ISSN: 1991-3494 (Print)
ISSN: 2518-1467 (Online)

# SCIENTIFIC JOURNAL OF PEDAGOGY AND ECONOMICS

№2
2026

ISSN 2518-1467 (Online),
ISSN 1991-3494 (Print)

CENTRAL ASIAN ACADEMIC
RESEARCH CENTER

# SCIENTIFIC JOURNAL OF PEDAGOGY AND ECONOMICS

PUBLISHED SINCE 1944

# 2 (420)

*March – April 2026*

ALMATY, 2026

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**Scientific Journal of Pedagogy and Economics**
**ISSN 2518-1467 (Online),**
**ISSN 1991-3494 (Print).**
**Owner:** «Central Asian Academic Research Center» LLP (Almaty).
The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Communications of the Republic of Kazakhstan
**№ KZ50VPY00121155**, issued on 05.06.2025
Thematic focus: *«publication of the results of new achievements inthe field of fundamental sciences»*
**Periodicity:** 6 times a year.
http://www.bulletin-science.kz/index.php/en/

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**Scientific Journal of Pedagogy and Economics**
**ISSN 2518-1467 (Online),**
**ISSN 1991-3494 (Print).**
**Меншіктенуші:** «Орталық Азия академиялық ғылыми орталығы» ЖШС (Алматы қ.).
Қазақстан Республикасының Ақпарат және коммуникациялар министрлігінің Ақпарат комитетінде 05.06.2025 ж. берілген **№ KZ50VPY00121155** мерзімдік басылым тіркеуіне қойылу туралы куәлік.
**Тақырыптық бағыты:** *«іргелі ғылым салалары бойынша жаңа жетістіктердің нәтижелерін жариялау»*
**Мерзімділігі:** жылына 6 рет.
http://www.bulletin-science.kz/index.php/en/

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**Scientific Journal of Pedagogy and Economics**
**ISSN 2518-1467 (Online),**
**ISSN 1991-3494 (Print).**
**Собственник:** ТОО «Центрально-азиатский академический научный центр» (г. Алматы).
Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и коммуникаций и Республики Казахстан
**№ KZ50VPY00121155** выданное 05.06.2025 г.
**Тематическая направленность:** *«публикация результатов новых достижений вобласти фундаментальных наук».*
**Периодичность:** 6 раз в год.
http://www.bulletin-science.kz/index.php/en/

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## CONTENTS

## PEDAGOGY

**Aitimbaev A., Issayev M., Apendiyev T.**
Scientific and methodological opportunities for using archival materials in teaching the history of Kazakhstan in higher education institutions.....19

**Akhmetova G., Kabdusheva A., Mussina A.**
A quantitative study on university students' academic writing challenges and learning needs.....40

**Akhmetova Zh.A., Nurgali S., Nurmetova D.**
Pedagogical foundations of using digital resources in teaching academic writing…….57

**Bekbolat Zh., Zholmakhanova A., Yildirim S.**
Theoretical foundations of teaching M. Shokai's letters through a research-based approach.....72

**Berdenkulova A.Zh., Zhandavletova R.B., Nazarova G.A.**
A pedagogical model for improving educational quality through the "comfortable school - society - university" partnership.....88

**Duisenova G., Shyndaliyev N., Shadiev R.**
Comparative analysis of traditional and virtualized programming education.....104

**Yeskendirova A., Kassenova N., Nogoyev Y.**
Comparative analysis of texts created by AI and texts developed using quantization technology…….....……121

**Zhanysbekova Sh., Nurmakhanova Zh., Akasheva A.**
Actual problems of the formation of pragmatic competence: research based on the results of content analysis.....136

**Zulpykhar Zh.E., Kapanova D.E., Zhilmagambetova R.Z.**
Modern resources and technologies as a foundation for the development of teachers' professional competencies.....153

**Isaeva A., Ananyeva S.**
Axiological interpretation of the Kazakhstan theme in the works of K. Paustovsky: methodological approaches to teaching at the university.....172

**Kabzhalelov K.R., Korganbayeva Zh.K., Nurakhmetova A.R.**
Developing critical thinking through modern chatbots in chemistry education.....190

**Kazhenova Zh.S., Kydyralina L.M., Rakhmatullina Z.T.**
Problems of developing students' engineering skills.....208

**Kaldarova A., Vasquez M., Kulgildinova T.**
Developing students' profession-oriented speaking skills through ChatGPT.....229

**Kapbarova G.Sh., Gundogdu A., Baidalieva E.A.**
History teaching methodology: theoretical and practical foundations of the competency-based approach.....243

**Kozhakhanova L., Amirova A.**
Prospects for developing media literacy among primary school students.....260

**Kuzhagulova G., Sydykova R., Smailova M**
Features of education of national values in visually impaired students through Kazakh lyric songs.....278

**Markhmadova Zh.K., Kassymova G.K., Okenova B.**
Pedagogical aspects of developing and assessing the digital competence of pedagogy-psychologists.....297

**Mateyeva M., Yeralin K., Burkitbaev T.**
Training future teachers of artistic work for art-historical regional studies.....318

**Makhanov N., Nishanova K.**
Development of students' cognitive competencies through museum-based education: evidence from South Kazakhstan.....333

**Myrzagereikyzy G., Yermekova Zh.K., Aldzhambekova G.T.**
The use of action research in preparing future physics teachers for the development of functional literacy of students.....348

**Reginbayeva N., Nametkulova F.**
Methodological foundations of professionally-oriented physics education based on STEM education for future air transport specialists.....365

**Serikbayeva N., Orynbekova A., Tuyakova U.**
Methodology for developing digital competence of educational psychologists in modern education.....385

**Toiganbekova M.E., Kazhigalieva G.A.**
Aspects of creation and specification of educational texts for increasing the effectiveness of training.....409

**Shegebayeva G., Zhumasheva T., Nurbekova S.**
Prerequisites for the preparation of future educators for the creation of a health-educational environment based on nutricology.....422

**Shishov S.E., Iovbak A.S., Verko Y.A.**
Integrated modular physics experiment as a means of organizing students' experimental activities in secondary school.....443

## ECONOMICS

**Abdimoldayeva A., Madysheva A., Zhunussova G.**
Transformation of logistics cost accounting in the agro-industrial complex under digitalization…….....461

**Abuova Zh., Duiskenova R., Kadyrbekova D.**
The concept of sustainable development of the hotel business based on digital transformation and environmental management.....479

**Amantay Mukhit, Kanabekova M., Oralbayeva Zh.**
Digitalization as a driver of Kazakhstan's economic growth: econometric analysis and structural effects…….....…….494

**Ashim N., Dzhrauova K., Kushenova M.**
Improving the management of agricultural subsidies: Kyzylorda region…….....….511

**Assemova R., Abdibekov S., Aitbayeva D.**
Energy efficiency and innovation in agriculture: empirical evidence from Southern Kazakhstan…….....535

**Assanova Zh., Baimukhanova S., Konysbaeva G.**
Environmental accounting, ESG reporting and digitalization: impact on cost reduction and sustainable development.....554

**Baigelova A., Sadykova Zh., Epanchintseva S.**
Industrial economy transformation in Kazakhstan: structural shifts, digitalization and productivity growth.....571

**Beisekova Zh., Mutaliyeva A., Kunshigarova L.**
Transformation of entrepreneurial activity in Kazakhstan in 2000–2025.....…590

**Beisenbayeva A., Kambarov B., Samenova N.**
Development of small and medium-sized enterprises in Almaty: ecosystem factors and structural dynamics…….....611

**Bekisheva A., Beketova K., Dorohova N.**
Human resource management practices and employee perceptions in Kazakhstan's civil service…….....629

**Bissenbayeva S., Kireyeva A., Zhumaxanova K.**
Digitalization, government support and innovation activity: evidence from regional analysis in Kazakhstan.....646

**Em O.L., Kim D.**
Features of risk management in collective investment…….....….665

**Ibrayeva A., Kenesheva G., Arynova Zh.**
Qualification mismatch in the labour market of an industrial region: a conceptual model and measurement mechanism…….....684

**Juman J., Mukhtarova K.S., Liao Z.**
The modern model of China's economic cooperation with Central Asian countries.…..701

**Karakulova A., Bakirbekova A., Zhangirova R.**
Improving the efficiency of digital transformation of agricultural enterprises: an empirical analysis of Kostanay region…….....718

**Kuralbayeva A.Sh., Issayeva G.K., Zhussipova E.E.**
Energy-saving technologies in irrigated agriculture of Southern Kazakhstan: economic and environmental effects…….....….734

**Naimanova Zh., Bakirbekova A., Kuralbayeva R.**
Digital inequality and agricultural productivity: evidence from Southern Kazakhstan....749

**Nartbayeva A., Dadabayeva D., Altuntas G.**
Economic resilience of single-industry towns in Kazakhstan: a dynamic analysis of socio-economic indicators…….....…….767

**Nurlanuly A., Petrovčiková K., Shalbolova U.Zh.**
Comparative analysis of aviation market development models in Kazakhstan and Slovakia.....785

**Nyshanbayeva U., Moldashbayeva L., Urazbayeva Z.**
Accounting and valuation of investment projects in digital tourism: an integrated approach…….....801

**Shegir G., Kerimova U., Kabi Sh.**
The transition of the agro-industrial complex of the Almaty region to the production of value-added products…….....819

**Shiganbayeva N., Razakova D., Orlowska R.**
Trade turnover between China and Kazakhstan in the context of contemporary analytical studies: factors, challenges, and risks…….....….840

**Tuzubekova M., Zhunusova A., Kadirova N.**
Analysis of SME support incentives in the manufacturing industry of the Republic of Kazakhstan…….....….857

**Yeraliyeva Ya., Ruziyeva E., Alimbekova B.**
Trend and structure of research on digital financial literacy: bibliometric approach…...877

**Zhassan G., Taibek Zh., Imanova G.**
Climate risk management in the banking sector: ESG-based global and Kazakhstani experience…….....891

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## ПЕДАГОГИКА

**Айтимбаев А.Т., Исаев М.С., Апендиев Т.А.**
Қазақстан тарихын жоғары оқу орындарында оқытуда архив материалдарын пайдаланудың ғылыми-әдістемелік мүмкіндіктері (1920–1950 жж. Оңтүстік Қазақстандағы саяси қуғын-сүргін құрбандары тағдырлары негізінде).....19

**Ахметова Г.С., Кабдушева А.Б., Мусина А.Б.**
Университет студенттерінің академиялық жазылымдағы қиындықтары мен оқу қажеттіліктеріне арналған сандық зерттеу.....40

**Ахметова Ж.А., Нұрғали С., Нурметова Д.**
Академиялық жазуды оқытуда сандық ресурстарды пайдаланудың педагогикалық негіздері…….....…. 57

**Бекболат Ж.Н., Жолмаханова А.Б., Сейфуллах Йылдырым**
Мұстафа Шоқай хаттарын зерттеушілік әдіс арқылы оқытудың теориялық негіздері….....72

**Берденкулова А.Ж., Жандавлетова Р.Б., Назарова Г.А.**
«Жайлы мектеп – қоғам – университет» серіктестігі негізінде білім сапасын арттырудың педагогикалық моделі…….....….88

**Ескендирова А.А., Касенова Н.Б., Ногоев Ю.Я.**
ЖИ арқылы жасалған мәтіндер мен кванттау технологиясы арқылы әзірленген мәтіндердің салыстырмалы талдауы.....104

**Жанысбекова Ш., Нурмаханова Ж., Акашева Ә.**
Прагматикалық құзіреттілікті қалыптастырудың өзекті мәселелері: контент-анализ нәтижелері бойынша зерттеу.....121

**Дүйсенова Г.А., Шындалиев Н.Т., Шадиев Р.Н.**
Дәстүрлі және виртуалды бағдарламалау білімінің салыстырмалы талдауы……136

**Зулпыхар Ж.Е., Капанова Д.Е., Жилмагамбетова Р.З.**
Педагогтердің кәсіби құзыреттілігін дамытудың негізі ретінде қазіргі заманғы ресурстар мен технологиялар…….....….153

**Исаева А.А., Ананьева С.В.**
К. Паустовский шығармашылығындағы Қазақстан тақырыбының аксиологиялық интерпретациясы: жоғары оқу орнында оқытудың әдіснамалық тәсілдері.....172

**Кабжалелов К.Р., Қорғанбаева Ж.Қ., Нурахметова А.Р.**
Химияны оқыту барысында заманауи чат-боттар арқылы сыни ойлауды дамыту…….....190

**Каженова Ж.С., Қыдыралина Л.М., Рахматуллина З.Т.**
Оқушылардың инженерлік дағдыларын дамыту мәселелері…….....208

**Калдарова А.К., Васкез М.А., Кульгильдинова Т.А.**
Студенттердің кәсіби-бағдарланған айтылым дағдыларын ChatGPT арқылы дамыту.....229

**Капбарова Г.Ш., Гюндогду А., Байдалиева Э.А.**
Тарихты оқыту әдістемесі: құзыреттілікке негізделген тәсілді қолданудың теориялық және практикалық негіздері…….....243

**Кожаханова Л., Амирова А.**
Бастауыш сынып оқушыларының медиасауаттылығын дамыту перспективалары.....260

**Кужагулова Г.Е., Сыдыкова Р.Ш., Смаилова М.С.**
Көру қабілеті бұзылған білім алушыларды қазақтың лирикалық әндері арқылы ұлттық құндылықтарға тәрбиелеудің ерекшеліктері…….....278

**Мархмадова Ж.Қ., Касымова Г.К., Өкенова Б.**
Педагог-психологтың цифрлық құзыреттілігін қалыптастыру және бағалаудың педагогикалық аспектілері…….....297

**Матеева М.А., Ералин Қ., Буркитбаев Т.**
Болашақ көркем еңбек мұғалімдерін өнертанымдық өлкетануға даярлау……318

**Маханов Н., Нишанова К.**
Музейлік білім беру негізінде оқушылардың танымдық құзыреттіліктерін дамыту (Оңтүстік Қазақстан мысалында)….....333

**Мырзагерейқызы Г., Ермекова Ж.К., Алджамбекова Г.Т.**
Болашақ физика мұғалімдерін оқушылардың функционалдық сауаттылығын дамытуға даярлауда action research пайдалану…….....348

**Регинбаева Н.А., Наметкулова Ф.Д.**
Болашақ әуе транспорты мамандарына физиканы STEM білім беру негізінде кәсіби-бағдарлы оқытудың әдістемелік негіздері.....365

**Серикбаева Н.Б., Орынбекова А.С., Туякова У.Ж.**
Қазіргі білім беруде педагог-психологтардың цифрлық құзыреттілігін дамыту әдістемесі…….....385

**Тойғанбекова М.Е., Қажиғалиева Г.А.**
Оқытудың тиімділігін арттыру үшін оқу мәтіндерін құру және нақтылау аспектілері…….....409

**Шегебаева Г.У., Жумашева Т.С., Нурбекова С.М.**
Болашақ тәрбиешілерді нутрициология негізінде денсаулық сақтау-білім беру ортасын құруға дайындаудың алғышарттары.....422

**Шишов С.Е., Иовбак А.С., Верко Е.А.**
Орта мектепте оқушылардың эксперименталдық қызметін ұйымдастыру құралы ретінде интеграцияланған модульді физика эксперименті…….....….443

## ЭКОНОМИКА

**Абдимолдаева А., Мадышева А., Жунусова Г.**
Цифрландыру жағдайында агроөнеркәсіптік кешендегі логистикалық шығындар есебін қайта құру…….....461

**Абуова Ж., Дүйскенова Р., Кадырбекова Д.**
Цифрлық трансформация және экологиялық басқару негізіндегі қонақ үй бизнесінің тұрақты даму тұжырымдамасы.....479

**Әшім Н., Джрауова К., Кушенова М.**
Ауылшаруашылығы субсидияларын басқаруды жетілдіру: Қызылорда облысы…494.

**Мұхит Амантай, Кенабекова М., Оралбаева Ж.**
Цифрландыру Қазақстанның экономикалық өсуінің драйвері ретінде: эконометрикалық талдау және құрылымдық әсерлер…….....511

**Асемова Р., Абдибеков С., Айтбаева Д.**
Ауылшаруашылығындағы энергия тиімділігі және инновациялар: Оңтүстік Қазақстан бойынша эмпирикалық дәлелдер…….....535

**Асанова Ж., Баймуханова С., Қонысбаева Г.**
Экологиялық есеп, ESG-есептілік және цифрландыру: шығындарды төмендетуге және орнықты дамуға әсері.....554

**Байгелова А., Садыкова Ж., Епанчинцева С.**
Қазақстандағы өнеркәсіп экономикасының трансформациясы: құрылымдық өзгерістер, цифрландыру және өнімділіктің өсуі.....571

**Бейсекова Ж., Муталиева А., Куншигарова Л.**
2000–2025 жылдары Қазақстандағы кәсіпкерлік қызметтің трансформациясы.....590

**Бейсенбаева А., Қамбаров Б., Саменова Н.**
Алматыда шағын және орта кәсіпкерлікті дамыту: экожүйелік факторлар және құрылымдық динамика…….....611

**Бекишева А., Бекетова К., Дорохова Н.**
Қазақстанның мемлекеттік қызметіндегі адам ресурстарын басқару тәжірибелері және қызметкерлердің қабылдауы…….....629

**Бисенбаева С., Киреева А., Жұмаксанова К.**
Цифрландыру, мемлекеттік қолдау және инновациялық белсенділік:
Қазақстан өңірлерінің талдауы.....646

**Эм О.Л., Ким Д.**
Ұжымдық инвестициялардағы тәуекелдерді басқарудың ерекшеліктері……..665

**Ибраева А., Кенешева Г., Арынова Ж.**
Өнеркәсіптік өңірдің еңбек нарығындағы біліктілік сәйкессіздігі:
тұжырымдамалық модель және өлшеу тетігі…….....….684

**Жұман Ж., Мұхтарова К.С., Ляо Чжан**
Қытайдың Орталық Азия елдерімен экономикалық ынтымақтастығының
заманауи моделі…….....701

**Қарақұлова А., Бакирбекова А., Жангирова Р.**
Ауыл шаруашылығы кәсіпорындарының цифрлық трансформациясының
тиімділігін арттыру: Қостанай облысының эмпирикалық талдауы…….....718

**Құралбаева А.Ш., Исаева Г.К., Жусипова Э.Е.**
Оңтүстік Қазақстанның суармалы ауыл шаруашылығындағы энергия үнемдеу
технологиялары: экономикалық және экологиялық тиімділік…….....734

**Найманова Ж., Бакирбекова А., Құралбаева Р.**
Цифрлық теңсіздік және ауыл шаруашылығының өнімділігі:
Оңтүстік Қазақстан деректері…….....749

**Нартбаева А., Дадабаева Д., Алтунташ Г.**
Қазақстан моноқалаларының экономикалық резилиенттілігі: әлеуметтік-
экономикалық көрсеткіштердің динамикалық талдауы…….....767

**Нұрланұлы А., Петровчикова К., Шалболова У.Ж.**
Қазақстан мен Словакияның авиациялық нарықтарының даму модельдерін
салыстырмалы талдау…….....….785

**Нышанбаева Ұ., Молдашбаева Л., Уразбаева З.**
Цифрлық туризмдегі инвестициялық жобаларды есепке алу және бағалау:
интеграцияланған тәсіл…….....….801

**Шегір Г., Керимова У., Қаби Ш.**
Алматы облысының агроөнеркәсіптік кешенінің қосылған құны бар өнім
өндіруге көшуі…….....819

**Шиганбаева Н., Разакова Д., Орловска Р.**
Қытай мен Қазақстан арасындағы тауар айналымы: факторлар, мәселелер
және тәуекелдер…….....….840

**Тузубекова М., Жунусова А., Кадирова Н.**
Қазақстан Республикасының өңдеу өнеркәсібіндегі шағын және орта бизнесті ынталандыруды талдау…….....….857

**Ералиева Я., Рузиева Э., Алимбекова Б.**
Цифрлық қаржылық сауаттылық бойынша зерттеулердің тенденциялары мен құрылымы: библиометриялық тәсіл…….....877

**Жасан Г.Ж., Тайбек Ж.Қ., Иманова Г.А.**
Банк секторындағы климаттық тәуекелдерді басқару: ESG негізіндегі әлемдік және қазақстандық тәжірибе.....891

## СОДЕРЖАНИЕ

## ПЕДАГОГИКА

**Айтимбаев А.Т., Исаев М.С., Апендиев Т.А.**
Научно-методические возможности использования архивных материалов при преподавании истории Казахстана в высших учебных заведениях (на примере судеб жертв политических репрессий в Южном Казахстане в 1920–1950 гг.).....19

**Ахметова Г.С., Кабдушева А.Б., Мусина А.Б.**
Количественное исследование проблем академического письма и образовательных потребностей студентов университета.....40

**Ахметова Ж.А., Нургали С., Нурметова Д.**
Педагогические основы использования цифровых ресурсов в обучении академическому письму…….....….57

**Бекболат Ж.Н., Жолмаханова А.Б., Сейфуллах Йылдырым**
Теоретические основы обучения письмам М. Шокая исследовательским методом.....72

**Берденкулова А.Ж., Жандавлетова Р.Б., Назарова Г.А.**
Педагогическая модель повышения качества образования на основе партнёрства «комфортная школа – общество – университет»…….....….88

**Дуйсенова Г.А., Шындалиев Н.Т., Шадиев Р.Н.**
Сравнительный анализ традиционного и виртуализированного обучения программированию…….....….104

**Ескендирова А.А., Касенова Н.Б., Ногоев Ю.Я.**
Сравнительный анализ текстов, созданных ИИ и текстов, разработанных с помощью технологии квантования.....121

**Жанысбекова Ш., Нурмаханова Ж., Акашева А.**
Актуальные проблемы формирования прагматической компетенции: исследование по результатам контент-анализа.....136

**Зулпыхар Ж.Е., Капанова Д.Е., Жилмагамбетова Р.З.**
Современные ресурсы и технологии как основа развития профессиональных компетенций педагогов…….....153

**Исаева А.А., Ананьева С.В.**
Аксиологическая интерпретация казахстанской тематики в творчестве К. Паустовского: методологические подходы к преподаванию в вузе.....172

**Кабжалелов К.Р., Корганбаева Ж.К., Нурахметова А.Р.**
Развитие критического мышления с помощью современных чат-ботов при обучении химии……190

**Каженова Ж.С., Кыдыралина Л.М., Рахматуллина З.Т.**
Проблемы развития инженерных навыков учащихся……208

**Калдарова А.К., Васкез М.А., Кульгильдинова Т.А.**
Развитие профессионально ориентированных навыков устной речи студентов с использованием ChatGPT.....229

**Капбарова Г.Ш., Гюндогду А., Байдалиева Э.А.**
Методика преподавания истории: теоретические и практические основы применения компетентностного подхода…….....243

**Кожаханова Л., Амирова А.**
Перспективы развития медиаграмотности среди учащихся начальной школы.....260

**Кужагулова Г.Е., Сыдыкова Р.Ш., Смаилова М.С.**
Особенности воспитания национальных ценностей у слабовидящих обучающихся через казахские лирические песни…….....278

**Мархмадова Ж.К., Касымова Г.К., Оценова Б.**
Педагогические аспекты формирования и оценки цифровой компетентности педагогов-психологов…….....297

**Матеева М.А., Ералин К., Буркитбаев Т.**
Подготовка будущих учителей художественного труда к искусствоведческому краеведению…….....318

**Маханов Н., Нишанова К.**
Развитие познавательных компетенций учащихся на основе музейного образования (на примере Южного Казахстана).....333

**Мырзагерейкызы Г., Ермекова Ж.К., Алджамбекова Г.Т.**
Использование action research в подготовке будущих учителей физики к развитию функциональной грамотности учащихся…….....348

**Регинбаева Н.А., Наметкулова Ф.Д.**
Методические основы профессионально-ориентированного обучения физике на основе STEM образования для будущих специалистов воздушного транспорта.....365

**Серикбаева Н.Б., Орынбекова А.С., Туякова У.Ж.**
Методика развития цифровой компетентности педагогов-психологов в современном образовании…….....385

**Тойганбекова М.Е., Кажигалиева Г.А.**
Аспекты создания и спецификации учебных текстов для повышения эффективности обучения…….....409

**Шегебаева Г.У., Жумашева Т.С., Нурбекова С.М.**
Предпосылки подготовки будущих воспитателей к созданию здоровьесберегающей образовательной среды на основе нутрициологии.....422

**Шишов С.Е., Иовбак А.С., Верко Е.А.**
Интегрированный модульный физический эксперимент как средство организации экспериментальной деятельности учащихся в средней школе…….....443

## ЭКОНОМИКА

**Абдимолдаева А., Мадышева А., Жунусова Г.**
Трансформация учета логистических затрат в агропромышленном комплексе в условиях цифровизации…….....461

**Абуова Ж., Дуйскенова Р., Кадырбекова Д.**
Концепция устойчивого развития гостиничного бизнеса на основе цифровой трансформации и экологического менеджмента…….....479

**Ашим Н., Джрауова К., Кушенова М.**
Совершенствование управления агросубсидиями: Кызылординская область…….....494

**Мухит Амантай, Канабекова М., Оралбаева Ж.**
Цифровизация как драйвер экономического роста Казахстана: эконометрический анализ и структурные эффекты…….....511

**Асемова Р., Абдибеков С., Айтбаева Д.**
Энергоэффективность и инновации в сельском хозяйстве: эмпирические данные Южного Казахстана…….....535

**Асанова Ж., Баймуханова С., Конысбаева Г.**
Экологический учет, ESG-отчетность и цифровизация: влияние на снижение издержек и устойчивое развитие.....554

**Байгелова А., Садыкова Ж., Епанчинцева С.**
Трансформация промышленной экономики Казахстана: структурные сдвиги, цифровизация и рост производительности.....571

**Бейсекова Ж., Муталиева А., Куншигарова Л.**
Трансформация предпринимательской деятельности в Казахстане в 2000–2025 годах.....590

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**Бейсенбаева А., Камбаров Б., Саменова Н.**
Развитие малого и среднего предпринимательства в Алматы: экосистемные факторы и структурная динамика…….....611

**Бекишева А., Бекетова К., Дорохова Н.**
Практики управления человеческими ресурсами и восприятие сотрудников в государственной службе Казахстана…….....629

**Бисенбаева С., Киреева А., Жумаксанова К.**
Цифровизация, государственная поддержка и инновационная активность: региональный анализ Казахстана.....646

**Эм О.Л., Ким Д.**
Особенности управления рисками в сфере коллективных инвестиций…….....665

**Ибраева А., Кенешева Г., Арынова Ж.**
Несоответствие квалификации на рынке труда промышленного региона: концептуальная модель и механизм измерения…….....684

**Жуман Ж., Мухтарова К.С., Ляо Чжан**
Современная модель экономического сотрудничества Китая со странами Центральной Азии…….....701

**Каракулова А., Бакирбекова А., Жангирова Р.**
Повышение эффективности цифровой трансформации сельскохозяйственных предприятий: эмпирический анализ Костанайской области…….....718

**Куралбаева А.Ш., Исаева Г.К., Жусипова Э.Е.**
Энергосберегающие технологии в орошаемом сельском хозяйстве Южного Казахстана: экономические и экологические эффекты…….....734

**Найманова Ж., Бакирбекова А., Куралбаева Р.**
Цифровое неравенство и продуктивность сельского хозяйства: данные из Южного Казахстана…….....749

**Нартбаева А., Дадабаева Д., Алтунташ Г.**
Экономическая резилиентность моногородов Казахстана: динамический анализ социально-экономических показателей…….....767

**Нурланулы А., Петровчикова К., Шалболова У.Ж.**
Сравнительный анализ моделей развития авиационных рынков Казахстана и Словакии…….....785

**Нышанбаева У., Молдашбаева Л., Уразбаева З.**
Учет и оценка инвестиционных проектов в цифровом туризме: интегрированный подход…….....801

**Шегир Г., Керимова У., Каби Ш.**
Переход агропромышленного комплекса Алматинской области к производству продукции с добавленной стоимостью…….....….819

**Шиганбаева Н., Разакова Д., Орловска Р.**
Товарооборот Китая и Казахстана: факторы, проблемы и риски…….....….840

**Тузубекова М., Жунусова А., Кадирова Н.**
Анализ стимулирования малого и среднего бизнеса в обрабатывающей промышленности Республики Казахстан…….....….857

**Ералиева Я., Рузиева Э., Алимбекова Б.**
Тенденции и структура исследований цифровой финансовой грамотности: библиометрический подход…….....….877

**Жасан Г.Ж., Тайбек Ж.Қ., Иманова Г.А.**
Управление климатическими рисками в банковском секторе: стандарты ESG в мировом и казахстанском опыте.....891

SCIENTIFIC JOURNAL OF PEDAGOGY AND ECONOMICS
ISSN 1991-3494
Volume 2.
Number 420 (2026), 554-570

***https://doi.org/10.32014/2026.2518-1467.1174***

UDC 657:502.131:004:330.131.7
IRSTI 06.73.15

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[1]Al-Farabi Kazakh National university, Almaty, Kazakhstan;
[2]Zhetysu University named after I. Zhansugurov, Taldykorgan, Kazakhstan.
E-mail: asanovazanna549@gmail.com

# ENVIRONMENTAL ACCOUNTING, ESG REPORTING AND DIGITALIZATION: IMPACT ON COST REDUCTION AND SUSTAINABLE DEVELOPMENT (USING THE EXAMPLE OF KAZAKHSTAN)

**Assanova Zhanna** — PhD student, Al-Farabi Kazakh National university, Almaty, Kazakhstan,
E-mail: asanovazanna549@gmail.com, ORCID: https://orcid.org/0000-0001-8244-9677;
**Baimukhanova Sariya** — Doctor of Economics, Professor, Al-Farabi Kazakh National University, Almaty, Kazakhstan,
E-mail: sariya.Baymukhanova@gmail.com, ORCID: https://orcid.org/0000-0002-9128-4891;
**Konysbaeva Gulvira** — Master of Economic Sciences, Zhetysu University named after I. Zhansugurov, Taldykorgan, Kazakhstan,
E-mail: konysbayeva.gulvira@mail.ru, ORCID: https://orcid.org/0000-0002-7104-7522.

**Abstract.** This study is devoted to the analysis of the relationship between environmental accounting, the environmental audit system and ESG reporting in the context of improving the efficiency and sustainable development of enterprises in the Republic of Kazakhstan. With the strengthening of the global environmental agenda and the transition to a green economy, the integration of environmental and managerial factors into the corporate governance system is becoming particularly important, especially for emerging markets. The empirical base of the study is based on panel data on 50 enterprises of key sectors of the economy of Kazakhstan for the period 2020-2025. Fixed-effect panel regression models supplemented by nonlinear specifications, mediation and interactive analysis, as well as a system of diagnostic tests were used as methodological tools. The share of environmental and logistical costs is considered as a dependent variable, and the key explanatory factors are the ESG index, the environmental audit index, the level of digitalization, and control variables. The results of the study show that the introduction of ESG practices and the development of an environmental audit system have a statistically significant impact on cost reduction. It was found that an increase in the ESG index

by 0.1 is accompanied by a decrease in costs by an average of 0.34 percentage points. Nonlinear effects and the effect of the threshold value of ESG ≈ 0.5 have been identified, after which the effectiveness of sustainable practices increases significantly. It has also been established that digitalization is a key mediation factor that enhances the influence of ESG, and the interaction of ESG and digital technologies forms a pronounced synergetic effect. The results obtained confirm that ESG should be considered not as an additional burden, but as a strategic tool for increasing business efficiency and sustainability.

**Keywords:** environmental accounting, ESG reporting; environmental audit, sustainable development, digitalization, logistical costs, panel analysis, Kazakhstan

*For citations: Assanova Zh., Baimukhanova S., Konysbaeva G. Environmental accounting, esg reporting and digitalization: impact on cost reduction and sustainable development (using the example of Kazakhstan). Scientific journal of pedagogy and economics, 2026. — No.2. — P. 554-570. DOI: https://doi.org/10.32014/2026.2518-1467.1174*

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[1]Әл-Фараби атындағы Қазақ ұлттық университеті, Алматы, Қазақстан;
[2] І. Жансүгіров атындағы Жетісу университеті, Талдықорған, Қазақстан.
E-mail: asanovazanna549@gmail.com

## ЭКОЛОГИЯЛЫҚ ЕСЕП, ESG-ЕСЕПТІЛІК ЖӘНЕ ЦИФРЛАНДЫРУ: ШЫҒЫНДАРДЫ ТӨМЕНДЕТУГЕ ЖӘНЕ ОРНЫҚТЫ ДАМУҒА ӘСЕРІ (ҚАЗАҚСТАН МЫСАЛЫНДА)

**Асанова Жанна** — PhD докторант, Әл-Фараби атындағы Қазақ ұлттық университеті, Алматы, Қазақстан,
E-mail: asanovazanna549@gmail.com, ORCID: https://orcid.org/0000-0001-8244-9677;
**Баймуханова Сария** — э.ғ.д., профессор, Әл-Фараби атындағы Қазақ ұлттық университеті, Алматы, Қазақстан,
E-mail:sariya.Baymukhanova@gmail.com, ORCID: https://orcid.org/0000-0002-9128-4891;
**Қонысбаева Гульвира** — э.ғ.м., І. Жансүгіров атындағы Жетісу университеті, Талдықорған, Қазақстан,
E-mail: konysbayeva.gulvira@mail.ru, ORCID: https://orcid.org/0000-0002-7104-7522.

**Аннотация.** Осы зерттеу Қазақстан Республикасы кәсіпорындарының тиімділігі мен орнықты дамуын арттыру контекстінде экологиялық есепке алу, экологиялық аудит жүйесі мен ESG-есептілік арасындағы өзара байланысты талдауға арналған. Жаһандық Экологиялық күн тәртібінің күшеюі және "жасыл" экономикаға көшу жағдайында экологиялық және басқару факторларын корпоративтік басқару жүйесіне интеграциялау, әсіресе дамушы нарықтары бар елдер үшін ерекше маңызға ие болады. Зерттеудің эмпирикалық базасы 2020-2025 жылдар кезеңінде Қазақстан

экономикасының негізгі салаларының 50 кәсіпорны бойынша панельдік деректер негізінде қалыптастырылды. Әдіснамалық құрал ретінде сызықтық емес ерекшеліктермен, медиациялық және интеракциялық талдаумен, сондай-ақ диагностикалық тесттер жүйесімен толықтырылған тіркелген әсерлері бар панельдік регрессия модельдері пайдаланылды. Тәуелді айнымалы ретінде экологиялық және логистикалық шығындардың үлесі қарастырылады, ал негізгі түсіндіруші факторлар ESG индексі, экологиялық аудит индексі, цифрландыру деңгейі және бақылау айнымалылары болып табылады. Зерттеу нәтижелері ESG тәжірибелерін енгізу және экологиялық аудит жүйесін дамыту шығындарды азайтуға статистикалық маңызды әсер ететінін көрсетеді. ESG-индексінің 0.1-ге артуы шығындардың орта есеппен 0.34 пайыздық тармаққа төмендеуімен қатар жүретіні анықталды. Сызықтық емес әсерлер және ESG ≈ 0.5 шекті мәнінің әсері анықталды, оған қол жеткізгеннен кейін тұрақты тәжірибелердің тиімділігі айтарлықтай артады. Сондай-ақ, цифрландыру ESG әсерін күшейтетін негізгі медиациялық фактор ретінде әрекет ететіні анықталды, ал ESG және цифрлық технологиялардың өзара әрекеттесуі айқын синергетикалық әсерді қалыптастырады. Нәтижелер ESG қосымша жүктеме ретінде емес, бизнестің тиімділігі мен тұрақтылығын арттырудың стратегиялық құралы ретінде қарастырылуы керек екенін растайды.

**Түйін сөздер:** экологиялық есеп, ESG-есептілік, экологиялық аудит, тұрақты даму, цифрландыру, логистикалық шығындар, панельдік талдау, Қазақстан

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[1]Казахский национальный университет им. аль-Фараби, Алматы, Казахстан;
[2]Жетысуский университет имени И. Жансугурова, Талдыкорган, Казахстан.
E-mail: asanovazanna549@gmail.com

## ЭКОЛОГИЧЕСКИЙ УЧЕТ, ESG-ОТЧЕТНОСТЬ И ЦИФРОВИЗАЦИЯ: ВЛИЯНИЕ НА СНИЖЕНИЕ ИЗДЕРЖЕК И УСТОЙЧИВОЕ РАЗВИТИЕ (НА ПРИМЕРЕ КАЗАХСТАНА)

**Асанова Жанна** — докторант PhD, Казахский национальный университет им. аль-Фараби, Алматы, Казахстан,
E-mail: asanovazanna549@gmail.com, ORCID: https://orcid.org/0000-0001-8244-9677;
**Баймуханова Сария** —д.э.н., профессор, Казахский национальный университет имени Аль-Фараби, Алматы, Казахстан,
E-mail: sariya.Baymukhanova@gmail.com, ORCID: https://orcid.org/0000-0002-9128-4891;
**Конысбаева Гульвира** — м.э.н., Жетысуский университет имени И. Жансугурова, Талдыкорган, Казахстан,
E-mail: konysbayeva.gulvira@mail.ru, ORCID: https://orcid.org/0000-0002-7104-7522.

**Аннотация.** Настоящее исследование посвящено анализу взаимосвязи между экологическим учетом, системой экологического аудита и ESG-

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отчетностью в контексте повышения эффективности и устойчивого развития предприятий Республики Казахстан. В условиях усиления глобальной экологической повестки и перехода к «зеленой» экономике интеграция экологических и управленческих факторов в систему корпоративного управления приобретает особую значимость, особенно для стран с формирующимися рынками. Эмпирическая база исследования сформирована на основе панельных данных по 50 предприятиям ключевых отраслей экономики Казахстана за период 2020–2025 гг. В качестве методологического инструментария использованы модели панельной регрессии с фиксированными эффектами, дополненные нелинейными спецификациями, медиирующим и интеракционным анализом, а также системой диагностических тестов. В качестве зависимой переменной рассматривается доля экологических и логистических издержек, а ключевыми объясняющими факторами выступают ESG-индекс, индекс экологического аудита, уровень цифровизации и контрольные переменные. Результаты исследования показывают, что внедрение ESG-практик и развитие системы экологического аудита оказывают статистически значимое влияние на снижение издержек. Установлено, что увеличение ESG-индекса на 0.1 сопровождается снижением издержек в среднем на 0.34 процентных пункта. Выявлены нелинейные эффекты и эффект порогового значения ESG ≈ 0.5, после достижения которого эффективность устойчивых практик существенно возрастает. Также установлено, что цифровизация выступает ключевым медиирующим фактором, усиливающим влияние ESG, а взаимодействие ESG и цифровых технологий формирует выраженный синергетический эффект. Полученные результаты подтверждают, что ESG следует рассматривать не как дополнительную нагрузку, а как стратегический инструмент повышения эффективности и устойчивости бизнеса.

**Ключевые слова:** экологический учет, ESG-отчетность, экологический аудит, устойчивое развитие, цифровизация, логистические издержки, панельный анализ, Казахстан

**Introduction.** In the context of global environmental transformation and increasing demands for sustainable development, the issues of integrating environmental aspects into the corporate governance system are becoming particularly relevant. The modern economic paradigm is shifting from the traditional model of profit maximization to the concept of sustainable development, which takes into account environmental, social and managerial factors (ESG). In this regard, environmental accounting and the environmental audit system are becoming key tools for ensuring transparency, accountability and effectiveness of environmental activities of organizations. Environmental accounting is a systematic process of identifying, measuring, and reflecting the environmental costs, obligations, and performance of an enterprise. Its development is driven by the need for internal

environmental impact control, as well as external requirements from investors, regulators, and society. In turn, environmental audit acts as a mechanism for independent assessment of the compliance of business activities with environmental standards, regulations and principles of sustainable development.

For the Republic of Kazakhstan, these processes are of strategic importance in the context of the transition to a "green economy", decarbonization and integration into international financial and investment markets. In recent years, the country has been paying increasing attention to ESG reporting issues, which is related both to obligations under international agreements and to the need to increase the investment attractiveness of national companies. However, the current practice of environmental accounting and auditing is characterized by fragmentation, insufficient institutionalization and a limited degree of standardization. Despite the existence of separate regulatory legal acts regulating environmental activities, there is no single methodological framework that ensures the integrated integration of environmental accounting into the corporate reporting system. In addition, the level of implementation of ESG principles in Kazakhstani companies remains heterogeneous, which makes it difficult to compare data and reduces the effectiveness of management decisions.

The purpose of this study is to develop the theoretical and methodological foundations for the formation of an environmental accounting and environmental audit system in the Republic of Kazakhstan, taking into account the principles of ESG reporting and sustainable development. The research is expected to:

– analyze theoretical approaches to environmental accounting and auditing;

– to assess the current state and institutional features of their development in Kazakhstan;

– identify key issues and limitations;

– to propose ways to improve the system, taking into account international experience and the ESG agenda.

The scientific novelty of the research lies in the comprehensive consideration of environmental accounting and auditing as interrelated elements of a sustainable corporate governance system, as well as in the development of an integration model aimed at increasing transparency and efficiency of environmental reporting in Kazakhstan.

**Literature Review.** Contemporary research in environmental accounting and ESG reporting is situated at the intersection of sustainable development theory, corporate governance, and environmental economics. The academic literature demonstrates a growing interest in integrating environmental factors into financial and managerial accounting systems, driven by increasing global environmental challenges and the transformation of corporate reporting requirements.

In recent years, this field has evolved toward the concept of integrated reporting, which combines financial and non-financial information into a unified system for assessing corporate performance and long-term value creation (Eccles and Krzus,

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2018). Integrated reporting is increasingly viewed as a strategic tool that allows companies to align sustainability objectives with financial performance and investor expectations, thereby enhancing long-term value creation.

One of the key research directions is the development of environmental accounting as a tool for assessing environmental costs and the impact of economic activities on the environment. Recent studies emphasize that environmental accounting enhances corporate transparency, improves managerial decision-making, and contributes to the formation of sustainable business models. In particular, empirical evidence suggests that environmental accounting and auditing systems enable more efficient management of environmental protection expenditures and help minimize ecological risks (Korabayev et al., 2023). Environmental management accounting further extends this approach by focusing on internal decision-making processes, enabling firms to identify hidden environmental costs and improve resource allocation efficiency (Schaltegger and Burritt, 2010).

From the perspective of stakeholder theory, environmental accounting is also considered a mechanism for balancing the interests of various stakeholders, including investors, regulators, and society, thereby increasing corporate accountability and legitimacy (Freeman, 1984). Complementary to this, legitimacy theory suggests that companies disclose environmental information to maintain social acceptance and respond to institutional pressures, particularly in environmentally sensitive industries (Suchman, 1995).

An important component of the current academic discourse is environmental auditing, which is viewed as a mechanism for monitoring and evaluating environmental performance. Empirical studies confirm that the implementation of environmental auditing contributes to reducing pollution levels, improving resource efficiency, and strengthening economic sustainability. For instance, analyses of Kazakhstan's practice indicate that environmental auditing significantly contributes to "green" economic growth, while also revealing institutional constraints such as an underdeveloped regulatory framework and a shortage of qualified specialists (Kyzdarbekova et al., 2025). Environmental auditing is also increasingly integrated into corporate risk management systems, where it helps identify environmental liabilities and ensures compliance with international environmental standards (Gray et al., 1996).

Parallel to this, research on ESG (Environmental, Social, and Governance) has been actively developing as an integrative platform for sustainable development. International literature demonstrates that ESG factors are becoming a key element of investment analysis and corporate strategy. In particular, studies show that mandatory ESG disclosure contributes to reducing the cost of capital and enhancing firms' investment attractiveness (Krueger et al., 2024). Moreover, ESG disclosure is increasingly linked to capital market outcomes, as investors incorporate sustainability risks into valuation models and portfolio allocation decisions (Eccles et al., 2014).

Meta-analytical evidence further confirms a positive relationship between ESG performance and financial outcomes, indicating that sustainability-oriented companies tend to demonstrate higher long-term profitability and lower risk (Friede et al., 2015). Recent studies also highlight that firms with high ESG ratings exhibit greater resilience to economic shocks, including financial crises and environmental disruptions (Zhou et al., 2022).

In the context of Kazakhstan, ESG research is at an active stage of development. Existing studies indicate that the adoption of ESG principles is becoming an important factor in improving the competitiveness of the national economy and attracting investment. Companies that integrate ESG practices demonstrate higher resilience, improved reputation, and a greater ability to adapt to global challenges (Uspanova et al., 2024). However, ESG implementation remains constrained by institutional weaknesses, including limited regulatory enforcement, insufficient methodological guidance, and low awareness among companies.

Special attention is also given to empirical studies examining the impact of ESG on environmental performance. For example, Adambekova (2025) identifies a statistically significant relationship between the implementation of ESG strategies and the reduction of pollutant emissions, confirming the effectiveness of integrating environmental, social, and governance factors into corporate management systems. These findings are consistent with the Porter hypothesis, which suggests that environmental regulation and sustainability-oriented innovations can enhance both environmental and economic performance (Porter and Van der Linde, 1995).

Additional studies highlight the role of ESG reporting as a tool for increasing business transparency. Analytical reports indicate that ESG disclosure in Kazakhstan is growing; however, the level of standardization and completeness remains limited. For instance, approximately 54% of large companies disclose ESG risks and targets, indicating the gradual institutionalization of sustainability reporting (PwC, 2024). At the same time, the problem of greenwashing remains significant, as companies may disclose selective or biased information to create a positive environmental image without substantive changes in performance (Delmas and Burbano, 2011).

From the perspective of international standards, key frameworks such as the Global Reporting Initiative (GRI), the Sustainability Accounting Standards Board (SASB), and IFRS Sustainability Disclosure Standards play a central role in the development of ESG reporting. These systems establish unified approaches to non-financial disclosure and ensure global comparability of data. In turn, the OECD emphasizes the importance of responsible business conduct and the integration of ESG principles into infrastructure and investment projects as a foundation for sustainable economic development. The recent introduction of IFRS Sustainability Disclosure Standards (ISSB, 2023) marks a significant step toward the harmonization of global ESG reporting practices and the integration of sustainability information into mainstream financial reporting.

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Despite significant progress, several unresolved issues remain in the literature. First, there is no unified methodology for integrating environmental accounting into ESG reporting systems. Second, the problem of "greenwashing" persists, reducing trust in non-financial disclosures. Third, developing countries, including Kazakhstan, face institutional fragmentation and insufficient integration of environmental and financial systems. In addition, there is a lack of empirical research focusing on the interaction between environmental accounting, ESG reporting, and corporate financial performance in transition economies.

Thus, the literature review demonstrates that environmental accounting, environmental auditing, and ESG reporting are interconnected elements of a unified system of sustainable management. Their integration enhances both environmental and economic efficiency and supports long-term sustainability. However, for Kazakhstan, the key challenge remains the development of a comprehensive institutional framework that ensures the effective integration of these instruments. This underlines the need for developing integrated models that combine accounting, auditing, and ESG analytics in order to improve transparency, decision-making quality, and sustainable economic development outcomes.

**Materials and Methods.** The methodological framework of the study is based on an interdisciplinary approach integrating the principles of sustainable development theory, environmental economics, and institutional theory. Within this framework, environmental accounting, environmental auditing systems, and ESG reporting are considered as interrelated elements of a unified system of sustainable corporate governance, affecting both cost structures and environmental and economic performance. This perspective allows costs to be interpreted not only as an accounting category but also as an indicator of institutional and technological efficiency.

The empirical base of the study is constructed using panel data for 50 large and medium-sized enterprises in the Republic of Kazakhstan over the period 2020–2025. The sample covers key sectors with high environmental impact, including extractive industries, energy, agriculture, manufacturing, and transport and logistics. This sectoral coverage ensures the consideration of structural heterogeneity in ESG adoption and environmental auditing practices.

Data sources include the Bureau of National Statistics of the Republic of Kazakhstan, annual and ESG reports of companies, data from the Kazakhstan Stock Exchange (KASE), international ESG disclosure databases, as well as analytical reports from PwC and OECD. To ensure comparability, all variables were normalized and transformed into a unified scale. The final dataset represents a balanced panel ($N = 50$; $T = 6$; 300 observations).

Descriptive statistics confirm sufficient variability of key variables, supporting the validity of subsequent econometric analysis.

Table 1 — Descriptive Statistics

| Variable | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| LC | 16.2 | 2.1 | 12.9 | 19.8 |
| ESG | 0.48 | 0.14 | 0.28 | 0.72 |
| EAI | 0.44 | 0.13 | 0.25 | 0.68 |
| DIG | 0.55 | 0.12 | 0.38 | 0.75 |
| INV | 20.4 | 4.8 | 12.3 | 29.5 |
| SIZE | 5.3 | 0.4 | 4.8 | 5.9 |
| ENERGY | 1.34 | 0.15 | 1.12 | 1.60 |

The dependent variable is $LC$ (Logistics and Environmental Cost Share), reflecting the share of environmental and logistics costs in total production costs, including environmental protection expenditures, ecological payments, waste management, and energy-saving measures.

The key explanatory variables are the ESG Index ($ESG$) and the Environmental Audit Index ($EAI$), capturing the level of non-financial disclosure and the degree of institutionalization of environmental control, respectively.

The model also includes a set of control variables: investment ($INV$), firm size ($SIZE$), energy intensity ($ENERGY$), digitalization level ($DIG$), and regional dummy variables.

To estimate the impact of ESG factors and environmental auditing, a panel regression model with fixed effects is applied:

$$LC_{it} = \alpha + \beta_1 ESG_{it} + \beta_2 EAI_{it} + \beta_3 DIG_{it} + \beta_4 INV_{it} + \\ + \beta_5 SIZE_{it} + \beta_6 ENERGY_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

where $i$ denotes the enterprise, $t$ represents the time period, $\mu_i$ captures individual fixed effects, $\lambda_t$ reflects time effects, and $\varepsilon_{it}$ is the error term.

Within this framework, the following hypotheses are tested:

• higher levels of ESG disclosure reduce the share of environmental costs;

• (ii) the development of environmental auditing systems optimizes cost structures;

• (iii) digitalization amplifies the effects of ESG and auditing by enhancing transparency and process efficiency.

Model estimation is conducted using the fixed effects estimator, with the choice supported by the Hausman test. To ensure statistical robustness, diagnostic tests are performed, including the Breusch–Pagan test for heteroskedasticity, variance inflation factors (VIF) for multicollinearity, and autocorrelation tests. Standard errors are adjusted using clustering at the firm level.

Additionally, robust estimators and alternative model specifications, including lagged variables, are employed to improve the reliability of results and partially address potential endogeneity issues.

Composite indices for ESG and environmental auditing are constructed through normalization and weighted aggregation:

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$$Index = \sum w_i \cdot x_i$$

Despite the comprehensive approach, the study has several limitations, including restricted availability of ESG data, differences in disclosure methodologies, and potential endogeneity. Nevertheless, the use of panel methods, an extended set of variables, and robust estimation techniques ensures the validity and reproducibility of the results.

**Results.** An empirical analysis of the indicators for the period 2020-2025 indicates the formation of a stable and structurally significant growth trend in the implementation of ESG practices and the development of an environmental audit system in Kazakhstan, accompanied by a simultaneous reduction in the share of environmental and logistical costs. This dynamic reflects not only quantitative changes, but also a qualitative transformation of enterprise management models, characterized by the transition to integrated, digital, and resource-efficient strategies.

An analysis of the dynamics of key indicators shows that the level of the ESG index has more than doubled, from 0.32 in 2020 to 0.66 in 2025, which indicates the accelerated institutionalization of sustainable practices and the expansion of non-financial reporting. At the same time, the share of environmental costs decreased by 4.5 percentage points, which indicates an increase in resource efficiency and a reduction in operating losses.

Table 2 — Dynamics of key indicators (average values for the sample)

| Year | LC (%) | ESG Index | EAI | Digital Index | Investments (billion tenge) |
|---|---|---|---|---|---|
| 2020 | 18.4 | 0.32 | 0.28 | 0.41 | 1250 |
| 2021 | 17.6 | 0.38 | 0.35 | 0.45 | 1380 |
| 2022 | 16.9 | 0.44 | 0.42 | 0.52 | 1560 |
| 2023 | 15.8 | 0.51 | 0.48 | 0.58 | 1720 |
| 2024 | 14.7 | 0.59 | 0.55 | 0.64 | 1890 |
| 2025 | 13.9 | 0.66 | 0.63 | 0.71 | 2050 |

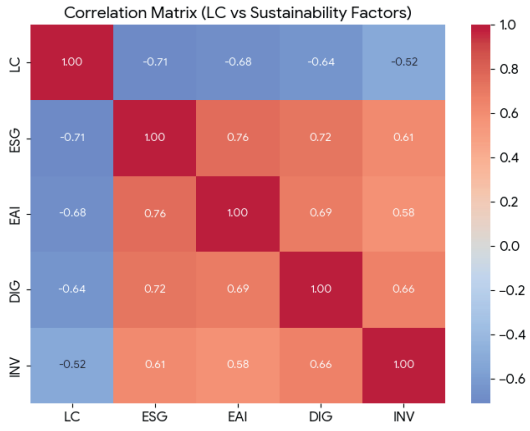


Figure 1 – Correlation matrix

The results demonstrate a pronounced negative relationship between LC and ESG, which indicates the systemic impact of sustainable management on cost reduction. At the same time, the high positive correlation between ESG, digitalization, and investment indicates the presence of a complementarity effect, in which the combined impact of factors exceeds their individual impact.

Regression analysis with fixed effects makes it possible to quantify the influence of factors.

Table 3 — Regression Results (Fixed Effects Model)

| Variable | Coefficient (β) | Std. Error | p-value |
|---|---|---|---|
| ESG | -3.42 | 0.58 | 0.000 |
| EAI | -2.87 | 0.64 | 0.001 |
| DIG | -1.95 | 0.72 | 0.006 |
| INV | -0.84 | 0.31 | 0.011 |
| SIZE | -0.56 | 0.27 | 0.039 |
| ENERGY | 2.14 | 0.49 | 0.000 |
| Constant | 24.87 | 2.91 | 0.000 |

$R^2 = 0.87$; Adjusted $R^2 = 0.84$; F-statistic = 32.6 ($p < 0.001$)

The results confirm that ESG and environmental audit are key cost-cutting factors. In particular, an increase in the ESG index by 0.1 leads to a decrease in LC by 0.34 percentage points, which indicates a high-cost sensitivity to sustainable practices. This indicates that ESG functions as a tool to increase efficiency, rather than as an additional burden on the business.

For a deeper understanding of the nature of this influence, the nonlinear specification of the model was evaluated, which makes it possible to identify possible scale effects and thresholds.

Table 4 — Nonlinear model

| Variable | Coefficient | p-value |
|---|---|---|
| ESG | -5.21 | 0.000 |
| $ESG^2$ | 2.08 | 0.021 |

As follows from the results, the coefficients for ESG and ESG2 are statistically significant, which confirms the presence of a nonlinear relationship. A positive coefficient value with a quadratic term indicates the formation of an effect of increasing returns: as the ESG increases, its effect on cost reduction increases. This allows us to interpret ESG as an accumulative efficiency factor, in which institutional and technological advantages are realized only after reaching a certain level of maturity.

Developing this interpretation, an analysis of the mechanisms of transmission of the ESG effect was further carried out, in which special attention was paid to the role of digitalization as an intermediate link.

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Table 5 – Mediation effect

| Link | **Coefficient** | **p-value** |
|---|---|---|
| ESG → DIG | 0.62 | 0.000 |
| DIG → LC | -1.95 | 0.006 |

The presented results indicate the presence of a statistically significant mediation effect: ESG has a positive impact on the level of digitalization, which, in turn, helps to reduce costs. Thus, ESG reduces LC not only directly, but also indirectly through the digital transformation of processes. This highlights the importance of integrating sustainable and digital strategies within a single management model.

Given the identified role of digitalization, it is logical to assume that the ESG effect may increase with a higher level of technological development. To test this hypothesis, a model with an interactive member was evaluated.

Table 6 – Interactive model

| Variable | Coefficient | p-value |
|---|---|---|
| ESG × DIG | -1.28 | 0.004 |

The negative and statistically significant coefficient for the interaction variable confirms the existence of a synergistic effect: the impact of ESG on cost reduction increases as the level of digitalization increases. This means that digital technologies not only complement ESG practices, but also enhance their effectiveness through automation, increased transparency, and improved control over resources.

Further analysis was aimed at identifying the heterogeneity of ESG effects depending on the characteristics of enterprises, which makes it possible to assess the sustainability of results in various institutional and industrial conditions.

Table 7 – Heterogeneity of effects

| Group of Enterprises | LC reduction (%) |
|---|---|
| Large ones | 20–22 |
| Medium | 12–15 |
| ESG > 0.6 | 18–22 |
| Capital intensive | up to 25 |

The results show that the effect of ESG varies significantly depending on the scale and structure of enterprises. The most pronounced reduction in costs is observed among large and capital-intensive companies, which indicates the presence of economies of scale and differences in access to financial and technological resources. It also confirms that the implementation of ESG practices requires a certain level of institutional and investment maturity.

In addition to the structural heterogeneity, the temporal stability of the identified effects is an important aspect. A model with an ESG lag variable was used to estimate it.

Table 8 – Lag model

| Variable | Coefficient | p-value |
|---|---|---|
| $ESG_{-1}$ | -1.87 | 0.008 |

The results show that the ESG values in the previous period have a significant impact on the current cost level. This indicates the presence of a cumulative effect and confirms the long-term nature of the impact of ESG practices. Thus, the effect of sustainable management is not instantaneous, but is formed gradually in the process of institutional development.

To quantify the economic significance of the ESG transition, a scenario analysis was conducted to compare the actual and potential cost values.

Table 9 – Scenario analysis

| The script | LC (%) | Change | Savings |
|---|---|---|---|
| Basic | 24 | - | - |
| ESG=0.7 | 19 | -5 percentage points. | ~2 billion tenge |

The results of the scenario modeling show that achieving a higher level of ESG can reduce costs by 5 percentage points. In absolute terms, this corresponds to significant resource savings, reaching up to 2 billion tenge per enterprise, which underlines the practical importance of implementing sustainable practices.

Finally, diagnostic tests were performed to confirm the reliability of the results obtained, assessing the correctness of the model specification.

Table 10 – Diagnostic tests

| Test | Result |
|---|---|
| Hausman | $p < 0.01$ |
| VIF | $< 3$ |
| Breusch–Pagan | there is no heteroskedasticity |
| Durbin–Watson | $\approx 2.1$ |

The test results confirm the correctness of the chosen model: the Haussmann test justifies the use of fixed effects, low VIF values indicate the absence of multicollinearity, and tests for heteroscedasticity and autocorrelation do not reveal violations. This allows us to conclude that the estimates obtained are highly reliable and stable.

**Discussion.** The results obtained make it possible to deepen understanding of the role of environmental accounting, ESG reporting and the environmental audit system in improving the efficiency and sustainability of enterprises. In contrast to the traditional approach, which assumes an increase in costs when implementing environmental practices, the results of this study demonstrate an inverse relationship: strengthening ESG and environmental audit helps reduce the share of environmental and logistical costs. This conclusion is consistent with the results of international studies, which emphasize that ESG factors can reduce the

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cost of capital and increase the operational efficiency of companies. In particular, Krueger P. and the co-authors show that mandatory disclosure of ESG information leads to increased transparency and reduced information asymmetry, which, in turn, improves the financial performance of companies (Krueger et al., 2024). The coefficients obtained in this study also confirm that an increase in the ESG index has a statistically significant negative impact on the cost level, which indicates its economic effectiveness.

The results also correlate with the theoretical provisions of the resource-based approach (resource-based view), according to which environmental and management practices can be considered as strategic resources that form competitive advantages. In the works of Porter M. E. and Van der Linde C. It is proved that environmental innovations can simultaneously reduce costs and increase productivity (Porter and Van der Linde, 1995). In the context of Kazakhstan, this hypothesis is empirically confirmed: enterprises implementing ESG and auditing demonstrate more efficient use of resources and reduced losses. Of particular importance in the study is the impact of environmental audit. The results obtained confirm that the development of the audit system helps to optimize environmental costs and reduce risks. This is consistent with the findings of studies conducted in developing economies, where environmental auditing is seen as a tool for institutional control and increased environmental responsibility (Kyzdarbekova et al., 2025). At the same time, Kazakhstan is characterized by the specifics associated with the insufficient maturity of the institutional environment, which limits the potential of this instrument.

A significant result is the identification of the synergistic effect of digitalization. Unlike a number of studies where digital technologies are considered in isolation, this paper shows that digitalization enhances the impact of ESG and environmental audit. This conclusion is consistent with modern research on the digital transformation of sustainable development, which emphasizes that digital tools increase transparency, accuracy of accounting and effective management of environmental data (OECD, 2025). A comparison of the results obtained with empirical studies in Kazakhstan also demonstrates their consistency. Thus, research shows that the implementation of ESG practices in national companies is accompanied by improved environmental performance and reduced emissions (Adambekova, 2025). Moreover, an analysis of the corporate reporting of the largest companies in Kazakhstan indicates a gradual increase in the level of ESG disclosure, which creates the prerequisites for the formation of a stable institutional environment (PwC, 2024).

However, despite the positive dynamics, the results of the study reveal a number of structural limitations. First, there remains the problem of low standardization of ESG reporting, which makes data comparability difficult. Secondly, there is a significant differentiation between companies in terms of the level of implementation of environmental accounting and auditing. Thirdly, there is a risk of formal implementation of ESG practices without real change in business processes (greenwashing), which is also noted in the international literature (Friede

et al., 2015). From a theoretical point of view, the results obtained expand the understanding of the role of ESG as not only a reputational management tool, but also an operational efficiency factor. In contrast to the traditional approach in which environmental costs are considered as costs, this study confirms their transformation into investments that contribute to reducing total costs and increasing sustainability.

The practical significance of the research lies in the possibility of using the results obtained to shape public policy and corporate strategies in the field of sustainable development. In particular, the results indicate the need for:

- Institutionalization of ESG standards at the national level;
- Development of a mandatory environmental audit system;
- integration of digital platforms into the environmental accounting system;
- Encouraging companies to disclose non-financial information.

Thus, the results of the study not only confirm the conclusions of the international literature, but also complement them, demonstrating the specifics of the implementation of ESG and environmental audit in the context of the economy of Kazakhstan. This allows us to consider environmental accounting and ESG reporting as key elements of the transition to a sustainable development model.

**Conclusion.** This study is aimed at a comprehensive analysis of the relationship between environmental accounting, environmental audit system and ESG reporting in the context of sustainable development of the Republic of Kazakhstan. The results obtained allow us to formulate a number of theoretical and practical conclusions that are important for both the scientific community and government and corporate policy.

Firstly, empirical analysis has confirmed that the integration of ESG principles and the development of an environmental audit system have a statistically significant impact on reducing the share of environmental and logistical costs of enterprises. In contrast to the traditional view of environmental costs as an additional burden, the results of the study demonstrate their transformation into a factor of increased operational efficiency and resource optimization. This indicates the transition from a costly to an investment model of environmental management. Secondly, it has been established that ESG reporting acts not only as a tool for increasing transparency, but also as a mechanism for the formation of sustainable business practices. Increasing the level of ESG disclosure helps to improve the quality of management decisions, reduce information asymmetry and strengthen investor confidence. Thus, ESG becomes a key element of modern corporate architecture and a factor of enterprise competitiveness.

Thirdly, a significant synergistic effect of digitalization has been identified, enhancing the impact of environmental accounting and auditing. Digital technologies provide improved accounting accuracy, automated monitoring, and expanded analytical capabilities, which together contribute to more effective environmental risk management. This is especially important in the context of the transition to the digital economy and the development of ESG infrastructure. At the same time,

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the study revealed a number of systemic limitations specific to Kazakhstan. These include insufficient standardization of ESG reporting, fragmented institutional environment, limited environmental auditing practices, and differences in the level of implementation of sustainable practices between enterprises. These factors constrain the potential of the ESG as a tool for sustainable development and require targeted institutional changes.

From the point of view of scientific contribution, this study expands existing theoretical approaches, considering environmental accounting, environmental audit and ESG reporting as an interconnected system that affects the economic efficiency of enterprises. Unlike most studies that focus on individual aspects of ESG, the proposed approach demonstrates their complex impact and allows us to identify synergetic effects, including the role of digitalization. The practical significance of the results lies in the formation of recommendations for public policy and corporate governance.:

• Development and implementation of national ESG reporting standards harmonized with international standards (GRI, IFRS Sustainability);

• Institutionalization of the mandatory environmental audit system for large and environmentally significant enterprises;

• Creation of digital platforms for environmental accounting and monitoring;

• Encouraging businesses to disclose non-financial information through tax and investment mechanisms;

• Development of human resources in the field of ESG and environmental management.

In the long term, the implementation of these measures will increase the sustainability of Kazakhstan's economy, improve environmental performance and strengthen the country's integration into the global ESG agenda.

Thus, environmental accounting, the environmental audit system and ESG reporting should be considered not as isolated tools, but as key elements of institutional transformation aimed at ensuring sustainable and competitive economic development.

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Managing Editor: A.Shormakova
Editors: D.S. Alenov, M.Konyrbekov
Computer layout: G.D. Zhadyranova

Подписано в печать 27.04.2026.
46,0 п.л.
Заказ 2.

*«Central Asian Academic Research Center» LLP*
*Алматы, Шевченко к-сі, 28*