result, it may not fully reflect nonlinear patterns and complex interactions among financial indicators (Peng et al., 2002).

Multivariate Adaptive Regression Splines (MARS) is considered a more flexible nonparametric approach for modeling complex relationships between dependent and independent variables. Introduced by Friedman (1991), MARS can identify nonlinear effects and interaction patterns without requiring a predefined functional form. This feature makes the method relevant to financial distress prediction, where the relationship between financial ratios and corporate financial vulnerability may vary with firm-specific conditions and market dynamics. Previous studies suggest that MARS can provide competitive or superior predictive performance compared with conventional statistical models, especially when the data contain nonlinear structures and interaction effects (Friedman, 1991; De Veaux & Ungar, 1994). Nevertheless, MARS may be more complex to interpret than logistic regression, particularly when many basis functions and interaction terms are included in the model (Lewis & Stevens, 1991). Overall, MARS is widely recognized as a strong alternative to, and complement of, logistic regression in binary classification, especially when flexibility and predictive accuracy are prioritized over strict parametric assumptions.

Building on signaling theory and prior empirical evidence, this study proposes an integrated conceptual framework linking liquidity, solvency, profitability, and activity ratios to the likelihood of financial distress among manufacturing firms. These financial ratios collectively signal a firm's financial condition, reflecting its ability to meet short-term obligations, manage its capital structure, generate profits, and utilize assets efficiently. Prior research confirms the relevance of financial ratios in explaining corporate distress. Beaver (1966) demonstrates that financial ratios have predictive power for identifying business failure, while Altman (1968) shows that combined financial indicators can effectively distinguish distressed from non-distressed firms. More recent evidence by Platt and Platt (2021) further supports the continued relevance of financial ratios as predictors of financial distress across different model specifications. Based on these theoretical and empirical foundations, this study posits that liquidity, solvency, profitability, and activity ratios jointly influence the probability of financial distress, forming the basis of the proposed conceptual framework and hypotheses.

Based on the theoretical discussion and previous empirical findings, this study proposes that liquidity, solvency, profitability, and activity ratios influence the probability of financial distress. The conceptual relationship among CR, TLTA, ROA, STA, and financial distress is presented in Figure 1.

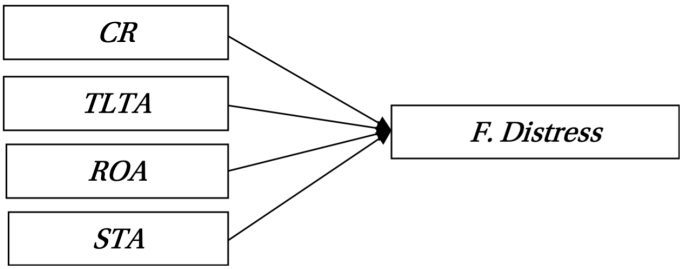


Figure 1. Conceptual framework of financial ratios and financial distress

CR, defined as current assets divided by current liabilities, is a widely used liquidity measure that reflects a firm's ability to meet its short-term obligations with readily available resources. From a theoretical perspective, higher liquidity reduces the likelihood of financial distress by strengthening a firm's capacity to absorb short-term cash flow shocks, maintain operational stability, and avoid default risk. Liquidity theory further suggests that firms with stronger short-term financial positions are better equipped to sustain operations during periods of economic uncertainty. Empirical evidence supports the relevance of financial ratios, including liquidity measures, in predicting financial distress and corporate failure. For instance, Moussa (2019) finds that liquidity ratios are significantly related to financial performance, which is closely linked to a firm's financial stability. Platt and Platt (2021) further emphasize that financial ratios, including liquidity indicators such as the current ratio, remain important predictors in corporate financial distress models, despite concerns related to sample bias in prediction studies. In addition, Beaver et al. (2005) demonstrate that financial ratios continue to possess strong explanatory power in predicting bankruptcy, highlighting the enduring relevance of liquidity measures in distress prediction models. However, the relationship between liquidity and financial distress may vary across industries and economic conditions and, in some cases, exhibit non-linear patterns due to differences in working capital management efficiency. Therefore, this study hypothesizes that CR has a significant effect on financial distress, with higher liquidity expected to reduce the probability of financial distress.

H1: CR has a significant influence on financial distress

TLTA ratio is a widely used proxy for leverage, reflecting the proportion of a firm's assets financed by debt, and serves as an important indicator of capital structure risk and long-term solvency. From a theoretical perspective, higher leverage increases the probability of financial distress by raising fixed financial obligations, reducing financial flexibility, and amplifying vulnerability to earnings volatility and macroeconomic shocks. In line with trade-off theory, although debt financing may provide tax advantages, excessive leverage increases expected financial distress costs, thereby elevating default risk. Recent empirical studies provide consistent evidence supporting the positive association between leverage and financial distress. For instance, Silalahi et al. (2024) find that leverage significantly affects financial distress in Indonesian listed firms, indicating that higher debt levels increase fi-

nancial vulnerability. Similarly, Ayatika et al. (2024) report that leverage has a significant effect on financial distress in state-owned enterprises, confirming its relevance as a predictor of financial instability. In addition, Sembiring et al. (2025) demonstrate that leverage is a key determinant of financial distress in consumer non-cyclical firms. However, the magnitude of its effect may vary across sectors and model specifications. However, some studies also indicate that leverage may not always be statistically significant when combined with other financial ratios, suggesting potential interaction effects with liquidity, profitability, and firm growth. Therefore, this study proposes that the TLTA ratio significantly influences financial distress, where higher leverage is expected to increase the probability of financial distress.

H2: TLTA ratio has a significant influence on financial distress

ROA, measured as net income relative to total assets, is widely recognized as a key indicator of a firm's profitability and operational efficiency. A higher ROA reflects management's ability to utilize organizational resources effectively to generate earnings, thereby strengthening the firm's financial position. From a theoretical perspective, profitable firms are generally less vulnerable to financial distress because they possess greater internal cash-generating capacity, stronger capital reserves, and enhanced access to external financing. Moreover, signaling theory suggests that sustained profitability conveys positive information about managerial effectiveness and the long-term viability of a firm's business model, reducing stakeholders' concerns regarding financial instability. Empirical evidence largely supports this view. For instance, Kebede et al. (2024) found that profitability significantly reduces the likelihood of financial distress, while Arya and Suhendah (2024) reported a similar negative relationship between profitability and financial distress among Indonesian firms. Nevertheless, prior studies have also documented inconsistent findings, indicating that the protective effect of profitability may vary across industries and economic conditions. Dahruji and Muslich (2022), for example, observed a negative but statistically insignificant relationship between profitability and financial distress in Islamic commercial banks. Such mixed results imply that the influence of profitability may be moderated by other financial characteristics, including leverage, liquidity, and firm-specific conditions. Given its strong theoretical foundation and extensive empirical support, ROA is expected to play a significant role in explaining variations in financial distress risk. Accordingly, this study hypothesizes that ROA has a significant effect on the probability of financial distress.

H3: ROA has a significant influence on financial distress

The STA ratio, also known as asset turnover, measures operational efficiency by quantifying revenue generated per unit of invested capital (Budhiarjo, 2024). Theoretically, higher asset turnover indicates effective resource utilization, which supports cash flow generation and reduces reliance on external financing, thereby mitigating distress risk. Signaling theory suggests that efficient asset deployment conveys managerial capability and competitive positioning, enhancing stakeholder confidence and reducing perceived operational risk. Empirical findings regard-

ing STA's predictive relevance exhibit notable heterogeneity: while some research documents significant relationships between asset turnover and financial distress in various industrial contexts, others report nonsignificant effects, potentially reflecting industry-specific dynamics, measurement differences, or unmodeled interaction effects (Ariefah & Hirdinis, 2025). Moreover, post-pandemic supply chain disruptions and demand volatility may have altered the relationship between asset efficiency and financial resilience, with firms maintaining flexible asset bases potentially outperforming those with rigid, high-turnover structures during periods of uncertainty. Studies employing multivariate approaches examining debt ratios, asset turnover, and profitability simultaneously demonstrate that total asset turnover significantly influences financial distress outcomes, suggesting that activity ratios warrant consideration in distress prediction models alongside leverage and profitability factors (Rafli & Nurismalatri, 2025).

H4: STA ratio has a significant influence on financial distress.

3 | RESEARCH METHODOLOGY

This study employs a quantitative research approach to examine the predictability of financial distress in manufacturing companies through financial ratios. The research design utilizes a structured sample of 70 manufacturing companies listed on the Indonesia Stock Exchange during the 2020–2023 period, generating a total of 210 observations to ensure robust statistical analysis. The sampling technique used is purposive sampling, with the selection criterion requiring that companies consistently publish complete financial statements in Indonesian rupiah throughout the research period. This stringent criterion ensures data reliability and continuity for longitudinal analysis. Secondary data were obtained from annual financial reports and the Indonesian Capital Market Directory, which provided standardized financial information for all sampled firms (Khotimah et al., 2026). Financial distress is operationalized as a sustained deterioration in a company's financial performance over time, characterized by low financial ratios and reduced capacity to meet financial obligations, with potential progression toward bankruptcy (Rech et al., 2025). The operational definition encompasses four key financial dimensions: liquidity, measured through the Current Ratio (CR) to assess short-term payment capability; solvency, proxied by Total Liabilities to Total Assets (TLTA) to evaluate long-term debt servicing capacity; profitability, represented by Return on Assets (ROA) to indicate asset efficiency in generating earnings; and activity, measured via Sales to Total Assets (STA) to capture asset utilization effectiveness in revenue generation (Putri & Irsan, 2025). This multidimensional operationalization aligns with established distress prediction frameworks and provides comprehensive coverage of financial health dimensions essential for accurate classification.

The analysis employs two complementary statistical techniques, logistic regression and MARS, to develop and compare financial distress prediction models. Logistic regression is the conventional statistical approach, with model validity assessed using the Hosmer and Lemeshow test (significance > 0.05), the Omnibus Test of Model Coefficients (significance < 0.05), and decreasing -2 log-likelihood

values converging to stable parameter estimates (Gajdosikova et al., 2025). The MARS model, a machine learning technique, is validated using F-statistics (Fcount > Ftable), thereby capturing nonlinear relationships between financial ratios and distress conditions (Kanapickienė et al., 2023). Classification accuracy for both models is measured as the proportion of correct predictions relative to the total number of observations, serving as a primary performance metric (Nair & Sachdeva, 2022). The influence of independent variables on financial distress is assessed using regression coefficient significance ($p < 0.05$), enabling the identification of key predictive factors. Comparative evaluation focuses on model validity, classification accuracy, and variable significance patterns to determine which approach more effectively identifies financial distress indicators among Indonesian manufacturing firms. This dual-method approach accommodates both linear and nonlinear patterns in financial data, enhancing predictive robustness. The comprehensive analysis framework provides stakeholders, including investors, creditors, and corporate managers, with reliable early-warning mechanisms to detect financial stress and support informed decision-making (Tang & Zhang, 2025).

4 | ANALYSIS AND RESULTS

The suitability test for the logistic regression model assesses whether the model is suitable for use and can be further analyzed. The suitability test of the logistic regression model consists of 3 tests: Hosmer and Lemeshow's Test, Omnibus Test, and -2 log-likelihood. The results of the model suitability test are significant; the model can explain the phenomenon of financial distress of manufacturing companies in the study period with a significance value of Hosmer and Lemeshow's Test of 0.298> 0.05, a significance value of the Omnibus Test of 0.000 <0.05, and a value of -2 log likelihood decreasing convergent from the initial value of 288.926 to 263.346. It can be concluded that the logistic regression model is feasible for use, meaning it can explain financial distress among manufacturing companies, with the factors involved being CR, TLTA, ROA, and STA. Hypothesis testing is conducted to assess the influence of independent variables on dependent variables, with a 5% tolerance level. The research hypothesis is accepted if the significance value of the independent variable is less than 0.05. The results of the hypothesis test using logistic regression are presented in Table 1 below.

Table 1. Logistic regression hypothesis testing

Variable	Sig.	Exp(B)
CR	0.396	1,093
TLTA	0.063	5,331
ROA	0.003	0.006
STA	0.587	0.894

Note: compiled by the authors based on SPSS 25 output

Table 1 presents the results of hypothesis testing using logistic regression to examine the effect of CR, TLTA, ROA, and STA on the dependent variable. The

significance level used in this study was 5% (α = 0.05). A variable is considered significant if its significance value (Sig.) is less than 0.05. Furthermore, the Exp(B) value, or odds ratio, measures the direction and magnitude of each variable's influence on the probability of the dependent variable occurring.

The test results show that the ROA variable has a significance value of 0.003, which is less than 0.05, thus having a significant effect on the dependent variable. The Exp(B) value of 0.006 indicates that an increase in ROA will reduce the probability of the dependent variable occurring by 99.4% [(1 - 0.006) × 100%], assuming other variables remain constant. Thus, higher profitability tends to reduce the likelihood of the condition measured by the dependent variable occurring. This finding indicates that a company's ability to generate profits is an important factor in determining the probability of the observed event.

The TLTA variable has a p-value of 0.063, which is slightly above the 5% significance threshold, making it statistically insignificant at the 95% confidence level. However, at the 10% significance level, this variable can be considered to have a marginal effect on the dependent variable. The Exp(B) value of 5.331 indicates that an increase in the total liabilities-to-total assets ratio increases the likelihood of the dependent variable by 5.331 times relative to the previous value. This indicates that companies with higher leverage are more likely to experience the condition measured by the dependent variable.

The CR variable has a significance value of 0.396, which is well above 0.05, so it does not have a significant effect on the dependent variable. The Exp(B) value of 1.093 indicates that an increase in the Current Ratio only increases the likelihood of the dependent variable occurring by 1.093 times. However, this effect is not statistically strong enough. Thus, the company's ability to meet short-term obligations was not proven to be a determining factor in this research model.

The STA variable also showed insignificant results with a significance value of 0.587. The Exp(B) value of 0.894 indicates that increasing the efficiency of asset utilization in generating sales tends to reduce the probability of the dependent variable occurring by 10.6%, but this effect is not statistically significant. Therefore, it can be concluded that the efficiency of company activities, as measured by STA, is not able to explain changes in the probability of the dependent variable convincingly.

The model accuracy classification shows the accuracy of the model in predicting the company's finances. The results of the model's classification accuracy are presented in Table 2 below.

Table 2. Model classification

Observed	Predicted NFD	Predicted FD	Percentage Correct
NFD	80	31	72.1
FD	41	58	58.6
Overall Percentage	–	–	65.7

Note: compiled by the authors based on SPSS 25 output

Table 2 indicates that the accuracy of the logistic regression model's classifi-

cation for manufacturing companies that do not experience financial distress is 80/(80+31) = 72.1%. The accuracy of the logistic regression model's classification for manufacturing companies experiencing financial distress is 58/(58+41) = 58.6%. The accuracy of the logistic regression model's classification for predicting financial distress among manufacturing companies is (80+58) / (80+31+41+58) = 65.7%. Thus, it can be concluded that the accuracy of the MARS model in predicting financial distress of manufacturing companies in the research period is 65.6%, namely, 137 out of 210 company observations.

The suitability test of the MARS model is to determine whether the model is feasible to use and can be analyzed further. The criteria for testing the significance test of the MARS model with error tolerance (α = 0.05) and obtained Ftable = F (0.05; 2; 107) = 3.039. The critical area / rejection of H0 for the MARS model significance test is, if Fcount> Ftable then the decision is to reject H0 and it can be concluded that the model is feasible to use which means the MARS model is able to explain the relationship between the independent variable and the dependent variable and vice versa. The results of the MARS model significance test on manufacturing companies listed on the IDX in the period 2022 - 2025, showed that the value of Fcount = 75.617> Ftable = 3.039, then reject H0, it can be concluded that the model is feasible to use which means the MARS model is able to explain the phenomenon of financial distress of manufacturing companies with the factors involved in it are CR, TLTA, ROA and STA.

Hypothesis testing in this study was conducted using the Multivariate Adaptive Regression Splines (MARS) method to identify the variables with the most significant influence on the dependent variable. Unlike conventional linear regression approaches, MARS can accommodate nonlinear relationships and interactions between variables frequently found in empirical data. In the testing process, the relative significance of each variable is evaluated through variable importance analysis, which indicates the contribution of each predictor to model performance. Variable importance is calculated based on the change in the Generalized Cross Validation (GCV) value when a variable is removed from the model. The greater the decline in model quality, as indicated by the -GCV value, the greater the variable's contribution in explaining the variation in the response variable. Therefore, this analysis allows researchers to determine the most dominant variables and objectively rank the influence of each predictor.

The results of the variable importance test in the MARS model are presented in Table 3.

Based on Table 3, the results of the MARS analysis show the variable importance of each variable in explaining the dependent variable studied. The MARS importance values are normalized, with the most influential variable assigned a value of 100%, and then the other variables are compared relative to that variable.

The ROA variable has an importance value of 100,000, indicating that ROA is the most dominant variable in shaping the prediction model. The -GCV value of 0.456 indicates that removing ROA from the model will result in the greatest decline in model performance compared to other variables. This finding indicates

that the company's ability to generate profits from its assets is the primary factor influencing the response variable. In other words, changes in the company's profitability level contribute the most to the variation in the observed dependent variable.

Table 3. Importance variable

Rank	Variable	Importance	−GCV
1	ROA	100.000	0.456
2	TLTA	84.678	0.234
3	CR	67.886	0.187
4	STA	28.987	0.145

Note: compiled by the authors based on SPSS 25 output

The TLTA variable ranks second with an importance value of 84.678 and α -GCV value of 0.234. These results indicate that the company's funding structure, reflected in the leverage level, has a fairly strong influence on the model, although its contribution is still below ROA. Furthermore, the CR (Current Ratio) variable has an importance value of 67.886 with a -GCV of 0.187, indicating that the company's ability to meet short-term obligations also contributes significantly to explaining the variation of the dependent variable. Meanwhile, the STA variable has the lowest value, namely 28.987, with a -GCV of 0.145, indicating that the efficiency of asset utilization in generating sales makes a relatively smaller contribution compared to other variables. Overall, the order of influence of variables, based on the MARS results, is ROA > TLTA > CR > STA, indicating that profitability is the main determinant in the model, followed by leverage, liquidity, and asset efficiency. These findings also indicate that the MARS model can identify the relative contribution of each variable more flexibly than conventional linear regression methods, as it accounts for nonlinear relationships and interactions among variables.

The classification accuracy shows the model's ability to predict the company's finances. The results of the model's classification accuracy are presented in Table 4 below.

Table 4. Model classification

Observed	Predicted NFD	Predicted FD	Percentage correct
NFD	95	16	85.6
FD	21	78	78.8
Overall percentage	–	–	82.4

Note: compiled by the authors based on SPSS 25 output

Table 4 indicates that the accuracy of the MARS model's classification for manufacturing companies that do not experience financial distress is 95/(95+16) = 85.6%. The accuracy of the MARS model's classification for manufacturing companies experiencing financial distress is 78/(78+21) = 78.8%. The accuracy of the MARS model classification in predicting financial distress in manufacturing companies is (95+78) / (95+16+21+78) = 82.4%. Thus, it can be concluded that the accuracy of the MARS model in predicting financial distress in manufacturing companies in the research period is 82.4%, namely, 173 out of 210 company observations.

The results from both methods (logistic regression and MARS) are consistent: ROA is the dominant factor. However, MARS shows that although CR and STA are not significant in the linear logistic model, both still contribute to prediction because MARS captures nonlinear relationships and interaction effects that logistic regression misses.

5 | DISCUSSION

CR reflects a company's ability to meet its short-term obligations using current assets, where a higher ratio theoretically indicates stronger liquidity and a lower likelihood of experiencing financial distress. However, the logistic regression results indicate that CR does not have a significant effect on financial distress (Sig. = 0.396), suggesting that manufacturing companies' liquidity levels during the study period were insufficient to directly explain the occurrence of financial distress. This finding indicates that a high current ratio does not necessarily represent strong financial health, as it may result from the accumulation of inventories or accounts receivable that cannot be readily converted into cash. Nevertheless, the MARS analysis shows that CR has an importance value of 67.886%, ranking third among the predictor variables. This result suggests that liquidity still contributes to predicting financial distress, although its influence is nonlinear and cannot be fully captured by the logistic regression model. The ability of MARS to identify complex relationships indicates that liquidity changes under certain conditions remain relevant for distinguishing distressed from non-distressed firms. These findings are consistent with Sari et al. (2025), who reported that stronger liquidity reduces the likelihood of financial distress by enhancing a firm's capacity to meet short-term obligations. However, the results differ from Febriyanti and Haryanto (2025), who found that the Current Ratio has a significant positive effect on financial distress, suggesting that excessive liquidity may indicate inefficient asset utilization rather than financial strength. Therefore, while liquidity is not the primary determinant of financial distress, it remains an important supporting factor in financial distress prediction models, particularly when nonlinear relationships are considered.

TLTA measures the proportion of a company's assets financed through liabilities and serves as an important indicator of leverage and financial risk. Theoretically, a lower TLTA ratio indicates a stronger asset base relative to liabilities, thereby reducing the likelihood of financial distress because the company has greater capacity to meet its financial obligations. The logistic regression results show that TLTA has a significance value of 0.063, indicating that although the variable is not statistically significant at the 5% level, it exhibits a marginal effect at the 10% level. Furthermore, the Exp(B) value of 5.331 suggests that an increase in leverage may increase the probability of financial distress by more than five times. This finding supports Trade-Off Theory, which argues that while debt financing can generate tax advantages, excessive reliance on debt increases financial costs and the risk of bankruptcy. In manufacturing companies, a high proportion of liabilities relative to assets may reduce financial flexibility, particularly during periods of economic uncertainty and fluctuating market demand. Although the logistic

regression model does not identify TLTA as a statistically significant predictor, the MARS analysis ranks it as the second most influential variable, with an importance value of 84.678%. This result suggests that the relationship between leverage and financial distress is likely nonlinear and therefore not fully captured by conventional logistic regression. The strong contribution of TLTA in the MARS model is consistent with previous studies showing that leverage remains one of the most important predictors of financial distress because highly leveraged firms face greater financial pressure and default risk (Liang et al., 2015; Kristanti & Pancawati, 2024). Therefore, despite its relatively weak linear effect, leverage remains a critical factor in predicting financial distress among manufacturing firms.

ROA measures a company's ability to generate net income from its total assets and serves as a key indicator of operational efficiency and financial performance. Theoretically, a higher ROA reflects a more effective utilization of corporate resources, thereby reducing the likelihood of financial distress. The logistic regression results demonstrate that ROA has a statistically significant negative effect on financial distress (Sig. = 0.003; Exp(B) = 0.006), indicating that an increase in profitability substantially decreases the probability of a firm experiencing financial distress. The odds ratio value below one suggests that profitable firms possess stronger capabilities to meet both operational and financial obligations, enhancing their resilience against financial difficulties. This finding is consistent with Signaling Theory, which posits that strong profitability serves as a positive signal of a firm's financial health, managerial effectiveness, and long-term sustainability to investors and creditors. The importance of profitability is further reinforced by the MARS analysis, which identifies ROA as the most influential predictor with an importance value of 100%, highlighting its dominant contribution to the model's predictive performance. This result indicates that variations in profitability generate more substantial changes in financial distress status than any other financial indicator included in the model. The findings are consistent with Waqas and Md-Rus (2018), who reported that profitability is among the most significant determinants of financial distress, and with Sari et al. (2025), who found that profitable firms are less likely to experience financial difficulties due to their stronger capacity to generate earnings and sustain operational activities. Therefore, within the context of Indonesian manufacturing companies during the 2022–2025 period, profitability emerges as the most critical factor distinguishing financially distressed firms from financially healthy firms.

STA represents the extent to which all assets are able to create sales, and according to theory, higher ratios indicate better asset efficiency and lower likelihood of financial distress. However, empirical evidence from Indonesian manufacturing companies during 2022–2025 reveals that STA has no significant effect on financial distress, with a logistic regression significance value of 0.587 and an Exp(B) of 0.894. This finding suggests that efficient asset utilization in generating sales is insufficient to explain financial distress likelihood in manufacturing companies. While Signaling Theory proposes that asset efficiency creates competitive advantage and improves company performance, research indicates that high asset turnover does

not necessarily translate into increased profitability, as companies must still cover substantial production, operational, and financing costs (Ariefah & Hirdinis, 2025). The low importance value of STA in MARS analysis (28.987%) further demonstrates that the information contained in STA is largely explained by other variables, particularly profitability and leverage ratios, meaning STA's additional contribution to the model's predictive ability is relatively small. This aligns with broader research showing that activity ratios have lower predictive power than profitability and leverage ratios in detecting financial distress (Sitompul et al., 2025). Therefore, both logistic regression and MARS results consistently demonstrate that asset efficiency is not the main determinant of financial distress in Indonesian manufacturing companies during the 2022–2025 period, although it still provides supplementary information in classifying the company's financial condition.

6 | CONCLUSION

This study was conducted to evaluate the effectiveness of logistic regression and MARS in predicting financial distress among manufacturing companies listed on the Indonesia Stock Exchange during the 2022–2025 period. The findings indicate that both models are capable of explaining financial distress; however, MARS demonstrates superior predictive performance with a classification accuracy of 82.4%, compared with 65.7% achieved by Logistic Regression. The results further reveal that ROA is the most influential predictor of financial distress across both analytical approaches. In contrast, CR, TLTA, and STA exhibit varying levels of contribution, particularly when nonlinear relationships are considered. These findings suggest that profitability remains the primary indicator of corporate financial health, while leverage, liquidity, and asset utilization provide additional explanatory value in identifying potential financial difficulties.

From a practical perspective, the results imply that managers should place greater emphasis on improving profitability and maintaining an optimal capital structure to reduce the likelihood of financial distress. Continuous monitoring of key financial indicators, particularly ROA and leverage-related measures, can support early detection of deteriorating financial conditions and facilitate timely corrective actions. In addition, investors, creditors, and other stakeholders may benefit from incorporating advanced predictive techniques such as MARS into their evaluation processes, as the method offers a more comprehensive understanding of complex financial patterns that are often overlooked by conventional linear models.

Despite its contributions, this study has several limitations. The analysis is restricted to manufacturing firms and relies primarily on accounting-based financial ratios, which may not fully capture broader determinants of financial distress such as macroeconomic conditions, corporate governance mechanisms, market performance, or cash flow dynamics. Furthermore, the observation period and sample size may limit the generalizability of the findings across different sectors and economic environments. Future studies are therefore encouraged to expand the scope of analysis by incorporating additional explanatory variables, extending

the observation horizon, and comparing MARS with other machine-learning techniques to enhance the robustness and predictive capability of financial distress models.

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Fiscal Dependence on Kazakhstan's National Fund: Macroeconomic Determinants and Scenario Assessment

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Abstract
The National Fund of the Republic of Kazakhstan is essential to stabilizing public finances and ensuring oil revenues for future generations of Kazakhstan. The aim of this study is to identify the key macroeconomic determinants of transfers from the National Fund of the Republic of Kazakhstan and to assess their sensitivity to external and domestic macroeconomic shocks using econometric modeling and scenario analysis. The empirical base covers 2001-2024 and includes annual data from the Ministry of Finance of the Republic of Kazakhstan, the National Bank of Kazakhstan, the Bureau of National Statistics, and the World Bank. The study uses regression analysis with lagged explanatory variables, diagnostic tests (Breusch–Godfrey, Zharko, and Breusch–Pagan), and scenario modeling. The results of the extended model showed that the price of Brent crude oil is negatively related to the volume of transfers: the coefficient was -9.152 at p = 0.002. Receipts to the National Fund, the cost of oil production, and inflation have a positive, statistically significant relationship with transfers: the corresponding coefficients were 1,047, 8,306, and 21,651. Scenario calculations showed that a 10% decrease in the Brent price increases the forecast value of the transfer logarithm from 14.465 to 15.430, while a 10% increase in the price reduces it to 13.593. The findings emphasize that better fiscal rules should be implemented to address procyclical withdrawals, transparency should be increased, and Kazakhstan's sovereign wealth management system should be maintained over time.

KEYWORDS
Macroeconomic, Emerging Economy, Fiscal Sustainability, Fiscal Policy, Oil Production, Oil Price, Transfer Policy

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1 | INTRODUCTION

Amid current global economic instability, countries with abundant natural resources must ensure the sustainable management of resource rents. With oil prices at record highs, geopolitical tensions, inflation, and the risk of recession increasing the vulnerability of commodity exporters, the importance of sovereign wealth funds as macroeconomic stabilizers and for redistributing natural resources across generations is heightened. The National Fund of the Republic of Kazakhstan, established in 2000, performs two principal functions: stabilization and savings. Its stabilization function is intended to mitigate the effects of external economic shocks and support the stability of the state budget, while its savings function seeks to preserve a share of oil and gas revenues for future generations. In recent years, however, Kazakhstan's fiscal policy has increasingly relied on transfers from the National Fund to finance current budget expenditures. Although these transfers can mitigate the short-term consequences of external and domestic shocks, their continued expansion may weaken the Fund's capacity to accumulate financial assets and fulfill its long-term savings function.

Questions about the rational management of oil revenues are traditionally considered in the context of the "resource curse" concept, according to which a significant economic concentration on the extraction and export of raw materials can be accompanied by structural imbalances, weakened institutions, increased corruption risks, and increased macroeconomic vulnerability. For countries in which oil and gas revenues constitute a significant portion of budget revenues, the development of fiscal mechanisms capable of mitigating the impact of price volatility in commodity markets, limiting the procyclical nature of fiscal policy, and ensuring a more balanced distribution of resource rents between current consumption and long-term accumulation is of paramount importance.

Despite extensive research on sovereign wealth funds and resource income management, the macroeconomic implications of transfers from the National Fund of the Republic of Kazakhstan have not been sufficiently studied. In practice, transfers have become an important source of financing for the state budget, and their volume depends on both the external conjuncture of commodity markets and internal fiscal and inflationary conditions. This problem is of particular importance for Kazakhstan, since oil revenues remain an essential component of public finances and the budget continues to depend heavily on the National Fund's resources.

Changes in world oil prices, oil production volumes, revenues to the National Fund, inflation rates, and the state budget can influence decisions on the amount of transfers and, consequently, the fund's ability to perform stabilization and savings functions. However, the influence of these factors on the dynamics of transfers has rarely been considered within a comprehensive empirical framework for Kazakhstan.

The aim of this study is to identify the key macroeconomic determinants of transfers from the National Fund of the Republic of Kazakhstan and to assess their sensitivity to external and domestic macroeconomic shocks using econo-

metric modeling and scenario analysis. The empirical base of the study covers the period 2001-2024 and includes annual data from official national and international sources. The study uses regression analysis, diagnostic tests, and scenario modeling, which allows not only to determine the statistical relationship between transfers and macroeconomic indicators, but also to assess possible changes in the volume of transfers under various scenarios of oil price dynamics, inflation, and oil production. The scientific contribution of the study consists of a comprehensive analysis of external raw materials and internal macroeconomic factors affecting transfers from the National Fund of Kazakhstan, as well as an assessment of their sensitivity to alternative economic scenarios.

2 | LITERATURE REVIEW

The most well-known hypothesis in the economic literature is the resource curse hypothesis, which suggests that resource-rich economies tend to experience slower economic growth, weaker institutions, and greater macroeconomic instability than economically diversified ones (Sachs & Warner, 2001). Resource-rich economies that depend on commodity exports in global markets tend to have lower long-run growth rates, so resource abundance is likely to create structural distortions rather than long-term prosperity. Van der Ploeg (2011) further rejects a deterministic interpretation of the resource curse. In fact, Mehlum et al. (2006) demonstrated that countries with strong institutions can transform resource wealth into long-term economic development, whereas weak institutions tend to promote rent-seeking, corruption, and inefficient public spending.

Gelb (1988) showed that many oil-exporting countries were unable to transform resource windfalls into sustainable long-term development because of procyclical public spending, weak institutions, and excessive dependence on commodity revenues. Similarly, Collier and Goderis (2012) found that positive commodity-price shocks may generate substantial short-term economic gains but do not necessarily support long-term growth when economies remain highly concentrated in resource-based sectors. These findings suggest that the developmental effects of resource abundance depend not only on the volume of available resources but also on the quality of fiscal and institutional arrangements. In this context, fiscal policy plays a central role in reducing the vulnerability of resource-rich economies to commodity-price fluctuations. Frankel et al. (2013) showed that countries with stronger institutions were more likely to shift from procyclical toward countercyclical fiscal policies, thereby improving macroeconomic stability. Sovereign wealth funds are among the main institutional mechanisms for managing natural resource revenues, intended to support macroeconomic stabilization, promote intergenerational savings, and reduce fiscal dependence on volatile commodity markets.

According to Balding (2012), sovereign wealth funds are often confronted with the tension between short-term fiscal needs (and long-term asset accumulation plans) and long-term asset purchase goals. When political pressures dominate economic considerations, funds can gradually evolve from savings to financing

current expenditures. Similarly, Bagnall and Truman (2013) showed that transparency, accountability, and institutional independence are among the strongest determinants of sovereign wealth fund effectiveness.

However, the literature does not provide a consensus on the effectiveness of sovereign wealth funds. Ossowski et al. (2001) and Barnett and Ossowski (2002) argued that resource funds can mitigate fiscal volatility and provide temporary financing during periods of revenue shortfalls. In contrast, Balding (2012) emphasized that political pressure and weak institutional constraints may transform sovereign wealth funds from savings mechanisms into instruments for financing current government expenditures. Consistent with this concern, Humphreys et al. (2007) found that the establishment of a sovereign wealth fund does not by itself guarantee the effective management of resource revenues. These differing perspectives suggest that the long-term performance of sovereign wealth funds depends not only on their financial capacity but also on governance quality, fiscal discipline, and institutional independence.

Bems and de Carvalho Filho (2009) emphasized the precautionary role of sovereign wealth funds as savings mechanisms in resource-exporting countries. By accumulating part of resource revenues during favorable periods, these funds can help smooth consumption, mitigate the effects of commodity price shocks, and enhance macroeconomic stability. Accordingly, the performance of sovereign wealth funds should be assessed not only in terms of their short-term stabilization effects but also in terms of their capacity to preserve national wealth across economic cycles.

A significant body of literature has also examined the role of fiscal rules in limiting the procyclicality of public spending in resource-dependent economies. Lopez-Murphy et al. (2010) showed that many commodity-exporting countries increase public expenditure during periods of high commodity prices and subsequently experience fiscal pressures during downturns. Such behavior may increase reliance on sovereign wealth fund transfers and weaken long-term fiscal sustainability. Sugawara (2014) found that fiscal rules can reduce expenditure volatility in resource-rich countries, particularly when supported by strong institutional oversight and effective enforcement mechanisms. Similarly, Lledó et al. (2017) argued that fiscal rules are more effective when they are transparent, legally binding, consistently enforced, and monitored by independent institutions.

More recent research has highlighted ESG-oriented investment strategies and portfolio diversification. Environmental, social, and governance considerations may contribute to the long-term resilience of investment portfolios amid geopolitical uncertainty and the global energy transition (Kansoy & Stasiulaitis, 2025). From this perspective, sovereign wealth funds serve not only as stabilization and savings mechanisms but also as strategic instruments for preserving and diversifying national wealth.

World oil prices are usually considered one of the main external factors determining sovereign fund receipts and the volume of withdrawals. Lopez-Murphy et al. (2010) have shown that fluctuations in commodity prices directly affect public

finances and can lead to adjustments in sovereign fund operations. Sugawara (2014) also noted that oil price volatility remains a significant source of fiscal instability in resource-dependent countries. Balasundharam et al. (2023) showed that pensions, social assistance benefits, and public-sector wages are formally or informally indexed to inflation in many countries. Such indexation may increase nominal budgetary obligations during periods of sustained price growth. Consequently, higher inflation may intensify fiscal pressures and increase the government's reliance on sovereign wealth fund resources to finance additional expenditures.

The volume of oil production is also an important factor, as it determines the basis for the state's resource revenues. Van der Ploeg (2011) points out that an increase in production can expand government financing opportunities but, with weak institutional constraints, can also increase budget dependence on commodity revenues. In oil-producing economies, increased production is often accompanied by increased government spending and increased use of sovereign wealth funds.

Inflation is an internal macroeconomic risk that can increase pressure on the state budget. Rising prices increase costs across the public sector, social benefits, public procurement, and budget program implementation. In periods of high inflation, the government can more often draw on the sovereign fund's resources to cover additional costs and maintain fiscal sustainability. Lopez-Murphy et al. (2010) noted that during periods of macroeconomic instability, increased budgetary pressures may be accompanied by increased withdrawals from stabilization funds. According to Ossowski et al. (2001), persistent budget deficits are among the main reasons for increased withdrawals of non-renewable resources, especially in countries with weak cost-control mechanisms. Barnett and Ossowski (2002) also noted that budget deficits often directly lead to the use of oil and stabilization funds. If fiscal imbalances persist, the sovereign wealth fund may gradually lose its savings function and become a permanent source of financing for current expenses.

Thus, an analysis of the literature makes it possible to identify oil prices, oil production, fund receipts, inflation, and the state budget as the main macroeconomic factors related to the dynamics of transfers from sovereign funds. These indicators form the theoretical basis for constructing the econometric models used in this study. Accordingly, the selection of explanatory variables for the econometric model is directly derived from previous studies. Oil prices represent the primary external determinant of fiscal revenues in resource-exporting economies (Lopez-Murphy et al., 2010; Sugawara, 2014). Oil production reflects the scale of resource extraction and the potential expansion of fiscal capacity (Van der Ploeg, 2011). National Fund revenues capture the accumulation of resource rents and their potential influence on public spending decisions (Frankel et al., 2013). Inflation reflects internal macroeconomic pressures that may increase fiscal expenditures (Lledó et al., 2017), while the budget balance serves as an indicator of fiscal stress and the need for additional financing (Barnett & Ossowski, 2002). Consequently, these variables provide the theoretical and empirical foundation for

the econometric specification employed in this study.

By contrast, Norway's Government Pension Fund Global is widely used as a benchmark for resource revenue management. The Norwegian model is based on strict fiscal rules, high transparency standards, and strong institutional independence, enabling resource revenues to be converted into long-term financial assets rather than short-term budget financing (NBIM, 2026). Kazakhstan, unlike Norway, depends much more on transfers from its sovereign wealth fund to finance budget expenditures. While the Norwegian model is primarily focused on the preservation and smooth intergenerational consumption of wealth, the National Fund of the Republic of Kazakhstan also serves stabilization, savings, and fiscal financing functions. Because of this institutional difference, transfer determinants are the key to assessing long-term fiscal sustainability and the preservation of National Fund assets.

Several studies have examined the formation and use of Kazakhstan's National Fund. The country's fiscal response to external shocks shows that transfers from the Fund were essential during the crisis of the global financial system in 2008-09, the oil price collapse of 2014-2016, and the COVID-19 pandemic. A number of studies are devoted to the formation and use of funds from the National Fund of Kazakhstan. Dodonov (2021) investigated the impact of devaluation and the National Fund's investment income on the formation of Kazakhstan's state budget, emphasizing the special role of transfers from the fund in the public finance system. Daribekova and co-authors (2024) reviewed the specifics of the formation and use of the National Fund's funds and proposed measures to improve the mechanism for managing its resources. Papyrakis and Parcero (2022) found that public attitudes toward resource wealth in Kazakhstan may reinforce expectations of increased government spending, thereby providing additional political incentives to use oil revenues to support the economy rather than accumulate them in the long run. This is consistent with a wider international trend of nations like Nigeria and Venezuela, where large resource revenues are often associated with increased fiscal dependence on commodity markets and less diversification efforts. These studies provide important evidence on the accumulation, investment income, use, and institutional management of the National Fund. However, they do not pay sufficient attention to the macroeconomic factors that determine the volume of transfers from the fund to the state budget, as well as to the sensitivity of these transfers to external and internal shocks.

Despite extensive research on sovereign wealth funds and resource-dependent economies, several important limitations remain in the existing literature. First, most studies focus more on institutional design, governance quality, transparency, and fiscal rules than on the mechanisms underlying withdrawal. Second, most empirical work on Kazakhstan concentrates on legal and policy aspects of the National Fund and very little on the actual reasons for transfers. Third, many studies do not consider oil prices, oil production, inflation, National Fund revenues, and fiscal conditions within a single empirical framework. Hence, the mechanisms by which external commodity-market shocks and internal macroeconomic pressures

interact to drive the transfer process are not well understood.

The present study addresses this gap by developing an integrated econometric framework that links the theoretical insights of the resource curse literature, sovereign wealth fund research, and fiscal policy studies to empirical evidence from Kazakhstan. Transfers from the National Fund are treated as dependent variables, and Brent oil prices, oil production, National Fund revenues, inflation, and the budget balance are also considered relevant factors in this study. By combining econometric estimation and scenario analysis, the study provides new evidence on how external commodity market shocks and domestic macroeconomic pressures jointly impact the sustainability of National Fund operations.

3 | RESEARCH METHODS

The research methodology combines theoretical analysis, econometric modelling, and scenario analysis. This approach makes it possible not only to identify the statistical relationships between transfers from the National Fund of the Republic of Kazakhstan and selected macroeconomic factors, but also to assess the sensitivity of transfers to external and domestic macroeconomic shocks. The results are subsequently interpreted in terms of their possible implications for the stabilization and savings functions of the Fund.

The aim of the empirical analysis is to identify the key macroeconomic determinants of transfers from the National Fund of the Republic of Kazakhstan. The study focuses on two groups of explanatory factors. The first group comprises external resource-related factors, including Brent crude oil prices, National Fund revenues, and oil production. The second group includes domestic macroeconomic and fiscal factors, represented by inflation and the budget balance.

The empirical analysis covers the period from 2001 to 2024. This period makes it possible to examine the dynamics of the National Fund since the early stage of its operation and includes several major episodes of external and domestic economic instability: the global financial crisis of 2008–2009, the decline in oil prices in 2014–2016, the COVID-19 pandemic in 2020, and the period of elevated global inflation and energy-market instability in 2022–2024.

The study uses data from official national and international sources, including the Bureau of National Statistics of the Republic of Kazakhstan, the National Bank of Kazakhstan, and the World Bank. The data were harmonized by period, measurement unit, and transformation procedure to ensure consistency across variables. Table 1 presents the variables used in the study, their measurement units, data sources, observation period, and transformation procedures.

All monetary indicators included in the analysis, namely transfers from the National Fund, National Fund revenues, and the value of oil production, are measured in current thousand U.S. dollars. Brent crude oil prices are measured in real U.S. dollars per barrel. Natural logarithms were applied to the monetary and oil-sector variables to reduce scale differences, mitigate heteroscedasticity, and interpret the coefficients of the log-transformed variables as elasticities. Inflation is measured as the annual percentage change in the consumer price index, while the

budget balance is expressed as a percentage of GDP. These variables are included in the model in their original form.

Table 1. Description of variables

Variable	Symbol	Unit of measurement	Data source	Period	Transformation
Transfers from the National Fund (dependent variable)	ln(Transfer)	Thousand USD, current prices	Ministry of Finance of the Republic of Kazakhstan	2001–2024	Natural logarithm
National Fund revenues	ln(Revenue)	Thousand USD, current prices	Ministry of Finance of the Republic of Kazakhstan	2001–2024	Natural logarithm
Brent crude oil price	ln(Brent)	Constant U.S. dollars per barrel	World Bank	2001–2024	Natural logarithm
Oil production	ln(Production)	Thousand USD, current prices	Bureau of National Statistics	2001–2024	Natural logarithm
Inflation	Inflation	Annual change in the consumer price index, in percentage	National Bank of Kazakhstan, Bureau of National Statistics	2001–2024	Original values
Budget balance	Balance	Percentage of GDP	Ministry of Finance of the Republic of Kazakhstan	2001–2024	Original values

Note: compiled by the authors based on Bureau of National Statistics (2025), Ministry of Finance of the Republic of Kazakhstan (2025), National Bank of Kazakhstan (2025), World Bank (2025)

The empirical analysis was conducted in several stages. First, annual data for 2001–2024 were collected from official national and international databases. Second, the data were checked for consistency, missing values, and measurement differences, after which selected variables were transformed into natural logarithms. Third, the time-series properties of the variables were examined using unit-root tests. Fourth, alternative econometric specifications were estimated to identify the determinants of transfers from the National Fund. Fifth, diagnostic tests were applied to assess residual autocorrelation, heteroscedasticity, normality, multicollinearity, and model specification. Finally, scenario analysis was conducted to evaluate the sensitivity of transfers to alternative changes in oil prices, inflation, and oil production.

Based on the variables presented in Table 1, the volume of transfers from the National Fund of the Republic of Kazakhstan was selected as the dependent variable. This variable reflects the actual intensity of the fund's resources used to finance the state budget. Because the absolute values of transfers exhibit a strong upward trend and are highly variable, the indicator was logarithmically transformed. The following indicators were used as independent variables: the real price of Brent crude oil, revenues to the National Fund, oil production volume, inflation, and budget balance. Monetary indicators were log-transformed so that the model's coefficients can be interpreted as elasticities. This is especially important when

analyzing macroeconomic data because percentage changes in indicators are more informative than changes in absolute values.

The general logic of the model can be expressed as follows (1):

$$\ln(Transfer_t) = f(\ln Brent_{t-1}, \ln Revenue_{t-1}, \ln Production_{t-1}, Inflation_{t-1}, Balance_{t-1}) \quad (1)$$

where:

$\ln(Transfer_t)$ – the natural logarithm of transfers from the National Fund to the state budget in year (t);

$\ln Brent_{t-1}$ – the natural logarithm of the real Brent crude oil price in the preceding year;

$\ln Revenue_{t-1}$ – the natural logarithm of National Fund revenues in the preceding year;

$\ln Production_{t-1}$ – the natural logarithm of the value of oil production in the preceding year;

$Inflation_{t-1}$ – the annual consumer price inflation rate in the preceding year;

$Balance_{t-1}$ – the state budget balance as a percentage of GDP in the preceding year.

The basic econometric specification is as follows (2):

$$\ln(Transfer_t) = \beta_0 + \beta_1 \ln(Brent_{t-1}) + \beta_2 \ln(Revenue_{t-1}) + \beta_3 \ln(Production_{t-1}) + \beta_4 Inflation_{t-1} + \beta_5 Balance_{t-1} + \varepsilon_t \quad (2)$$

where:

$\ln(Transfer_t)$ – the natural logarithm of transfers from the National Fund to the state budget in year (t);

$\beta_0 \dots \beta_5$ – the estimated coefficients reflecting the effects of the explanatory variables on transfers;

ε_t – the error term.

Lagged values of the independent variables were selected for several reasons. First, decisions on transfers from the National Fund are made as part of the budget process rather than instantaneously; therefore, responses to changes in oil prices, inflation, or the budget balance may be delayed. Second, the use of lagged variables may partially reduce, although not eliminate, the problem of reverse causality, because macroeconomic conditions may influence transfers, while transfers themselves may also affect fiscal and inflation indicators. Third, lagged variables allow the model to account for the inertia of fiscal decision-making.

For the study, two model specifications were constructed. The first, parsimonious Model A, includes a limited set of explanatory variables and is used to estimate the relationships among transfers, oil production value, and the budget balance. This model avoids specification overload with a limited number of observations.

The second, extended model B, includes a broader set of factors: Brent oil prices, fund receipts, oil production volumes, and inflation. This specification allows for a more comprehensive assessment of the balance between risk and opportunity factors. The second, extended Model B, includes a broader set of variables: Brent crude oil prices, National Fund revenues, the value of oil production, and inflation. This specification provides a more comprehensive assessment of external resource-related and domestic macroeconomic factors. Model B was subsequently used for scenario analysis because it provides greater explanatory power and a clearer interpretation of the simulated shocks.

The choice of the different specifications was motivated by three criteria. The first is the statistical significance of the coefficients. The second is the economic interpretability of the parameter signs. The third is the model's quality, assessed using R^2, AIC, and BIC. This approach allows consideration not only of formal statistical indicators but also of the substantive logic of economic relationships.

Particular attention was paid to the expected signs of the coefficients. Inflation was expected to be positively associated with transfers, as higher inflation may increase nominal budget expenditures and create a need for additional financing. A deterioration in the budget balance, reflected in a larger deficit, was also expected to increase the demand for transfers. Changes in oil prices may have a dual effect. On the one hand, higher oil prices increase resource revenues and strengthen the National Fund's financial base. On the other hand, under effective fiscal rules, favorable oil-market conditions may reduce the need for transfers and create greater opportunities for asset accumulation.

Several diagnostic tests were applied to evaluate the statistical adequacy of the estimated models. The Jarque–Bera test is used to assess the normality of the residual distribution. Normality of residuals is important for the correct interpretation of t-statistics and confidence intervals, especially with small sample sizes. The Breusch–Pagan test is used to check for heteroscedasticity. The presence of heteroscedasticity may indicate that the error variance depends on the explanatory variables, which reduces the reliability of the model's standard errors.

The next step involves scenario modeling. This aims to assess how changes in key factors affect the projected volume of transfers from the National Fund. The model forecast with constant factor values is used as the baseline scenario. Alternative shocks are then modeled: a 10% increase in the Brent price, a 10% decrease in the Brent price, a 2-percentage-point increase in inflation, a 3% increase in oil production, and a 3% decrease in oil production.

Scenario analysis has important practical implications because it allows us to assess the fund's resilience to various types of shocks. An increase in oil prices is viewed as a positive external shock, creating opportunities for accumulation. A decrease in oil prices is interpreted as a negative external shock, increasing pressure on the fund. Increased inflation is viewed as an internal macroeconomic risk, increasing the need for budget financing. Changes in oil production reflect the resource and production channels of influence on the fund. The scenario simulations also enable comparison of the magnitudes of projected responses to

favorable and adverse shocks. If a decline in oil prices produces a larger simulated increase in transfers than the reduction from an equivalent favorable shock, this may indicate an uneven response of transfers to changes in oil-market conditions. However, such differences in scenarios do not, by themselves, constitute a formal econometric test of asymmetry or fiscal procyclicality.

Thus, the chosen methodology allows us to address several research objectives. First, it identifies the key factors influencing the use of the National Fund's resources. Second, it allows us to separate these factors into risks and opportunities. Third, it enables us to quantitatively assess the sensitivity of transfers to macroeconomic shocks. Finally, the results provide an empirical basis for recommendations to reduce fiscal dependence on transfers and to preserve the stabilization and savings functions of the National Fund.

A limitation of the methodology is the relatively small sample size, due to the annual frequency of data collection and the relatively short history of the National Fund's operations. Furthermore, the use of annual data does not fully account for short-term fluctuations in oil prices and operational budget decisions. Nevertheless, the chosen approach is justified for the initial assessment of long-term relationships and for identifying key patterns in the use of the fund's resources.

4 | RESULTS

An econometric analysis of the factors affecting the use of funds from the National Fund of the Republic of Kazakhstan revealed a stable relationship between the volume of transfers and key macroeconomic indicators that reflect both the economy's resource capacity and fiscal risks. The study constructed two model specifications: a parsimonious model, A, and an extended model, B. Using two specifications allowed us to assess the robustness of the results under different factor structures and to avoid overcomplicating the model, given the limited number of observations.

Parsimonious model A includes the minimum required set of variables: the oil resource base indicator and the budget balance. The estimation results indicate that both variables are statistically significant predictors of transfers from the National Fund (Table 2).

Table 2. Results of model A

Variable	Coefficient	Standard Error	t-statistic	p-value
const	−42.694	8.583	−4.975	0.001
$\ln(Production_{t-1})$	3.243	0.517	6.271	0.001
$Balance_{t-1}$	−95.13	29.87	−3.185	0.005
Model statistics:				
R^2 = 0.827				
Adjusted R^2 = 0.809				
AIC = 84.939				
BIC = 88.345				
Observations = 23				

Note: compiled by the authors

The positive coefficient on the cost of oil production indicates that an increase in this indicator is associated with greater use of funds from the National Fund. The result obtained may reflect the peculiarities of Kazakhstan's fiscal model, in which the expansion of the resource base is not always accompanied by a proportional accumulation of funds, but may instead be associated with an increase in government spending and budget transfers. However, this dependence should not be interpreted as direct evidence of the causal effect of oil production on the volume of transfers.

The coefficient for the budget balance indicator is negative and statistically significant. This means that an improvement in the state budget is associated with a decrease in the volume of transfers, while a deterioration in the fiscal position is accompanied by a greater dependence on funds from the National Fund. The result is consistent with the National Fund's role as a fiscal buffer during periods when current budget revenues are insufficient to finance government spending. In general, the results of model A indicate that the use of National Fund funds is related to both the state of the oil sector and the state's fiscal position. However, the identified dependencies should not be interpreted as direct cause-and-effect relationships.

The extended model B includes Brent crude oil prices, revenues to the National Fund, oil production volume, and inflation. This specification allows for a more comprehensive assessment of the interaction of risk factors and the potential use of the fund's resources (Table 3).

Table 3. Results of model B

Variable	Coefficient	Standard Error	t-statistic	p-value
const	−108.252	20.456	−5.292	0.000
$\ln(Brent_{t-1})$	−9.152	2.591	−3.532	0.002
$\ln(Revenue_{t-1})$	1.047	0.491	2.133	0.047
$\ln(Production_{t-1})$	8.306	2.007	4.138	0.001
$Inflation_{t-1}$	21.651	8.408	2.575	0.019
Model statistics:				
R^2 = 0.885				
Adjusted R^2 = 0.859				
AIC = 79.542				
BIC = 85.220				
Observations = 23				

Note: compiled by the authors

The model results show that Brent crude oil prices have a statistically significant negative impact on the volume of transfers. This means that rising global oil prices reduce the need to use the fund's resources. Economically, this can be interpreted as the formation of an "accumulation window" in which increased export revenues partially alleviate budget pressure and enable the fund to retain a larger share of oil revenues.

The negative coefficient on the Brent price has important practical significance, as it confirms the fund's stabilization function. During periods of high oil prices, the

government can limit withdrawals and increase the fund's assets, thereby creating reserves for future crises.

At the same time, the model results show that higher National Fund revenues are associated with larger transfers to the state budget. This finding should not be interpreted as evidence of improved fund sustainability. On the contrary, it may indicate a stronger dependence of fiscal policy on resource revenues. Rather than being fully accumulated within the Fund, additional oil-related revenues appear to create incentives for increased budget expenditures and higher withdrawals. Such a pattern is characteristic of procyclical fiscal behavior, whereby periods of favorable commodity market conditions are accompanied by an expansion of public spending. Consequently, the positive relationship between Fund revenues and transfers suggests that a significant share of resource revenues is directed toward current fiscal needs rather than long-term savings, potentially weakening the accumulation function and the National Fund's long-term sustainability.

The coefficient for the value of oil production proved particularly significant. Increased oil production statistically significantly increases the volume of transfers from the National Fund. This result confirms that an increase in the resource base expands the state's ability to finance expenditures and implement investment programs. However, it also increases the budget's dependence on the oil sector and may limit incentives for economic diversification.

The positive impact of inflation on the volume of transfers confirms the hypothesis that inflationary pressure increases the budget burden and stimulates the use of the Fund's resources. Rising inflation leads to increased government spending, the need to index social benefits, and higher costs for implementing government programs. As a result, the budget's dependence on transfers from the National Fund increases.

These results are particularly important in the context of recent years, when Kazakhstan, like many other countries, has faced accelerating inflation, rising global food and energy prices, and increased external economic instability. Under these conditions, the National Fund effectively becomes an instrument for compensating for internal macroeconomic imbalances. All coefficients in model B are statistically significant at the 5% level, indicating the high robustness of the results.

A comparison of model quality indicators further supports selecting model B as the preferred specification. The extended model demonstrates higher explanatory power, with an R^2 of 0.885 and an adjusted R^2 of 0.859, compared to 0.827 and 0.809 for model A, respectively. In addition, model B exhibits lower AIC and BIC values, indicating a better balance between goodness of fit and model parsimony. These results suggest that the inclusion of additional macroeconomic variables improves the model's explanatory capacity without introducing excessive complexity. Therefore, model B was selected as the preferred specification for the scenario simulations.

To assess the validity of the constructed model, diagnostic tests for autocorrelation, normality of residual distribution, and heteroscedasticity were conducted (Table 4).

Table 4. Specification validity tests for the extended model B

Test	Statistic	p-value
Breusch-Godfrey (lag=1)	0.187	0.665
Breusch-Godfrey (lag=2)	0.203	0.903
Jarque-Bera	2.442	0.295
Breusch-Pagan	1.781	0.776

Note: compiled by the authors

The Breusch–Godfrey tests show no autocorrelation of the residuals at either the first or second lag. This means that the model residuals do not exhibit a systematic time dependence, and therefore the model coefficients can be considered statistically reliable. The Jarque–Bera test revealed no significant deviations from normality in the residuals. Normality is especially important in the context of a relatively small sample, as it allows for the correct interpretation of t-statistics and confidence intervals. The Breusch–Pagan test results indicate the absence of heteroscedasticity. This means the model's error variance remains stable and independent of the explanatory variables' levels.

Further evidence of the model's adequacy is provided by the comparison of actual and fitted values presented in Figure 1.

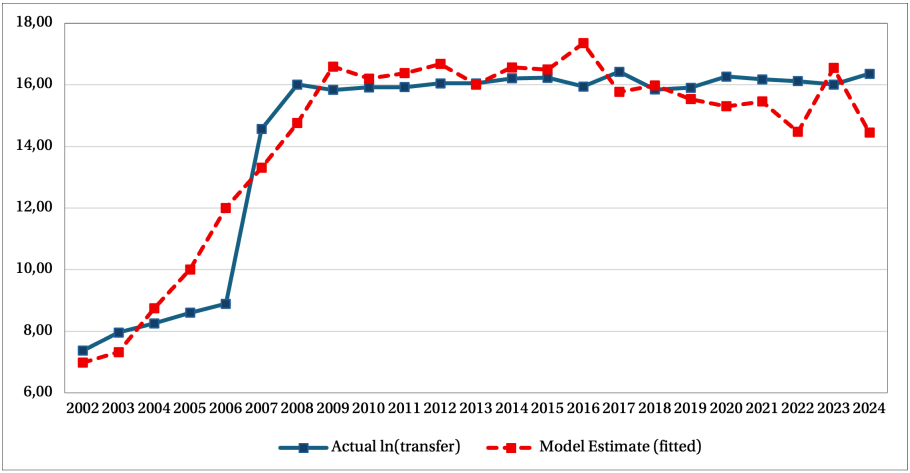


Figure 1. Actual and fitted values of the logarithm of transfers from the National Fund based on model B

Overall, the model successfully captures the main long-term dynamics of transfers from the National Fund and reproduces the general trend observed in the data. At the same time, several years exhibit noticeable deviations between actual and fitted values, reflecting the influence of extraordinary economic events, policy decisions, or other factors not explicitly included in the model specification. These discrepancies are expected, given the complexity of fiscal policy and the limited number of explanatory variables. Nevertheless, the overall correspondence

between actual and predicted values, together with the diagnostic test results, suggests that the model provides a reasonable representation of the key determinants of transfer dynamics.

Thus, the diagnostic tests confirm the adequacy of the model specification and enable the use of its results for further scenario analysis.

At the final stage of the study, scenario modeling was conducted to assess the sensitivity of transfer volumes to changes in key macroeconomic factors (Table 5).

Table 5. Alternative scenarios

Scenario	**Forecast** $\ln(Transfer)$	**% of baseline**
Brent +10%	13.593	−87.22
Brent −10%	15.430	96.42
Inflation +2 p.p.	14.623	15.72
Oil production +3%	14.711	24.55
Oil production −3%	14.212	−25.30

Note: compiled by the authors

The baseline scenario was the model forecast under constant macroeconomic factors, yielding a predicted $ln(Transfer)$ of 14.465. Alternative scenarios for changes in oil prices, inflation, and oil production were then simulated.

The results of the scenario analysis show that a 10% increase in the Brent price reduces the predicted value of $ln(Transfer)$ to 13.593, corresponding to a deviation of -87.22% relative to the baseline scenario. This indicates that a favorable external oil market environment significantly reduces the need to use the National Fund and creates conditions for asset accumulation. A high increase in oil prices opens up new fiscal space and reduces the budget's dependence on transfers from the Fund.

The strongest impact is observed with a negative oil price shock. With a 10% decrease in the Brent price, the predicted value increases to 15.430, representing a 96.42% increase relative to the baseline scenario. The obtained result indicates the high sensitivity of Kazakhstan's budget system to deteriorating external commodity prices. A fall in oil prices almost automatically increases pressure on the National Fund and increases the need for additional transfers to maintain fiscal sustainability.

A 2-percentage-point increase in inflation raises the projected value of $ln(Transfer)$ to 14.623, corresponding to a 15.72% increase relative to the baseline scenario. This confirms that inflationary processes are a key internal risk factor for the fund's sustainability. Accelerating inflation increases government spending, increases the budget burden, and stimulates additional use of National Fund resources to finance the state's social and economic obligations.

Changes in oil production demonstrate a dual effect. If oil production increases by 3%, the predicted value of $ln(Transfer)$ rises to 14.711, representing a 24.55% increase relative to the baseline scenario. This is due to the economy's expanding resource base and the government's greater ability to finance expenditures and investments. But this is also a sign of the high dependence of fiscal policy on the

oil-sector-dependent budget, and it remains very strong.

If oil production decreases by 3%, the predicted value of $ln(Transfer)$ drops to 14.212, a deviation of -25.30% from the baseline. This shows that a reduction in production threatens the fund's resource base and the use of oil and gas revenues to finance government spending.

The scenario deviation graph in Figure 2 shows that transfers respond differently to different types of oil shocks. It is particularly clear that negative oil shocks affect the fund more than positive ones.

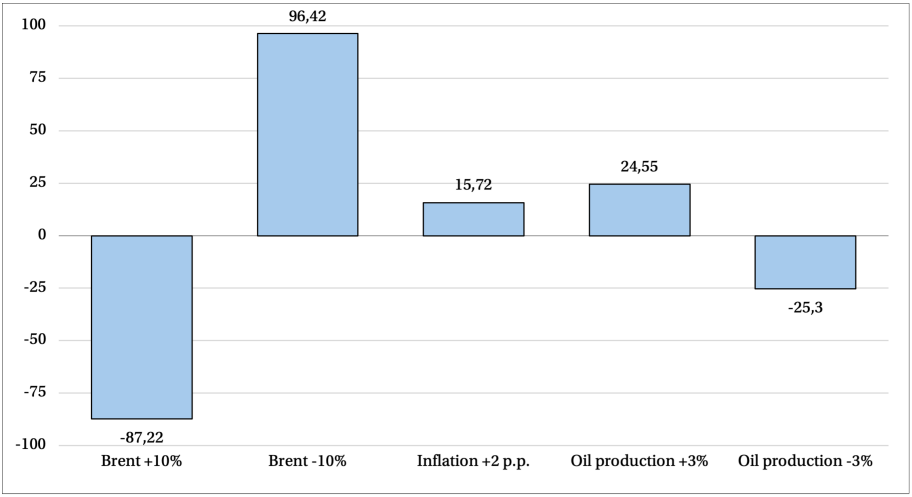


Figure 2. Scenario deviations of the forecast according to Model B

Figure 2 provides an additional insight into the importance of the shocks we have analyzed by showing their effects on transfer dynamics. We see that external oil market conditions are much more important than domestic macroeconomic factors for projected transfers. Changes in oil prices are much more significant than inflation and production changes driven by oil prices, so commodity market developments play a very important role in the National Fund's fiscal dependence.

The figure shows that external shocks are much more negative for fiscal pressure than positive ones. This pattern indicates that the National Fund is primarily a stabilization mechanism during economic stress, whereas it is relatively difficult to accumulate funds during economic prosperity.

Overall, the numerical results show that the sustainability of National Fund operations remains closely tied to volatility in the external commodities market. It is therefore imperative for us to strengthen countercyclical fiscal policies and reduce the budget's dependence on oil revenues to improve long-term fiscal resilience.

5 | DISCUSSION

The results are generally in line with the international literature on resource dependence and sovereign wealth fund management. As Sachs & Warner (2001) have

shown, a high level of budget dependence on commodity revenues is a source of macroeconomic instability and exacerbates external shocks. The results of this study confirm that Kazakhstan is still heavily dependent on the oil market. The procyclicality in the use of the fund's resources is consistent with Van der Ploeg (2011), who noted that resource revenues, without rigid institutional controls, can spur increased government spending as long as oil prices are high. The results of the study show that increased Fund revenues are accompanied by larger transfers, which may limit the National Fund's accumulation capacity and reinforce fiscal dependence on resource revenues.

Also, from an institutional economics perspective, the study's results confirm the necessity of resource rent management, as explained by Mehlum et al. (2006). The effective use of oil revenues depends on the state's ability to relieve short-term political pressure and focus on the long-term sustainability of fiscal policy in Kazakhstan. So the fund does both stabilization and expenditure functions.

Compared with international experience, the National Fund's management model differs significantly from the Norwegian approach. In Norway, the use of oil revenues is strictly limited by the fiscal rule, and the majority of assets are invested abroad. In Kazakhstan, the fund is primarily used to cover current budget needs. This increases the risk of a decline in the fund's assets during periods of unfavorable oil prices.

The study's results are also consistent with recent research by the IFSWF and ESG-oriented sovereign wealth funds, which finds that the stability of sovereign wealth funds is largely determined by asset diversification, management transparency, and institutional independence. In the context of the global energy transition, Kazakhstan increasingly needs to gradually reduce the fund's dependence on the oil and gas sector and expand the share of alternative investment instruments.

The identified impact of inflation on the volume of transfers is particularly significant. The obtained results demonstrate that domestic macroeconomic risks can have an equally strong impact on the fund as external oil shocks. This means that the stability of the National Fund depends not only on global oil price dynamics but also on the quality of domestic monetary and fiscal policies.

The findings of the study suggest that the National Fund of the Republic of Kazakhstan remains a key part of macroeconomic stability. However, the budget's heavy dependence on transfers, procyclical use of oil revenues, and sensitivity to external shocks increase the risk that the fund's long-term stability will be compromised. This is why budget rules need to be strengthened, unscheduled transfers to be limited, management transparency increased, and mechanisms for long-term asset accumulation developed.

6 | CONCLUSION

Econometric analysis and scenario modeling were conducted in depth to establish the risks and opportunities for the National Fund of the Republic of Kazakhstan in the context of global economic instability and for the country. The study demonstrated that the National Fund remains a major pillar of macroeconomic stability

in the face of external and domestic shocks, as it maintains stability and remains central to Kazakhstan's budget system. To the extent that the National Fund is a macroeconomic stabilizer, given its dependence on oil and gas revenues and transfers from the Fund, the study demonstrated the structural risks of Kazakhstan's budget system in general.

The econometric analysis showed that the quantity of transfers from the National Fund was statistically linked to macroeconomic factors. Oil and gas production and spending on the budget increased, and funds were transferred to the Fund, so Kazakhstan's economy remains quite heavily dependent on the commodity sector. At the same time, a higher oil price means less need for transfers and more opportunities to accumulate Fund assets.

Beyond this statistical relationship, the results indicate that higher resource revenues do not necessarily strengthen the National Fund's sustainability. Instead, they might increase the budget's dependence on oil, thereby increasing the procyclical use of National Fund resources. We found that much of the additional resource revenues is used for immediate fiscal needs rather than long-term savings, which may reduce the Fund's accumulation function and long-term sustainability.

Higher inflation puts pressure on the state budget, increases the state's debt burden, raises state spending, and increases the need for more transfers in the future. This means that, in the end, the sustainability of the fund depends not only on oil and external shocks but also on the quality of domestic monetary and fiscal policies.

Diagnostic tests confirmed the model's validity and the statistical robustness of the results. The absence of autocorrelation, heteroscedasticity, and significant deviations from the normal distribution of residuals suggests that the econometric specification is reliable.

Of particular importance is the scenario analysis, whose results demonstrated a pronounced asymmetry in the impact of macroeconomic shocks on the volume of transfers from the fund. A favorable oil market creates opportunities for asset accumulation and reduces fiscal pressure, while falling oil prices and rising inflation significantly increase the burden on the National Fund. This confirms the highly procyclical nature of the fund's use and the continued vulnerability of Kazakhstan's budget system to external shocks. A comparison of the study's results with international experience revealed that the governance model of the National Fund of the Republic of Kazakhstan differs significantly from the practices of countries with more stringent budget constraints and high institutional independence of sovereign wealth funds. In Kazakhstan, the Fund is mainly used as a tool to meet current budget needs, weakening its accumulation function and increasing the risk of a decline in the long-term sustainability of assets.

The study findings have theoretical, methodological, and practical consequences across the three dimensions. From a theoretical perspective, the paper contributes to research on sovereign wealth funds and resource-dependent economies by showing that higher resource revenues do not necessarily imply stronger fund sustainability. Rather, increased revenues may be accompanied

by larger transfers in line with the persistence of procyclical fiscal policy and the continuing reliance of public finances on commodity-related income.

From a methodological perspective, the study develops an integrated econometric and scenario-based framework for assessing the determinants of National Fund transfers. The combination of regression analysis, diagnostic testing, and scenario modeling enables evaluation not only of the statistical significance of key macroeconomic factors but also of the sensitivity of transfers to alternative external and internal shocks.

From a practical policy perspective, the results suggest several specific measures to strengthen the long-term sustainability of the National Fund. First, fiscal rules should impose stricter limits on discretionary and unscheduled withdrawals during periods of favorable oil market conditions. Second, a larger share of additional oil revenues should be directed toward asset accumulation rather than current budget financing. Third, transparency can be enhanced through more detailed public disclosure of asset allocation, investment performance, and transfer decisions. Finally, continued diversification of the Fund's investment portfolio, including a broader range of international and non-resource-related assets, would reduce exposure to oil market volatility and improve long-term resilience.

A limitation of the study is the reliance on annual data and a relatively short time series for the historical functioning of the National Fund. Future research may benefit from applying more advanced dynamic models, using quarterly data, and including institutional and global financial variables that may further influence the dynamics of National Fund transfers.

AUTHOR CONTRIBUTIONS

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