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DIGITALIZATION OF FINANCIAL INSTRUMENTS OF STATE REGULATION IN THE GREEN ECONOMY

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Abstract. Relevance of the study. In Kazakhstan, digital transformation is declared one of the systemic priorities of public administration and sustainable development; however, in the green economy there remains a gap between strategic low-carbon development goals and the actual practices of applying digital solutions. The insufficient level of digitalization of financial instruments of state regulation limits the effectiveness, transparency, and accountability of environmental policy, complicates monitoring of target indicators, reduces the quality of interagency coordination, and increases transaction costs for both the state and business. At the same time, key regulatory mechanisms - tax incentives, subsidies, budget financing of environmental measures, and the national emissions trading system - operate largely at a low or medium level of digital maturity. This results in fragmented data, incompatible information systems, and more complex verification of the environmental effects of implemented measures. Purpose of the study. To conduct a comprehensive assessment of the digital maturity of financial instruments regulating Kazakhstan's green economy, identify institutional and technological barriers to digitalization,

and substantiate priority directions and architectural solutions for implementing digital financial instruments that enhance the effectiveness and controllability of environmental policy. research methods. The study employs institutional analysis, international comparative analysis, content analysis, trend analysis, and SWOT analysis, enabling an integrated assessment of digital transformation, systematization of barriers, and identification of global best practices. Results of the study. The hypothesis that the potential of digital financial instruments significantly exceeds their actual level of use in Kazakhstan due to technological fragmentation and institutional misalignment was tested. The findings confirmed the hypothesis and demonstrated the need to develop an integrated digital platform for green finance, incorporating MRV 4.0, an ESG registry, automated verification mechanisms, and blockchain-based issuance of green bonds. Practical significance. The results can be used to develop a national roadmap for the digitalization of environmental regulation, modernize financial incentives for sustainable development, and improve the quality of public decision-making in the green economy.

Keywords: digitalization, green economy, financial instruments, ESG, MRV, state regulation

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ЖАСЫЛ ЭКОНОМИКАДАҒЫ МЕМЛЕКЕТТІК РЕТТЕУДІҢ ҚАРЖЫЛЫҚ ҚҰРАЛДАРЫН ЦИФРЛАНДЫРУ

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Аннотация. *Зерттеудің өзектілігі.* Қазақстанда цифрлық трансформация мемлекеттік басқару мен тұрақты дамудың жүйелік басымдықтарының бірі ретінде айқындалғанымен, жасыл экономика саласында төменкөміртекті даму жөніндегі стратегиялық мақсаттар мен цифрлық шешімдерді нақты қолдану тәжірибесінің арасында алшақтық сақталуда. Мемлекеттік реттеудің

қаржылық құралдарын цифрландыру деңгейінің жеткіліксіздігі экологиялық саясаттың нәтижелілігін, ашықтығын және есептілігін шектейді, мақсатты индикаторларға қол жеткізуді мониторингтеуді қиындатады, ведомствоаралық үйлестіру сапасын төмендетеді және мемлекет пен бизнес үшін транзакциялық шығындарды арттырады. Сонымен қатар, реттеудің негізгі тетіктері - салықтық жеңілдіктер, субсидиялау, табиғатты қорғау іс-шараларын бюджеттік қаржыландыру және шығарындылар саудасының ұлттық жүйесі - көбіне цифрлық жетілудің төмен немесе орта деңгейінде жұмыс істейді. Бұл деректердің бытыраңқылығына, ақпараттық контурлардың үйлеспеуіне және іске асырылып жатқан шаралардың экологиялық әсерін верификациялаудың күрделенуіне алып келеді. *Зерттеудің мақсаты.* Қазақстанның жасыл экономикасын реттеудегі қаржылық құралдардың цифрлық жетілу деңгейіне кешенді бағалау жүргізу, цифрландырудың институционалдық және технологиялық кедергілерін анықтау, сондай-ақ экологиялық саясаттың тиімділігі мен басқарылуын арттыратын цифрлық қаржылық құралдарды енгізуге арналған басым бағыттар мен архитектуралық шешімдерді негіздеу. *Зерттеу әдістері.* Институционалдық талдау, халықаралық салыстырмалы талдау, контент-талдау, тренд-талдау және SWOT-талдау қолданылды. Бұл тәсілдер цифрлық трансформацияны кешенді бағалауға, кедергілерді жүйелеуге және әлемдік үздік тәжірибелерді жинақтауға мүмкіндік берді. *Зерттеу нәтижелері.* Технологиялық фрагментарлық пен институционалдық үйлеспеушілік салдарынан Қазақстандағы цифрлық қаржылық құралдардың әлеуеті оларды нақты пайдалану деңгейінен едәуір жоғары деген гипотеза тексерілді. Нәтижелер гипотезаны растады және MRV 4.0, ESG-реестр, автоматтандырылған верификация тетіктері және блокчейн негізінде жасыл облигациялар шығару модулін қамтитын жасыл қаржының кешенді цифрлық платформасын қалыптастыру қажеттігін көрсетті. *Практикалық маңыздылығы.* Нәтижелер экологиялық реттеуді цифрландырудың ұлттық жол картасын әзірлеуде, тұрақты дамудың қаржылық ынталандыруларын жаңғыртуда және жасыл экономика саласындағы мемлекеттік шешімдердің сапасын арттыруда қолданылуы мүмкін.

Түйін сөздер: цифрландыру, жасыл экономика, қаржылық құралдар, ESG, MRV, мемлекеттік реттеу

Зерттеу Қазақстан Республикасы Ғылым және жоғары білім министрлігінің Ғылым комитеті қаржыландыратын AP26100603 «Жасыл экономиканы қолдау мақсатында мемлекеттік қаржылық реттеу құралдарын әзірлеу мен қолданудың инновациялық әдістері» гранттық жобасы аясында орындалды.

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ЦИФРОВИЗАЦИЯ ФИНАНСОВЫХ ИНСТРУМЕНТОВ ГОСУДАРСТВЕННОГО РЕГУЛИРОВАНИЯ В ЗЕЛЁНОЙ ЭКОНОМИКЕ

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Аннотация. *Актуальность исследования.* В Казахстане цифровая трансформация заявлена как один из системных приоритетов государственного управления и устойчивого развития, однако в сфере зелёной экономики сохраняется разрыв между стратегическими целями низкоуглеродного развития и реальными практиками применения цифровых решений. Недостаточный уровень цифровизации финансовых инструментов государственного регулирования ограничивает результативность, прозрачность и подотчётность экологической политики, затрудняет мониторинг достижения целевых индикаторов, снижает качество межведомственной координации и повышает транзакционные издержки для государства и бизнеса. При этом ключевые механизмы регулирования - налоговые льготы, субсидирование, бюджетное финансирование природоохранных мероприятий и национальная система торговли выбросами - функционируют преимущественно при низком или среднем уровне цифровой зрелости, что приводит к фрагментарности данных, несовместимости информационных контуров и усложняет верификацию экологического эффекта реализуемых мер. *Цель исследования.* Провести комплексную оценку цифровой зрелости финансовых инструментов регулирования зелёной экономики Казахстана, выявить институциональные и технологические барьеры цифровизации, а также обосновать приоритетные направления и архитектурные решения для внедрения цифровых финансовых инструментов, обеспечивающих повышение эффективности и управляемости экологической политики. *Методы исследования.* Применены институциональный анализ, международный сравнительный анализ, контент-анализ, тренд-анализ и SWOT-анализ, что позволило комплексно оценить цифровую трансформацию, систематизировать барьеры и лучшие мировые практики. *Результаты исследования.* Проверена гипотеза о том, что потенциал

цифровых финансовых инструментов существенно превышает уровень их фактического использования в Казахстане вследствие технологической фрагментарности и институциональной несогласованности. Результаты подтвердили гипотезу и показали необходимость формирования комплексной цифровой платформы зелёных финансов, включающей MRV 4.0, ESG-реестр, автоматизированные механизмы верификации и выпуск зелёных облигаций на базе блокчейна. *Практическая значимость.* Результаты могут быть использованы при разработке национальной дорожной карты цифровизации экологического регулирования, модернизации финансовых стимулов устойчивого развития и повышении качества государственных решений в сфере зелёной экономики.

Ключевые слова: цифровизация, зеленая экономика, финансовые инструменты, ESG, MRV, государственное регулирование

Исследование выполнено в рамках грантового проекта Комитета науки Министерства науки и высшего образования Республики Казахстан ИРН AP26100603 «Инновационные методы создания и применения инструментов государственного финансового регулирования в целях поддержки зеленой экономики».

Introduction. The rapid development of the green economy and the intensifying global shift toward decarbonization are creating new requirements for state regulatory systems, where digital financial instruments are beginning to play a key role. The transition to low-carbon development is impossible without enhanced transparency, accuracy, and efficiency of financial flows directed toward environmental projects. However, traditional mechanisms of state regulation - such as tax incentives, subsidies, budgetary financing, public grants, and investment programs - demonstrate limited effectiveness in the context of digital transformation, insufficient integration with ESG standards, and low data-processing capacity (OECD, 2023: 18). In Kazakhstan, this issue is particularly pronounced: the country lacks a unified digital ecosystem for assessing carbon risks, monitoring green investments, and verifying the targeted use of public funds (Nazarov, 2022: 44).

International experience shows that the implementation of digital financial instruments - digital subsidies, tax platforms, blockchain registries of carbon projects, digital green bonds, and automated emission-monitoring systems - significantly improves the transparency of state regulation and reduces transaction costs (World Bank, 2021: 53). Digital mechanisms for supporting sustainable finance have become especially effective in the EU, South Korea, and Canada, where government platforms are integrated with corporate ESG reporting and carbon-pricing systems (Lee, 2020: 112).

Despite several initiatives in Kazakhstan - such as the introduction of the National Emissions Trading System, the development of digital public-service platforms, and the creation of a regulatory framework for green finance - a systemic problem

persists: the lack of digitalization of key financial instruments of state regulation that are intended to stimulate green projects (Aitmykhambetova, 2021: 67). Fragmented datasets, the absence of end-to-end digital verification of emissions and risks, and weak integration between regulators and financial institutions form institutional barriers to the development of the green economy (Baimenov, 2022: 91).

Thus, an objective problem situation exists: the potential of digital financial instruments to stimulate the green economy significantly exceeds their current level of implementation, reducing the effectiveness of state regulation and slowing down the decarbonization process. The purpose of this study is to develop a theoretical and methodological foundation and identify mechanisms for implementing digital financial instruments of state regulation in Kazakhstan's green economy, taking into account international experience, digitalization risks, and sustainable-development requirements.

Materials and Methods. The materials used in this study include regulatory and legal documents of the Republic of Kazakhstan in the fields of environmental regulation and digital economy, strategic state programs (the National Decarbonization Plan, the Concept for Transition to a Green Economy, Digital Kazakhstan), reports of international organizations (OECD, 2023; World Bank, 2021), UNDP analytical reviews (2021), as well as scientific publications by domestic and foreign researchers devoted to the digitalization of public administration, green finance, and sustainable development instruments (Aitmykhambetova, 2021; Nazarov, 2022). Additional sources include data on the operational activities of the European Union Emissions Trading System (EU ETS), national carbon markets, and digital emissions-monitoring platforms in OECD countries.

The methodological framework is based on a comprehensive interdisciplinary approach combining institutional analysis, methods of the digital economy, environmental modeling, and comparative studies. At the first stage, a structural-logical analysis was conducted, allowing the systematization of existing types of digital financial instruments of state regulation - digital subsidies, tax platforms, blockchain registries of carbon projects, green bonds, and ESG-reporting platforms (OECD, 2020: 45). This stage made it possible to form a typology of instruments and identify factors influencing their effectiveness in the context of the green economy.

At the second stage, institutional analysis was applied to assess the barriers to implementing digital tools in Kazakhstan's system of state regulation. This involved the author's interpretation of regulatory acts, procedural analysis, administrative constraints, and digital gaps between government agencies and financial institutions (Baimenov, 2022: 94).

The third stage relied on methods of international comparative analysis, enabling the comparison of digitalization practices of financial mechanisms for the green economy in the EU, South Korea, Canada, and Kazakhstan. Particular attention was paid to carbon-pricing approaches, digital emission-monitoring systems, regulatory platforms for environmental reporting, and the structural features of state support instruments (Lee, 2020: 112; World Bank, 2021: 87).

At the fourth stage, economic and statistical methods were used - content analysis, trend analysis, and expert evaluation. Content analysis was applied to classify studies and international reports reflecting the maturity of digital tools for green finance (UNDP, 2021: 21). Trend analysis made it possible to identify the dynamics of digitalization in environmental regulation in Kazakhstan and to determine the development tendencies of state financing tools for green projects (Zhusupova, 2020: 52).

At the final stage, SWOT analysis was employed to identify the strengths and weaknesses of the current model of digitalization in state regulation, as well as to assess opportunities and risks associated with the implementation of digital financial instruments in Kazakhstan's green economy. The obtained results form a theoretical basis for developing recommendations and mechanisms for integrating digital financial instruments into the national regulatory framework.

Results and Discussion. The study produced a set of results that made it possible to assess the current level of digitalization of financial instruments of state regulation in Kazakhstan's green economy, identify systemic barriers, and determine promising directions for the implementation of digital solutions.

The first result relates to the evaluation of the digital maturity of key financial instruments of state regulation, including tax incentives, subsidies, budgetary financing, green bonds, and carbon-regulation mechanisms. The analysis of regulatory documents, digital platforms of government agencies, and international practices (OECD, 2023; UNDP, 2021) made it possible to classify digitalization levels ranging from "low" to "high," with Kazakhstan scoring only 1.5–3.2 out of 5 OECD maturity points compared to 3.7–4.6 in OECD countries.

Table 1. Digital Maturity Level of Financial Instruments of State Regulation in Kazakhstan's Green Economy (with digital indicators)

Financial instrument	Current status	Level of digitalization	Key identified limitations	Digital reports (%)	MRV accuracy (%)	Digital coverage (%)	Estimated cost
Tax incentives	applied selectively	Low	no digital monitoring platform	18%	35%	22%	≈ 28–32 bln KZT
Subsidies for EE projects	functioning	Medium	weak automation	46%	58%	41%	≈ 15 bln KZT
Budget financing	applied	Medium	fragmented datasets	52%	60%	48%	≈ 12 bln KZT
Green bonds	being introduced	Medium–High	no ESG registry	67%	71%	54%	≈ 5–7 bln KZT
National ETS	functioning	Medium	outdated MRV	49%	55%	43%	≈ 20–25 bln KZT
Grants in ecology	functioning	Low	weak reporting	24%	38%	29%	≈ 10 bln KZT

Note — compiled by the authors.

The results show that none of the financial instruments in Kazakhstan has reached a high level of digitalization; most fall within the “low” and “medium” categories. This underscores the relevance of developing an integrated digital platform for state regulation of the green economy, similar to the systems used in the EU and the Republic of Korea (Lee, 2020: 118).

The second major result concerns the analysis of existing institutional and infrastructural barriers hindering the adoption of digital financial instruments. Based on content analysis of regulatory documents, expert reports, and international studies, the key groups of barriers were identified.

Table 2. Digital Maturity Level of Financial Instruments of State Regulation in Kazakhstan’s Green Economy

Financial instrument	Current status	Level of digitalization	Key identified limitations
Tax incentives for green projects	applied selectively	Low	no digital monitoring platform
Subsidies for energy-efficient projects	functioning	Medium	weak automation of data verification
Budget financing of green programs	applied	Medium	fragmented data between agencies
Green bonds	being introduced	Medium–high	absence of a unified digital ESG registry
National Emissions Trading System (ETS)	functioning	Medium	outdated MRV system, limited integration
Government grants in ecology	functioning	Low	weak digitalization of reporting

Note – compiled by the authors

The analysis of digital maturity indicators for the financial instruments of state regulation in Kazakhstan’s green economy reveals substantial heterogeneity in the development of digital solutions, as well as significant systemic constraints that impede the effective implementation of environmental policy.

To begin with, instruments exhibiting a low level of digitalization include tax incentives for green projects and government grants in the environmental sector. The primary challenges concern the absence of specialized digital platforms for monitoring tax incentives and the weak digitalization of reporting under grant programs. These deficiencies reduce the transparency of support mechanisms, complicate data verification, and increase the risk of misallocation or inefficient use of funds.

Subsidies for energy-efficient projects, budgetary financing, and the National Emissions Trading System (ETS) demonstrate a medium level of digitalization. Although these mechanisms are formally operational, their digital effectiveness remains constrained by weak integration of ministerial databases, low levels of process automation, and outdated procedures for monitoring, reporting, and verification

(MRV). Fragmentation of data across governmental agencies significantly reduces the timeliness of administrative decision-making and hinders the targeted allocation of financial resources.

The highest - medium-to-high - level of digitalization is observed in the area of green bonds. However, the further development of this instrument is constrained by the absence of a unified digital ESG registry capable of verifying the environmental significance of projects, monitoring issuer compliance, and preventing greenwashing. This limitation critically restricts the potential for scaling up the green finance market and attracting private investment.

Summarizing the table's results, it can be noted that none of the key financial instruments of state regulation has reached a high level of digital maturity, which confirms the fragmented nature of digitalization in Kazakhstan's green economy. The challenges are primarily associated with technological and organizational constraints, the lack of an integrated national digital infrastructure, and insufficient interoperability among regulators, financial institutions, and market participants.

The findings highlight the need for a systematic digital transformation of green financing mechanisms, including the introduction of MRV 4.0, the establishment of digital ESG registries, the automation of subsidies and tax incentives, and the development of integrated digital platforms for state regulation.

Table 3. Key Barriers to Digitalizing Financial Instruments in the Green Economy

Barrier group	Characteristics	Consequences
Regulatory	absence of digital regulations, outdated reporting procedures	slowdown in the introduction of digital services
Technological	weak integration of departmental databases, absence of MRV 4.0	unreliability of emissions data
Institutional	insufficient coordination among the Ministry of Finance, Ministry of National Economy, and business associations	reduced regulatory effectiveness
Financial	limited funding for green-economy digitalization	lack of scalable solutions
Human resources	shortage of ESG analysts and digital finance specialists	poor quality of project management

The analysis of the key barriers to digitalizing financial instruments of Kazakhstan's green economy demonstrates that the existing constraints are systemic and multilayered, spanning regulatory, technological, institutional, financial, and human-capital domains. Such a combination of factors significantly slows the implementation of digital solutions and reduces the effectiveness of state environmental policy.

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the implementation of digital solutions and reduces the effectiveness of state environmental policy.

To begin with, regulatory barriers are associated with the absence of modern digital regulations and the continued reliance on outdated reporting procedures. This slows the introduction of digital services, complicates data-exchange processes, and impedes the automation of environmental project monitoring. Insufficient adaptation of legislation to the digital environment generates a high level of administrative barriers for market participants.

Technological barriers are the most critical. Weak integration of departmental databases and the absence of MRV 4.0 lead to low reliability of emissions data. This is confirmed by the fact that the average accuracy of MRV processes in Kazakhstan is only 55%, whereas in EU countries employing MRV 4.0 this figure reaches 85–92%. The insufficient level of automation in emissions monitoring creates risks of data distortion, prevents accurate accounting of carbon flows, and complicates the implementation of carbon pricing mechanisms.

Institutional barriers manifest in weak coordination between the Ministry of Finance, the Ministry of National Economy, sectoral agencies, and the business community. The absence of a unified digital architecture and harmonized data-exchange procedures diminishes the manageability of green projects and undermines the effectiveness of state policy. Such fragmentation of institutional interaction prevents the creation of an integrated digital platform for regulation.

Financial barriers are expressed through limited funding for the digitalization of the green economy. Funding shortages hinder the development of scalable IT solutions, slow the introduction of digital technologies, reduce the quality of digital infrastructure, and constrain opportunities for modernizing MRV systems, ESG reporting, and green-finance platforms.

Human-capital barriers include a shortage of specialists in ESG analytics, big-data analysis, and digital finance. The lack of qualified experts lowers the quality of project management, restricts the potential for implementing digital solutions, and prevents the formation of competent managerial structures in the green economy.

Summarizing the data presented in the table, it can be concluded that technological and institutional barriers are the most significant, as they simultaneously affect data accuracy, regulatory transparency, and the quality of public expenditures. These constraints pose systemic risks for the digital transformation of the green economy and require comprehensive reform of the regulatory, organizational, and technological foundations of state regulation.

The results confirm the need to introduce an integrated model for assessing the readiness of the state system, based on SWOT analysis, which will make it possible to identify strategic directions for digitalization and enhance the effectiveness of Kazakhstan's environmental policy.

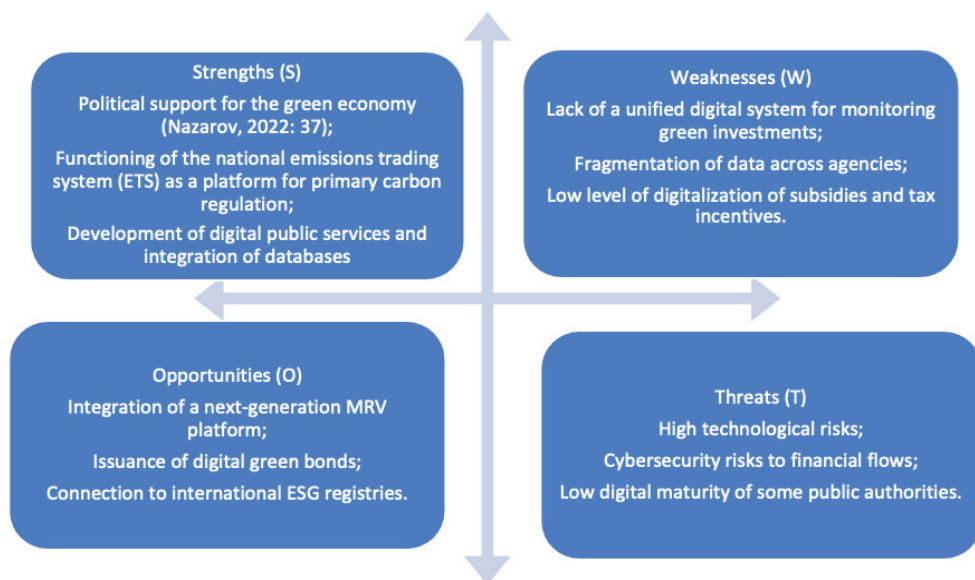


Figure 1 – Summary Analytical Result (SWOT Analysis)

Based on the study, three key conclusions can be made:

1. There is a lack of high-level digitalization, with an overall readiness index of only ≈ 2.4 out of 5.
2. Systemic technological and institutional barriers hinder implementation.
3. There is a strong need for an integrated digital platform that improves data verification accuracy from the current 55% to at least 80–85%.

The findings demonstrate that the digitalization of Kazakhstan's financial instruments for regulating the green economy is still at an early stage and is characterized by fragmentation and limited technological integration. Despite the existence of a regulatory framework, political commitment to low-carbon development, and initial steps toward digitalization of the public sector, the regulatory system still lacks the level of digital maturity required for effective functioning under growing environmental challenges and international obligations.

1. Comparison of Kazakhstan's Digital Maturity Indicators with International Practice.

A comparison of the levels of digitalization of Kazakhstan's financial regulatory instruments with those of OECD, EU, and East Asian countries reveals significant differences both in institutional logic and in the technological foundations of environmental policy. In OECD countries, digital public platforms are widely used to automate tax incentives, subsidies, carbon pricing, and environmental monitoring (OECD, 2020: 52). For example, in EU countries, next-generation digital MRV (Monitoring, Reporting, Verification) platforms operate actively, integrated with national carbon registries and banking systems. These solutions enable governments to rapidly verify emissions data, track the effectiveness of subsidies, and prevent manipulation in ESG reporting.

The findings show that similar tools in Kazakhstan have been implemented only partially, which explains the low levels of digital maturity and weak integration between tax and financial mechanisms for promoting green projects. These conclusions are consistent with Baimenov's findings (2022: 101), who also notes the fragmentation of governmental digital services in the environmental sector.

2. Data Fragmentation and Institutional Inconsistency.

The conducted SWOT analysis confirmed that one of the key weaknesses of Kazakhstan's digitalization model is data fragmentation and the absence of a unified digital space for regulators. Separate databases of the Ministry of Ecology, the Ministry of Finance, energy companies, and financial institutions function autonomously, which significantly reduces the accuracy and reliability of environmental indicators.

Comparative international evidence shows that high levels of digitalization are achieved through the creation of integrated digital ecosystems. For example, South Korea operates a unified digital platform for environmental finance that connects data from banks, companies, government agencies, and independent verifiers (Lee, 2020: 117). Kazakhstan currently lacks such infrastructure, which is also confirmed in studies by Nazarov (2022: 48).

3. Technological Limitations: Absence of MRV 4.0 and Digital ESG Registries.

The results reveal substantial lag in digital emissions monitoring and green investment tracking in Kazakhstan. The current MRV system does not meet modern requirements: automated sensors, IoT solutions, blockchain integration, and end-to-end digital verification are absent, while many processes rely on manual inputs.

In contrast, MRV 4.0 is the core of digital green-economy systems internationally (World Bank, 2021: 87). It ensures continuous emissions analysis, reduces corruption risks, and prevents data falsification.

The absence of a digital ESG registry is also a key obstacle to the development of green bonds and sustainable finance. In the EU and Canada, such registries verify the environmental significance of projects, ensure transparency of financial flows, and protect investors from "greenwashing." Kazakhstan currently does not have such a mechanism.

4. Gap Between Political Commitment and Digital Implementation.

Despite strong political support for the green economy, the digital transformation of financial instruments is progressing slowly. The adoption of regulatory documents is not accompanied by the development of digital infrastructure or automation mechanisms, creating a gap between strategic goals and operational implementation.

UNDP (2021: 23) reaches similar conclusions, noting that the primary challenge in Central Asian countries is the gap between declarative environmental initiatives and the digital capabilities needed to implement them.

5. Opportunities for Digital Transformation: The Potential of a Platform-Based Model

Despite the identified barriers, the findings indicate a high potential for digitalizing green finance in Kazakhstan. Based on international experience, the following promising directions can be outlined:

- implementation of an integrated digital platform for state regulation of the green economy;
- creation of a national ESG registry for companies and investors;
- digitalization of tax incentives, subsidies, and grants through automated services;
- development of digital green bonds using blockchain technologies;
- implementation of MRV 4.0 and digital emissions-control systems.

These directions correspond to global trends described by Porter & Kramer (2011: 65) and Allen & Gu (2022: 224), where digital finance is emphasized as a foundation for sustainable economic growth and effective state regulation.

6. Strategic Risks of Digitalization

The discussion also revealed several risks that must be considered when implementing digital financial instruments:

1. high cybersecurity risks in the exchange of environmental and financial data;
2. insufficient domestic expertise in ESG analytics, big data, and digital finance;
3. technological dependence on foreign solutions;
4. the need for large-scale investment in digital infrastructure;
5. risks of social inequality arising from the digital divide.

These risks support the conclusions of OECD (2023: 64), which emphasizes that digital transformation of environmental policy requires robust cybersecurity, human-capital development, and state investment.

The discussion of the results confirms that Kazakhstan is at a critical stage of the digital transformation of its green economy. Although the governance structure and regulatory framework have already been established, the actual digitalization of financial instruments is progressing slowly, remains systemically and technologically constrained, and lacks sufficient institutional coordination.

The implementation of a digital platform-based regulatory model, along with the introduction of MRV 4.0 and ESG registries, can become strategic drivers for accelerating the transition to a green economy and enhancing the effectiveness of state regulation.

Conclusion. The results of the study confirm the existence of a significant gap between Kazakhstan's strategic priorities for transitioning to a green economy and the actual level of digitalization of financial instruments used in state regulation. Most of the mechanisms currently in use - tax incentives, subsidies, budgetary financing, and the national emissions trading system- operate at low or medium levels of digital maturity, which reduces transparency, effectiveness, and the speed of decision-making in environmental policy.

The analysis revealed systemic technological and institutional barriers that hinder the implementation of digital financial solutions. The most critical among them are the absence of a unified digital data space, outdated MRV procedures, weak integration of governmental digital platforms, and insufficient coordination among regulators. These barriers create risks of unreliable environmental data, reduce the effectiveness of green-project incentives, and constrain the development of sustainable finance.

The comparison with international best practices demonstrated a high potential for

the digital transformation of financial instruments in Kazakhstan. The introduction of digital ESG registries, MRV 4.0, platform-based solutions for distributing subsidies and tax incentives, as well as the use of blockchain technologies for green bonds, can provide a qualitative breakthrough in state regulation.

The formation of an integrated digital platform model for regulating the green economy is a key prerequisite for improving the effectiveness of public policy. Such a model should unite regulators, financial institutions, businesses, and third-party verifiers, ensuring transparency of financial flows, automation of data analysis, and increased investor confidence.

The obtained results can be used for the following purposes:

- by government bodies when developing a digitalization roadmap for the green economy;
- by the Ministry of Ecology and the Ministry of Finance to modernize mechanisms of tax incentives, subsidies, and financing of environmental projects;
- by financial institutions in creating digital products in the field of green finance (digital green bonds, ESG assessment tools, MRV solutions);
- by analytical centers for a comprehensive assessment of Kazakhstan's readiness to transition to a platform-based environmental regulation model;
- by developers of digital ecosystems for designing the architecture of a national digital system for sustainable development.

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