МРНТИ 06.71.07
УДК 338.432,001.895
DOI 10.58319/26170493_2026_3_150

INNOVATIVE DEVELOPMENT OF KAZAKHSTAN'S AGRO-INDUSTRIAL COMPLEX: A FRAMEWORK FOR EFFICIENCY ASSESSMENT

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ABSTRACT. The article addresses pressing issues concerning the assessment of the economic efficiency of innovative development in agricultural enterprises in the Republic of Kazakhstan. These issues stem from the systemic transformation of the sector, global food security challenges, climate change, and the imperative for technological modernization. Gaps in existing methodological approaches have been identified, such as insufficient inclusion of institutional specificities, natural and climatic factors, and the organizational and economic heterogeneity of the industry.

The objective of this research is to systematize and critically analyze methodological approaches to assessing the economic efficiency of innovative development in agricultural enterprises, considering the specific context of Kazakhstan.

The methodological foundation is based on systemic and comprehensive approaches, as well as a systematic literature review using an adapted PRISMA 2020 protocol. The source selection procedure included searches in Web of Science, Scopus, RSCI, KazNEB databases, and repositories of international organizations.

The originality and value of the research lie in identifying five key gaps in existing methodological approaches and proposing a conceptual framework for a four-level assessment, adapted to the conditions of Kazakhstan's agricultural sector. The novelty of the framework lies in integrating a contextual level, combining institutional and climatic factors, with standard assessment levels.

The research results enabled the formulation of a conceptual framework for assessing the economic efficiency of innovative development in agricultural enterprises in Kazakhstan. This framework integrates financial-economic, production-resource, innovation-performance, and institutional aspects. Five priority directions for adapting methodological tools are proposed, introducing a subsidiarity adjustment factor, stratifying assessment by agro-climatic zones, developing specialized statistics, differentiating methodologies by the scale of economic entities, and evaluating digital innovations. The findings highlight the multidimensional nature of innovative development outcomes in the agro-industrial complex and the need for further empirical validation of the proposed framework.

KEYWORDS: economic efficiency, innovative development, agricultural enterprises, Kazakhstan, methodological approaches, innovation assessment, PRISMA.

ИННОВАЦИОННОЕ РАЗВИТИЕ АПК КАЗАХСТАНА: РАМКА ОЦЕНКИ ЭФФЕКТИВНОСТИ

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АННОТАЦИЯ. В статье рассматриваются актуальные вопросы оценки экономической эффективности инновационного развития аграрных предприятий в Республике Казахстан, обусловленные системной трансформацией сектора, глобальными вызовами продовольственной безопасности, климатическими изменениями и необходимостью технологической модернизации. Выявлены пробелы в существующих методических подходах, такие как недостаточное включение институциональных особенностей, природно-климатических факторов и организационно-экономической неоднородности отрасли.

Целью исследования является систематизация и критический анализ методических подходов к оценке экономической эффективности инновационного развития аграрных предприятий с учётом специфики Казахстана.

Методологической основой послужили системный и комплексный подходы, а также систематический обзор литературы с использованием адаптированного протокола PRISMA 2020. Процедура отбора источников включала поиск в базах Web of Science, Scopus, РИНЦ, КазНЭБ и репозиториях международных организаций.

Оригинальность и ценность исследования заключаются в идентификации пяти ключевых пробелов существующих методических подходов и предложении концептуальной рамки четырёхуровневой оценки, адаптированной к условиям аграрного сектора РК. Новизна рамки заключается в интеграции контекстуального уровня, объединяющего институциональные и климатические факторы, со стандартными уровнями оценки.

Результаты исследования позволили сформулировать концептуальную рамку для оценки экономической эффективности инновационного развития аграрных предприятий Казахстана, интегрирующую финансово-экономические, производственно-ресурсные, инновационно-результативные и институциональные аспекты. Предложены пять приоритетных направлений адаптации методического инструментария, введение поправочного коэффициента субсидиарности, стратификация оценки по агроклиматическим зонам, развитие специализированной статистики, дифференциация методик по масштабу хозяйствующих субъектов и оценка цифровых инноваций. Выводы работы подчёркивают многомерный характер результатов инновационного развития в АПК и необходимость дальнейшей эмпирической апробации предложенной рамки.

КЛЮЧЕВЫЕ СЛОВА: экономическая эффективность, инновационное развитие, аграрные предприятия, Казахстан, методические подходы, оценка инноваций, PRISMA.

ҚАЗАҚСТАН АӨК-ІНІҢ ИННОВАЦИЯЛЫҚ ДАМУЫ: ТИІМДІЛІКТІ БАҒАЛАУ ТҰЖЫРЫМДАМАЛЫҚ НЕГІЗІ

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[1]«Turan-Astana» университеті, Астана, Қазақстан; [2]Қазақстан Республикасы Еңбек және халықты әлеуметтік қорғау министрлігінің Республикалық еңбек қорғау ғылыми-зерттеу институты, Астана, Қазақстан; [3]Astana International University, Астана, Қазақстан

АҢДАТПА. Мақалада Қазақстан Республикасының аграрлық кәсіпорындарының инновациялық дамуының экономикалық тиімділігін бағалаудың өзекті мәселелері қарастырылады. Бұл мәселелер сектордың жүйелі трансформациясымен, азық-түлік қауіпсіздігінің жаһандық сын-қатерлерімен, климаттың өзгеруімен және технологиялық жаңғырту қажеттілігімен байланысты. Қолданыстағы әдістемелік тәсілдердегі олқылықтар, мысалы, институционалдық ерекшеліктерді, табиғи-климаттық факторларды және саланың ұйымдастырушылық-экономикалық біркелкі еместігін жеткіліксіз ескеру анықталды.

Зерттеудің мақсаты - Қазақстанның ерекшеліктерін ескере отырып, аграрлық кәсіпорындардың инновациялық дамуының экономикалық тиімділігін бағалаудың әдістемелік тәсілдерін жүйелеу және сыни талдау.

Әдістемелік негіз ретінде жүйелік және кешенді тәсілдер, сондай-ақ бейімделген PRISMA 2020 хаттамасын қолдана отырып, әдебиеттерге жүйелі шолу жасалды. Дереккөздерді іріктеу рәсімі Web of Science, Scopus, РИНЦ, КазНЭБ дерекқорларында және халықаралық ұйымдардың репозиторийлерінде іздеуді қамтыды.

Зерттеудің өзіндік ерекшелігі мен құндылығы қолданыстағы әдістемелік тәсілдердегі бес негізгі олқылықты анықтауда және Қазақстанның аграрлық секторының жағдайларына бейімделген төрт деңгейлі бағалаудың тұжырымдамалық негізін ұсынуда жатыр. Негіздің жаңалығы институционалдық және климаттық факторларды біріктіретін контекстік деңгейді стандартты бағалау деңгейлерімен біріктіруде.

Зерттеу нәтижелері Қазақстанның аграрлық кәсіпорындарының инновациялық дамуының экономикалық тиімділігін бағалау үшін қаржылық-экономикалық, өндірістік-ресурстық, инновациялық-нәтижелі және институционалдық аспектілерді біріктіретін тұжырымдамалық негізді тұжырымдауға мүмкіндік берді. Әдістемелік құралдарды бейімдеудің бес басым бағыты ұсынылды, субсидиарлық түзету коэффициентін енгізу, агро-климаттық аймақтар бойынша бағалауды стратификациялау, мамандандырылған статистиканы дамыту, шаруашылық субъектілерінің масштабы бойынша әдістемелерді саралау және цифрлық инновацияларды бағалау. Жұмыстың қорытындылары АӨК-дегі инновациялық даму нәтижелерінің көп өлшемді сипатын және ұсынылған негізді одан әрі эмпирикалық апробациялау қажеттілігін көрсетеді.

ТҮЙІН СӨЗДЕР: экономикалық тиімділік, инновациялық даму, аграрлық кәсіпорындар, Қазақстан, әдістемелік тәсілдер, инновацияларды бағалау, PRISMA.

INTRODUCTION. The agricultural sector of the Republic of Kazakhstan is undergoing a systemic transformation driven by global food security challenges, climate change, and the need for technological modernization. The Concept for the Development of the Agro-Industrial Complex for 2021–2030 defines strategic priorities, including ensuring food security, industrializing agricultural production, and stimulating competitiveness [1]. The government has set a goal of doubling gross agricultural output through the modernization of the agro-industrial complex and the diversification of crop production [2]. By the end of 2024, agriculture accounted for 3.94% of GDP, employing 11% of the working-age population [3], while the volume of agro-industrial exports for 2020–2024 increased by 51%—from $3.4 billion to $5.1 billion [4]. In the Global Food Security Index, Kazakhstan ranks 32nd among 113 countries [5].

At the same time, the development of the agro-industrial complex is associated with systemic risks. Land degradation threatens two-thirds of the country's territory [6], wheat yields could decline by 20–50% by 2050 without adaptation [7], innovation activity remains low, with innovative products accounting for only 1.8% of GDP, and the country ranks 81st out of 132 in the Global Innovation Index [8]. At the same time, 80% of the agricultural machinery fleet has reached the end of its service life [9]. Karymsakova, Kerimova, and Deliana identified a lack of innovation infrastructure, dependence on imported machinery, and limited access to credit [10], while Madiev, Kerimova, and Nigmatjanov justify the key role of state regulation [11], while Seitov notes the ineffectiveness of subsidies—for every 1 tenge of profit, 0.69–0.92 tenge of subsidies were spent [12]. The FAO and the EBRD identify precision and resource-efficient agriculture as promising technologies for Kazakhstan [13], while an OECD report notes a decline in innovation expenditures despite a 56% increase in budgetary support [14].

The theoretical basis of the study is the fundamental concept of J. Schumpeter, who defined innovation as the implementation of new combinations of production factors [15], while the mechanism of "creative destruction" reveals the dual nature of innovation [16]. The endogenous growth models of P. Aghion and P. Howitt [17], as well as the neo-Schumpeterian approach of K. Freeman and B.-O. Lundvall, which shifted the focus to national innovation systems [18], justify the need for a systematic analysis of institutional conditions. The Oslo Manual proposed a universal definition of innovation [19], but the OECD recognized the need for substantial adaptation of standard approaches for the agricultural sector, taking into account the interplay of productivity, sustainability, and innovation [20].

An analysis of the scientific literature identifies four groups of methodological approaches to assessing the economic efficiency of innovation-driven development. Financial and economic approaches (NPV, IRR, ROI) do not account for the external effects of innovation [21]. Production-resource approaches, including the total factor productivity (TFP) indicator, are recommended by the OECD [20]; however, the World Bank notes a slowdown in productivity growth in Kazakhstan's agriculture since 2010 [22]. Innovation-outcome approaches, represented by Semyonov's composite indicator [23], and integrated approaches, including DEA, BSC, and composite indices [24, 25], reflect a paradigm shift toward multidimensional models. A systematic review by Markulis et al. showed that DEA in the agricultural sector requires special modifications [25], while three-stage DEA with the Malmquist index allows for isolating the influence of external factors [26]. Akhilzhanova and co-authors, using data from 21 regions of Kazakhstan, confirmed that human capital, innovation, and government support are key factors of efficiency [27], while Tayshikov and co-authors substantiated the need to integrate institutional factors into the evaluation system [28].

The central issue determining the scientific and practical significance of this study is the lack of adapted methodological approaches to assessing the economic efficiency of innovative development that take into account the specifics of Kazakhstan's agricultural sector, seasonality, climatic dependence, social significance, the role of subsidies, and the sector's organizational and economic heterogeneity [10, 14]. Existing methodologies do not include a systematic assessment of the influence of natural and climatic factors [29], do not account for the heterogeneity of the industry—ranging from large agricultural holdings to small-scale farms—and systematic reviews based on standardized protocols are virtually absent in Russian-language agricultural and economic literature. The appropriateness of the chosen methodological approach—a systematic review based on the adapted PRISMA 2020 protocol [30, 31]—is driven by the need to ensure the transparency, reproducibility, and comparability of results, as confirmed by international practice [25, 32].

The objective of this study is to systematize and critically analyze methodological approaches to assessing the economic efficiency of innovative development in agricultural enterprises, taking into account the specific

conditions of Kazakhstan. In accordance with the objective, the following tasks are addressed: summarizing the theoretical foundations of innovation assessment in the agro-industrial complex; classifying existing methodological approaches while identifying their advantages and limitations as they apply to the conditions of the Republic of Kazakhstan; and formulating recommendations for adapting and improving the methodological toolkit.

RESEARCH MATERIALS AND METHODS. The object of this study is methodological approaches to assessing the economic efficiency of innovative development in agricultural enterprises in the Republic of Kazakhstan. The subject of the study encompasses the theoretical and methodological foundations, indicators, and assessment tools, as well as their applicability to the conditions of the agricultural sector in the Republic of Kazakhstan.

The methodological foundation consists of systemic and comprehensive approaches. The systemic approach allows for the assessment of effectiveness to be viewed as a holistic problem, encompassing theoretical justification, informational and statistical support, the institutional context, and the practice of managerial decisions. The comprehensive approach is implemented by simultaneously considering financial and economic, production and resource, innovation and performance, and institutional aspects, which allows for overcoming the limitations of single-criterion methods.

The adapted PRISMA 2020 protocol (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) [30, 31] was used for the systematization and critical analysis of sources. The choice of this protocol was driven by three reasons: ensuring the transparency and reproducibility of the selection procedure, reducing subjectivity in the inclusion and exclusion of sources, and ensuring the comparability of results with international reviews, in particular with the systematic review by Markulis et al., which covered 120 publications on the application of DEA in agriculture [25], and the review by Rashidgalam et al. on environmental efficiency in the agro-industrial complex [32]. Adaptation of the protocol involved abandoning meta-analysis in favor of qualitative synthesis, taking into account the heterogeneity of the studies, as well as replacing standard medical quality assessment scales with the authors' methodology for assessing the validity and reliability of sources.

The source selection procedure consisted of four consecutive stages. During the identification stage, a search was conducted for publications in the international scientific databases Web of Science, Scopus, RINC, KazNEB, as well as in the repositories of international organizations (OECD, FAO, World Bank, EBRD) for the period 2010–2025. Search queries were formulated based on the following keywords: «economic efficiency of innovations in the agro-industrial complex», «efficiency of agricultural innovations», «DEA in Central Asian agriculture», and «total factor productivity of agriculture».

During the screening phase, sources were selected based on their titles and abstracts. The inclusion criteria considered were the methodological significance of the study, its relevance to the agricultural sector, and the presence of empirical data. During the suitability assessment stage, full-text publications were analyzed, taking into account the methodology used, the system of indicators, the sectoral focus, and the presence of empirical validation of the results.

The final sample included 42 sources out of the 187 initially identified.

Methodological approaches were compared using a unified analytical matrix that included the following parameters: research subject, indicators used, data requirements, advantages and limitations of the methods, as well as their adaptability to conditions in Kazakhstan.

The information base for the study consisted of data from the National Statistics Bureau of the Republic of Kazakhstan [3], analytical reports from the OECD [14, 20], the World Bank [7, 22, 29], and the FAO [5, 13], as well as the results of domestic scientific research [11–13, 29, 33].

RESULTS AND DISCUSSION. The systematic literature search procedure, based on the adapted PRISMA 2020 protocol, was conducted in four consecutive stages. During the identification stage, 187 potentially relevant sources were identified, of which 156 were found in international and national scientific databases (Web of Science, Scopus, RSCI, KazNEL), and 31 in the repositories of international organizations (OECD, FAO, World Bank, EBRD). After removing 24 duplicates, 163 records were admitted to the screening stage.

During the screening stage, conducted based on titles and abstracts, 89 sources were excluded on the following grounds: irrelevance to the research topic (n=41), absence of a methodological component for effectiveness assessment (n=28), and narrowly biological topics without economic analysis (n=20). A total of 74 full-text sources were admitted to the acceptability assessment stage.

During the acceptability assessment stage, full-text publications were analyzed based on the criteria of methodological soundness, the presence of a system of indicators, sectoral relevance to the agricultural sector, and the presence of empirical validation. Thirty-two sources were excluded due to the absence of empirical validation (n=14), a predominantly descriptive nature without an analytical component (n=11), and the unavailability of the full text (n=7). The final sample included 42 sources; the selection flowchart is presented in Figure 1.

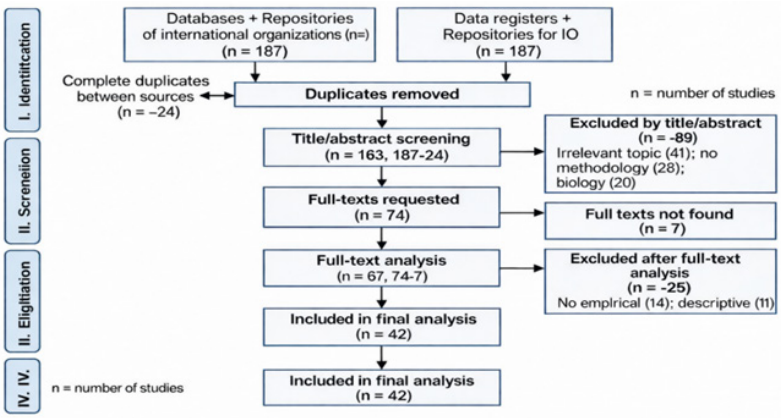


Figure 1 - Flowchart of source selection according to the PRISMA2020 protocol

Note: Compiled by the authors.

Classifying the 42 included sources by their predominant methodological approach revealed four groups: production-resource approaches—12 sources (28.6%); financial-economic approaches—11 (26.2%); integrated approaches—11 (26.2%); innovation- and results-oriented—8 (19.0%). The characteristics of the 18 key studies comprising the analytical core of the review are presented in Table 1.

Table 1—Characteristics of the key studies included in the systematic review

Author(s)	Year	Group	Object / Country	Key Findings
Zainullina D.R. [21]	2021	FE	Innovation projects, Russia	Financial indicators do not account for external effects of innovations in technological, environmental, and social domains
Seitov S.K. [12]	2023	FE	Agricultural subsidies, Kazakhstan	Subsidies are inefficient: 0.69–0.92 tenge of gross profit per 1 tenge of subsidies
World Bank, Risk Assessment [29]	2016	FE/PR	Agricultural risks, Kazakhstan	Agriculture in Central Asia is subject to a "shock–recovery–shock" cycle
OECD, Innovation, Productivity [20]	2019	PR	Agricultural sector, OECD countries	Framework "productivity–resilience–innovation", with TFP as the main indicator
World Bank, Reversing Productivity [22]	2019	PR	Productivity, Kazakhstan	Slowdown in within-sector productivity growth in Kazakhstan's agriculture since 2010
Markoulis G. et al. [25]	2023	PR/IN	DEA in agriculture, 120 publications	DEA in agriculture requires weighting coefficients and consideration of undesirable outputs; PRISMA-based review
Frontiers, Three-Stage DEA [26]	2025	PR/IN	16 cities, Anhui Province, China	Three-stage DEA + Malmquist index isolates the impact of external factors
FAO & EBRD, FINTECC [13]	2018	PR	Agrotechnologies, Kazakhstan and Kyrgyzstan	Ranking of 11 technologies by climate, adaptation, and financial potential
OECD/Eurostat, Oslo Manual [19]	2018	IR	Innovation measurement methodology, all sectors	Universal definition of innovation and standardized approaches to data collection
Semenov A.V. [23]	2024	IR	Innovative development of agriculture, Russia	Composite indicator based on four blocks: socio-economic, scientific-technical, innovation, and policy
Taishykov Z. et al. [28]	2024	IR	Innovation management in agriculture, Kazakhstan	Need to integrate institutional factors into the evaluation system
Karymsakova Zh.K. et al. [10]	2024	IR	Innovative development of agriculture, Kazakhstan	Deficit of innovation infrastructure, dependence on imported machinery, limited access to credit
Vestnik of Eurasian Science [24]	2024	IN	Economic efficiency of agriculture	Paradigm shift: integration of financial, production, innovation, and ESG indicators
Perevoshchikova A.A. [33]	2022	IN	Digitalization of agriculture, Russia	Comprehensive approach to evaluating digitalization efficiency based on statistical and expert methods
Akilzhanova L. et al. [27]	2025	IN	21 regions of Kazakhstan, panel data (2015–2024)	Human capital, innovation, government support, and exports are key efficiency factors
Madiev G. et al. [11]	2025	IN	State regulation of agriculture, Kazakhstan	State regulation is a key driver of innovation; need to develop domestic machinery production
OECD, AgPolicy 2025 [14]	2025	IN	Agricultural policy, Kazakhstan	Innovation expenditures are declining; subsidies redirected to input producers (+56%)
World Bank, Climate Adaptation [7]	2024	PR/IN	Climate adaptation in agriculture, Kazakhstan	Wheat yields may decrease by 20–50% by 2050 without adaptation measures

Note: FE – financial-economic; PR – production-resource; IR – innovation-resultative; IN – integral. 18 out of 42 key sources are presented. Compiled by the authors.

An analysis of the chronological distribution of sources revealed a significant pattern indicating a paradigm shift in evaluation methodology (Table 2). Of the 42 sources, 27 (64.3%) were published between 2020 and 2025, indicating that the issue has gained renewed relevance. The most pronounced concentration is observed in the group of integrated approaches: of the 11 works in this group, 9 (82%) were published after 2020, whereas there are no works of an integrated nature in the sample from the 2010–2014 period. This indicates a shift in the scientific community from single-criterion to multidimensional evaluation models that take into account multiple aspects of innovative development.

Table 2 - Distribution of sources by thematic groups and publication periods

Group of Approaches	2010–2014	2015–2019	2020–2025	Total	Share, %
Financial-economic	2	4	5	11	26.2
Production-resource	1	4	7	12	28.6
Innovation-resultative	1	1	6	8	19.0
Integral	0	2	9	11	26.2
Total	4	11	27	42	100.0

Note: compiled by the authors based on PRISMA review results.

An analysis of 11 sources from the financial and economic literature (Zainullina [21], Seitov [12], World Bank [29], and others) revealed a systemic gap: none of them provides a mechanism for distinguishing the effect of government subsidies from the effect of the innovation itself. Zainullina [21] notes the limitations of financial indicators (NPV, IRR, ROI) due to their failure to account for the external effects of innovation in the technological, environmental, and social spheres; however, she does not consider subsidies as a distorting factor in calculating returns.

Meanwhile, for Kazakhstan, this gap is critical. The OECD report «Agricultural Policy Monitoring and Evaluation 2025» notes that budgetary support for the agricultural sector increased by 56% in 2024, the volume of subsidized loans doubled, and subsidies were redirected through domestic producers of means of production [14]. Seitov [12] empirically demonstrated the ineffectiveness of subsidies—for every 1 tenge of gross profit, there were 0.69–0.92 tenge in subsidies in 2023–2024. When evaluating drip irrigation projects (158,000 ha commissioned in 2024), the NPV varies by 25–30% depending on whether subsidies are included in the cash flows [2]. This restructuring of the support system creates a fundamentally new context for financial and economic evaluation methods; the calculation of NPV and IRR for innovative projects is becoming increasingly dependent on the form and channels of government support. Without adjusting for subsidies, financial and economic evaluations systematically overestimate the profitability of innovations in Kazakhstan's agro-industrial complex.

Of the 12 sources in the production-resource group, only 3 directly include climate variables in the analytical model. These include the World Bank report on agricultural sector risk assessment [29], the report on climate adaptation [7], and the FAO/EBRD FINTECC methodology [13]. The World Bank [22] applies a decomposition of total factor productivity (TFP) but does not account for the impact of droughts and land degradation. The OECD [20] proposes a comprehensive «productivity–resilience–innovation» framework that includes an environmental dimension, but does not elaborate on it for arid and semi-arid farming conditions.

For Kazakhstan, the absence of a climate component represents a serious methodological limitation. According to the World Bank [7], spring wheat yields could decline by 20–50% by 2050 without the implementation of adaptation measures. The FAO notes that land degradation threatens two-thirds of the country's territory [6], and Central Asian agriculture is subject to a "shock-recovery-shock" cycle caused by alternating climatic and price stresses [29]. Under these conditions, production and resource indicators without climate stratification do not allow for the accurate isolation of the contribution of innovations to changes in productivity.

A review by Markulis et al. [25], covering 120 PRISMA-compliant publications, showed that standard DEA models have low discriminatory power in the agricultural sector and require modifications, the use of weighting coefficients, accounting for undesirable outputs (environmental externalities), and integration with the Malmquist index to analyze productivity dynamics. A study published in Frontiers in Earth Science [26] demonstrated that a three-stage DEA with the Malmquist index allows for isolating the influence of external factors on efficiency, as confirmed by data from 16 cities in Anhui Province (China). For Kazakhstan, with its pronounced agroclimatic differentiation—from the arid steppes of Central Kazakhstan to the irrigated foothills of the south—this modification is particularly relevant. However, none of the studies included in the review tested the three-stage DEA on Kazakhstani data, which determines the direction of future research.

The smallest share of innovation-oriented approaches in the sample (19.0%, 8 sources) is due not to a lack of scientific interest in the problem, but to a fundamental issue—the weakness of the statistical basis for innovation activity in the agricultural sector. Semenov [23] proposes a system of four indicator blocks (socio-economic, scientific-technical, innovation, and policy), but notes significant difficulties in obtaining data at the regional level. Taishikov et al. [28] confirm that the integration of institutional factors into the evaluation system is hampered by the lack of systematized information. Karymsakova and co-authors [10] identify a lack of innovation infrastructure, dependence on imported technology, and limited access to credit as systemic barriers, but do not propose quantitative indicators for monitoring them.

This gap is particularly acute in the case of Kazakhstan. The National Statistics Bureau publishes data on the innovation activity of manufacturing enterprises, but sectoral breakdowns for agriculture remain fragmented, R&D expenditures in the agro-industrial complex are not systematically identified, and patent activity in the sector remains low [3]. Innovative products account for only 1.8% of GDP, and in the WIPO Global Innovation Index, the country ranks 81st out of 132, placing it in the group with an inefficient cost-to-outcome ratio [8].

Of the 11 studies on integrated approaches, 9 were published after 2020 (Table 2), reflecting a marked paradigm shift. *Bulletin of Eurasian Science* [24] demonstrates the integration of financial, operational, innovation, and ESG indicators into a unified assessment system. Perevoshchikova [33] proposes a comprehensive approach to assessing the effectiveness of digitalization in the agro-industrial complex based on a synthesis of statistical and expert methods. Akilzhanova et al. [27], analyzing panel data for 21 regions of Kazakhstan for 2015–2024, show that human capital, innovation, government support, and export orientation are key factors in improving the efficiency of the agricultural sector. Madiev and co-authors [11] justify the key role of government regulation in the innovative development of the agro-industrial complex and the need to develop domestic agricultural machinery manufacturing.

At the same time, none of the 11 studies by the integrated group proposes a model specifically adapted to simultaneously account for the institutional characteristics of Kazakhstan (JSC "AKK," the Ken Dala program), its climatic zones (from arid steppes to irrigated foothills), and the sector's organizational and economic structure (large agricultural holdings, medium-sized farms, and small-scale private farms) [10, 11, 14]. This gap is the central finding of the review.

The results of the critical analysis identified five key gaps in existing methodological approaches and their corresponding adaptation strategies, summarized in Table 3.

The combination of the five identified gaps demonstrates that the isolated application of any single group of methodological approaches does not ensure a comprehensive assessment of the economic efficiency of innovative development within the agricultural sector of Kazakhstan. Based on the identified gaps, a conceptual framework for a four-level assessment adapted to the conditions of Kazakhstan's agricultural sector is proposed (Table 4). The novelty of the framework lies in the integration of a contextual level—combining institutional and climatic factors—with standard assessment levels. The framework's modular architecture ensures its applicability

to enterprises of various scales—from large agricultural holdings to small-scale farms. Each level of the framework addresses a specific finding of the review.

Table 3 - Synthesis of findings, gaps in existing approaches, and directions for adaptation

No.	Key Findings	Gap for the Agricultural Sector of Kazakhstan	Direction for Adaptation
1	None of the 11 studies in the FE group include adjustments for subsidies	Subsidies distort NPV/ROI; growth of state support by +56% in 2024; inefficiency at 0.69–0.92 tenge per 1 tenge of subsidies	Introduction of a subsidy adjustment coefficient; use of data from ACC and KazAgroFinance
2	Only 3 out of 12 studies in the PR group account for climate factors	80% of territory affected by degradation; wheat yields may decline by 20–50% by 2050	Stratification by agro-climatic zones; application of drought indices
3	DEA requires modifications and has not been tested on Kazakhstan data	Agro-climatic heterogeneity; lack of enterprise-level data	Three-stage DEA + Malmquist index; use of microdata from the 2025 agricultural census
4	IR indicators are the least represented (19%); authors note data scarcity	Innovation statistics in agriculture are fragmented; share of innovative products is 1.8% of GDP	Inclusion of a digital innovation block (ISR, ISL, GIS); expansion of statistical reporting
5	Paradigm shift (82% of IN studies after 2020); no model adapted for Kazakhstan	Institutional factors (ACC, KenDala), climate, and structural features (agroholdings vs. households) are not considered	Development of a four-level framework with a contextual block

Note: compiled by the authors based on PRISMA review results.

The study's findings have direct practical significance for two groups of users. For agricultural enterprises, the proposed conceptual framework enables the informed selection of tools for evaluating innovative projects, taking into account the scale of operations, the agroclimatic zone, and the form of government support received. It is recommended to use a subsidiarity adjustment factor when calculating NPV and ROI, as well as to stratify the results by agroclimatic zones.

Table 4 - Conceptual framework for a multi-level assessment of the agricultural sector of Kazakhstan

Level	Indicators	Data Sources	Problem Addressed
I. Financial-economic	NPV, IRR, ROI adjusted for subsidies, profitability, liquidity	Enterprise financial statements, ACC, KazAgroFinance	Distortion of financial indicators due to subsidies
II. Production-technological	Labor productivity, capital productivity with depreciation coefficient, crop yields by agro-climatic zones, TFP, DEA + Malmquist index	Bureau of National Statistics, National Agricultural Census 2025	مدع accounting for climate factors and low discriminatory power of DEA
III. Innovation-digital	Share of innovative products, R&D, capital renewal ratio, precision agriculture, ISR, ISL, GIS	Bureau of National Statistics, Ministry of Agriculture, FAO	Fragmentation of agricultural innovation statistics
IV. Contextual	Government support (KenDala), agro-climatic zone, land degradation, water availability, rural employment, cooperation	OECD, World Bank, FAO, local administrations (akimats)	Lack of an adapted model for Kazakhstan's conditions

Note: The framework is conceptual in nature and requires empirical validation. Compiled by the authors.

For government agencies, the framework can serve as a methodological basis for evaluating the effectiveness of state programs supporting the agro-industrial complex, including the Ken Dala-1 and Ken Dala-2 lending programs, the Concept for the Development of the Agro-Industrial Complex for 2021–2030, and the FAO-Kazakhstan Partnership Program. In its 2025 report, the OECD explicitly recommends that Kazakhstan conduct periodic sectoral assessments to analyze the impact of support programs on innovation, competitiveness, and the situation of beneficiaries [14]. Five priority areas have been identified: adaptation of methodological tools, introduction of a subsidiarity adjustment factor into financial and economic indicators, stratification of assessments by agro-climatic zones taking into account the projected 20–50% decline in crop yields by 2050 [7], the development of specialized statistics on innovation activity in the agro-industrial complex based on data from the 2025 National Agricultural Census [5], the differentiation of assessment methodologies by the scale of economic entities, and the inclusion of a module for evaluating the effectiveness of digital innovations (precision agriculture, ISR, ISZ, GIS with AI elements) [1, 33].

When interpreting the results, several limitations must be taken into account. The search was conducted in three languages (Russian, Kazakh, and English), which may have resulted in the exclusion of relevant publications in other languages. The size of the final sample (42 sources) is sufficient for a qualitative synthesis but does not allow for a quantitative meta-analysis. The conceptual framework has not undergone empirical validation and requires testing on panel data from agricultural enterprises in Kazakhstan. Adapting the PRISMA protocol to economic analysis involved replacing standard quality assessment scales with the authors' assessment of methodological soundness, which may reduce the formalization of the screening procedure [34]. A range of data on the innovation activity of agricultural enterprises in Kazakhstan is not available in a systematized form, which led to the predominantly qualitative nature of the analysis.

These limitations determine the directions for further research: empirical testing of the conceptual framework on panel data of agricultural enterprises in Kazakhstan using data from the 2025 National Agricultural Census, the development of standardized criteria for evaluating the quality of economic research for the purposes of PRISMA reviews in the agricultural sector, and the creation of an integrated information system for monitoring innovation

activity in the agro-industrial complex using digital platforms and data from development institutions.

CONCLUSION. A systematic review of the scientific literature, conducted according to the adapted PRISMA 2020 protocol (187 identified sources, 42 included in the final analysis), allowed for the classification of four groups of methodological approaches to assessing the economic efficiency of innovative development in agricultural enterprises: financial and economic (NPV, IRR, ROI), production-resource-based (TFP, DEA, labor productivity), innovation-outcome-based (share of innovative products, R&D costs, patent activity), and integrated (multifactor indices, BSC, DEA with the Malmquist index, ESG indicators). It has been established that the greatest growth in publications (73% for 2020–2025) is attributed to integrated approaches, indicating a paradigm shift from single-criterion to multidimensional evaluation models.

It was found that the isolated application of any single group does not ensure a comprehensive assessment within the context of the agricultural sector of the Republic of Kazakhstan. Financial and economic methods are systematically distorted by government subsidies (a 56% increase in budgetary support in 2024); production and resource indicators do not isolate the innovative contribution from the influence of climatic factors; and innovation-outcome indicators are limited by the fragmentary nature of the statistical database (share of innovative output in GDP—1.8%, 81st place in the Global Innovation Index), and integrated methodologies are not adapted to the institutional, climatic, and organizational conditions of Kazakhstan.

A conceptual framework for a four-level assessment, adapted to the conditions of Kazakhstan's agricultural sector, is proposed. The framework includes a financial-economic level adjusted for subsidies, allowing the effect of state support to be separated from the effect of innovation; a production-technological level with indicators stratified by agroclimatic zones; and an innovation-digital level that accounts for the implementation of precision farming, crop and livestock information systems, geoinformation systems, and a contextual level integrating institutional and climatic factors. The framework's modular architecture ensures its applicability to enterprises of various scales—from large agricultural holdings to small-scale farms.

Five priority areas have been identified for adapting the methodological toolkit: introducing a subsidiarity correction factor into financial and economic indicators; stratifying assessments by agroclimatic zones, taking into account the projected 20–50% decline in crop yields by 2050; the development of specialized statistics on innovation activity in the agro-industrial complex based on data from the 2025 National Agricultural Census; the differentiation of methodologies according to the scale of economic entities; and the inclusion of a module for assessing the effectiveness of digital innovations.

The proposed conceptual framework is theoretical in nature and requires empirical validation. Priority areas for further research include validating the framework using panel data on agricultural enterprises in Kazakhstan, developing standardized criteria for assessing the quality of economic research for PRISMA reviews in the agricultural sector, and establishing an integrated information system for monitoring innovation activity in the agro-industrial complex using digital platforms and data from development institutions.

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МРНТИ 82.13.00
УДК 351

DOI 10.58319/26170493_2026_3_157

DIGITAL TRANSFORMATION OF PUBLIC SERVICES IN KAZAKHSTAN BASED ON DIGITAL PUBLIC INFRASTRUCTURE

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ABSTRACT. The article examines the digital transformation of public services in Kazakhstan through the lens of Digital Public Infrastructure (DPI) and citizen-centred project management. The purpose of the study is to develop a methodological justification for modernising the issuance and replacement of the national identity card as a priority case for moving from e-government to a proactive, secure and integrated digital state model. The methodology combines a review of international literature published in 2020-2026, analysis of regulatory and policy documents, a comparative review of Estonia's experience, service mapping, a service prioritisation matrix, and As-Is/To-Be process modelling. The originality of the study lies in integrating three analytical frameworks: a whole-of-government approach, the DPI/GovStack architecture, and a cost/benefit matrix for selecting a digital transformation quick win. The findings show that the national ID issuance and replacement service has high transformational potential, as it relies on existing DPI components in Kazakhstan, including eGov.kz, eGov Mobile, digital identity, e-signature, payment services and inter-agency data exchange. At the same time, sustainable impact requires legal and organisational safeguards: biometric data governance, algorithmic audit, transparent logs, independent cybersecurity monitoring, preservation of alternative offline