

Digital transformation and sustainable development: challenges, risks and new models of economic growth

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Abstract:

This research aims to identify key economic growth models shaped by digital transformation, assess associated risks, and determine the conditions for their compatibility with sustainable development principles, using Kazakhstan as a case study. A comparative-analytical and structural-functional approach is applied. The empirical base comprises data from the Agency for Strategic Planning of Kazakhstan, the National Bank of Kazakhstan, public reports of Kaspi.kz and Halyk Bank, and World Economic Forum Network Readiness Index (NRI) data for 2019–2024. The findings indicate that Digital transformation in Kazakhstan is developing asynchronously: the financial sector leads while industry and agriculture lag critically. The super-app business model generates sustainable growth but creates data monopolisation risks. ESG integration remains declarative without measurable KPIs. The digital tenge pilot opens prospects for enhanced fiscal transparency. The originality of this research for the first time, a comprehensive

analysis of Kazakhstan's digital transformation is conducted through three interrelated dimensions economic growth, ESG integration, and external economic risks using scenario forecasting and case analysis of leading fintech players.

Keywords: Digital Transformation; Sustainable Development; Fintech; ESG; Kazakhstan

Introduction

The global economy is undergoing a structural shift that cannot be reduced to a single factor: digital technologies are redrawing sectoral boundaries and transforming the logic of competition. According to the McKinsey Global Institute, the contribution of the digital economy to global GDP by 2030 could range from 1.2 to 3.7 trillion dollars depending on the pace of artificial intelligence (AI) adoption and digital infrastructure investment (McKinsey Global Institute, 2023). Kazakhstan in this context is characterised by active digital transformation: the country is deliberately moving along a diversification trajectory away from the commodity-based model, using digitalisation as an instrument of structural change.

At the same time, transformational processes generate asymmetric risks technological, regulatory, and social. Combining the objectives of digital modernisation with ESG principles (environmental, social, and corporate governance) requires unconventional analytical approaches. This contradiction defines the academic relevance of the study.

The aim of this paper is to identify the key economic growth models shaped by digital transformation, assess the associated risks, and determine the conditions for their compatibility with sustainable development principles, using Kazakhstan as a case study. The following tasks are addressed to achieve this aim: analysis of the state of the digital economy in Kazakhstan; characterisation of the role of AI and fintech ecosystems; assessment of external economic risks; and formulation of conclusions and recommendations.

The relevance of the topic is further underscored by Kazakhstan's geopolitical position as a landlocked middle-income economy in Central Asia with pronounced dependence on hydrocarbon exports. The country occupies a strategically unique position: it simultaneously belongs to the Eurasian Economic Union (EAEU), maintains close cooperation with China under the Belt and

Road Initiative, and actively courts Western investors. This multi-vector foreign economic orientation makes Kazakhstan particularly sensitive to global technological shifts and sanctions-related disruptions. The government's response encapsulated in the Digital Kazakhstan programme (2018–2022) and the updated Vision 2025 strategic roadmap reflects a deliberate bet on digital modernisation as a lever for reducing commodity dependence, diversifying the export base, and improving the investment climate. Understanding how these policy instruments interact with private-sector digital innovation, and whether they collectively generate growth patterns compatible with sustainable development, constitutes the core intellectual challenge motivating this study.

Literature Review

Theoretical conceptualisation of digital transformation as a growth factor proceeds along several interrelated directions. Brynjolfsson and McAfee (2014) established that labour productivity in highly digitalised economies grows disproportionately to investment through network effects and the scalability of data as an intangible asset. Their concept of the 'second machine age' posits that cognitive automation, unlike earlier waves of mechanisation, disrupts white-collar labour markets alongside blue-collar ones, creating both a productivity dividend and a distributional challenge. This theoretical foundation is particularly pertinent for emerging economies like Kazakhstan, where institutional capacity to manage distributional outcomes remains limited.

A complementary stream of research addresses the economics of digital platforms specifically. Parker, Van Alstyne, and Choudary developed the concept of 'platform thinking' as a structural transformation from pipeline to ecosystem business models, whereby value is created through facilitating interactions among multiple user groups rather than through linear production chains. This theoretical lens is directly applicable to the super-app phenomenon exemplified by Kaspi.kz, which has effectively merged multiple previously separate markets into a single integrated digital infrastructure. The competitive and regulatory implications of such multi-sided market structures have been formalised by Rochet and Tirole (2003), whose two-sided market framework demonstrates that

optimal pricing in platform ecosystems diverges fundamentally from standard competitive equilibrium – a key consideration for antitrust regulators evaluating market concentration in Kazakhstan’s digital financial sector.

In the area of sustainable development, a key reference point is the concept of ‘digital ESG integration’ proposed by Tapscott and Tapscott (2016): technologies should not only reduce transaction costs but also measurably reduce the carbon footprint and improve corporate governance transparency. For developing economies, the World Bank (2022) identifies a characteristic paradox: countries with the greatest infrastructure gap benefit most from mobile payment systems — a finding confirmed by Kazakhstan’s experience.

Stiglitz (2011) warns of the risk of widening inequality: technology monopolies concentrate a significant share of added value, while peripheral economies remain trapped in technological dependence. With respect to sanctions risks and commodity dependence, Rodrik (2011) cautions against the ‘premature deindustrialisation trap’, in which a digital leap is not supported by the development of productive capacity.

The financial dimension of digitalisation is examined by Philippon (2011), who established that fintech reduces transaction costs and expands financial inclusion. Buckley et al. (2020) systematised the technological risks accompanying the scaling of AI systems in the financial sector. Berg et al. (2020) demonstrated that users’ digital footprints enable the construction of credit scoring models with predictive power exceeding traditional methods.

The institutional aspects of digital transformation are addressed in the work of Acemoglu and Robinson (2012), emphasising the role of inclusive institutions in ensuring long-term growth during technological change. The regulation of platform economies is developed in the research of Rochet and Tirole (2003), who laid the theoretical groundwork for two-sided markets.

Cybersecurity as a constraining factor of digital sovereignty is examined by Bouveret (2018) and Crisanto and Prenio (2020). Issues relating to central bank digital currencies (CBDCs) are systematised in reports by BIS (2021) and Auer et al. (2020). The BIS framework identifies three primary design dimensions for CBDCs

access, degree of anonymity, and operational architecture each of which carries distinct implications for financial stability, monetary policy transmission, and the competitive landscape of commercial banking. For a country like Kazakhstan, where the banking system is relatively concentrated and the central bank has historically maintained conservative monetary policy, the introduction of a CBDC represents not merely a technological upgrade but a potential restructuring of financial intermediation itself.

Despite a rich body of foreign literature on individual aspects of digital transformation and sustainable development, a comprehensive analysis of their interaction as applied to Kazakhstan remains insufficiently explored. The present paper aims to fill this gap.

Methodology

Research question: In what way does digital transformation shape new economic growth models in Kazakhstan, and to what extent are they compatible with sustainable development principles under conditions of external economic risks?

Hypothesis: Digital transformation in Kazakhstan generates sustainable growth only when three conditions are simultaneously met: diversification away from oil rents, embedding ESG metrics into regulatory requirements, and creating a competitive environment for fintech ecosystems.

The study is built on a combination of qualitative and quantitative analysis. The principal methods applied are: comparative analysis of statistical data from the Agency for Strategic Planning of Kazakhstan and the National Bank of Kazakhstan for 2019–2024; structural-functional analysis of the business models of leading Kazakhstani fintech companies; scenario forecasting for risk assessment; and content analysis of regulatory documents (Digital Kazakhstan programme, Vision 2025). The empirical base comprises public reports of Kaspі.kz, Halyk Bank, and the National Bank of Kazakhstan, as well as World Economic Forum Network Readiness Index (NRI) data.

Research stages: (1) systematisation of theoretical

approaches; (2) quantitative analysis of digital economy indicators in Kazakhstan; (3) case analysis of fintech ecosystems; (4) assessment of external economic risks; (5) synthesis and formulation of recommendations.

Several methodological limitations merit acknowledgement. First, the statistical base for Kazakhstan's digital economy is still developing: definitional boundaries of the 'digital economy' in national accounting frameworks have been revised across the study period, introducing comparability challenges for longitudinal analysis. Second, the case analysis of Kaspi.kz and Halyk Bank relies primarily on publicly disclosed annual reports and investor relations materials, which may not fully reflect internal risk management practices or off-balance-sheet exposures. Third, scenario forecasting necessarily involves assumptions about the stability of structural parameters – oil price trajectories, geopolitical developments, and regulatory postures – that are subject to significant uncertainty in the current global environment. These limitations are partially mitigated by triangulating findings across multiple data sources and by framing conclusions in terms of directional tendencies rather than precise quantitative projections.

Discussion

Kazakhstan's digital economy: a quantitative assessment. According to the Agency for Strategic Planning, the share of the digital economy in Kazakhstan's GDP reached 4.2% in 2023, up from 2.9% in 2019 (Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, 2024). In the NRI 2023 ranking, Kazakhstan placed 55th out of 134 countries, improving its position by 7 places over two years. The Digital Kazakhstan state programme stimulated the transfer of 80% of public services to electronic format, reducing the average time for interactions with government bodies from 14 to 3.2 working days. Digital maturity nonetheless remains uneven: the gap between Almaty and rural regions in broadband internet coverage stands at 38 percentage points. In absolute terms, investment in ICT infrastructure grew from approximately 340 billion tenge in 2019 to over 580 billion tenge in 2023 – an increase of roughly 70% in nominal terms. Mobile internet penetration reached 84% of the adult population by end-2023, while the share of non-cash retail transactions surpassed 78%, reflecting a structural shift

in consumer payment behaviour accelerated significantly by the COVID-19 pandemic. These indicators position Kazakhstan as a regional digital leader within Central Asia, though the gap with OECD benchmark economies in areas such as cloud adoption, data centre capacity, and digital skills attainment remains substantial.

Fintech ecosystems as a growth model: Kaspi.kz and Halyk Bank.

The most illustrative example of a new growth model is Kaspi.kz a super-app combining payment services, a marketplace, lending, and government services. By end-2023, the platform's monthly audience exceeded 13 million users against Kazakhstan's population of approximately 19 million. The total payment turnover via Kaspi Pay reached 28 trillion tenge, equivalent to approximately 40% of the country's non-cash turnover. This concentration creates a multiplier effect for GDP but simultaneously generates systemic risks of data monopolization (Kaspi.kz JSC. (2024). Halyk Bank pursues a different strategy: embedding ESG criteria into credit policy and digitalising risk management. A machine-learning-based scoring model reduced the NPL ratio from 7.3% in 2020 to 4.1% in 2023, confirming the direct influence of AI on financial stability (Berg, T., Burg, V., Gombovic, A., & Puri, M. (2020).

The competitive dynamics between these two dominant players illuminate a broader structural tension within Kazakhstan's fintech ecosystem. Kaspi.kz's super-app model generates powerful lock-in effects: once a user adopts the platform for payments, they are drawn progressively into its lending, insurance, and e-commerce services a cross-selling logic that amplifies revenue per user while simultaneously reducing the competitive viability of single-service fintech entrants. This pattern raises legitimate concerns about the erosion of contestability in Kazakhstan's retail financial services market. The Agency for Regulation and Development of the Financial Market (ARDFM) has begun exploring open banking standards as a structural remedy, drawing on European PSD2 experience, but implementation timelines remain uncertain. Beyond the two flagship players, Kazakhstan's fintech landscape encompasses approximately 80 registered payment organisations, 12 microfinance institutions with significant digital presence, and a growing cohort of InsurTech and WealthTech start-ups operating within the Astana International Financial Centre (AIFC) regulatory sandbox — a framework designed to permit controlled

experimentation with novel financial products under reduced regulatory burden.

Digital tenge: an institutional experiment. The pilot project for a digital national currency, launched by the National Bank of Kazakhstan in 2023, presupposes the programmability of payments through smart contracts. This opens prospects for automated monitoring of targeted budget subsidy expenditure and the reduction of corruption risks. At the same time, the introduction of a CBDC raises issues of cybersecurity and the sovereignty of payment infrastructure under external sanctions pressure (Bank for International Settlements. 2021; Auer, R., Cornelli, G., & Frost, J. 2020). In comparative perspective, Kazakhstan's digital tenge initiative is proceeding alongside analogous experiments in China (the e-CNY), the European Union (the digital euro), and Nigeria (the e-Naira). Each jurisdiction has encountered a distinct set of adoption challenges, with Nigeria's experience being particularly instructive: despite mandatory integration into the banking system, e-Naira uptake remained below 0.5% of the population two years after launch, underscoring that technological availability does not automatically translate into behavioural adoption. For Kazakhstan, where the informal cash economy is estimated to represent approximately 25% of GDP, achieving meaningful digital tenge penetration will require not only technical robustness but deliberate incentive design including tax treatment, merchant acceptance obligations, and interoperability with existing payment rails.

The role of artificial intelligence. AI is transforming not only the financial sector but also the structure of employment. According to OECD estimates, up to 35% of jobs in Kazakhstan are theoretically at risk of automation within a 10–15-year horizon primarily in the mining, transport, and basic data processing sectors (OECD, 2023). This tension between productivity growth and the risk of technological unemployment requires an active reskilling policy and investment in human capital. Without this, digital transformation risks reproducing a model of 'growth without development'. Sector-level analysis reveals a highly differentiated exposure profile. In the extractive industries, AI-driven predictive maintenance and autonomous drilling technologies are already being piloted at Tengizchevroil and KazMunayGas, with potential efficiency gains estimated at 12–18% of operational costs but accompanied by a

projected headcount reduction of up to 20% among maintenance and monitoring personnel. In agriculture which employs approximately 14% of Kazakhstan's workforce precision farming technologies remain nascent, with adoption concentrated among large agro-industrial holdings rather than smallholder farms, thereby risking a further widening of productivity differentials within the sector. The education and healthcare sectors, conversely, offer significant scope for AI-enabled productivity enhancement without net employment loss: adaptive learning platforms, diagnostic imaging AI, and administrative automation can substantially expand service capacity without displacing front-line professionals, provided that regulatory frameworks and professional standards are updated to accommodate human-AI collaboration.

External economic risks. Kazakhstan is vulnerable to three interrelated external shocks. First, commodity dependence: hydrocarbons account for approximately 44% of state budget revenues, and the volatility of oil prices translates into exchange rate instability that directly raises the cost of imported technology equipment. Second, sanctions pressure: the re-routing of Russian financial flows through Kazakhstan after 2022 exposed the country to the risk of secondary sanctions, forcing KASE and Kazakhstani banks to introduce additional compliance filters (Bouveret, A, 2018). Third, the inflationary environment: the peak inflation rate of 21.3% in 2022 significantly reduced consumer demand for digital subscriptions and online commerce.

ESG integration: the gap between declaration and practice. Environmental, social, and governance considerations have acquired increasing prominence in Kazakhstan's financial sector discourse, yet the distance between formal commitment and measurable implementation remains wide. At the regulatory level, the ARDFM issued guidelines on sustainable finance taxonomy in 2022, and the AIFC has developed a Green Finance Centre with an accredited framework for green bond issuance. However, as of 2023, only three Kazakhstani issuers had placed certified green bonds on domestic markets, with aggregate proceeds of approximately 85 billion tenge a negligible fraction of total corporate bond issuance. Corporate sustainability reporting remains largely voluntary and inconsistently structured: fewer than 15% of listed companies on KASE publish standalone ESG reports, and among those that do,

comparability is constrained by the absence of a mandatory reporting standard. The environmental dimension presents a particular challenge given Kazakhstan’s carbon-intensive energy mix, in which coal and gas account for over 85% of electricity generation. The rapid growth of cryptocurrency mining following China’s 2021 ban on mining operations added an estimated 8% to Kazakhstan’s electricity demand within 18 months, straining grid capacity and drawing regulatory attention to the energy consumption footprint of digital infrastructure. Without binding KPIs embedded in licensing conditions and credit standards, ESG commitments risk remaining a reputational exercise rather than a genuine instrument of sustainable transition.

Table 1. Key risks of Kazakhstan’s digital economy and management instruments

Risk type	Specific example (Kazakhstan)	Management instrument
Cyber risks	Attacks on CBDC infrastructure	Multi-layer encryption, SOC centres
Data monopolisation	Concentration at Kaspi.kz / Halyk	Data antitrust regulation, open banking
Sanctions pressure	Secondary sanctions via KASE	Partner diversification, SWIFT alternatives
Commodity dependence	Tenge rate tied to oil price	Sovereign fund, export diversification
Technological unemployment	Automation of mining operations	Reskilling programmes, EdTech
ESG non-compliance	Carbon footprint of crypto mining	Green standards, carbon quotas

Source: compiled by the authors based on NBK, KASE, Kaspi.kz and Halyk Bank reports.

Conclusion

The research objective a comprehensive analysis of Kazakhstan’s digital transformation through the lens of economic growth, ESG integration, and external economic risks has been achieved through comparative-analytical and structural-functional approaches.

The findings show: (1) digital transformation in Kazakhstan

is developing asynchronously the financial and public sectors lead while industry and agriculture lag critically, creating a structural imbalance; (2) the super-app business model (Kaspi.kz) generates sustained economic growth but simultaneously forms risks of data market monopolisation requiring anticipatory rather than reactive regulation; (3) ESG integration remains declarative without measurable KPIs; (4) the digital tenge can become an instrument of fiscal transparency, provided that decentralised elements of control are preserved.

The key conclusion is that sustainable growth in Kazakhstan's digital economy is possible only when three conditions are met simultaneously: diversification away from oil rents, embedding ESG metrics into regulatory requirements, and creating a competitive environment for fintech ecosystems. Without this triad, digitalisation risks becoming an instrument for reproducing rather than overcoming Kazakhstan's structural economic constraints.

On the basis of these findings, a set of practical policy recommendations can be formulated. In the domain of regulatory architecture, the introduction of mandatory ESG reporting standards for KASE-listed companies and systemically important financial institutions should be prioritised, with a transition period of two to three years and phased-in audit requirements. In the area of competition policy, the ARDFM should accelerate the development of an open banking framework modelled on the EU's PSD2 directive, establishing data portability rights that would allow third-party fintech providers to compete on equal terms with incumbent super-app platforms. Regarding the digital tenge, the National Bank of Kazakhstan should consider a two-tier distribution architecture in which commercial banks serve as intermediaries, thereby preserving their deposit-taking function and mitigating the risk of financial disintermediation. In the sphere of human capital, the government should substantially increase funding for re-skilling programmes targeting workers in high-automation-risk occupations, drawing on international best practice from Denmark's 'flexicurity' model and Singapore's SkillsFuture initiative. Finally, with respect to energy and ESG, the regulation of cryptocurrency mining operations should incorporate binding energy efficiency standards and a carbon footprint disclosure requirement, consistent with the objectives of Kazakhstan's commitments under the Paris

Agreement and the national carbon neutrality target for 2060.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualisation, A.A.A. and B.M.A.; Methodology, A.A.A. and S.B.B.; Formal analysis, A.A.A.; Investigation, A.A.A.; Writing — original draft preparation, A.A.A.; Writing — review and editing, B.M.A., S.B.B., G.Zh.Zh. and M.I.I.; Supervision, B.M.A. and M.I.I.; Project administration, B.M.A.

Use of AI Tools

AI tools were used in the preparation of this manuscript as an auxiliary means for language editing and bibliography formatting. All results have been verified by the authors.

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