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**DIGITAL-AI INTEGRATION OF THE NEW SILK ROAD, DISTANCE
COST AND CROSS-BORDER ECONOMIC COOPERATION:
A PERSPECTIVE OF SPATIAL ECONOMICS**

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Abstract. The Digital-AI integration represents one of the major trends in the current and future technological revolution. This development is reshaping the patterns of international economic cooperation and improving the efficiency of cross-border collaboration. From the perspective of spatial economics, this paper conducts a preliminary study on the prospects and potential impacts of digital-AI integration on cross-border economic cooperation between China and countries along the Silk Road Economic Belt, mainly Central Asian nations. The research finds that digital-AI integration will reduce the distance costs for cross-border cooperation, namely overcoming three types of distance-related costs: the cost of goods movement, the cost of information transmission, and the cost of face-to-face interaction. The reduction in these three forms of distance costs will greatly boost economic cooperation between China and the Central Asian countries and deliver win-win outcomes for all parties involved.

Keywords: Digital-AI integration, China, Central Asian countries, cross-border economic cooperation, spatial economics

Introduction

The digital-AI integration (integration of digitization and artificial intelligence) has become an irreversible global trend. It is not only reshaping the existing pattern of international trade but also comprehensively enhancing the efficiency and depth of regional cross-border economic cooperation. This technological progress serves as a new driving force in China's domestic economic restructuring and upgrading, while also exerting a great impact on international cross-border economic cooperation and development.

Proposed by President Xi Jinping over a decade ago, the Belt and Road Initiative (BRI) has yielded remarkable outcomes in cross-border economic cooperation and received positive responses from the countries involved. The 21st Century Maritime Silk Road has facilitated connectivity between China and Southeast Asian nations, whereas the Silk Road Economic Belt economic corridor spanning Europe and Asia. The five Central Asian countries (Kazakhstan, Uzbekistan, Kyrgyzstan, Tajikistan, Turkmenistan) stand as the geopolitical and economic pillars in the Silk Road Economic Belt, holding an irreplaceable

strategic position in advancing BRI-driven digital-intelligent cooperation. Over the past five years, China and CACs (Central Asian countries) have carried out digital-intelligent cross-border cooperation in accordance with the “five connectives” - policy coordination, infrastructure connectivity, unimpeded trade, financial integration, and people-to-people bonds. This cooperation has delivered substantial benefits and gradually attracted academic attention in international economic cooperation and regional digital [1].

Description of Materials and Methods

The theoretical and methodological foundation of the study is based on the principles of spatial economics theories, scientific works, research by Chinese and foreign scholars, documents summarizing the outcomes of summits, and materials from periodicals. The methodological basis of the study consists of general scientific methods, which are used in combination to achieve the research goal and address the identified problems.

To understand the integration of digital technologies and artificial intelligence along the New Silk Road within the framework of cooperation between China and the countries of Central Asia, we used the theory of spatial economics as interpreted by Masahisa Fujita [2, 3 – cited in Zhao], the main provisions of which boil down to studying the location of resources, people, and cities, transport costs, the proximity of neighbors and borders, and how they affect prices and regional development. S. Redding’s interpretation is used, viewing spatial economics as a branch of network economics that explains the formation and evolution of cross-border economic networks based on institutional and digital spaces [4].

Quantitative, qualitative, and statistical methods track the dynamics of digital artificial intelligence integration between China and the five Central Asian states. Thus, pilot projects in the field of AI covering customs clearance demonstrate the potential to reduce costs associated with cross-border goods inspection and to increase the efficiency of trade in primary products. The qualitative method used for analysis in the field of AI technical services in Central Asia has demonstrated opportunities to improve the efficiency of trade in primary products.

A comparative analysis showed that the turnover of cross-border e-commerce between China and five countries in Central and Eastern Europe increased by 95 % in 2022 compared to 2021.

The issue of integrating digital artificial intelligence into the New Silk Road cannot be examined without considering the approach to ensuring security and cybersecurity, as well as combating cross-border digital crimes, which requires harmonizing regulatory rules and strengthening cooperation in this area.

Approaches such as “hard connectivity” and “soft connectivity” in the analysis of digital infrastructure contribute to deepening digital cooperation between China and the countries of Central Asia.

A predictive approach makes it possible to identify promising areas for the development of the spatial economy and to substantiate the corresponding recommendations. The study also used mathematical models to assess the development of the integration of digital technologies and artificial intelligence in the short, medium, and long term.

Literature Review

Existing studies on digital-AI integration and China-Central Asia cross-border economic cooperation can be broadly categorized into three strands.

The first strand focuses on the institutional foundation and current development of the Digital Silk Road under the BRI, dominated by research centered on digital infrastructure construction, while relevant independent research on artificial intelligence application remains relatively scattered. Research indicates that cooperation between China and Central Asia in 5G infrastructure deployment, cross-border e-commerce, cross-border digital finance, and smart cities has expanded rapidly [5]. Xu and Guo systematically review ten years of progress in Digital Silk Road construction, emphasizing that “hard connectivity” of digital infrastructure and “soft connectivity” of institutional standards are mutually reinforcing and critical to deepening China-Central Asia digital cooperation [6]. Sun et al. further explore the practical difficulties and optimization paths for jointly building digital standards between China and CACs under the BRI, clarifying the value of unified industry standards in breaking down regional digital trade barriers [7]. Wang conducts a case study on China-Kazakhstan digital cooperation, confirming that digital infrastructure investment and cross-border e-commerce innovation have become core growth drivers of bilateral digital economic cooperation [8]. Statistics show that cross-border e-commerce transactions between China and the five CACs surged by 95% year-on-year in 2022, reflecting robust growth in digital trade [9].

Supplementarily, a small batch of independent literature explores single-scenario AI cooperation. Central Asian scholars Tursun & Alimov focus on standalone AI pilot projects covering customs intelligent clearance and agricultural intelligent planting cooperation between China and Uzbekistan and Kazakhstan, verifying that independent AI technology application can reduce cross-border commodity inspection costs and improve the efficiency of primary product trade [10]; Li sorts out China’s outbound AI technical service output toward Central Asia, pointing out that most existing AI cooperation stays at single project demonstration rather than large-scale industrial matching [11].

The second one examines the operational mechanisms and effectiveness of China-Central Asia digital-AI integration cooperation, differentiating pure digital cooperation research and integrated digital-intelligent collaborative research. Scholars widely agree that multilateral platforms, such as the China-Central Asia Summit and the Shanghai Cooperation Organization (SCO), have established a comprehensive coordination framework for aligning digital policies,

unifying technical standards, and facilitating cross-border data flows [12]. Oreglia and Zheng analyze the multi-level governance logic of Digital Silk Road construction, illustrating the divergent implementation characteristics between top-level national strategies and local-level execution in China – Central Asia digital cooperation [13]. Nimatullaev & Mavlonov empirically evaluate the impact of China's digital investment projects in Central Asia, demonstrating that digital infrastructure initiatives - such as 5G coverage and e-government systems - have significantly accelerated the overall digital transformation of Central Asian states [14].

In terms of digital-intelligence integrated research, limited existing papers start from industrial chain synergy: Liu pioneers the discussion on how digital base carriers empower AI cross-border landing, analyzing the integrated application of big data + intelligent logistics in China-Central Asia cross-border industrial parks; however, such integrated mechanism research is still in the preliminary exploratory stage, lacking systematic empirical testing on how digital-AI integration changes cross-border trade costs and spatial economic layout [15].

The third strand addresses constraints, potential risks, and practical challenges in China-Central Asia digital-AI cooperation. Current research identifies uneven digital development, fragmented data regulations, shortages of skilled digital talent, and complex geopolitical competition as major bottlenecks hindering deeper cooperation [16]. Wang and Li argue that the inherent digital divide and institutional disparities between China and CACs create implicit barriers to cross-border data flows and optimal resource allocation [17]. Additionally, studies highlight that inadequate cross-border digital payment systems, insufficient transnational regulatory coordination, and opaque digital investment information are prominent practical challenges in China-Central Asia digital economic cooperation [18].

From the intelligentization perspective, newly supplemented literature points out extra unique obstacles restricting digital-AI synergy: inconsistent cross-border AI access specifications, a serious shortage of compound talents proficient in both digital engineering and artificial intelligence across Central Asian countries, and differing domestic data security laws limiting the cross-border circulation of training data required for AI iterative upgrading [19].

Overall, the existing research literature still exhibits significant shortcomings. The vast majority of literature relies on perspectives from international relations and industrial economics, focusing on institutional design, project effectiveness evaluation, and descriptions of cooperative phenomena, with a prominent structural bias: existing studies heavily lean toward pure digital economy and digital infrastructure research, while independent research on artificial intelligence industrial cooperation is insufficient, and research targeting the economic spillover effect generated by digital-intelligence deep integration on cross-border cooperation remains scarce. Few studies directly examine the

impact of this integration on economic cooperation between China and CACs, particularly those grounded in mature economic theories for in-depth analysis. This paper aims to fill this gap. Adopting a spatial economics perspective, it systematically analyzes the practical and potential impacts and future prospects of digitization-AI integration on cross-border economic cooperation between China and the Central Asian “Stan” nations, identifies existing obstacles to such integration, and proposes corresponding policy recommendations.

Results

Major Progress in Digital-AI Integration between China and the CACs

China and the five CACs (Kazakhstan, Uzbekistan, Kyrgyzstan, Tajikistan, Turkmenistan) have achieved substantial, tangible results in the integration of digitalization and artificial intelligence in the past five years. Their cooperation is underpinned by six pillars: top-level institutional consensus, digital infrastructure connectivity, expansion of digital trade, interlinked financial systems, deployment of smart cities and AI applications, and collaborative data governance. These outcomes are based on intergovernmental documents, memoranda of understanding (MoUs), flagship projects, and authoritative statistics, representing the most dynamic phase of digital cooperation between the two sides since the launch of the Belt and Road Initiative (BRI). The major advances are reflected in the following six aspects:

First, at the institutional level, the landmark progress lies in translating consensus declarations into concrete action plans. Institutional alignment has laid a solid foundation for deep digital-AI integration. In 2022, the “China + Five CACs” Foreign Ministers’ Meeting jointly issued the Initiative on Data Security Cooperation, defining basic cooperation norms for cross-border data flows, sovereign data governance, and anti-monopoly practices in digital services [1]. In 2023, the first China–Central Asia Summit was held in Xi’an, releasing the Xi’an Declaration and signing an MoU on Digital Trade Cooperation. This formally established the China–Central Asia E-commerce Cooperation Dialogue Mechanism and designated AI, big data, and smart cities as priority cooperation areas [5]. In 2025, the second China - Central Asia Summit adopted the Action Plan for High-Quality Belt and Road Cooperation and signed four cooperation documents on AI and digital infrastructure. These included an MoU with Kyrgyzstan to build an AI Application Cooperation Center and an AI cooperation agreement with Tajikistan, elevating digital - AI cooperation to a core agenda of the China - Central Asia multilateral framework [6, 20].

Second, in digital infrastructure, breakthroughs have been made in cross-border backbone networks and nationwide 5G coverage. Hardware connectivity has advanced steadily, effectively narrowing the regional digital divide. China supported the construction of the China–Kyrgyzstan–Uzbekistan (CKU) Cross-Border Optical Cable, which reduced regional network latency by 40% and

significantly enhanced cross-border data transmission efficiency [9]. (Xinhua News Agency, 2025). In terms of 5G deployment, Chinese telecommunications firms have built over 3,000 5G base stations in Kazakhstan, covering major cities and industrial zones. In Kyrgyzstan, 5G services are now available in all key cities, raising the national internet penetration rate from 43% to over 70% [5]. By 2025, China had invested in or constructed more than 15 large-scale data centers and backbone communication projects across Central Asia, forming a regional digital transmission and computing backbone [21].

Third, in cross-border e-commerce and digital trade, the sector has achieved rapid scale expansion and localized platform implementation. Digital trade has become a new engine of bilateral economic cooperation. In 2022, cross-border e-commerce turnover between China and the five CACs surged by 95% year-on-year, making it the fastest-growing segment of bilateral trade [9]. Chinese platforms such as Alibaba and JD.com have forged deep partnerships with local platforms, including Kazakhstan's Kaspi.kz, Uzbekistan's OrientSwiss, and Zood, shortening cross-border logistics time to 5–7 days. In 2024, order volumes via Chinese platforms rose by 68% year-on-year [8]. In 2025, the dedicated Silk Road e-commerce platform "Suhao Cloud" was launched, connecting over 500 Chinese suppliers with more than 30 Central Asian buyers and advancing China–Central Asia trade facilitation [18]. In the same year, China built a 1,000-square-meter dedicated overseas warehouse in Tashkent, Uzbekistan—the first of its kind for Chinese cross-border e-commerce in Central Asia [5].

Fourth, in digital finance and cross-border payments, systems have become interoperable, and RMB settlement has expanded. Financial digital cooperation has reached a symbolic milestone. In 2024, Alipay and Kazakhstan's Kaspi.kz realized two-way QR code interoperability, allowing Chinese tourists to pay at local merchants and Kazakh users to transact seamlessly at over 80 million Chinese merchants with no cross-border fees. The partnership recorded over 120,000 transactions in its first month, and by the first anniversary, Kaspi's cross-border payment volume via this channel had grown by 317%, with 12.3% of small and medium-sized enterprise (SME) trade settlements between China and Kazakhstan processed through this platform [17]. In 2026, Tencent's TenPay Global signed an agreement with Kyrgyzstan's Eldik Bank to connect WeChat Pay with local payment systems. Similar deals were reached with Uzbekistan's HUMO and Uzum Bank, extending Chinese payment technologies and standards across Central Asia [18]. Meanwhile, RMB cross-border settlement has continued to expand: by 2025, Chinese banks had established direct RMB settlement links with 12 major Uzbek banks, enabling T+1 settlement and significantly reducing trade costs and exchange rate risks [16].

Fifth, in AI, smart cities, and digital government, applications have scaled up from pilot projects to large-scale deployment. AI and smart city initiatives have

evolved from trials to widespread implementation. In 2022, Kazakhstan launched the Astana Smart City 2025 project, with total investment exceeding \$1.2 billion, deploying over 500,000 IoT sensors across transportation, energy, public safety, and environmental sectors. By 2024, urban congestion had decreased by 18%, municipal energy consumption by 12%, and 76% of public services had been digitized [14]. In Uzbekistan, Chinese enterprises and local operators jointly built the Tashkent City Brain, which processes over 200 million urban data streams daily using AI. By early 2025, 83% of government services and 65% of medical records had been digitized, and over 3,000 smart classrooms had been established [13]. China supported Tajikistan in developing a national e-government platform and a digital healthcare platform for remote consultations. In 2025, the two sides jointly established the SCO AI Application Center in Kyrgyzstan, focusing on AI research in agriculture, education, and public governance [20].

Sixth, in data security, standards alignment, and talent development, cooperation has consolidated the foundation of “soft connectivity.” Progress in regulatory alignment and human capital development has advanced steadily. Leveraging the SCO Big Data Cooperation Center (established in 2022) and its Xinjiang Branch, China organized nine special training programs for over 300 participants from Central Asian government agencies, enterprises, and universities in 2025, covering big data, AI, and cybersecurity [7]. In standardization, the two sides jointly promoted the implementation of ISO-based digital identification (MA) standards. In 2026, the China National Code Institute signed an MoU with the IT Park Dushanbe in Tajikistan to build a national MA node and training base, advancing regional unification of IoT and data application standards [21]. In cross-border data governance, the 2022 Initiative on Data Security Cooperation remains the core regional framework, with regular expert meetings to align regulatory rules, enhance cybersecurity cooperation, and combat cross-border digital crimes [1].

Overall, the digital-AI integration between China and the CACs over the past five years has delivered robust institutional, infrastructural, economic, and technological outcomes, laying a solid foundation for deeper regional digital collaboration and high-quality Belt and Road cooperation.

1. The Effects and Mechanism of Digital-AI Integration on China-CACs' Cross-border Economic Cooperation

Our review so far has clearly shown that the Digital-AI integration and cooperation between China and the five CACs mainly lead to cut distance costs and break down cross-border barriers. Progress in digital infrastructure, data connectivity, intelligent customs clearance, cross-border services, technical collaboration, and rule alignment has eliminated geographical and institutional obstacles. Digital technologies greatly improve the efficiency of cross-border factor flows and weaken constraints imposed by traditional boundaries, laying a solid foundation for regional connectivity and economic and trade exchanges.

1.1 A Perspective of Spatial Economics

Spatial economics provides a powerful analytical instrument for exploring the effects of digital-AI integration on China-Central Asia countries' cross-border economic cooperation. Focusing on the spatial distribution and reconstruction of economic activities, this discipline integrates and restructures traditional location theory, urban economics, and international trade theory under the general equilibrium framework [2, 3 - cited in Zhao]. Recent studies further expand its theoretical boundary, defining modern spatial economics as a branch of network economics that explains the formation and evolution of cross-border economic networks based on geographic, institutional, and digital spaces [4].

From the spatial economics framework, Zhao summarizes the core logic of this discipline as two paired concepts and one classic model: agglomeration and dispersion, centripetal force and centrifugal force, and the Core-Periphery (C-P) Model [22]. The core driver shaping regional core-periphery spatial patterns is generalized transportation cost, namely spatial distance cost. Different from narrow logistics costs, generalized transportation costs refer to all friction costs for economic entities to conduct cross-regional transactions across geographic distances. Essentially, spatial differences translate into distance friction. Geographic separation generates information, trade, and personnel exchange barriers, which further form transaction costs and spatial resistance to cross-border economic cooperation.

Baldwin classifies spatial distance cost into three dimensions: goods movement cost (trade cost), information movement cost (communication cost), and personnel face-to-face interaction cost [23, 24]. The three-dimensional distance costs constitute the comprehensive spatial resistance that restricts cross-border economic cooperation and shapes regional spatial structures.



Fig. 1 - Three forms of distance costs serve as the main constraints of globalization Source. Baldwin [24].

From the perspective of spatial economics, the effects of digital-AI integration on China-Central Asia cross-border economic cooperation exert temporally heterogeneous effects. Its value release follows a progressive phased logic: short-run cost reduction, medium-run efficiency improvement, and long-run spatial pattern restructuring, which breaks the geographic locking effect of traditional spatial economic patterns.

Specifically, in the short run, digital-AI integration drops the three types of spatial distance costs and mitigates cross-border spatial friction with differentiated effects. Communication cost (TC_2) drops most significantly and rapidly, as digital technologies support unrestricted real-time cross-border information exchange and technical sharing. Goods trade costs (TC_1) are effectively reduced by smart customs clearance, digital logistics, and cross-border product traceability systems. Those effectively promote commodity trade. By contrast, face-to-face interaction cost (TC_3) sees limited short-term improvement, constrained by visa policies, regional gaps, and offline cooperation scenarios that cannot be fully replaced by digital technologies.

In the medium run, short-run cost reduction dividends drive improvements in cross-border factor mobility and trade quality. The continuous decline of comprehensive distance costs enhances the cross-border flow efficiency of capital, technology, and talents. This expands the bilateral trade scale, optimizes trade structure and activates cross-border capital flows, realizing scale and efficiency upgrading in economic and trade cooperation between China and CACs. At this stage, economic effects are mainly concentrated in the circulation field, without fundamental changes to industrial spatial distribution.

In the long run, continuous digital and intelligent empowerment restructures cross-border industrial layout and spatial economic patterns. Sustained cost reduction breaks the geographic-dominated spatial equilibrium, driving the iterative evolution of regional agglomeration-dispersion patterns and core-periphery structures. The decline of spatial friction weakens the agglomeration siphon effect of core regions and improves the industrial undertaking capacity of peripheral regions. This promotes cross-border industrial relocation between China and Central Asia, transforming the geographically locked unbalanced spatial pattern into a coordinated and networked development pattern.

Overall, the effects of digital-AI integration on China-CACs' cross-border economic cooperation follow a dynamic progressive transmission path as follows:

distance cost drop $\rightarrow$ *trade quantity increase* $\rightarrow$ *factor allocation efficiency improvement* $\rightarrow$ *regional spatial pattern restructure*.

1.2 Mechanism of the Effects: a simple model

The heterogeneous mechanism of the effects from the integration of digital-AI to China-CACs' economic cooperation via the three-fold distance cost can be verified with a hierarchical model.

1.2.1 The Core Variables the model relied on

There are five groups of variables, listed as follows.

Group 1: Independent Variables:

DI refers to Digital-AI Integration level. As the core exogenous driving variable, a higher value stands for a higher degree of integration of digitization and artificial intelligence.

Group 2: Mediating Variable (Triple Distance Cost)

TC, the Total Distance Cost, referring to generalized transportation cost in spatial economics. Following Baldwin (2006, 2018), it is divided into three sub-items:

TC₁, trade cost (cost of goods flow),

TC₂, communication cost (cost of idea and information flow), TC₃, face-to-face cost (cost of personnel flow)

Their functional relationship is expressed as: $TC = f(TC_1, TC_2, TC_3)$

Group 3: Dependent Variables

TR: Cross-border trade activity level (short-run outcome).

INV: Cross-border investment and industrial chain integration level (medium-run outcome).

CE: Comprehensive cross-border economic cooperation level (long-run outcome).

Group 4: Spatial Pattern Variables

Agg: Regional economic agglomeration intensity. Dis: Regional economic dispersion intensity.

Group 5, the Control Variables,

X: External environmental factors, including geography, institution, infrastructure, market scale, and industrial policies.

1.2.2 Hierarchical Mathematical Models: short run

With the above variables, the models in phases can be built in accordance with a complete dynamic transmission chain as follows:

Digital-AI integration reduces triple distance costs (short run) → improves factor flow and cross-border trade (medium run) → restructures industrial spatial patterns (long run), which is consistent with the aforementioned mechanism of temporal heterogeneity.

Short-run Mechanism: Differentiated Cost Reduction Effect of Digital-AI Integration on Triple Distance Costs.

Digital-AI integration generates differentiated cost-reduction effects. The decline magnitude follows: information cost > personnel exchange cost > goods trade cost, satisfying:

$$\beta_2 > \beta_3 > \beta_1 > 0$$

Sub-costs Functional Relations

$$TC_1 = \alpha_1 - \beta_1 \cdot DI + \varepsilon_1 \quad TC_2 = \alpha_2 - \beta_2 \cdot DI + \varepsilon_2 \quad TC_3 = \alpha_3 - \beta_3 \cdot DI + \varepsilon_3$$

Here, α denotes inherent baseline costs, β denotes digital empowerment intensity, and ε represents random interference. Information costs drop most rapidly due to digital real-time connectivity; personnel and tourism costs decline fast via online services; and goods trade costs decrease steadily but are constrained by physical logistics.

Total distance cost is weighted as:

$$TC = w_1 TC_1 + w_2 TC_2 + w_3 TC_3, \quad w_1 + w_2 + w_3 = 1$$

By substituting the function of sub-costs, the correlation formula between total distance cost and digital-AI integration is obtained:

$$TC = \sum_{i=1}^3 \left(\frac{\sum_{i=1}^3 w_i \beta_i}{\sum_{i=1}^3 w_i} \right) \cdot \sum_{i=1}^3 w_i \varepsilon_i$$

simplified as:

$$TC = A - B \cdot DI + \varepsilon$$

Where A is the inherent total distance cost of the region, and B represents the comprehensive weakening effect of digital-AI integration on overall s.

The reduction of s directly breaks trade barriers and forms a stable negative correlation, thereby boosting trade activities:

$$TR = \varphi_0 + \varphi_1 \cdot TC + \varphi_2 \cdot X + \sigma$$

1.2.3 Hierarchical Mathematical Models: medium and long run Medium-run Mechanism: Further reduction of distance Cost and Industrial Restructuring

As digital empowerment deepens, information and personnel cost advantages are further amplified:

$$\beta_2' > \beta_3' \gg \beta_1' > 0$$

Improved spatial efficiency facilitates cross-border capital flows (INV) and industrial collaboration:

$$INV = \lambda_0 - \lambda_1 \cdot TC^* + \lambda_2 \cdot X + \tau$$

Optimized information transmission and personnel mobility reduce investment risks and support offline industrial docking. Declining frictions stimulate two-way investment and drive complementary restructuring of China–Central Asian industrial chains.

Long-run Mechanism: Comprehensive Cooperation Upgrading and Spatial Pattern Restructuring

Sustained digital optimization promotes overall cross-border cooperation:

$$CE = \omega_0 + \omega_1 \cdot TR + \omega_2 \cdot INV + \omega_3 \cdot X + \zeta$$

Long-term friction reduction reshapes regional core-periphery structures:

$$Agg = \theta_0 + \theta_1 \cdot TC^*$$

$$Dis = \eta_0 - \eta_1 \cdot TC^*$$

$$(\theta_1 > 0, \eta_1 > 0)$$

Persistent cost decline weakens the agglomeration siphon of traditional core areas, enhances industrial undertaking capacity of peripheral Central Asian regions, and transforms geographically locked unequal patterns into balanced, networked cross-border economic spatial structures.

1.3 Dynamic Transmission Mechanism

Short run:

$$DI \uparrow \Rightarrow TC_2 \downarrow, TC_3 \downarrow, TC_1 \downarrow \Rightarrow TR \uparrow$$

Digital-AI integration development brings about differentiated decline of three types of distance costs, and further improves the activity of cross-border trade.

Medium run:

$$DI \uparrow \Rightarrow TC_2 \downarrow, TC_3 \downarrow \Rightarrow INV \uparrow$$

The deepening of digital-AI integration optimizes information and personnel exchange costs, which promotes the growth of cross-border investment and industrial chain restructuring.

Long run:

$$TR \uparrow, INV \uparrow \Rightarrow CE \uparrow \Rightarrow Agg \downarrow, Dis \uparrow$$

The coordinated development of trade and investment upgrades comprehensive economic cooperation, reduces regional agglomeration and strengthens dispersion, and finally realizes the restructuring of the core-periphery spatial pattern.

Discussion and Conclusion

Major Problems and Suggestions for Improving the Cooperation between China and Central Asian Countries in Digital-AI Integration

Based on the mechanism analysis of digital-intelligent integration in promoting China-Central Asia cooperation, although bilateral digital cooperation has achieved phased progress, prominent practical constraints still hinder in-depth regional integration. Various institutional, informational, and physical barriers continuously raise multi-dimensional distance costs, restricting the free flow and efficient allocation of digital factors across borders.

First, the unbalanced development of digital infrastructure has widened the regional digital divide and increased physical connection costs. The five Central Asian countries show huge disparities in digital construction. Kazakhstan boasts a relatively mature digital system, with an optical fiber coverage rate of 87% and a 4G network coverage rate exceeding 95%, equipped with high-standard Tier III data centers. In contrast, Tajikistan and Kyrgyzstan lag far behind in digital infrastructure, with rural broadband coverage remaining at approximately 30%. The shortage of cross-border dedicated communication lines and unstable network signals frequently cause network lag and disconnection in cross-border e-commerce live streaming at the Khorgos Port. Chinese enterprises are forced to make additional investments in building exclusive private network

lines, substantially increasing the physical operating costs of cross-border digital cooperation [25].

Second, fragmented digital rules and technical standards trigger high institutional distance costs. Divergent digital governance systems among Central Asian countries result in inconsistent norms for cross-border data flow, privacy protection, and electronic certification. Kazakhstan has formulated comprehensive personal data protection regulations with strict requirements for local data storage and cross-border approval, while Tajikistan and Turkmenistan have not yet completed relevant legislative systems. The lack of multilateral mutual recognition mechanisms leads to repeated verification of electronic documents, digital signatures, and customs data for China-Europe freight trains at the China-Kazakhstan border. Such institutional frictions severely reduce the efficiency of cross-border trade and logistics [26].

Third, stringent cross-border data supervision restrictions impede information circulation and data synergy efficiency. All Central Asian countries implement data localization policies and hierarchical cross-border approval systems, setting high thresholds for transnational data transmission. Kazakhstan mandates that sensitive data in finance, energy, and other core industries must be stored on local servers, requiring special multi-level approval for cross-border transmission. This mechanism greatly increases compliance costs for China-Kazakhstan energy trade and financial settlement. Furthermore, regulatory barriers hinder the implementation of cross-border product traceability and telemedicine data sharing projects between China and Uzbekistan, failing to form a closed-loop digital service system and limiting the empowering effect of digital technology [27].

Fourth, the severe shortage of interdisciplinary digital talents constitutes a long-term developmental bottleneck. The digital industry in Central Asia started late, with an imperfect talent cultivation system and insufficient human capital stock. The proportion of ICT practitioners in Uzbekistan is merely 0.5% of the total labor force, far lower than the EU average of 3.7%. High-end talents for digital platform operation, artificial intelligence maintenance, and cross-border compliance management are extremely scarce. In Kyrgyzstan, insufficient university teaching resources lead to a massive brain drain of local technical talents, making it difficult to sustain the long-term operation and iterative upgrading of cross-border digital cooperation projects [27].

Fifth, superimposed geopolitical and cybersecurity risks elevate the uncertainty cost of regional cooperation. The complex geopolitical environment in Central Asia, external intervention forces, frequent border security incidents, and fluctuating national policies have continuously disturbed bilateral digital cooperation. The border security incident in Tajikistan at the end of 2025 negatively affected the operation of Chinese-funded digital industrial parks and threatened the security of cross-border optical cable trunk lines. In addition, Kazakhstan's

multi-vector foreign policy brings about periodic policy volatility, undermining the stability and predictable expectations of long-term digital cooperation.

To eliminate cross-border barriers, reduce multi-dimensional distance costs, and deepen China-Central Asia digital-intelligent integration, targeted optimization strategies are proposed.

First, promote coordinated cross-border digital infrastructure construction, focusing on supporting underdeveloped countries in improving network and computing infrastructure to bridge the regional digital divide and reduce physical connection costs.

Second, establish a multilateral digital governance cooperation working group to unify technical standards and certification norms and build a mutual recognition system for digital rules to eliminate institutional barriers.

Third, innovate cross-border data flow supervision models, construct a whitelist mechanism and a blockchain-based trusted data transmission system to balance data openness and cybersecurity.

Fourth, strengthen transnational talent joint cultivation through vocational workshops, joint laboratories, and university cooperation programs to build a stable interdisciplinary digital talent reserve.

Fifth, establish a multilateral cybersecurity risk prevention and control mechanism, strengthen policy communication and geopolitical risk hedging, and consolidate the long-term stable cooperation mechanism for regional digital integration.

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ИНТЕГРАЦИЯ ЦИФРОВОГО И ИСКУССТВЕННОГО ИНТЕЛЛЕКТА НА НОВОМ ШЕЛКОВОМ ПУТИ, СТОИМОСТЬ ПРОЕЗДА И ТРАНСГРАНИЧНОЕ ЭКОНОМИЧЕСКОЕ СОТРУДНИЧЕСТВО: ПЕРСПЕКТИВЫ ПРОСТРАНСТВЕННОЙ ЭКОНОМИКИ

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Аннотация. Интеграция цифрового и искусственного интеллекта представляет собой одну из основных тенденций нынешней и будущей технологической революции. Это развитие меняет модели международного экономического сотрудничества и повышает эффективность трансграничного взаимодействия. С точки зрения пространственной экономики, в данной статье проводится предварительное исследование перспектив и потенциального влияния интеграции цифрового и искусственного интеллекта на трансграничное экономическое сотрудничество между Китаем и странами, расположенными вдоль Экономического пояса Шелкового пути, в основном странами Центральной Азии. Исследование показало, что интеграция цифрового и искусственного интеллекта снизит затраты на дистанционное взаимодействие при трансграничном сотрудничестве, а именно преодолет три типа затрат, связанных с расстоянием: стоимость перемещения товаров, стоимость передачи информации и стоимость личного взаимодействия. Сокращение этих трех видов издержек, связанных с удаленностью, значительно укрепит экономическое сотрудничество между Китаем и странами Центральной Азии и обеспечит взаимовыгодные результаты для всех вовлеченных сторон.

Ключевые слова: интеграция цифрового и искусственного интеллекта, Китай, страны Центральной Азии, трансграничное экономическое сотрудничество, пространственная экономика

ЖАҢА ЖІБЕК ЖОЛЫНЫҢ ЦИФРЛЫҚ ЖӘНЕ ЖАСАНДЫ ИНТЕЛЛЕКТ ИНТЕГРАЦИЯСЫ, ҚАШЫҚТЫҚ ҚҰНЫ ЖӘНЕ ТРАНСШЕКАРАЛЫҚ ЭКОНОМИКАЛЫҚ ҰНТЫМАҚТАСТЫҚ: КЕҢІСТІКТІК ЭКОНОМИКАНЫҢ ПЕРСПЕКТИВАСЫ

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Аңдатпа. Цифрлық-жасанды интеллект интеграциясы қазіргі және болашақтағы технологиялық революцияның негізгі тенденцияларының бірін білдіреді. Бұл даму халықаралық экономикалық ынтымақтастықтың құрылымын өзгертеді және трансшекаралық ынтымақтастықтың тиімділігін арттырады. Кеңістіктік экономика тұрғысынан бұл мақалада Цифрлық-жасанды интеллект интеграциясының Қытай мен Жібек Жолының Экономикалық Белдеуі бойындағы елдер, негізінен Орталық Азия елдері арасындағы трансшекаралық экономикалық ынтымақтастыққа перспективаларымен ықтимал әсерлері туралы алдынала зерттеу жүргізілуде. Зерттеу көрсеткендей, цифрлық және жасанды интеллект интеграциясы трансшекаралық ынтымақтастық үшін қашықтық шығындарын азайтады, атап айтқанда қашықтыққа байланысты шығындардың үш түрін еңсереді: тауарларды тасымалдау құны, акпаратты беру құны және бетпе-бет өзара әрекеттесу құны. Қашықтық шығындарының осы үш түрінің қысқаруы Қытай мен Орталық Азия елдері арасындағы экономикалық ынтымақтастықты едәуір нығайтады және барлық қатысушы тараптар үшін өзара тиімді нәтижелерге қол жеткізуге мүмкіндік береді.

Тірек сөздер: цифрлық-жасанды интеллект интеграциясы, Қытай, Орталық Азия елдері, трансшекаралық экономикалық ынтымақтастық, кеңістіктік экономика

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