IV. The Impact of Digital Economy on Innovation Performance Among Belt and Road Countries

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The digital economy has deeply influenced all sectors of national economic development, becoming a critical engine for global economic growth and national innovation performance. Nevertheless, significant gaps persist among developed, developing, and less-developed countries in their levels of digital economic advancement. Given this imbalance, exploring how the digital economy impacts innovation performance in "Belt and Road" countries is essential. This study examines mechanisms through which the digital economy influences innovation performance across these nations. Findings provide valuable insights to enhance competitiveness, support innovation, and address global disparities. The study offers practical recommendations for policymakers in "Belt and Road" countries aiming t.

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1 Introduction

The digital economy, as a new economic form, has been widely considered around the world because of its characteristics of high efficiency, intelligence, and greenness. At present, the world is facing technological and industrial innovation, digital economy, as an important driving force for global economic growth, is having an important impact on the innovation-driven development of the social economy of countries along the "Belt and Road", the Belt and Road Initiative aims to strengthen economic, political, cultural and other fields of cooperation among countries along the route, and achieve common prosperity. Therefore, it is significant to explore the impact of the digital economy on the innovation performance of Belt and Road countries to achieve the common prosperity of China and countries along the Belt and Road.

2 Literature review

In recent years, the digital economy has received extensive attention and research worldwide. Many scholars have discussed the impact of the digital economy on economic growth, employment and innovation from different perspectives. In particular, the integration and development of the digital economy and the local economy and its impact on innovation performance have become the focus of research, and many authors have done a lot of research on innovation performance based on the digital economy. Based on the existing literature's research on the impact of the digital economy on innovation performance, Li and Mao (2023) conducted a more in-depth study on the regional differences and spatial effects of the digital economy on innovation performance in countries along the "Belt and Road". It is concluded that the digital economy can significantly improve countries' innovation performance along the "Belt and Road". It has a stronger promoting effect on countries with a higher level of digital economy development (Li and Mao, 2023). The existing literature mainly carries out a series of studies on the innovation performance of the digital economy from the aspects of market, network and region after the digital economy promotes global economic growth.

At the market level, Dong (2023) discusses the impact of the development of the digital economy on the innovation performance of commercial circulation enterprises and its mechanism. It is believed that the development of a digital

economy can promote the improvement of the innovation performance of commercial circulation enterprises by stimulating enterprises to increase R&D investment and optimise their human capital structure. Tang et al. (2022) found through their research that the development of the digital economy promoted the improvement of innovation performance overall, but it had a typical dynamic nonlinear impact. Hou et al. (2021) put the digital economy, market integration and enterprise innovation performance into the same analytical framework. They tested the impact mechanism and path of digital economy and market integration on enterprise innovation performance. The results show that both digital economy and market integration are conducive to promoting the improvement of enterprise innovation performance. The digital economy has a positive regulating effect on the innovation incentive effect of market integration.

At the network level, Xin et al. (2022) discussed the economic effects of dual network embedment on innovation performance from the perspective of social networks and digital networks of digital economy enterprises. They believed that social networks and knowledge networks can effectively alleviate the financing constraints of enterprises, thus improving innovation performance. Chen (2021) explored how enterprise network embeddedness affects the decision of enterprise openness to innovation, thus affecting enterprises' innovation performance. The experimental conclusion shows that innovation network structure embeddedness has a significant positive impact on both innovation quantity and innovation quality. In contrast, relationship embeddedness has a U-shaped effect on innovation quantity.

At the regional level, Liu (2022) tested the internal impact between the development of the digital economy and regional innovation performance, and the final study showed that the development of the digital economy had a significant positive impact on regional innovation performance, and this impact was characterised by increasing "marginal effect". Through research, Xu and Hou (2020) found that the development of the digital economy significantly promoted the improvement of regional innovation performance. The development of the digital economy has a nonlinear effect of increasing marginal effect on regional innovation performance and invention innovation performance. The development of the digital economy has a significant negative impact on the innovation performance and non-invention innovation performance of neighbouring regions. However, it has no significant

impact on invention innovation performance. Accordingly, corresponding policy suggestions are put forward. Based on previous studies, this paper will explore the internal impact of the digital economy on the innovation performance of Belt and Road countries, which is of great significance for the in-depth cooperation between China and "Belt and Road" countries to improve innovation performance.

3 Digital economy and innovation performance status and characteristics

3.1 Analysis of the current situation and characteristics of the digital economy

Based on digital technology, the digital economy promotes the digital, networked and intelligent development of economic activities by mining and utilising data resources. In recent years, the scale of the digital economy has continued to expand, with a growth rate far exceeding that of the traditional economy. The wide application of the Internet, big data, artificial intelligence and other technologies has provided a solid foundation for the rapid growth of the digital economy; the digital economy has penetrated various industries, including retail, finance, manufacturing, etc. Digital technology has improved production efficiency, reduced operating costs, and brought more choices to consumers. At the same time, the globalisation trend of the digital economy has become increasingly obvious. Multinational enterprises use digital technology to break geographical restrictions and realise the optimal allocation of resources.

First of all, the digital economy level of Belt and Road countries is measured by Internet popularity. According to data availability, this paper will evaluate the mobile network coverage rate, fixed telephone penetration rate and fixed broadband penetration rate obtained from the WDI database. It can be seen from Table 1 that the development level of the overall digital economy of the countries along the "Belt and Road" from 2010 to 2022 continues to rise. From Table 1, it can be seen that the growth rate of network penetration of the countries along the "Belt and Road" is fluctuating but tends to increase slowly. Rapid growth in fixed broadband penetration between 2010 and 2022. In addition, the number of fixed and mobile phones in the countries along the "Belt and Road" has been increasing, and the ICT infrastructure has been continuously improved, laying a good foundation for

developing the digital economy. The continuous popularisation of fixed broadband, mobile broadband and the Internet has provided great convenience for the application of the digital economy industry. This will also, to a certain extent, promote the competitiveness of ICT innovation, the "Belt and Road" countries along the increasing attention to the cultivation of human capital, technology research and development capabilities and innovation and transformation capabilities are gradually enhanced, providing technical support for the development of the digital economy. Under the combined effect of the above mobile network coverage rate, fixed telephone penetration rate, and fixed broadband penetration rate, the development level of the digital economy in the "Belt and Road" countries continues to improve.

Table 1: Internet penetration rate in Belt and Road countries

	Mobile network coverage	Fixed-line telephone penetration	Fixed broadband penetration
2010	29.068	16.397	7.060
2011	31.810	16.042	7.560
2012	34.763	15.947	8.280
2013	37.354	15.505	8.954
2014	40.448	15.166	9.414
2015	43.123	15.032	10.015
2016	46.533	14.300	10.325
2017	49.759	13.962	11.151
2018	49.124	12.926	11.280
2019	55.770	13.480	12.119
2020	58.697	13.398	13.042
2021	62.106	13.086	13.455
2022	21.939	10.947	12.295

Data source: WDI database

From the perspective of the export situation of digital economy-related enterprises, ICT service exports generally show a steady growth trend from 2010 to 2022, and reach a rising peak in 2020, but there is a significant decline in 2022. The growth of the export of information and communication services is generally consistent with that of the export of ICT services, which also achieved substantial growth in 2020 and a relatively large decline in 2022, with a large fluctuation in these two years; the details are shown in Table 2.

Table 2 Export situation of enterprises related to the digital economy

	ICT service exports	Export of information and communication services
2010	1125.603	5079.153
2011	1199.968	5056.822
2012	1156.491	5134.032
2013	1263.063	5450.064
2014	1265.680	5715.392
2015	1171.760	5596.611
2016	1167.775	5668.293
2017	1099.051	5444.081
2018	1112.436	5437.910
2019	1140.241	5512.053
2020	1635.700	6302.020
2021	1593.677	5615.014
2022	1012.502	3628.660

Data source: UNCTAD database

3.2 Analysis of current situation and characteristics of innovation performance

Innovation performance refers to the achievements and benefits achieved by enterprises in innovation activities. Innovation performance reflects the achievements and benefits of enterprises in innovation activities. In the era of the knowledge economy, the level of innovation performance directly determines the competitiveness of enterprises. With the increase of innovation input, enterprises have made remarkable achievements in product innovation, process innovation and organizational innovation, which effectively improves the competitiveness of enterprises. The Global Innovation Index (GII), jointly constructed by Cornell University, InSEAD and the World Intellectual Property Organization (WIPO), is a comprehensive indicator for evaluating innovation performance. This paper will use this data to evaluate the innovation performance of the Belt and Road countries.

From the perspective of overall innovation performance, from 2011 to 2023, the overall innovation performance of the countries along the Belt and Road fluctuates, but the change is small. As can be seen from Figure 1, the level of innovation output drops from 32.47 to 27.67, which may be due to the low level of digital economy development in most countries along the Belt and Road. Solidified at the downstream level, it is difficult to promote improving innovation performance.

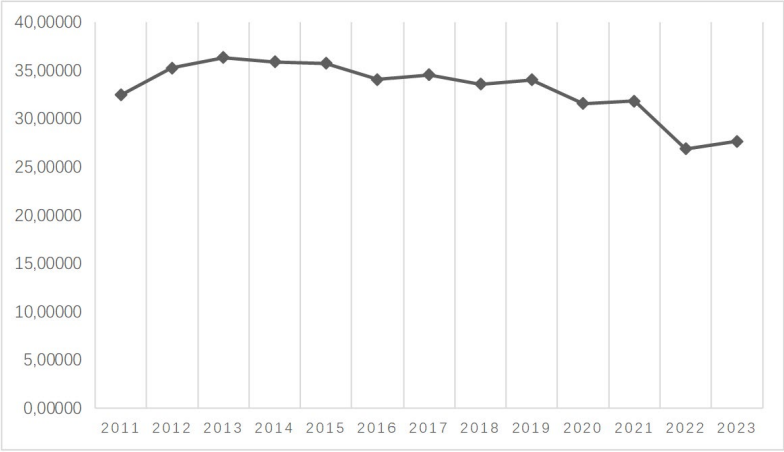

Figure 1: Average innovation index of Belt and Road countries
Data Source: Global Innovation Index Report

Secondly, from the perspective of sub-regional innovation performance, there is a big difference in the average annual growth rate of innovation output in Europe, Asia, and Africa from 2011 to 2023. The innovation output in Europe is at a higher level and its growth is relatively stable. This also reflects from the side that the innovation performance in Asia and Africa has a huge room for growth.

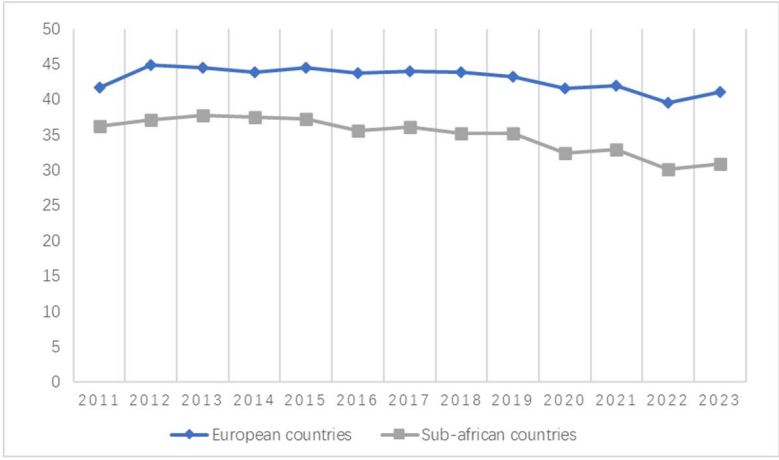

Figure 2: Average innovation index for Europe and Asia Africa
Data Source: Global Innovation Index Report

From the perspective of the innovation performance of various countries, there are also large differences in the level of innovation output of sample countries along the Belt and Road from 2010 to 2023. As can be seen from Table 3, the top five countries with annual average growth rates from 2010 to 2023 are Italy, Philippines, Indonesia, Lithuania and Greece.

Table 3: The top 30 Belt and Road countries in the Innovation Index (unit:%)

Rank	Nation	Average annual growth rate
1	Italy	0.011
2	The Philippines	0.010
3	Indonesia	0.008
4	Republic of Lithuania	0.008
5	Greece	0.008
6	Estonia	0.007
7	Portugal	0.005
8	Austria	0.004
9	The United Arab Emirates	0.003
10	Singapore	0.003
11	Denmark	0.003
12	Belgium	0.002
13	Latvia	0.002
14	Bulgaria	0.002
15	Israel	0.001
16	Cyprus	0.001
17	Australia	0.001
18	Vietnam	-4.535
19	Morocco	-0.001
20	Thailand	-0.001
21	Croatia	-0.001
22	Norse	-0.002
23	Luxembourg	-0.002
24	Georgia	-0.002
25	Czech Republic	-0.003
26	Saudi Arabia	-0.003
27	Slovenia	-0.004
28	Ukraine	-0.004
29	Jamaica	-0.004
30	Romania	-0.004

Data Source: Global Innovation Index Report

The bottom five countries - Slovenia, Ukraine, Jamaica, and Romania - have large differences in average annual growth rates, which also indicates large differences in innovation performance among countries in the same region.

4 The impact mechanism of digital economy on the innovation performance of "Belt and Road" countries

In Figure 3, we present the impact mechanism of how the digital economy, through technological innovation, industrial upgrades, and new business forms and models, affects innovation performance, which is explained in more detail in the following subsections.

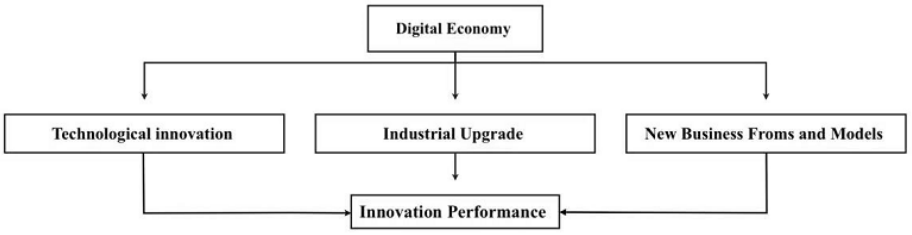

Figure 3 Impact Mechanism

4.1 Digital economy promotes technological innovation

Through the wide application of digital technology, the technological innovation of the countries along the Belt and Road is promoted in the transformation and upgrading of traditional industries, and the cultivation and development of emerging industries and innovation performance is improved. The digital economy has a direct transmission mechanism for the improvement of innovation performance, mainly through three levels.

First, digital technology is the foundation of the development of the digital economy and the driving force for the iterative upgrading of new business forms and models. It will also stimulate consumers' innovative demand for product diversification. The one-way output flow of traditional producers and suppliers will be transformed into a two-way exchange flow between producers and suppliers, thus promoting the increase of product output and the expansion of service types and gradually producing scale effects. By increasing returns to scale, various production costs can be saved, which improves the R&D efficiency of innovation entities and ultimately improves the innovation performance of the entire region.

Second, the digital economy breaks the limitation of time and space and expands the path and scope of information transmission, thus promoting the spillover of information, which makes it more convenient for innovation subjects and participants of innovation activities to obtain external information and enjoy efficient innovation services more easily, thus releasing the innovation spillover dividends in the digital economy. In addition, the digital economy has changed traditional industries' innovation methods and promoted emerging industries' innovation methods. In order to meet the diversified innovation needs of consumers, innovation entities will continuously improve their innovation capabilities. After consumers enjoy the innovation spillover dividends the digital economy brings, they will put forward higher level and dynamic innovation needs. Encourage innovation entities to enhance the innovation spillover effect further and achieve a virtuous cycle of continuous improvement of the digital economy and innovation performance.

Third, the development of the digital economy will optimise products and promote the improvement of product quality. On the one hand, the expansion of product scale and the increase of product types increase the complexity of the economic system and bring new matching problems. In this process, the digital economy improves the flow efficiency of production factors, speeds up the diffusion of logistics, capital flow, business flow and information flow, optimises the environment for the use of factors, reduces the cost of factor flow, and thus promotes the optimal allocation of various production factors. In addition, the development of digital technologies such as big data, the Internet, and blockchain has provided solutions to the matching problems in the economic market. On the other hand, the digital economy makes the market more transparent, reduces the information asymmetry between the supply and demand of innovation factors, intensifies competition among enterprises, and forces them to improve their innovation ability, produce more optimised products, and thus improve innovation performance.

4.2 Digital economy helps industrial upgrading

The development of the digital economy will help countries along the Belt and Road optimise and upgrade their industrial structure, promote the development of traditional industries in the direction of high-end, intelligent and green, and improve

the overall innovation performance of industries. The digital economy improves innovation performance by promoting the optimisation and upgrading of traditional industries. The digital economy is characterised by high permeability and creativity. Digital technologies and digital services have penetrated every link of traditional industries through big data, cloud computing, information technology and other means, changing the production mode and organisation mode of traditional industries, stimulating the innovation ability of traditional industries, and promoting the optimal allocation of production factors of various traditional industries. It has promoted the upgrading of the industrial chain of traditional industries to the middle and high-end, helped the transformation of traditional industries to the direction of digitalisation and intelligence, and reconstructed the industrial ecology of traditional industries. In contrast, the transformation and optimisation of traditional industries have further provided a strong driving force for the improvement of industrial innovation performance.

On the other hand, the digital economy improves innovation performance by promoting the formation of new industries. The high permeability of the digital economy breaks the boundaries between industries, promotes the deep integration of information and communication technology with various fields, accelerates the speed of upstream and downstream integration of the industrial chain, and then realises the increase of product types and the innovation of product models through digital industrialisation and industrial digitalisation, and gives birth to a new form of networked, intelligent and collaborative industry. Continuously promoting the optimisation and upgrading of industrial structure will force the digital economy to carry out technological innovation and product innovation, thus further promoting the improvement of innovation performance.

4.3 The digital economy has spawned new business forms and models

The digital economy has spawned a series of new business forms and models, providing a broader space and platform for innovation activities in countries along the Belt and Road and helping to improve innovation performance. The digital economy is spawning many new business forms and models, injecting new vitality into economic development. The continuous innovation of digital technology provides technical support for generating new business forms and models. For example, the integrated application of technologies such as big data, artificial

intelligence and the Internet of Things has promoted the rapid development of new business forms such as smart manufacturing, smart logistics and the sharing economy.

Secondly, consumer demand drives the emergence of new business forms and models, and in the era of the digital economy, consumer demand is increasingly diversified and personalised. To meet the needs of consumers, enterprises continue to innovate business models, giving birth to new business forms and models such as customised economy and experience economy.

Finally, industrial upgrading accelerates the development of new formats and models: the digital economy has promoted the digital transformation and upgrading of traditional industries and the reconstruction of industrial chains and value chains. In this process, new business forms and models came into being, supporting industrial upgrading. The new business forms and models spawned by the digital economy have profoundly impacted economic development. On the one hand, new business forms and models have improved economic efficiency and promoted industrial upgrading and structural adjustment. On the other hand, new business forms and models have also brought new employment opportunities and social challenges.

Looking forward to the future, with the continuous innovation and popularisation of digital technology, the digital economy will continue to give birth to new business forms and models and promote the sustainable development of economic society.

5 Conclusion and countermeasure suggestions

The development of the digital economy has promoted the wide application of digital technology, improving production efficiency and economic growth rate. Data and information technology have become important production factors in the digital economy, promoting industrial upgrading and economic transformation. This trend also exists in the countries along the Belt and Road, already impacting economic growth patterns. First, the rapid development of the digital economy has provided countries with broad opportunities and platforms for entrepreneurship. In the digital economy, entrepreneurs can use new media, such as the Internet, to innovate and start businesses, thus stimulating more innovative vitality. At the same time, the

digital economy has also promoted cultural exchange integration and mutual understanding and respect among different civilisations. Second, the development of the digital economy requires global collaboration and sharing. In the field of digital economy, countries along the "Belt and Road" can carry out international cooperation by jointly setting standards and sharing experience and technology to achieve mutual benefit and win-win results. This is conducive to China's development and the prosperity and development of the digital economy of countries along the route.

However, to take full advantage of this opportunity and achieve sustainable development, countries need to strengthen policy communication and cooperation, promote digital infrastructure construction, strengthen personnel training and cooperation, and deepen market opening and cooperation. This will help promote the economic development and social progress of countries along the Belt and Road and achieve common prosperity and development. First, we need to strengthen policy communication and cooperation. By strengthening policy communication and cooperation in the field of digital economy, we will promote the development and mutual benefit of the digital economy of all countries. This includes establishing dialogue mechanisms, sharing experiences and exchanging technologies in the field of digital economy to promote cooperation and development among countries. Second, promote the construction of digital infrastructure. Digital infrastructure is an important support for developing the digital economy and needs further promotion and improvement. Countries can jointly fund the construction of digital infrastructure, improve network coverage and speed, and provide better basic conditions for the development of the digital economy. Third, strengthen personnel training and cooperation. Talent is one of the key factors in the development of the digital economy. Countries can strengthen cooperation in personnel training, jointly train digital economy talents with an international perspective, and promote the exchange and sharing of digital economy technologies. Fourth, deepen market opening and cooperation. The digital economy is an open economic form which needs to deepen the openness of the market further and promote the interconnection of the markets of all countries. Countries can jointly formulate market access rules, remove trade barriers and obstacles, and promote the free flow and development of the digital economy. Fifth, strengthen supervision and risk prevention. The digital economy faces new challenges and risks, requiring countries to strengthen supervision and risk prevention. Countries can jointly formulate

relevant standards and norms, strengthen supervision and management of the digital economy, and ensure the healthy and orderly development of the digital economy.

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