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Research on the Digital Economy Development Levels of Countries Along the Belt and Road Initiative

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Abstract

This study constructs a three-dimensional indicator system encompassing digital infrastructure, digital economic competitiveness, and the innovation environment for the digital economy. Using the entropy method, we quantitatively measure the digital economy development levels of 43 countries along the Belt and Road Initiative (BRI) from 2003 to 2022. The findings reveal significant disparities in digital economic development among these nations: Central and Eastern Europe exhibit relatively advanced levels, while South Asia, Central Asia, and Mongolia lag behind and require substantial improvement. Developed countries maintain a leading position in the digital economy, whereas developing countries display pronounced internal divergence. Over time, the digital economies of BRI countries generally show an upward trend, though growth rates vary significantly across nations. Based on these findings, we propose policy recommendations, including enhancing regional cooperation, narrowing the digital divide, and optimizing the policy environment, to foster coordinated digital economic development among BRI countries.

Keywords: Belt and Road Initiative, digital economy, entropy method.

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1. Introduction

In 2015, the General Secretary of the Central Committee of the Communist Party of China first proposed the joint construction of a "Digital Silk Road" at the Second World Internet Conference, emphasizing deepened cooperation in key areas such as network infrastructure, digital industries, and cybersecurity. By 2022, the report to the 20th National Congress of the CPC further aligned "accelerating the development of a Digital China" with "promoting high-quality Belt and Road cooperation," underscoring the strategic role of the digital economy in China's new era of opening-up. In 2023, the National Data Administration refined the policy

framework, calling for "high-standard advancement of the Digital Silk Road." This progressive policy evolution demonstrates that the Digital Silk Road has become a core vehicle for digital economic cooperation under the Belt and Road Initiative (BRI).

The digital economy, through its effects on productivity enhancement, new business model generation, and green transition acceleration, has increasingly emerged as a critical engine for global sustainable growth. Since the Initiative's launch, BRI partner countries have made notable progress in cross-border e-commerce, digital trade facilitation mechanisms, and digital infrastructure connectivity. However, significant regional disparities persist, shaped by heterogeneous patterns of technology diffusion, institutional environments, and factor endowment constraints. Given these regional divergences and complex influencing factors, this study systematically evaluates the digital economy development levels of BRI countries and explores viable pathways for coordinated digital transformation and high-quality BRI cooperation.

2. Literature Review on the Digital Economy

2.1 Conceptualization of the Digital Economy

The concept of the digital economy was first introduced by Tapscott (1996). Since then, scholars and institutions worldwide have continuously expanded its conceptual boundaries, though a unified definition remains elusive. In terms of definitional evolution, the United Nations Conference on Trade and Development (UNCTAD, 2019) adopts a broad perspective, defining it as "all economic activities enabled by digital technologies" [1]. In contrast, the China Academy of Information and Communications Technology (CAICT, 2023) further specifies that the digital economy treats digitalized knowledge and information as key production factors, relies on digital technologies as the core driver, and utilizes modern information networks as critical infrastructure. Through deep integration with the real economy, it reshapes economic and social operations as well as governance models [2].

Regarding core characteristics, existing studies widely recognize that the digital economy exhibits three fundamental attributes—digitization, networking, and intelligence—which collectively induce systemic transformations in production methods, organizational structures, and business

models. These transformations enhance total factor productivity (TFP), reduce transaction costs, and stimulate new market demands and employment opportunities (Wei Jiang et al., 2021) [3].

Concerning industrial boundaries, Bukht & Heeks (2017) regard the ICT sector as the core domain of the digital economy [4]. However, Wen Dongwei et al. (2023) extend its scope to include e-commerce activities (e.g., digitally delivered services and platform transactions) and traditional industries transformed by digital penetration, thereby proposing a "core-convergence" dual-layer industrial framework [5].

2.2 Measurement of the Digital Economy

In measurement practices, official institutions and academia have developed two parallel approaches. First, international organizations focus on macroeconomic accounting and composite indices. The Organisation for Economic Co-operation and Development (OECD) pioneered the index compilation method, incorporating ICT access, usage, and skills into composite indicators. The Network Readiness Index (NRI) released by the World Economic Forum (WEF) and the ICT Development Index (IDI) by the International Telecommunication Union (ITU) are also widely used to characterize the scale and maturity of national-level digital economies.

Domestically, the China Academy of Information and Communications Technology (CAICT) has constructed the TIMG index based on four dimensions - Technology, Infrastructure, Market, and Governance - for global comparative studies [6]. Beyond official frameworks, academia predominantly employs multi-indicator evaluation systems. Zhang Bochao and Shen Kaiyan (2018) comprehensively assessed the ICT readiness of Belt and Road countries using "network readiness" [7]. Li Xiaozhong and Mao Fangting (2021) established an evaluation framework encompassing infrastructure, industrial development, industrial application, and innovation competitiveness [8]. Xu Jianhui (2021) further incorporated indicators such as the proportion of electronic payments, ICT penetration in B2B transactions, logistics performance, government online service levels, and ICT promotion policies to capture the micro-foundations and institutional environment of digital economic development [9].

These studies have collectively enriched the toolbox for measuring the digital economy, providing methodological references for this paper to construct a more targeted indicator system.

3. Indicator System Construction and Measurement Analysis

3.1 Selection of Indicator System

Building upon The Global Information Technology Report (WEF, 2016), this study selects and supplements indicators that are highly relevant to the digital economy. The evaluation framework encompasses three key dimensions: digital infrastructure, digital economic competitiveness, and the innovation environment for the digital economy.

To quantify the development levels of the digital economy, we employ the entropy method for measurement, incorporating 15 secondary indicators across these dimensions. For individual missing data points, linear interpolation is applied to ensure data completeness.

Table 1 Measurement of the Comprehensive Level of Digital Economy along the Belt and Road Initiative

Oil level indicator tap-changer	Two grade index evaluation	Index weight	Data sources
Digital infrastructure construction	Fixed-line telephone penetration rate (per 100 people)	0.129	WDI
	Fixed broadband penetration rate (per 100 people)	0.173	WDI
	The number of mobile network users (proportion of the total population)	0.116	WDI
	Mobile cellular subscription volume (per 100 people)	0.056	WDI
	Availability of the latest technology	0.017	WEF
Competitiveness of the digital	The proportion of digital	0.274	OECD

economy	service exports		
	Export of information and communication services	0.017	WDI
	Readiness for cutting-edge ICT technologies	0.035	UNCTAD
	Enrollment rate in higher education	0.018	WDI
	Logistics performance index	0.007	WDI
	The proportion of R&D expenditure in GDP	0.044	WDI
	Institutional quality	0.076	WB
The innovative environment of the digital economy	Business facilitation score	0.007	WB
	Entrepreneurship convenience score	0.011	WB
	Availability of venture capital	0.020	WEF

3.2 Sample Country Selection

Based on the latest official list published by China's Ministry of Commerce, Belt and Road Initiative (BRI) participating countries are categorized into six geographic regions: Central and Eastern Europe (19 countries), West Asia and the Middle East (19 countries), Southeast Asia (11 countries), South Asia (8 countries), Central Asia (5 countries), and Mongolia-Russia (2 countries). To ensure data integrity and comparability in panel data analysis, this study excluded 11 countries with severe deficiencies in key indicators or incomplete data records, resulting in a final sample of 43 countries. For analytical purposes, these were reclassified into five consolidated regions: ASEAN (Southeast Asia), South Asia, Central Asia and Mongolia, West Asia, and Central and Eastern Europe, thereby facilitating robust cross-regional comparisons while maintaining methodological rigor in the empirical analysis.

Table 2 Selection of Countries along the Belt and Road Initiative

Regions	Countries
Asean (7 countries)	Indonesia, Malaysia, Singapore, the Philippines, Cambodia, Thailand, Vietnam
South Asia (5 countries)	Bangladesh, India, Nepal, Sri Lanka, Pakistan
Central Asia and Mongolia (4 countries)	Kazakhstan, Kyrgyzstan, Tajikistan, Mongolia
West Asia (14 countries)	Saudi Arabia, Cyprus, the United Arab Emirates, Lebanon, Qatar, Turkey, Israel, Kuwait, Iran, Jordan, Oman, Bahrain, Greece, Egypt
Central and Eastern Europe (13 countries)	Armenia, Croatia, Bulgaria, Slovakia, Slovenia, Russia, Ukraine, Hungary, Lithuania, the Czech Republic, Poland, Bosnia and Herzegovina, Montenegro

3.3 Indicator Data Processing

The entropy method is a research approach that determines indicator weights by combining the informational value derived from entropy measures. This study employs information entropy theory to construct a multidimensional evaluation system, quantifying the comprehensive digital economy levels of BRI countries through the following methodological steps:

First, Equation (1) is applied to perform data normalization and non-negative translation processing. The original indicators undergo range standardization to eliminate dimensional differences, followed by the addition of a minimal constant to ensure computational feasibility in subsequent operations.

$$X_{tij}^{\text{norm}} = \frac{X_{tij} - X_j^{\min}}{X_j^{\max} - X_j^{\min}} + \alpha, \quad \alpha = 0.001 \tag{1}$$

Next, Formulas (2) and (3) are employed for entropy weight calculation. Based on 20-year panel data from 43 countries, we compute the information entropy (degree of disorder) for each indicator. A smaller entropy value indicates higher discriminative power of the corresponding

indicator.

$$P_{tij} = \frac{X_{tij}^{\text{norm}}}{\sum_{i=1}^{43} X_{tij}^{\text{norm}}} \tag{2}$$

$$e_j = -\frac{1}{\ln(43 \times 20)} \sum_{t=2003}^{2022} \sum_{i=1}^{43} P_{tij} \ln(P_{tij}) \tag{3}$$

Formula (4) is applied to determine the final indicator weights through entropy-based inversion. The weighting principle follows the inverse relationship between entropy and information content: higher entropy values indicate greater data disorder and consequently less useful information, resulting in lower assigned weights. The complete weighting results are presented in Table 1.

$$w_j = \frac{1 - e_j}{\sum_{k=1}^{m} (1 - e_k)} \tag{4}$$

Finally, the comprehensive digital economy development index is calculated using Equation (5), generating standardized and comparable scores across all evaluated economies.

$$\text{Digital}_{ti} = \sum_{j=1}^{m} w_j \cdot X_{tij}^{\text{norm}} \tag{5}$$

Following the aforementioned methodology, we have derived the comprehensive digital economy development levels for 43 host countries during the 2003-2022 period, with detailed results presented in Table 3.

Table 3 Comprehensive Level of Digital Economy in Countries along the Belt and Road Initiative

Rank-ing	Countrie-s	Economic level	Area	Level of aggrega-tion	Infrastructure	Competi-tiveness	Innovatio-n environm-ent
1	Singapore	Developed	ASEAN	1.000	0.996	1.000	1.000

		country					
2	Israel	Developed country	West Asia	0.783	1.000	0.454	0.897
3	Hungary	Developed country	Central and Eastern Europe	0.708	0.842	0.620	0.594
4	Malaysia	Developing country	ASEAN	0.667	0.536	0.902	0.592
5	Czech-Republic	Developed country	Central and Eastern Europe	0.658	0.781	0.534	0.640
6	cyprus	Developed country	Central and Eastern Europe	0.657	0.975	0.303	0.604
7	Slovenia	Developed country	Central and Eastern Europe	0.652	0.937	0.302	0.669
8	Greece	Developed country	Central and Eastern Europe	0.643	0.969	0.357	0.453
9	Slovakia	Developed country	Central and Eastern	0.596	0.706	0.498	0.571

			Europe				
10	Lithuania	Developed country	Central and Eastern Europe	0.555	0.749	0.294	0.633
11	UAE	Developed country	West Asia	0.548	0.807	0.200	0.638
12	Croatia	Developed country	Central and Eastern Europe	0.525	0.798	0.245	0.463
13	Poland	Developed country	Central and Eastern Europe	0.522	0.651	0.379	0.543
14	Bulgaria	Developing country	Central and Eastern Europe	0.454	0.645	0.256	0.443
15	Republic of Montenegro	Developing country	Central and Eastern Europe	0.426	0.689	0.155	0.388
16	Philippines	Developing country	ASEAN	0.423	0.160	0.932	0.200
17	Thailand	Developing country	ASEAN	0.417	0.346	0.565	0.399

18	Bahrain	Developed country	West Asia	0.414	0.660	0.149	0.403
19	Russia	Developing country	Central Asia and Mongolia	0.409	0.646	0.241	0.247
20	Qatar	Developed country	West Asia	0.386	0.585	0.077	0.566
21	Vietnam	Developing country	ASEAN	0.368	0.325	0.540	0.249
22	Turkey	Developing country	Central and Eastern Europe	0.360	0.484	0.261	0.343
23	Saudi-Arabia	Developed country	West Asia	0.350	0.547	0.176	0.303
24	Kuwait	Developed country	West Asia	0.313	0.461	0.133	0.390
25	KZ(Kazakhstan)	Developing country	Central Asia and Mongolia	0.299	0.474	0.163	0.243
26	Bosnia and Herzegovin-a	Developing country	Central and Eastern Europe	0.289	0.529	0.116	0.153
27	Ukraine	Developing country	Central and Eastern	0.287	0.438	0.218	0.167

			Europe				
28	Oman	Developed country	West Asia	0.279	0.383	0.117	0.428
29	Iran	Developing country	West Asia	0.255	0.472	0.156	0.043
30	Armenia	Developing country	Central Asia and Mongolia	0.254	0.388	0.113	0.304
31	Lebanon	Developing country	West Asia	0.233	0.386	0.147	0.144
32	Jordan	Developing country	West Asia	0.207	0.248	0.144	0.334
33	Mongolia	Developing country	Central Asia and Mongolia	0.171	0.215	0.129	0.264
34	Indonesia	Developing country	ASEAN	0.167	0.157	0.194	0.259
35	Egypt	Developing country	West Asia	0.149	0.222	0.113	0.165
36	SriLanka	Developing country	South Asia	0.137	0.189	0.053	0.289
37	Kyrgyzstan	Developing country	Central Asia and Mongolia	0.132	0.186	0.126	0.144
38	India	Developing country	South Asia	0.090	0.035	0.113	0.301

39	Nepal	Developing country	South Asia	0.025	0.048	0.000	0.154
40	Cambodia	Developing country	ASEAN	0.015	0.053	0.037	0.031
41	Pakistan	Developing country	South Asia	0.008	0.000	0.020	0.145
42	Tajikista-n	Developing country	Central Asia and Mongolia	0.004	0.048	0.029	0.000
43	Bangladesh	Developing country	South Asia	0.000	0.018	0.013	0.078

4. Measurement Comparison and Analysis

4.1 Overall Rankings

To visually illustrate disparities, the 43 countries are classified into three tiers using cutoff thresholds of 0.6 and 0.2:

High-Level Group (≥0.6): Developed economies such as Singapore, Israel, and Hungary dominate the top positions, leveraging dual advantages in infrastructure and innovation environments. Notably, Singapore achieves near-perfect scores (≈1) across all three sub-indices, reflecting a holistically balanced digital ecosystem.

Medium-Level Group (0.2–0.6): Emerging economies like Malaysia and the Philippines rely primarily on competitiveness sub-index contributions. The Philippines, in particular, ranks second regionally due to its specialization in global ICT outsourcing services.

Low-Level Group (<0.2): Countries in South and Central Asia (e.g., Pakistan, Bangladesh) lag behind, constrained by dual deficiencies in infrastructure and innovation investment. Their index values (<0.15) place them at the bottom of the rankings.

4.2 Regional Analysis

Spatial distribution reveals pronounced disparities:

Central & Eastern Europe (CEE): Claims 8 of the top 10 positions, benefiting from the EU's Digital Single Market strategy. Countries like Hungary and Lithuania lead in 5G deployment and data center infrastructure, with robust industry-academia collaboration accelerating technology commercialization.

ASEAN: Exhibits a "competitiveness-driven" duality. While Malaysia and the Philippines excel in electronics manufacturing and digital service exports, Indonesia and Cambodia lag due to rural connectivity gaps, depressing regional averages.

West Asia: Gulf states leverage sovereign wealth funds to rapidly develop smart cities (e.g., UAE's AI initiatives), yet their innovation systems remain constrained by path dependency on energy sectors.

South & Central Asia: Face systemic challenges from urban-rural digital divides and fragmented policies, relying heavily on external partnerships to compensate for weak endogenous growth drivers.

Structural Determinants:

Institutional Alignment: CEE's integration with EU digital policies vs. ASEAN's heterogeneous governance.

Investment Patterns: Gulf's capital-intensive projects vs. South Asia's aid-dependent models.

Sectoral Composition: Export-oriented digital services (ASEAN) vs. commodity-driven economies (Central Asia).

Key Implication: The BRI digital economy exhibits coexisting spatial polarization (inter-regional gaps) and intra-regional stratification (domestic disparities), necessitating differentiated cooperation frameworks.

4.3 Income-Level Analysis

Income stratification reveals a distinct "frontrunner stability vs. catch-up divergence" pattern:

Developed Economies

Demonstrate significant advantages in both infrastructure and innovation sub-indices (standardized scores: 0.142 vs. 0.089 for infrastructure; 0.111 vs. 0.073 for innovation).

Policy drivers:
Cyprus and Greece achieved universal high-speed broadband coverage through EU structural funds.
Israel and Lithuania leveraged tax incentives to create technology clusters (e.g., Vilnius fintech hub).

Developing Economies

Exhibit internal polarization:
High performers (e.g., Philippines, Malaysia): Boost competitiveness via labor-intensive digital services (e.g., BPO, electronics exports).
Laggards (e.g., South Asia): Innovation environment scores <0.05 due to chronic underinvestment in R&D (avg. 0.3% of GDP vs. OECD 2.7%), creating a structural bottleneck for digital upgrading.

Structural Insights:

Path dependency: Developed economies reinforce lead through policy-institutional synergies, while developing economies face middle-income traps in digital transformation.

Convergence threshold: Innovation environment emerges as critical differentiator - no country with score <0.05 achieved >0.4 composite index.

Policy Implications:

For frontrunners: Sustain advantage through next-gen infrastructure (e.g., quantum networks).

For catch-up economies: Prioritize R&D co-investment models (e.g., BRI joint labs) to break low-innovation equilibrium.

4.4 Temporal Trends

From 2003 to 2022, the sample countries achieved an average annual growth rate of 2.8% in their digital economy indices, with notable divergence among nations. Among high-growth economies (>5% annual growth), Vietnam's index rose from 0.158 to 0.578, registering 6.64% yearly growth, while Cambodia and Tajikistan similarly exceeded 5% growth through infrastructure investments under the Digital Silk Road initiative. In contrast, low-growth economies (<2%) included Singapore, where growth plateaued at just 0.72% due to index ceiling effects, and Hungary and the Czech Republic, which shifted focus toward technological refinement despite already high baseline scores. These patterns demonstrate that latecomer economies can leverage external funding and policy support to achieve leapfrogging growth, whereas advanced economies must rely on institutional innovation and technology commercialization to sustain their competitive edge.

Table 4 Changes in the Comprehensive Level of Digital Economy in Countries along the Route from 2003 to 2022

Country	2003	2022	Average annual growth rate (%)	Country	2003	2022	Average annual growth rate (%)
Armenia	0.183	0.393	4.07	Malaysia	0.505	0.573	0.67
Bahrain	0.253	0.441	3.16	Mongolia	0.153	0.385	4.72
Bangladesh	0.105	0.229	4.02	Republic of Montenegro	0.240	0.511	4.19
Bosnia and Herzegovina	0.189	0.404	4.14	Nepal	0.090	0.262	5.67
Bulgaria	0.287	0.473	2.74	Oman	0.203	0.390	3.69
Cambodia	0.095	0.248	5.32	Pakistan	0.127	0.204	2.72
Croatia	0.320	0.495	2.36	The	0.305	0.499	2.89

				Philippines			
Cyprus	0.349	0.589	3.05	Poland	0.324	0.485	2.36
Czech Republic	0.392	0.574	2.17	Qatar	0.258	0.440	3.06
Egypt	0.136	0.339	4.80	Russia	0.233	0.439	3.35
Greece	0.377	0.610	2.74	Saudi Arabia	0.188	0.531	5.44
Hungary	0.468	0.580	1.15	Singapore	0.687	0.789	0.72
India	0.153	0.281	3.19	Slovakia	0.324	0.524	2.86
Indonesia	0.185	0.322	3.17	Slovenia	0.376	0.570	2.34
Iran	0.176	0.401	4.43	Sri Lanka	0.171	0.296	3.27
Israel	0.480	0.659	1.64	Tajikistan	0.079	0.213	5.29
Jordan	0.192	0.332	3.09	Thailand	0.331	0.493	2.25
KZ(Kazakhstan)	0.181	0.398	4.18	Turkey	0.263	0.431	2.89
Kuwait	0.258	0.403	2.54	Ukraine	0.188	0.364	3.41
Kyrgyzstan	0.160	0.326	3.92	UAE	0.322	0.621	3.57
Lebanon	0.173	0.326	3.49	Vietnamese	0.158	0.578	6.64
Republic of Lithuania	0.314	0.494	2.44				

5. Conclusions and Policy Recommendations

5.1 Key Findings

The study reveals significant cross-country and regional disparities in digital economy development among Belt and Road Initiative (BRI) economies: Central and Eastern Europe

maintains leadership through mature digital infrastructure and innovation systems; Southeast Asian countries achieve upward mobility via competitive advantages in specific sectors; while South Asia, Central Asia, and Mongolia lag due to infrastructure deficits and innovation capacity constraints. Income levels further amplify divergence—developed economies consistently outperform in infrastructure and innovation environment, whereas developing economies show uneven competitiveness and weak innovation ecosystems. During 2003-2022, while most countries demonstrated index growth, rates varied substantially: latecomers like Vietnam achieved leapfrogging growth through policy incentives and external support, whereas some advanced economies experienced growth deceleration due to base effects. These findings highlight three core challenges: (1) infrastructure gaps exacerbating digital divides; (2) heterogeneous institutional and policy environments; and (3) underdeveloped regional coordination mechanisms.

5.2 Policy Recommendations

To address these challenges, this study proposes the following policy measures:

Enhance Regional Cooperation and Knowledge Sharing.

Establish multilateral/regional platforms to reduce information barriers and facilitate efficient flows of technology, talent, and capital.

Central and Eastern European countries should leverage the EU's Digital Single Market framework to share best practices in infrastructure connectivity and industry-academia collaboration with neighboring regions.

ASEAN members should deepen specialization in digital services and electronics manufacturing, adopting the Philippines' export-oriented competitiveness model, while institutionalizing regular policy exchange mechanisms.

Bridge the Digital Divide to Empower Less-Developed Regions.

International organizations and developed economies should provide technical assistance and concessional financing to accelerate broadband network and data center deployment in South Asia, Central Asia, and Mongolia.

Governments must implement targeted subsidies for remote areas and expand digital literacy

programs to ensure inclusive access and capability building.

Optimize Policy Frameworks to Foster Sustainable Innovation.

Developed countries should refine data governance and industrial integration policies to deepen digital technology adoption in traditional sectors.

Developing economies need to incentivize R&D through tax incentives, subsidies, and venture capital guidance, cultivating robust local innovation ecosystems.

Cross-national policy dialogue mechanisms should be established to harmonize standards and regulations, ensuring institutional support for long-term digital economy growth.

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