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Measuring the Digital Economy in Kazakhstan: From Global Indices to a Contextual Composite Index (IDED)

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Abstract

This study examines the development of the digital economy and society in the Republic of Kazakhstan by combining international benchmarking with a context-specific national framework. It highlights the limitations of existing global indices such as DESI, NRI, and EGDI in capturing the structural and institutional dimensions of digital transformation in emerging economies. To address this gap, the study introduces a novel composite metric, the Index of Digital Economy Development (IDED), which integrates five sub-indices: infrastructure, usage, human capital, economic digitization, and transformation effectiveness. The methodology involves comparative index analysis, the construction of the IDED, and statistical validation through a public opinion survey and regression modeling. Key findings indicate that cybersecurity is a critical yet under-represented component of digital development, showing strong empirical correlations with DESI scores in benchmark countries. The results also highlight Kazakhstan's strengths in digital public services and internet access, contrasted with weaknesses in business digitization and innovation. The proposed IDED offers a more comprehensive and policy-relevant tool for assessing digital progress in transitional economies. This study contributes to the literature by proposing a replicable index structure and providing empirical evidence for the inclusion of cybersecurity in national digital economy assessments. The aim of the study is to assess Kazakhstan's digital economy development by addressing limitations in global measurement frameworks. Methodologically, it combines comparative index analysis, the construction of a national composite index (IDED), and statistical validation using a regional survey and regression analysis. The findings reveal both strengths and gaps in Kazakhstan's digital landscape, particularly in cybersecurity and SME digitalization. The IDED introduces an innovative, context-sensitive framework that enhances the measurement of digital transformation in transitional economies.

Keywords: digital economy; digital transformation; Kazakhstan; composite index; IDED; cyber-security; DESI; development economics

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1. Introduction

In the context of an increasingly digitized global economy, measuring and promoting digital transformation has become a critical priority for policymakers, researchers, and international organizations. The digital economy, which encompasses the production,

distribution, and consumption of goods and services enabled by digital technologies, has transformed traditional economic paradigms and reshaped the contours of global competitiveness (Sembekov et al., 2021; Sultanova & Naser, 2024). This transformation is driven by rapid advances in information and communication technologies (ICTs), which affect nearly all sectors of modern economies and societies (Sultanova & Naser, 2024; Yilmaz, 2021).

For emerging economies, digitalization is not only a lever for improving productivity and service delivery, but also a potential tool for overcoming historical development constraints and institutional rigidities (Hung, 2023; Van, 2021). The digital economy enables new forms of value creation and innovation, helping countries overcome industrial stagnation and build more inclusive growth pathways (Kalinin, 2024; Kamalu & Ibrahim, 2024).

Kazakhstan, an upper-middle-income country with an active digitization agenda, has embarked on a series of strategic programs, such as Informational Kazakhstan 2020, Digital Kazakhstan, and DigitEL, aimed at modernizing infrastructure, improving public sector efficiency, and promoting digital entrepreneurship (Kuanaliyev et al., 2024; OECD, 2023). These initiatives reflect a broader commitment to positioning Kazakhstan as a regional leader in digital transformation. In particular, Kazakhstan has made progress in expanding broadband access, promoting digital public services, and investing in ICT education and infrastructure (Alimbaev et al., 2021; Goloshchapova et al., 2023).

Despite measurable improvements in connectivity and public e-services, key barriers remain, including uneven digitization of the private sector, weak innovation systems, and regulatory gaps in data governance and cybersecurity (OECD, 2023; Otarbayeva et al., 2024; Sembekov et al., 2021). These persistent weaknesses suggest the need for a nuanced understanding of how digital transformation unfolds in transition economies and how it can be better measured. While numerous global indices provide benchmarks for the digital economy, such as DESI, EGDI, and NRI, the recent literature highlights their limited sensitivity to national contexts, particularly in countries such as Kazakhstan (Liu & Kharchenko, 2023; L. Yang & Lin, 2024). Most indices aggregate data at the macro level and under-represent critical components such as cybersecurity, firm-level adoption, and regional disparities.

This literature review synthesizes conceptual, empirical, and methodological contributions on digital transformation in emerging economies and identifies the need for a contextualized, multidimensional measurement framework. Specifically, it supports the conceptual rationale for the Index of Digital Economy Development (IDED), which is tailored to the institutional and structural realities of Kazakhstan.

The research gap addressed in this study arises from the lack of a context-sensitive, multidimensional framework capable of accurately measuring and interpreting the level of digital economy development in countries such as Kazakhstan. Although existing global benchmarks have contributed to the development of comparative tools for assessing digital economies, they often fail to capture critical dimensions such as cybersecurity, the policy environment, and SME digitization factors essential for evaluating digital transformation in emerging markets. Moreover, few studies have attempted to integrate international index-based assessments with empirical data derived from national or regional surveys.

The main objective of this study is to assess the level of development of the digital economy and society in Kazakhstan using a combined methodology that integrates international benchmarking, the construction of a proprietary national index (IDED), and statistical validation through public opinion surveys and regression modeling. Specifically, the study seeks to (1) assess Kazakhstan's current position in leading global indices; (2) construct a composite index of digital economy development tailored to Kazakhstan's institutional and economic context; and (3) validate the inclusion of additional indicators, particularly cybersecurity, through empirical survey analysis and cross-country regression modeling.

The scientific contribution of this research lies in the development of a novel Hierarchical Composite Index (IDED) that complements and extends existing measurement frameworks. The IDED integrates both supply- and demand-side indicators, provides a balanced assessment of infrastructural, human, and economic dimensions, and can be replicated in other emerging digital economies. The study also provides empirical evidence on the statistical relationship between cybersecurity and digital performance, addressing a growing concern in digital policy debates that is often neglected in traditional indices.

The remainder of this paper is organized as follows. Section 2 presents the research methodology, including the analytical framework, the construction of the Index of Digital Economy Development (IDED), and the survey design. Section 3 discusses the empirical results, including Kazakhstan's position in international indices, the structure and results of the IDED, and the results of the public opinion survey and regression analysis. Section 4 provides a detailed discussion of the results, exploring their implications for digital policy and identifying key areas for improvement. Finally, Section 5 concludes the study by summarizing the main findings, highlighting contributions to the literature, and suggesting directions for future research.

2. Literature Review

2.1. Digital Transformation in Emerging Economies

A growing body of literature highlights the promise and complexity of digital transformation in emerging and transitional economies. In contrast to high-income countries, where technology adoption is often demand-driven and led by the private sector, digitalization in developing contexts often requires deliberate policy intervention, infrastructure investment, and institutional adaptation (Hung, 2023; Kruss et al., 2025; Van, 2021). For countries such as Kazakhstan, the State plays a central role in establishing digital foundations, from broadband expansion to e-government services (Kalinin, 2024; Kuanaliyev et al., 2024; OECD, 2023).

However, empirical evidence suggests that digital transformation is uneven and fragmented across sectors and regions. Gertzen et al. (2022), Kee et al. (2025), and Sembekov et al. (2021) highlight the limited readiness of SMEs to adopt digital technologies due to capacity constraints, lack of incentives, and insufficient awareness. Similar findings are reported in South Africa (Nkwei et al., 2023), Indonesia (Anatan & Nur, 2023), and Morocco (Nassir et al., 2023), where SMEs consistently report low levels of internal ICT expertise and limited access to support structures.

Beyond the firm level, digital skills gaps in the general population further inhibit transformation. Intalar et al. (2024) highlight the role of education systems and lifelong learning in building human capital for Industry 4.0, noting that countries in Southeast and Central Asia alike face deficits in a digitally literate workforce (Liu & Kharchenko, 2023; Stankovic et al., 2021). This human capital deficit is compounded by infrastructure shortcomings: inadequate mobile and fixed broadband coverage, especially in rural or peripheral regions, remains a persistent bottleneck (Digital Progress and Trends Report 2023, n.d.; Stankovic et al., 2021; Tsapova et al., 2024).

The role of institutional capacity is also critical. Heeks et al. (2021) introduce the concept of "institutional voids," where the lack of effective regulatory frameworks, enforcement mechanisms, and stakeholder engagement limits the impact of digital policy. In Kazakhstan, the private sector often perceives digital policies as top-down and technocratic, with limited consultation and practical support (OECD, 2023; Development of the Digital Economy of Kazakhstan, 2025; Ualtayev et al., 2024). Moreover, the mismatch between rapid technological change and slow regulatory adaptation creates uncertainty for business stakeholders (Sultanova & Naser, 2024).

The digital economy characteristics in Central Asian countries, particularly Kazakhstan, exhibit notable parallels with other emerging economies such as South Africa, Indonesia, Pakistan, and Poland (Anatan & Nur, 2023; Jankowska & Gotz, 2024; Nassir et al., 2023). Shared structural challenges include limited SME readiness for digital adoption, underdeveloped ICT infrastructure, and persistent human capital gaps (Kee et al., 2025; Nadeem et al., 2024; Sembekov et al., 2021). These similarities underscore the relevance of cross-regional comparisons and suggest that common policy lessons may be applicable across transitional digital economies.

In Kazakhstan, digital transformation is largely State-driven, as exemplified by initiatives such as Digital Kazakhstan and Informational Kazakhstan 2020 (Kuanaliyev et al., 2024). However, the impact of these efforts is often limited by institutional bottlenecks—slow legal adaptation, low digital literacy in SMEs, and limited coordination with stakeholders (OECD, 2023; Ualtayev et al., 2024). These dynamics closely mirror those in South Africa and Indonesia, where centralized digital strategies face similar execution challenges (Anatan & Nur, 2023; Nkwei et al., 2023). The evidence suggests that successful digital policy requires not only infrastructure and investment but also inclusive governance and adaptive institutions.

Taken together, these studies suggest that digital transformation in emerging markets requires a systemic approach that considers technological infrastructure, institutional arrangements, user capabilities, and sector-specific readiness. This complexity underscores the need for robust, contextual measurement tools that go beyond general connectivity or digital usage statistics (Chen et al., 2023; W. Yang et al., 2024; Digital Progress and Trends Report 2023, n.d.).

2.2. Limitations of Global Indices in Capturing Context

Despite their value for standardization and policy benchmarking, global digital indices developed by international organizations such as DESI, EGDI, and NRI have come under increasing criticism for their limited applicability in developing and transition contexts (Tokmergenova et al., 2021; Vovk et al., 2021; OECD, 2023; Digital Progress and Trends Report 2023, n.d.). The following limitations are most commonly noted in both academic and policy literature:

1. Reliance on Obsolete Infrastructure Indicators

Many indices continue to emphasize foundational infrastructure metrics such as broadband penetration or basic connectivity that no longer capture the real depth of digital transformation (Godlewska-Majkowska et al., 2023; Liu & Kharchenko, 2023). For example, Kazakhstan has achieved broad mobile and fixed broadband access, but this should be considered a baseline condition, not a marker of advanced digital maturity.

More meaningful indicators such as the level of automation in public service delivery, the share of services incorporating AI, or the adoption of big data in State administration are often absent from index frameworks, despite being essential to evaluating actual digital capacity and innovation in governance.

2. Lack of Regional and Sectoral Granularity

Most global indices aggregate data at the national level, masking disparities between urban and rural areas or between sectors such as public administration and SMEs (Tsapova et al., 2024; Liu & Kharchenko, 2023). As a result, economies like Kazakhstan appear stronger in rankings than they actually are at the firm or regional level, particularly outside major urban centers.

Empirical research shows that while Kazakhstan performs relatively well on basic indicators such as mobile broadband penetration and e-government infrastructure, actual

digital adoption among SMEs remains limited and uneven across regions (Kulzhambekova et al., 2023; Dinh et al., 2023). These sectoral nuances are rarely captured in global indices, which often lack firm-level or microeconomic data, including enterprise diagnostics or bottom-up user assessments (Anatan & Nur, 2023; Kee et al., 2025).

3. Neglect of Qualitative and Behavioral Dimensions

Beyond technical metrics, digital transformation depends on intangible enablers such as digital trust, user confidence, and institutional credibility. These dimensions, closely linked to data protection, service reliability, and cybersecurity, are rarely captured in composite indicators, leading to an incomplete picture of actual adoption and usage (Mikhno et al., 2022; Kruss et al., 2025; Heeks et al., 2021).

4. Limited Consideration of Institutional and Regulatory Readiness

Indexes often fail to assess the institutional flexibility and regulatory adaptability required to support innovation. Static or outdated legal frameworks hinder the scaling of new technologies and platforms. In Kazakhstan, regulatory uncertainty in areas such as data sovereignty, electronic contracting, and AI governance continues to be a barrier, particularly for SMEs (Ualtayev et al., 2024; OECD, 2023).

5. Methodological Inflexibility and Lack of Local Calibration

Common methodologies used in global indices such as PCA, entropy, or AHP are often applied without adaptation to local contexts. This undermines transparency and makes it difficult for national governments to use these indices as actionable tools for policy design (Chen et al., 2023; Tokmergenova et al., 2021; W. Yang et al., 2024).

To ensure contextual relevance, index construction should include both standardized benchmarks and country-specific dimensions based on national development priorities and empirical enterprise-level data (Karacuka et al., 2024; Kee et al., 2025; Petkovski et al., 2024). In Kazakhstan's case, integrating data from SMEs, regional diagnostics, and user feedback may substantially improve index validity and policy applicability (Anatan & Nur, 2023).

6. Under-representation of Cybersecurity and Risk Management

Cybersecurity is a critical determinant of digital trust, business resilience, and systemic integrity. However, it is either omitted or marginally addressed in most global digital indices. This under-representation is particularly problematic in countries like Kazakhstan, where cyber threats are rising, and protective mechanisms for SMEs remain weak (Kalinin, 2024; Chen et al., 2023; Stankovic et al., 2021).

The lack of attention to cybersecurity also diminishes the ability of international indices to reflect citizens' digital trust and the business environment's exposure to operational risks. As Kazakhstan continues to expand e-services and digitize State functions, the exclusion of such critical dimensions significantly limits the diagnostic utility of international rankings (Sembekov et al., 2021; OECD, 2023).

Consequently, scholars advocate for context-sensitive composite indices that integrate standardized metrics with locally meaningful data, address institutional diversity, and better reflect firm-level realities (Godlewska-Majkowska et al., 2023; Heeks et al., 2021).

2.3. Kazakhstan-Specific Challenges and the Need for Contextualization

Kazakhstan provides a compelling case study of both ambition and structural limitations in digital development. On the one hand, it has developed some of the most comprehensive national digital strategies in the post-Soviet space, investing heavily in state infrastructure, e-government platforms, and mobile internet coverage (OECD, 2023). Programs such as Digital Kazakhstan and DigitEL have improved the delivery of public

services, expanded connectivity, and introduced digital identity tools to facilitate access to e-services (Sembekov et al., 2021; Tazhiyev et al., 2024).

However, these efforts have not been matched in the private sector. Firm-level surveys and international reports consistently show that Kazakhstan's SMEs lag behind in digital adoption, innovation, and productivity-enhancing technologies (Kulzhambekova et al., 2023; Kee et al., 2025). Barriers include lack of in-house technical expertise, limited awareness of digital opportunities, and high perceived costs of technology integration (Gertzen et al., 2022). In addition, many SMEs operate in a regulatory environment that lacks clear rules on data ownership, electronic signatures, digital payments, and cybersecurity (Ualtayev et al., 2024).

Cybersecurity is another underdeveloped area. The Cyber Shield Kazakhstan initiative, launched in 2017, has focused primarily on securing critical state systems. The private sector, especially SMEs, remains underprotected and ill-prepared to manage cyber risks (Kalinin, 2024). Recent studies point to a low level of cyber culture, with minimal investment in secure data infrastructure, incident response, or employee awareness training (Li et al., 2024). This poses systemic risks not only to business continuity, but also to overall trust in the digital economy, an element rarely captured in current measurement frameworks (Goloshchapova et al., 2023).

The regulatory environment, while evolving, remains fragmented and often reactive rather than anticipatory. Legal gaps exist in areas such as digital contracts, intellectual property protection for software, and data residency (Ualtayev et al., 2024). Moreover, while Kazakhstan has adopted various international data protection principles, their enforcement is inconsistent, particularly with respect to private sector actors (OECD, 2023). These issues create uncertainty and increase the cost of compliance, especially for smaller businesses.

Institutional fragmentation also hinders coordinated policy implementation. Ministries and agencies often operate with overlapping mandates, and the integration of business sector needs into national digital strategies remains limited. The resulting "policy disconnect" leads to the duplication of efforts, the underutilization of digital platforms, and ineffective support for innovation ecosystems (Kulzhambekova et al., 2023). These observations are consistent with the notion of Heeks et al. (2021) regarding institutional gaps that impede not only digital policy implementation, but also market readiness for digital products and services.

Importantly, despite the existence of high-level strategies, data availability and measurement capacity remain limited. Kazakhstan lacks disaggregated data on the digital economy by company size, sector, or region. Publicly available indicators are typically collected for reporting to international bodies, not for internal diagnostic use. This measurement gap prevents targeted policy interventions and obscures key areas of performance, such as SME digital adoption or regional digital divides (Godlewska-Majkowska et al., 2023).

2.4. Towards a Contextual Index: Rationale and Conceptual Framework for IDED

Given the limitations of existing indices and the contextual complexity of Kazakhstan's digital trajectory, there is a growing need for a composite, multidimensional index specifically designed for emerging economies undergoing digital transformation. The proposed Index of Digital Economy Development (IDED) aims to fill these gaps by incorporating localized indicators and capturing qualitative dimensions of digital maturity often ignored by global tools.

The conceptual structure of the Index of Digital Economy Development (IDED) is grounded in methodological best practices in index construction (Chen et al., 2023; Liu & Kharchenko, 2023; Tokmergenova et al., 2021) and consists of five key pillars, each representing a critical domain of digital development:

- ICT infrastructure: This pillar includes indicators such as broadband coverage, average internet speed, and access to digital devices. These reflect the foundational technological environment required for digital participation and are further contextualized to account for regional disparities and service quality.
- Human capital and digital literacy: Indicators in this pillar assess digital skills, educational attainment in ICT-related fields, and workforce readiness for digital transformation. The emphasis extends beyond formal education to include lifelong learning and the adaptability of human resources to emerging technologies.
- Economic digitization: This dimension focuses on SME digital adoption, e-commerce penetration, and innovation output. It captures the extent to which businesses integrate digital tools into their operations and contribute to the creation of digital value.
- Digital public services: This pillar includes the availability and interoperability of e-government services, the level of automation, and citizen satisfaction with online platforms. Unlike global indices, the IDED also evaluates the degree to which AI and big data technologies are embedded in public administration, reflecting more advanced stages of digital government transformation.
- Cybersecurity and institutional trust: This pillar conceptualizes cybersecurity as the ability of public and private actors to protect systems, data, and infrastructure from cyber threats. Indicators include the presence of legal frameworks, business cyber preparedness, and incident response capacity. Digital trust is defined as users' perceived reliability, integrity, and safety of digital systems, and is influenced by factors such as policy transparency, data protection, legal enforcement, and the consistency of public service delivery (Kalinin, 2024; Brici & Achim, 2023).

Unlike standard indices, the IDED integrates both supply- and demand-side indicators and applies mixed methods: quantitative metrics from national statistics, administrative records, and firm-level surveys, alongside perception-based data from citizens and stakeholders. The index allows for both regional and sectoral disaggregation, offering a more precise diagnosis of internal disparities.

By embedding dimensions such as cybersecurity resilience and institutional digital trust at the core of its structure, the IDED presents a replicable and policy-relevant framework capable of guiding targeted interventions in Kazakhstan and comparable transition economies pursuing inclusive and sustainable digital transformation.

3. Methodology

3.1. Analytical Framework and Data Sources

This study adopts a multi-level methodological approach, combining a comparative analysis of international indices, the development of a proprietary composite index, and an empirical, statistical investigation based on primary survey data. The overall objective is to provide a comprehensive assessment of the level of development of the digital economy and society in the Republic of Kazakhstan, while identifying structural shortcomings in existing measurement tools and proposing improvements based on quantitative reasoning.

The methodological framework is based on the recognition that the digital economy is a multidimensional and evolving phenomenon. Consequently, assessing its evolution requires an integrative approach that takes into account infrastructural, societal, economic, and institutional dimensions. To this end, the study uses both secondary and primary data.

Secondary data was obtained from well-established international indices used to assess the digital economy across countries. These include the Digital Economy and Society Index (DESI), the Network Readiness Index (NRI), the ICT Development Index (IDI), the E-Government Development Index (EGDI), the Global Connectivity Index (GCI), and the Global Innovation Index (GII). Each of these indices aggregates various indicators related

to information and communication technologies (ICTs), human capital, innovation, digital government services, and the overall digital maturity of economies.

However, despite their widespread use, these indices have several methodological limitations. In particular, they often neglect local contextual variables, apply inconsistent indicator groupings, and may fail to capture the full complexity of digital transformation processes in developing and transition economies such as Kazakhstan. In response to these shortcomings, this research has developed a new composite indicator: the Index of Digital Economy Development (IDED).

3.2. Design and Construction of the IDED Index

To operationalize the concept of digital economy development in a structured and context-sensitive manner, this study constructs a composite Index of Digital Economy Development (IDED). The index is designed to identify critical gaps in Kazakhstan's digital transformation and improve policy responsiveness. The Table 1 below summarizes the conceptual structure, data sources, normalization procedures, and methodological steps involved in the construction of the IDED.

Table 1. Structure and calculation procedure of the Index of Digital Economy Development (IDED).

Stage	Description
Conceptual Framework	Hierarchical model comprising three tiers: (1) readiness to implement digital technologies, (2) intensity of usage, and (3) impact on national development.
Sub-Indices	Five key sub-indices: (1) ICT infrastructure and access, (2) internet usage, (3) human capital, (4) economic digitalization, and (5) effectiveness of digital transformation.
Data Sources	Primary and secondary data from international (ITU, World Bank, UNDP) and national (KazStat) sources.
Normalization	Min–max scaling method applied to ensure comparability across indicators with different units.
Weighting Scheme	Linear weighted aggregation. Weights range from 15% to 25%, assigned based on thematic relevance and expert consultation.
Calculation Procedure	Step 1: Justification of indicator structure. Step 2: Data collection. Step 3: Indicator normalization. Step 4: Weighting and aggregation. Step 5: Scoring.
Outcome	Composite IDED score capturing readiness, usage, and macroeconomic impact. Enables cross-country comparison and internal policy diagnostics.

This structured approach enables a more accurate and multidimensional assessment of digitalization processes by combining infrastructural readiness, actual usage patterns, and macroeconomic outcomes. By distinguishing these three levels, the IDED overcomes the limitations of global indices and provides a policy-relevant framework tailored to Kazakhstan's institutional and socioeconomic environment.

The normalization of indicators was conducted using the min–max scaling method, which ensures the comparability of variables measured in different units by transforming all values to a standardized scale between 0 and 1. The formula for min–max normalization is as follows:

$$X_{norm} = \frac{X - X_{min}}{X_{max} - X_{min}} \quad (1)$$

where X is the original value, and X_{min} and X_{max} represent the minimum and maximum observed values for the respective indicator. This technique preserves the distribution of

the data and facilitates integration into composite indices (Chen et al., 2023; Tokmergenova et al., 2021; Anatan & Nur, 2023).

Aggregation was performed using a weighted linear model, where normalized indicators were combined according to their thematic importance:

$$IDED = \sum_{i=1}^{n} \omega_i \cdot X_{i,\ norm} \quad (2)$$

Weights (ω_i) were assigned based on expert consultations and previous methodological practices, generally ranging from 15% to 25%. This approach follows the structure adopted in comparable national digital indices (Tokmergenova et al., 2021; OECD, 2023).

Such methodology allows the IDED to reflect not only the statistical structure of the data but also policy priorities and expert judgment, as recommended in modern composite index construction (Development of the Digital Economy of Kazakhstan, 2025; Kalinin, 2024).

3.3. Empirical Survey and Statistical Validation

To enrich the index-based analysis and validate key assumptions regarding the relevance and comprehensiveness of selected indicators, a structured empirical survey was conducted in the East Kazakhstan region. This region was selected for its representative mix of urban and rural populations, as well as its active participation in national digital transformation programs.

A total of 300 completed responses were collected via an online questionnaire distributed throughout Kazakhstan. Although the survey was disseminated nationally, the majority of responses were obtained from the East Kazakhstan region. Due to this regional concentration, the results presented here reflect primarily the perceptions of respondents from that area and are not intended to be nationally representative. Nonetheless, the data provide valuable insights into the public's perceptions of digital infrastructure, services, and trust in digital institutions.

The survey instrument included 11 structured questions aimed at assessing the perceived importance of various indicators and sub-indices among the population. Special attention was paid to dimensions that are often under-represented in global indices, such as cybersecurity, digital literacy, and business digitalization, yet are increasingly critical for sustainable digital development.

Three population strata were targeted:

1. Demographic audience: Includes people aged 20 to 60 years, without division by gender, nationality, education, and other demographic characteristics;
2. Consumer audience: Includes customers or potential customers who use Internet resources and digital technologies;
3. Geographic audience: Includes people living in the East Kazakhstan region.

Data analysis proceeded in several stages:

1. Descriptive statistical analysis: The frequency distribution, arithmetic mean, variance, and standard deviation were calculated for each survey item to evaluate response patterns.
2. Correlation analysis: Pearson and Spearman correlation coefficients were used to determine the strength and direction of relationships between proposed indicators (e.g., cybersecurity) and composite digital development scores.
3. Regression modelling: To further substantiate the inclusion of new indicators, such as cybersecurity, in the measurement of digital economy development, linear regression models were estimated for selected countries (Netherlands, Sweden, and Denmark).

In these models, the DESI index served as the dependent variable and the national level of cybersecurity as the independent variable.

All statistical analyses in this study were performed using Python 3.11, a widely used programming language for scientific computing and data analysis. Processing of the raw survey data involved importing structured datasets in CSV format and transforming them into data frames using the pandas library. The calculation of key descriptive statistics, such as arithmetic mean, variance, and standard deviation, was performed using numerical functions provided by the NumPy package. These metrics allowed for the quantitative assessment of central tendencies and dispersion for each survey question, thereby facilitating comparative analysis across different indicators. To visualize the distribution of responses, histograms and mean comparison plots were generated using the matplotlib plotting library. These graphs illustrated the degree of consensus or polarization among respondents. In cases where hypothesis testing or validation of normality assumptions was relevant, additional statistical functions from the SciPy library were used. The entire data analysis procedure was implemented in a reproducible Python script. While the code itself is not included in the manuscript for brevity, it can be made available upon request to ensure methodological transparency and reproducibility.

These methods were selected to provide a robust, data-driven foundation for the refinement of the IDED index and to ensure alignment with international academic standards in the field of development economics and digital transformation research.

4. Results

4.1. Kazakhstan's Position in International Digital Economy Indices

The level of development of Kazakhstan's digital economy and society can be assessed using various international composite indices. These indices measure digital progress through several sub-indices that capture the level of technological infrastructure, human capital, the digitization of services, and societal readiness. The most commonly used indices include the ICT Development Index (IDI) (International Telecommunication Union, 2024), the Digital Economy and Society Index (DESI) (European Commission, 2024), the Network Readiness Index (NRI) (Portulans Institute, 2024), the World Digital Competitiveness Index (WDCI) (IMD World Competitiveness Center, 2024), the Digital Evolution Index (DEI) (Fletcher School, Tufts University, 2024), the e-Intensity Index (Boston Consulting Group, 2024), the UN E-Government Development Index (EGDI) (United Nations Department of Economic and Social Affairs, 2024a), the E-Participation Index (EPART) (United Nations Department of Economic and Social Affairs, 2024b), the Global Digitalization Index (GDI) (Huawei, 2024), and the Global Innovation Index (GII) (WIPO, 2024). While all of these differ in methodology, scope, and structure, together they provide an overview of Kazakhstan's global digital standing.

Every year, the European Commission assesses the digitalization state of EU countries using the Digital Economy and Society Index (DESI), which provides an overview of the digital economy development level in the global community. The Digital Economy and Society Index is a composite index published annually by the European Commission since 2014. It measures the progress made by EU Member States towards a digital economy and society by combining a set of relevant indicators.

DESI consists of five main policy areas and is the arithmetic mean of their five sub-indices, which are aggregated with different weights: communication, human capital, internet use, digital integration, and digital public services (European Commission, 2024).

According to the Network Readiness Index, published annually by the Portulans Institute and WITSA, Kazakhstan ranked 61st in 2024 (Portulans Institute, 2024), with a score of 52.17, which is 36% lower than the leading country, the United States. The top 10

countries in this ranking include the United States, Singapore, Finland, Sweden, South Korea, the Netherlands, Switzerland, the United Kingdom, Germany, and Denmark.

Another important metric is the Human Development Index (HDI), a composite measure of the level of human development that is, therefore, sometimes used as a synonym for concepts such as "quality of life" or "standard of living". The United Nations Development Programme (UNDP) ranks countries by their HDI level. It is also often referred to as a country's standard of living index or quality of life index because it is a true measure of the quality of life and opportunities available to citizens. UNDP Human Development Reports are prepared at regional, national, and international levels. According to the HDI, Kazakhstan ranks 67th, with a value of 0.802. Compared to Switzerland, which leads with a score of 0.967, this is a difference of 17.1%. The HDI is often interpreted as a measure of the overall quality of life and capability of the population, which are important factors in digital adoption (United Nations Development Programme, 2024).

The ICT Development Index is a composite indicator that characterizes countries' performance in developing information and communication technologies (ICTs). It is calculated using the methodology of the International Telecommunication Union, a specialized agency of the United Nations that sets global standards in the field of ICT. The index was developed in 2007 and is based on 11 indicators that the International Telecommunication Union uses to assess ICT development. These include access to the internet, mobile communications, television systems, radio systems, the development of IT infrastructure, etc. Kazakhstan ranked 42nd in 2024. Leading positions in this index are held by Kuwait, Finland, Estonia, Qatar, Singapore, and others (International Telecommunication Union, 2024).

Kazakhstan's digital competitiveness, particularly in the domains of business digitization and e-commerce, is reflected in its performance in the Network Readiness Index (NRI). This index, published annually by the Portulans Institute in collaboration with WITSA, evaluates countries across four dimensions: technology, people, governance, and impact. In the 2024 edition, Kazakhstan ranked 69th out of 134 countries. Northern and high-income countries dominate the top positions, including Denmark, Estonia, Singapore, South Korea, and Finland (Portulans Institute, 2024).

In contrast, Kazakhstan scores well in e-government development. The E-Government Development Index (EGDI) ranks Kazakhstan 24th in the world, with a score of 0.901, ahead of many countries in its income bracket. Leading countries on this index include Denmark, South Korea, Estonia, Finland, Australia, Sweden, the United Kingdom, New Zealand, the United States, and the Netherlands (United Nations Department of Economic and Social Affairs, 2024a).

A comprehensive synthesis of Kazakhstan's digital status is provided by a comparative DESI-style table, which was constructed based on public data. Table 2 and Figure 1 show the composite I-DESI scores of selected countries. Kazakhstan's total score is 40.371, compared to Finland's 51.846. This ranks Kazakhstan about 50th in the world, with a gap of 11.5% to the top performers.

Compared to 2024, Kazakhstan shows mixed dynamics: a drop of 5 places in the Network Readiness Index (Portulans Institute, 2024), a drop of 16 places in the HDI (United Nations Development Programme, 2024), but a gain of 10 places in the ICT Development Index (International Telecommunication Union, 2024) and a gain of 5 places in the EGDI (United Nations Department of Economic and Social Affairs, 2024a). However, the country dropped 33 places in the global ranking of technologically advanced countries (IMD World Competitiveness Center, 2024). This divergence between indicators reflects fragmented development: public sector digitization has progressed significantly, while the private sector and innovation systems remain less developed.

Table 2. Digital Economy and Society Index (DESI) country rankings, 2024.

Rank	State	Composite Index (I-DESI)	Communication	Human Capital	Using the Internet	Integration of Digital Technologies	Digital Government Services
1	Finland	51.846	75.76	0.942	98.10	83.47	0.958
2	Denmark	51.257	72.70	0.952	97.10	84.55	0.985
3	Sweden	51.169	74.99	0.952	95.30	83.67	0.933
4	United States of America	50.989	78.96	0.927	96.70	77.44	0.920
5	Singapore	50.974	76.94	0.949	97.80	78.21	0.969
6	Switzerland	50.279	73.71	0.967	92.40	83.42	0.900
7	Netherlands	50.132	73.94	0.946	92.50	82.32	0.954
8	UK	49.804	73.57	0.940	93.60	79.95	0.958
9	Norway	49.718	69.7	0.966	93.40	83.59	0.932
10	Australia	49.159	69.43	0.946	95.10	79.36	0.958
11	South Korea	49.043	74.85	0.929	94.40	74.07	0.968
12	Estonia	48.986	67.85	0.899	97.90	77.31	0.973
13	Japan	48.847	70.96	0.920	93.20	78.22	0.935
14	Germany	48.808	73.54	0.950	87.80	80.81	0.938
15	Iceland	48.741	64.86	0.959	95.90	81.02	0.967
16	Russia	41.303	55.74	0.821	90.60	58.50	0.853
17	Kazakhstan	40.371	50.52	0.802	90.10	59.53	0.901

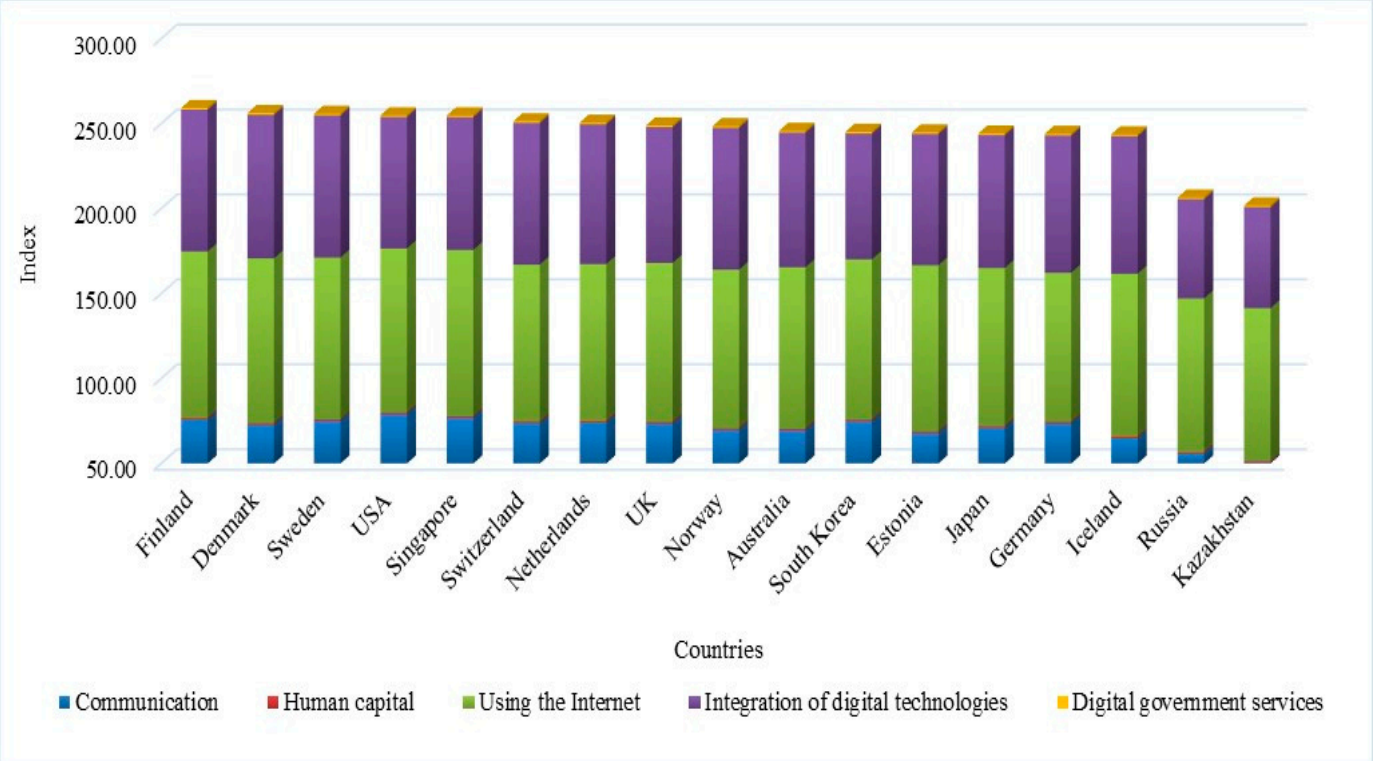


Figure 1. Ranking of countries by the Digital Economy and Society Index (DESI).

To facilitate comparison, countries can be grouped into three development levels based on DESI:

- Group 1—The "leading" countries, with a composite DESI index of over 17;
- Group 2—The "developing" countries, with a composite DESI index of over 10;
- Group 3—The "lagging" countries, with a composite DESI index of under 10.

Kazakhstan clearly fits into Group 2, i.e., developing digital economies.

A detailed analysis of the common indicators used across various indices is presented in Table 3. It reveals that all indices include telecommunications infrastructure, while dimensions such as cybersecurity, ICT sector development, and international cooperation are much less frequently addressed.

Table 3. Analysis under the consideration of international ratings group indicators of digital economics development.

Indicators	WDCI	DEI	DESI	e-Intensity	IDI	NRI	EGDI	EPART	GCI
Institutional Environment Assessment	+	+	-	-	-	+	-	-	+
Innovative Environment Level Assessment	+	+	-	-	-	+	-	-	+
Development of Telecommunications Infrastructure	+	+	+	+	+	+	+	+	+
Availability of ICT Services at a Price	-	-	+	+	-	+	-	-	-
Education Level of the Population	+	-		-	+	-	+	-	-
Development of Practical Skills in Using ICT	+	-	+	+	+	+	+	-	-
Directions of Internet Use by the Population	+	+	+	+	-	+	-	-	-
Use of Digital Technologies in Business	+	+	+	+	-	+	-	-	+
Access to State Electronic Services	+	+	+	+	-	+	+	+	+
Assessment of Information Security	+	+	-	-	-	-	-	-	-
Development of the ICT Sector	-	-	-	-	-	-	-	-	+
Level of International Cooperation in the Field of ICT	-	-	-	-	-	-	-	-	-
Impact of ICT on the Economy	-	-	-	-	-	+	-	-	+
Impact of ICT on Society	-	-	-	-	-	+	-	-	-
Institutional Environment Assessment	+	+	-	-	-	+	-	-	+

This overview highlights the strengths and limitations of existing indices. While they effectively capture infrastructure and public services, they tend to under-represent private sector transformation, digital entrepreneurship, and digital security. Therefore, Kazakhstan's moderate position in many rankings should be interpreted with caution, especially in light of structural asymmetries in digital development. These observations also justify the need to supplement global indices with national composite models such as the Index of Digital Economy Development (IDED), which will be introduced in the following section.

4.2. Index of Digital Economy Development (IDED)

Given the methodological limitations of existing international indices, such as their limited adaptability to national contexts and uneven coverage of essential components of digital transformation, the construction of a composite national-level index—the Index of Digital Economy Development (IDED)—has been proposed as an alternative approach for Kazakhstan. The goal of the IDED is to more accurately reflect the country's digital readiness, usage intensity, and transformation effectiveness by integrating indicators tailored to Kazakhstan's socioeconomic and technological realities.

The overall index score is composed of five sub-indices. These sub-indices reflect the readiness of ICT infrastructure, the intensity of digital technology use, the human capital base, the level of digitization of economic structures, and the effectiveness of digital transformation outcomes. Each sub-index aggregates a set of normalized indicators using assigned weights based on their perceived relevance and data availability. The methodological procedure includes justification of the sub-index structure, data normalization, aggregation using weighted means, and calculation of a final composite index.

The structure of the IDED and the weighting of the sub-indices and indicators are presented in Figure 2. The weights were determined on the basis of expert judgment and international practice. Each sub-indicator was given a specific contribution to the final index, with the greatest emphasis on the effectiveness of digital transformation (25%), followed by infrastructure quality, human capital, and economic digitalization (20% each), and intensity of use (15%).

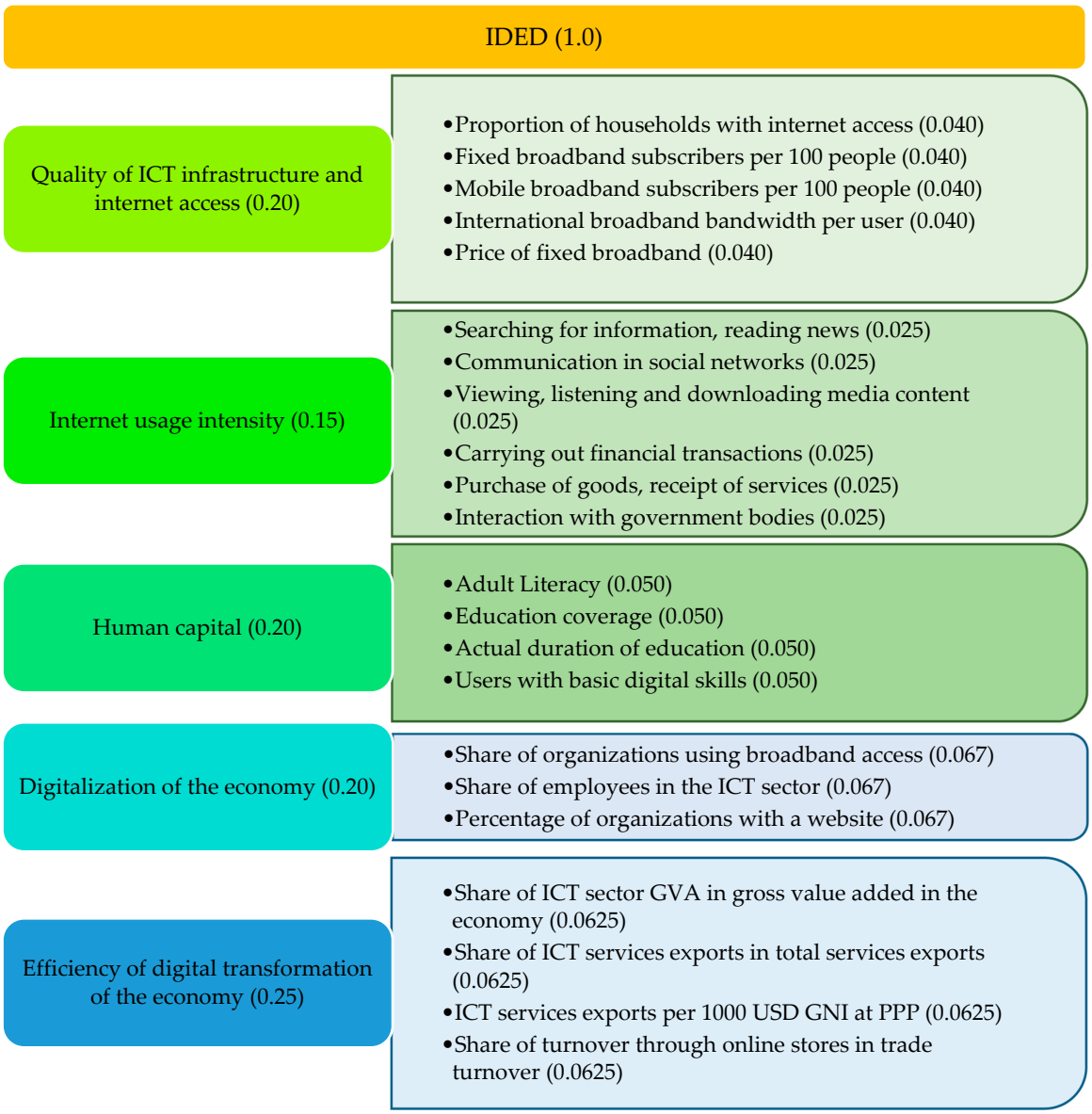


Figure 2. Scheme of the digital economy development index structure indicating the weighting coefficients of the indicators.

4.3. Survey Results and Statistical Analysis

To support the analytical framework of the IDED index and to validate the relevance of individual indicators from the perspective of citizens and users, an empirical survey was conducted in the East Kazakhstan region. The survey aimed to capture public opinion on the appropriateness and importance of various sub-indices and indicators proposed for measuring the digital economy, particularly within the DESI and IDED frameworks. The study sought to identify which aspects of digital development are prioritized by citizens and to statistically analyze patterns of agreement and disagreement in their responses.

A total of 11 questions were asked, primarily in the form of Likert scale items (1 to 5), where 1 indicates strong disagreement and 5 indicates strong agreement. Each question addressed the perceived importance of a specific subindex or indicator. The full list of questions and the statistical representation of the responses are presented in Table 4, including the response scores (xi), probability weights (pi), and number of respondents (ni).

Table 4. Survey questions and statistical series.

QN	Question Topic	xi	pi	ni
1	In your opinion, are the five sub-indices mentioned above sufficient to accurately calculate DESI?	1	0.066667	20
		2	0.17	51
		3	0.186667	56
		4	0.243333	73
		5	0.333333	100
2	In your opinion, are the Communication and Internet Use sub-indexes correlated?	1	0.136667	41
		2	0.123333	37
		3	0.2	60
		4	0.34	102
		5	0.2	60
3	Do you think it is worth revising the sub-indices?	1	0.056667	17
		2	0.12	36
		3	0.29	87
		4	0.366667	110
		5	0.166667	50
4	Should the following indicator be included in the DESI calculation? Broadband Internet Access: Percentage of the population with access to high-speed Internet	1	0.086667	26
		2	0.216667	65
		3	0.293333	88
		4	0.233333	70
		5	0.17	51
5	Should the following indicator be included in the DESI calculation? Citizen Internet Use: Percentage of Citizens Who Regularly Use the Internet	1	0.086667	26
		2	0.216667	65
		3	0.17	51
		4	0.233333	70
		5	0.293333	88
6	Should the following indicator be included in the DESI calculation? Digital Infrastructure: Assessing the quality and availability of digital infrastructure, including communications networks, hardware, and software	1	0.106667	32
		2	0.143333	43
		3	0.166667	50
		4	0.236667	71
		5	0.346667	104
7	Should the following indicator be included in the DESI calculation? Digital skills and education: the level of digital literacy of the population, and the availability of educational programs on digital technologies	1	0.143333	43
		2	0.24	72
		3	0.326667	98
		4	0.2	60
		5	0.09	27

Table 4. *Cont.*

QN	Question Topic	xi	pi	ni
8	Should the following indicator be included in the DESI calculation? Integration of digital technologies in business: The share of enterprises using digital technologies in their operations	1	0.326667	98
		2	0.24	72
		3	0.2	60
		4	0.143333	43
		5	0.09	27
9	Should the following indicator be included in the DESI calculation? Digital Public Services: Availability and quality of digital government and public services	1	0.143333	43
		2	0.17	51
		3	0.176667	53
		4	0.213333	64
		5	0.296667	89
10	Should the following indicator be included in the DESI calculation? Innovation and research in digital technologies: The volume of investment in research and development in digital technologies, and the number of patents in this area	1	0.126667	38
		2	0.163333	49
		3	0.286667	86
		4	0.243333	73
		5	0.18	54
11	Should the following indicator be included in the DESI calculation? Cybersecurity: the level of protection of information systems from cyber threats	1	0.093333	28
		2	0.08	24
		3	0.1	30
		4	0.276667	83
		5	0.45	135

The data provided for analysis includes the mean, variance, and standard deviation for each question. Based on this data, the following conclusions can be drawn:

- The highest mean value was recorded for Question 11 (Cybersecurity), with a mean of 3.91, indicating high agreement and perceived importance;
- The lowest mean value was for Question 8 (Integration of digital technologies into business), at 2.43, suggesting dissatisfaction or skepticism regarding this domain;
- Question 9 (Digital public services) exhibited the highest variance (2.02) and standard deviation (1.42), implying wide variation in public opinions;
- The lowest variance (1.16) and standard deviation (1.08) were observed for Question 3 (Revision of sub-indices), indicating consistency in responses.

The distribution of answers is graphically presented in Figure 3, which includes histograms of responses for selected questions. The figure clearly shows that responses to the cybersecurity question are skewed towards agreement (scores 4 and 5), while the digital business question shows more neutral and negative ratings.

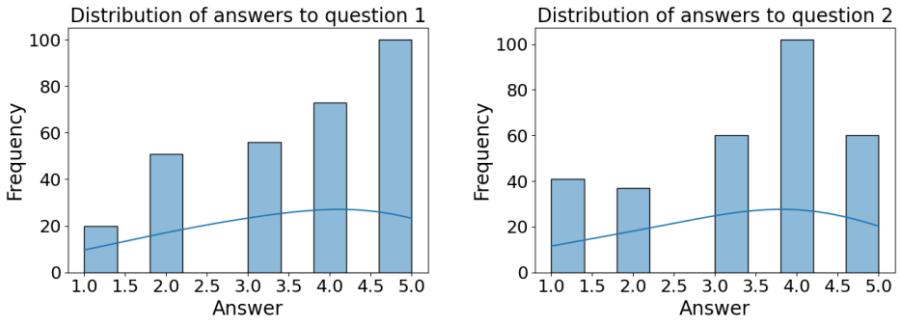


Figure 3. *Cont.*

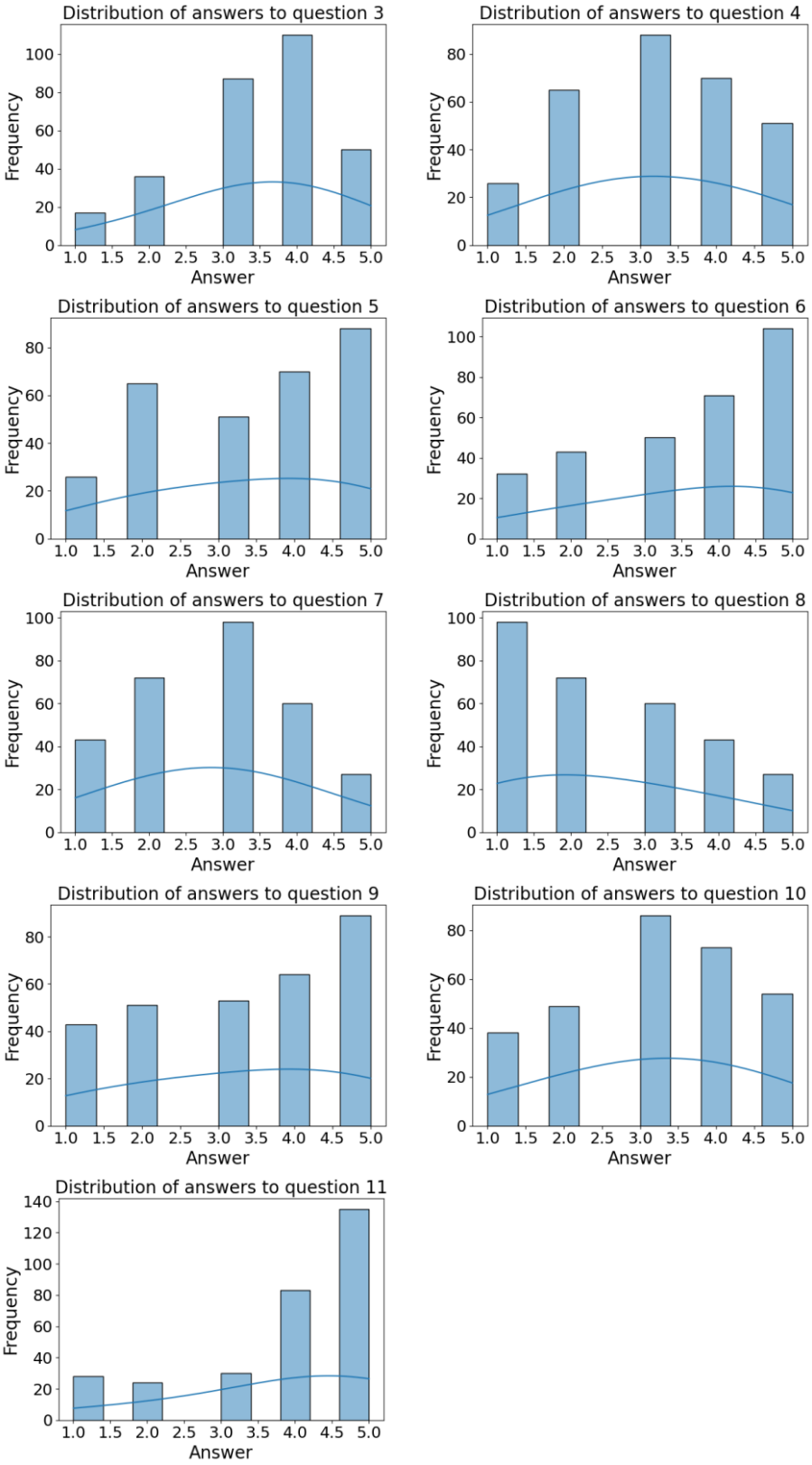


Figure 3. Distribution graphs of answers to questions.

Additionally, Figure 4 presents the mean scores for all questions, confirming that cybersecurity was evaluated most favorably, while digital business and education scored relatively low.

An interpretative analysis of the statistical results leads to several important conclusions. The high mean and low dispersion of responses to the cybersecurity question

confirms its perceived relevance and urgency in the context of measuring the digital economy. This supports the recommendation to include a dedicated cybersecurity indicator in future iterations of national and international indices. In contrast, the low mean and high variance in responses regarding the digitization of enterprises points to an area that requires both empirical investigation and policy attention. The lack of consensus among respondents may be due to different business practices, limited awareness of digital tools in enterprises, or heterogeneous levels of digital maturity across sectors.

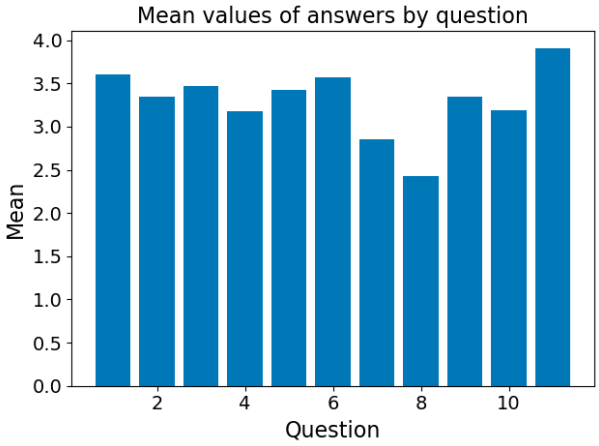


Figure 4. Average values of answers to questions.

The case of digital public services, which received a relatively high mean but also the largest variance, suggests that while the majority consider these services important, their availability, quality, or accessibility may vary significantly depending on the respondent's location or personal experience.

To support the reliability of the data analysis, all calculations were performed using statistical software based on structured datasets. Arithmetic means, variances, and standard deviations were calculated for each survey item, and graphs were generated to assess trends and response consistency. The methodology ensured transparency, comparability of indicators, and reproducibility of results.

The survey results confirm the relevance of several proposed indicators, especially those related to cybersecurity, public services, and access to infrastructure. At the same time, they reveal notable weaknesses in public perceptions of the economic and educational aspects of digitalization, which may indicate gaps in national digital policy implementation or awareness. These findings provide the empirical basis for the regression analysis presented in the following section, which examines the statistical relationship between selected indicators, particularly cybersecurity, and overall DESI performance in the benchmark countries.

4.4. Regression Analysis of Cybersecurity and DESI

The results of the survey conducted in East Kazakhstan indicated strong public support for including cybersecurity as an explicit component of national and international indices measuring digital economy development. In order to substantiate this qualitative finding with empirical evidence, a statistical analysis was carried out to evaluate the relationship between national levels of cybersecurity and DESI scores.

The objective of this analysis was to determine whether a statistically significant and consistent correlation exists between a country's cybersecurity performance and its overall DESI score. To this end, a regression-based approach was adopted to model the relationship and assess its explanatory power. Three countries were selected as case studies for this purpose: the Netherlands, Sweden, and Denmark. These countries were chosen due to their

high DESI rankings, consistent digital policy frameworks, and availability of longitudinal cybersecurity metrics.

The analysis involved the formulation of the following hypotheses:

- H0 (null hypothesis): The cybersecurity indicator does not have a statistically significant impact on the DESI index;
- H1 (alternative hypothesis): The cybersecurity indicator has a statistically significant impact on the DESI index.

Time-series data were compiled for each country for the years 2021, 2022, 2023, and 2024, covering DESI index scores and corresponding national cybersecurity levels. These data are presented in Table 5.

Table 5. DESI index scores and cybersecurity levels in the Netherlands, Sweden, and Denmark (2021–2024).

Year	Data for The Netherlands		Data for Sweden		Data for Denmark	
	DESI Index	Cybersecurity Level	DESI Index	Cybersecurity Level	DESI Index	Cybersecurity Level
2021	45.59	0.76	45.71	0.733	46,48	0.617
2022	48.06	0.885	48.74	0.81	48.69	0.852
2023	54.68	0.9705	55.75	0.9455	55.97	0.926
2024	62.36	0.971	60.49	0.946	65.25	0.926

The strength of the relationship between cybersecurity and DESI was first assessed using Pearson's correlation coefficient. The results are as follows:

- The Netherlands: r = 0.8416;
- Sweden: r = 0.9522;
- Denmark: r = 0.7405.

The Chaddock scale is used to interpret the strength of the relationship between two observed values. It defines the strength of the relationship as follows: 0—no relationship at all; 0–0.3—very weak; 0.3–0.5—weak; 0.5–0.7—medium; 0.7–0.9—high; 0.9–1—very high. According to the Chaddock scale, these values indicate strong to very strong correlations, with Sweden showing the highest degree of linear association between the two variables.

To quantify this relationship further, a simple linear regression was performed for each country, with the DESI index as the dependent variable (y) and the cybersecurity score as the independent variable (x). The regression models yielded the following equations and statistical parameters:

The Netherlands:

- Regression equation: $y = 29.31 + 27.47x$;
- Coefficient of determination: $R^2 = 0.70$;
- *p*-value of β: <0.05.

Sweden:

- Regression equation: $y = 22.58 + 40.12x$;
- Coefficient of determination: $R^2 = 0.90$;
- *p*-value of β: <0.05.

Denmark:

- Regression equation: $y = 35.27 + 21.43x$;
- Coefficient of determination: $R^2 = 0.55$;
- *p*-value of β: <0.05.

These models indicate that cybersecurity is a statistically significant predictor of DESI performance in all three cases. The regression coefficients are positive and significantly different from zero, with all p-values below the 0.05 threshold, confirming rejection of the null hypothesis. The R^2 values indicate that the models explain 70% (The Netherlands), 90% (Sweden), and 55% (Denmark) of the variance in the DESI scores.

The relatively high explanatory power of these models supports the theoretical assumption that cybersecurity is not just a technical requirement, but a fundamental component of trust, continuity, and resilience in the digital economy. Countries with higher cybersecurity standards are more likely to foster trust among users, businesses, and institutions, which in turn facilitates broader digital adoption, innovation, and service development.

The robustness of these findings across three digitally advanced economies reinforces the recommendation to integrate cybersecurity indicators as core components of indices such as DESI or IDED. This is consistent with the strong support for cybersecurity inclusion observed in the public survey (mean = 3.91), as well as with global trends emphasizing the strategic importance of a secure digital infrastructure.

Therefore, based on both statistical significance and theoretical reasoning, it is suggested that the cybersecurity dimension be institutionalized as a dedicated sub-index or weighted indicator in future assessments of the development of the digital economy. This would not only align measurement frameworks with current digital policy priorities but also enhance their ability to inform resilient and inclusive digital transformation strategies.

5. Discussion

The proposed Index of Digital Economy Development (IDED) provides a comprehensive framework for assessing national digital transformation by integrating infrastructural, behavioral, educational, economic, and macroeconomic indicators. Unlike existing international indices that focus primarily on access and basic services, IDED emphasizes the transformative economic impact of digital technologies through indicators such as ICT sector contribution to GDP, ICT services exports, and e-commerce penetration.

The empirical analysis reveals that Kazakhstan demonstrates moderate progress in digital economy development, with notable strengths in digital public services and internet usage, but persistent weaknesses in technological integration within the business sector. The regression analysis confirmed cybersecurity's statistically significant impact on overall digital development (R^2 = 0.90 for Sweden), providing empirical justification for its inclusion in composite indices and supporting the weighting scheme where transformation effectiveness carries the highest weight (25%).

The cybersecurity digital economy relationship represents a crucial theoretical contribution. Recent evidence increasingly supports the proposition that cybersecurity is not a peripheral element, but a core determinant of national digital maturity. According to the 2025 Global Digital Trust Insights Report by PwC (2025), only 2% of surveyed organizations have achieved enterprise-wide cyber resilience, despite over two-thirds of technology leaders identifying cybersecurity as their top digital transformation priority. Similarly, the 2025 Global Cybersecurity Outlook published by the World Economic Forum (World Economic Forum, n.d.) emphasizes that nations with higher levels of cyber readiness tend to exhibit stronger institutional capacity for digital innovation and coordination. As noted by the 2025 Gartner Cybersecurity Trends report (Gartner, n.d.), the integration of cybersecurity into strategic business functions is essential for enabling innovation, continuity, and public trust in digital services. The modified DESI ranking incorporating cybersecurity indicators (Figure 5) demonstrates how this dimension substantially reshapes global digital assessments, with cybersecurity-strong nations like the United States and Singapore rising to the top, underscoring cybersecurity's diagnostic value for assessing genuine digital maturity.

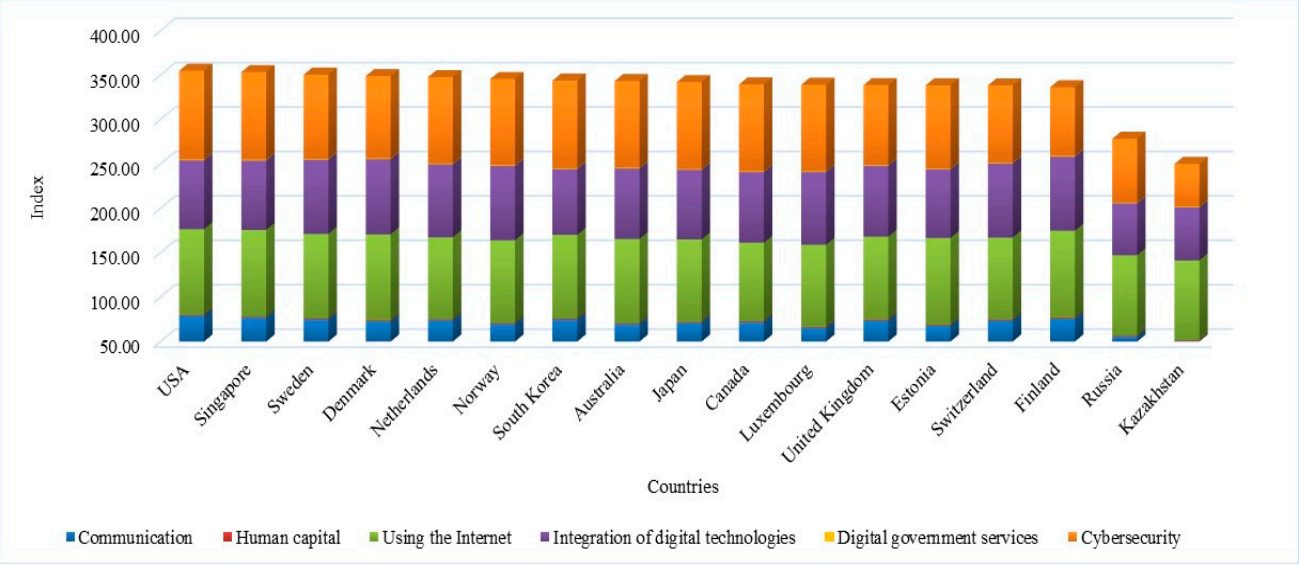


Figure 5. Modified DESI ranking after inclusion of the Cybersecurity indicator.

Based on IDED scores, Table 6 presents a strategic typology differentiating digital policy approaches for leading, developing, and lagging economies. For Kazakhstan, positioned in the developing category, the analysis suggests prioritizing high-speed infrastructure investment, digital literacy programs, and regulatory frameworks supporting e-commerce and data protection. The transition from administrative digitization to innovation-driven transformation requires greater SME support for digital adoption and integration of advanced technologies.

The public opinion survey in the East Kazakhstan region validated the importance of cybersecurity (mean = 3.91 on a 5-point scale), confirming both the statistical modeling results and the perceived relevance among the population. These findings are consistent with Sembekov et al. (2021), who highlight a significant lag in the development of digital business in Kazakhstan due to limitations in technological capacity and infrastructure. This convergence between empirical evidence and stakeholder perceptions supports the formal inclusion of cybersecurity in national digital measurement tools, thereby enhancing their explanatory power and policy relevance.

Table 6. Development strategies of countries with different levels of digital economy development.

No. pp	The Country's Place in the Ranking by Digital Economy	Target	Necessary Measures (Actions)
1	"Lagging" countries are countries that occupy the bottom places in the ranking of countries in the digital economy	Become a leader	• Conduct an analysis and determine the reasons for the low development level of the digital economy; • Develop a strategy for the digital economy development, taking into account the characteristics and needs of a particular country; • Attract investments into the digital economy; • Develop education and support professional retraining of the population in the field of IT; • Create favorable conditions for digital startup development and innovative projects; • Cooperate with other countries and international organizations to exchange experiences and develop the digital economy on a global scale.

Table 6. *Cont.*

No. pp	The Country's Place in the Ranking by Digital Economy	Target	Necessary Measures (Actions)
2	"Developing" countries	Increase the level of development of the digital economy	• Invest in digital infrastructure and high-speed internet; • Develop education and support professional retraining of the population in the field of IT; • Create favorable conditions for the development of digital startups and innovative projects. • Develop legal and regulatory frameworks for the digital economy; • Cooperate with other countries and international organizations to exchange experiences and develop the digital economy on a global scale.
3	Countries "leaders"	Maintaining a leadership position	• Invest in new technologies and innovations to maintain your competitive advantage; • Develop digital infrastructure and improve the quality of internet access to ensure high-speed access to information and the ability to use digital technologies; • Support the development of digital startups and innovative projects to ensure a constant flow of new ideas and technologies; • Improve qualifications and train highly qualified specialists in the field of IT in order to ensure the availability of personnel for the development of the digital economy; • Create favorable conditions for business in order to attract investment in digital technologies and stimulate economic growth; • Cooperate with other countries and international organizations to exchange experiences and develop the digital economy on a global scale.

The findings also indicate that infrastructure investment alone is insufficient to achieve transformative digital outcomes. The 2025 World Bank report (World Bank, 2024) emphasizes that without complementary investments in digital skills, institutional reforms, and enabling environments for the private sector, particularly micro, small, and medium enterprises (MSMEs), the benefits of digital infrastructure remain constrained. This perspective is further reinforced by Zhao and Cao (2024), who examined the coupling between infrastructure development and digital transformation in emerging markets, concluding that effective outcomes require coordinated progress across human capital, regulatory frameworks, and organizational readiness.

The IDED framework offers both diagnostic and prescriptive capabilities for evidence-based digital economy assessment and targeted policy formulation. Kazakhstan's sustainable digital growth depends on strengthening institutional capacity, enhancing digital skills, and fostering innovative capabilities that support an inclusive transformation beyond mere technological adoption. The empirical validation of cybersecurity as a core determinant of digital maturity suggests that measurement frameworks excluding this dimension may be structurally incomplete for assessing comprehensive digital development.

6. Conclusions

This study has developed and tested a context-sensitive approach to measuring the level of digital economy and society development in Kazakhstan. By integrating global benchmarking tools with a newly proposed composite indicator, the Index of Digital Economy Development (IDED), the research offers a multidimensional framework tailored to the specific economic and institutional realities of a transition economy.

The findings of this study align with earlier research emphasizing the limitations of existing global indices such as DESI, EGDI, and NRI in capturing regional disparities, cybersecurity readiness, institutional trust, and the digitalization of SMEs (Heeks et al., 2021; Godlewska-Majkowska et al., 2023; Kalinin, 2024; Liu & Kharchenko, 2023). As seen in other emerging economies, Kazakhstan's digital progress remains uneven, and standard indicators often fail to reflect critical qualitative and behavioral factors (Tokmergenova et al., 2021; Chen et al., 2023).

The proposed IDED model addresses these gaps by combining supply- and demand-side indicators, allowing for disaggregated analysis by region and sector. In particular, the inclusion of cybersecurity and digital trust as integral dimensions of digital maturity enhances the explanatory and policy relevance of the index. These results reinforce the growing consensus in the literature that digital policy design must be informed by locally calibrated and empirically validated measurement tools (Kruss et al., 2025; Petkovski et al., 2024; Ualtayev et al., 2024).

One key limitation of this study lies in the geographical scope of the survey data, which was limited to the East Kazakhstan region. While this area offered practical access and relevant digital infrastructure dynamics, it may not fully capture the diversity of digital development patterns across Kazakhstan. In particular, differences between urban and rural areas, or among other regions, could significantly influence digital access, adoption, and infrastructure quality. As such, the generalizability of the findings to the national level is constrained. Future research is encouraged to broaden the sampling frame to include multiple and more demographically diverse regions of Kazakhstan in order to better reflect the country's heterogeneity in digital transformation processes.

Future research can also focus on the longitudinal application of the IDED, expanding its geographic scope, integrating dynamic indicators such as AI adoption and big data governance, and refining its methodological robustness through advanced econometric modeling. Practical implications include the use of the IDED by policymakers to identify bottlenecks, design evidence-based interventions, and monitor progress in real time. For Kazakhstan and other transition economies, such an instrument can help chart a more inclusive, innovative, and resilient path toward digital transformation.

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References

Alimbaev, A., Bitenova, B., & Bayandin, M. (2021). Information and communication technologies in the healthcare system of the republic of Kazakhstan: Economic efficiency and development prospects. *Montenegrin Journal of Economics*, *17*(3), 145–156. [CrossRef]

Anatan, L., & Nur. (2023). Micro, small, and medium enterprises' readiness for digital transformation in Indonesia. *Economies*, *11*(6), 156. [CrossRef]

Boston Consulting Group. (2024). *e-Intensity index*. Available online: https://media-publications.bcg.com/HTML5Interactives/e-intensity/index.html (accessed on 3 March 2025).

Brici, I., & Achim, M. V. (2023). Does the digitalization of public services influence economic and financial crime? *Studies in Business and Economics*, *18*(2), 67–85. [CrossRef]

Chen, Y., Xu, S., Lyulyov, O., & Pimonenko, T. (2023). China's digital economy development: Incentives and challenges. *Technological and Economic Development of Economy*, *29*(2), 518–538. [CrossRef]

Development of the Digital Economy of Kazakhstan. (2025). *Post-soviet issues*. Available online: https://www.postsovietarea.com/jour/article/view/270 (accessed on 3 June 2025).

Digital Progress and Trends Report 2023. (n.d.). World Bank. [CrossRef]

Dinh, K. C., Ngo, T. Q., & Nguyen, D. V. (2023). Firm-level digital technology and Total Factor Productivity in a developing country: Evidence from panel data in Vietnam. *Cuadernos de Economia-Spain*, *46*(130), 41–55. Available online: https://cude.es/submit-a-manuscript/index.php/CUDE/article/view/348 (accessed on 3 June 2025).

European Commission. (2024). *The Digital Economy and Society Index (DESI) | shaping Europe's digital future*. Available online: https://digital-strategy.ec.europa.eu/en/policies/desi (accessed on 3 June 2025).

Fletcher School, Tufts University. (2024). *Digital evolution index: Trajectory*. Available online: https://digitalevolutionindex.tufts.edu/trajectory (accessed on 15 July 2025).

Gartner. (n.d.). *Top cybersecurity trends and strategies for securing the future*. Available online: https://www.gartner.com/en/cybersecurity/topics/cybersecurity-trends (accessed on 3 June 2025).

Gertzen, W. M., Van der Lingen, E., & Steyn, H. (2022). Goals and benefits of digital transformation projects: Insights into project selection criteria. *South African Journal of Economic and Management Sciences*, *25*(1), a4158. [CrossRef]

Godlewska-Majkowska, H., Komor, A., Pilewicz, T., & Zarebski, P. (2023). The regional environment of smart organisations as a source for entrepreneurship development in the EU. *Entrepreneurial Business and Economics Review*, *11*(3), 143–162. [CrossRef]

Goloshchapova, T., Yamashev, V., Skornichenko, N., & Strielkowski, W. (2023). E-government as a Key to the economic prosperity and sustainable development in the post-COVID era. *Economies*, *11*(4), 112. [CrossRef]

Heeks, R., Erasmo Gomez-Morantes, J., Graham, M., Howson, K., Mungai, P., Nicholson, B., & Van Belle, J.-P. (2021). Digital platforms and institutional voids in developing countries: The case of ride-hailing markets. *World Development*, *145*, 105528. [CrossRef]

Huawei. (2024). *Global digital index*. Available online: https://www.huawei.com/en/gdi (accessed on 3 March 2025).

Hung, N. T. (2023). The effects of digitalization, energy intensity, and the demographic dividend on Viet Nam's economic sustainability goals. *Asian Development Review*, *40*(2), 399–425. [CrossRef]

IMD World Competitiveness Center. (2024). *World digital competitiveness ranking*. Available online: https://www.imd.org/centers/wcc/world-competitiveness-center/rankings/world-digital-competitiveness-ranking/ (accessed on 15 July 2025).

Intalar, N., Ueki, Y., & Jeenanunta, C. (2024). Enhancing competitiveness: Driving and facilitating factors for Industry 4.0 adoption in Thai manufacturing. *Economies*, *12*(8), 210. [CrossRef]

International Telecommunication Union. (2024). *ICT development index (IDI)*. Available online: https://www.itu.int/en/ITU-D/Statistics/Pages/IDI/default.aspx (accessed on 3 March 2025).

Jankowska, B., & Gotz, M. (2024). Attracting and hosting foreign direct investment in digital transformation time. The case of post-transition economies. *Ekonomista*, *2*, 119–137. [CrossRef]

Kalinin, O. (2024). Investment security in the development of the digital economy. *Economics Ecology Socium*, *8*(2), 73–84. [CrossRef]

Kamalu, K., & Ibrahim, W. H. B. W. (2024). Does the digitalization crusade a way out of poverty and income inequality? Evidence from developing countries. *International Journal of Social Economics*, *51*(12), 1662–1679. [CrossRef]

Karacuka, M., Myovella, G., & Haucap, J. (2024). Productivity paradox in Africa: Does Digitalization foster labor productivity in African economies? *Journal of the Knowledge Economy*, *16*(2), 8374–8393. [CrossRef]

Kee, D. M. H., Cordova, M., & Khin, S. (2025). The key enablers of SMEs readiness in Industry 4.0: A case of Malaysia. *International Journal of Emerging Markets*, *20*(3), 1042–1062. [CrossRef]

Kruss, G., Petersen, I., Sanni, M., Adeyeye, D., & Egbetokun, A. (2025). Do we measure what should be measured? Towards a research and theoretical agenda for STI measurement in Africa. *Innovation and Development*, 1–25. [CrossRef]

Kuanaliyev, A., Taubayev, A., Kunyazov, Y., Ernazarov, T., Mussipova, L., & Saduakassova, A. (2024). Digital and economic transformation in the public administration system. *Montenegrin Journal of Economics*, *20*(3), 63–78. Available online: https://mnje.com/sites/mnje.com/files/v20n3/063-078%20%20-%20Kuanaliyev%20et%20al.pdf (accessed on 3 June 2025).

Kulzhambekova, B., Tashenova, L., & Mamrayeva, D. (2023). Theoretical and practical approach to the essential characteristics and structure of digital ecosystems of industrial enterprises. *Economic Annals-XXI*, *205*(9–10), 14–33. [CrossRef]

Li, D., Han, Q., & Lu, H. (2024). Can information construction promote the digital transformation of enterprises? Evidence from the "Pilot Zone for the Integration of Informatization and Industrialization". *Economic Change and Restructuring*, *57*(3), 123. [CrossRef]

Liu, Z., & Kharchenko, T. (2023). Innovations in the field of sports industry management: Assessment of the digital economy's impact on the qualitative development of the sports industry. *Baltic Journal of Economic Studies*, *9*(3), 10–21. [CrossRef]

Mikhno, I., Koval, V., Sedikova, I., & Kotlubai, V. (2022). Digital globalization in the international development of strategic alliances. *Economics Ecology Socium*, *6*(1), 11–21. [CrossRef]

Nadeem, M., Ali, Y., Rehman, O. U., & Saarinen, L. T. (2024). Barriers and strategies for digitalisation of economy in developing countries: Pakistan, a case in point. *Journal of the Knowledge Economy*, *15*(1), 4730–4749. [CrossRef]

Nassir, S., Lebdaoui, I., Chetioui, Y., & Lebdaoui, H. (2023). Factors influencing SMEs' intention to adopt electronic tendering: Empirical evidence from an emerging African market. *Journal of Economic and Administrative Sciences*. [CrossRef]

Nkwei, E. S., Rambe, P., & Simba, A. (2023). Entrepreneurial intention: The role of the perceived benefits of digital technology. *South African Journal of Economic and Management Sciences*, *26*(1), a4936. [CrossRef]

OECD. (2023). *Improving framework conditions for the digital transformation of businesses in Kazakhstan*. OECD. [CrossRef]

Otarbayeva, A. B., Arupov, A. A., Abaidullayeva, M. M., Dadabayeva, D. M., & Khajiyeva, G. U. (2024). Investment cooperation as a digital economy development method for the Republic of Kazakhstan and the EU. *World Development Perspectives*, *36*, 100636. [CrossRef]

Petkovski, I., Fedajev, A., & Mihajlovic, I. (2024). Technology-based factors of globalization in market and transition economies. *Is there a difference?* Business Management and Economics Engineering, *22*(1), 33–52. [CrossRef]

Portulans Institute. (2024). *The network readiness index (NRI)*. Available online: https://networkreadinessindex.org/ (accessed on 15 July 2025).

PwC. (2025, January 16). *2025 global digital trust insights report*. Available online: https://library.cyentia.com/report/report_024530.html (accessed on 3 March 2025).

Sembekov, A., Tazhbayev, N., Ulakov, N., Tatiyeva, G., & Budeshov, Y. (2021). Digital modernization of Kazakhstan's economy in the context of global trends. *Economic Annals-XXI*, *187*(1–2), 51–62. [CrossRef]

Stankovic, J. J., Marjanovic, I., Drezgic, S., & Popovic, Z. (2021). The digital competitiveness of European countries: A multiple-criteria approach. *Journal of Competitiveness*, *13*(2), 117–134. [CrossRef]

Sultanova, G., & Naser, H. (2024). The impact of information and communication technologies on export diversification: Evidence from developing countries. *The Journal of International Trade & Economic Development*, 1–35. [CrossRef]

Tazhiyev, R. O., Dirsehan, T., Baimukhanbetova, E. E., & Sandykbaeva, U. D. (2024). Road freight quality management in industry 4.0: International experience and perspectives in Kazakhstan. *Economies*, *12*(8), 218. [CrossRef]

Tokmergenova, M., Banhidi, Z., & Dobos, I. (2021). Analysis of I-DESI dimensions of the digital economy development of the Russian Federation and EU-28 using multivariate statistics. *Vestnik Sankt-Peterburgskogo Universiteta-Ekonomika-St Petersburg University Journal of Economic Studies*, *37*(2), 189–204. [CrossRef]

Tsapova, O., Zhailaubayeva, S., Kendyukh, Y., Smolyaninova, S., & Abdulova, O. (2024). Industry specifics and problems of digitalization in the agro-industrial complex of the Republic of Kazakhstan. *Journal of the Knowledge Economy*, *16*, 9492–9511. [CrossRef]

Ualtayev, M. D., Ualtayeva, A. S., Kaliyeva, S. A., & Vasa, L. (2024, September 1). *Problems and prospects for legal regulation of innovations in digital and information technologies of the labour market in Kazakhstan. | ebscohost*. Available online: https://openurl.ebsco.com/contentitem/gcd:181126100?sid=ebsco:plink:crawler&id=ebsco:gcd:181126100 (accessed on 3 June 2025).

United Nations Department of Economic and Social Affairs. (2024a). *E-government development index (EGDI): Kazakhstan*. Available online: https://publicadministration.un.org/egovkb/en-us/Data/Country-Information/id/87-Kazakhstan (accessed on 3 June 2025).

United Nations Department of Economic and Social Affairs. (2024b). *E-participation index (EPI)*. Available online: https://publicadministration.un.org/egovkb/en-us/About/Overview/E-Participation-Index (accessed on 3 March 2025).

United Nations Development Programme. (2024). *Human development index (HDI). Human development reports*. Available online: https://hdr.undp.org/data-center/human-development-index#/indicies/HDI (accessed on 3 March 2025).

Van, B. N. (2021). The digitalization—Economic growth relationship in developing countries and the role of governance. *Scientific Annals of Economics and Business*, *68*(4), 481–493. [CrossRef]

Vovk, V., Denysova, A., Rudoi, K., & Kyrychenko, T. (2021). Management and legal aspects of the symbiosis of banking institutions and fintech companies in the credit services market in the context of digitization. *Estudios de Economia Aplicada*, *39*(7), e5013. [CrossRef]

World Bank. (2024). *Overview*. Available online: https://www.worldbank.org/en/topic/digital/overview (accessed on 3 June 2025).

World Economic Forum. (n.d.). *Global cybersecurity outlook 2025*. Available online: https://www.weforum.org/publications/global-cybersecurity-outlook-2025/ (accessed on 3 June 2025).

World Intellectual Property Organization (WIPO). (2024). *Global innovation index 2024*. Available online: https://www.wipo.int/web-publications/global-innovation-index-2024/en/ (accessed on 3 March 2025).

Yang, L., & Lin, Z. (2024). Opportunity or risk? Mobile phones and the social inclusion gap among people with visual impairments. In *Disability and society* (Vol. 39, Issue 1, pp. 126–144). Routledge. [CrossRef]

Yang, W., Zhu, C., & Yang, Y. (2024). Does urban digital construction promote economic growth? Evidence from China. *Economies*, *12*(3), 59. [CrossRef]

Yilmaz, Y. (2021). Transition to the digital economy, its measurement and the relationship between digitalization and productivity. *Istanbul Iktisat Dergisi-Istanbul Journal of Economics*, *71*(1), 283–316. [CrossRef]

Zhao, S., & Cao, J. (2024). Measurement of coupling development level of new infrastructure investment and digital transformation and its temporal and spatial evolution trend. *arXiv*, arXiv:2412.19861. [CrossRef]

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