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A Study on the Impact Efficiency of the Digital Economy on the Tourism Economy in Western Regions

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Abstract: *To investigate the intrinsic relationship between the digital economy and tourism in western China, this study utilizes the DEA-CCR model to analyze panel data from 11 provinces (autonomous regions and municipalities) in the western region from 2018 to 2022. The results show that the digital economy has a positive impact on tourism in the western region, with developments in informatization, internet infrastructure, and digital transactions significantly influencing tourism. The research demonstrates that the digital economy can drive the transformation of the tourism industry toward high-quality development, providing strong support for policy formulation and practical implementation. This study holds practical significance for promoting high-quality development of the tourism industry in the western region.*

Keywords:*Digital Economy; DEA-CCR Model; Western Tourism; Efficiency Study*

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I. INTRODUCTION

Currently, China is experiencing a period of rapid development in the digital economy. As a technological force that strengthens national strategy and an important channel for adjusting and optimizing industrial structure, the digital economy plays a critical role in promoting high-quality economic development [1]. Tourism, as a significant component of the modern service industry, holds comprehensive advantages in industrial linkage, employment stimulation, investment promotion, cultural dissemination, and environmental friendliness, making it a vital driver of economic growth and social development [2]. The "14th Five-Year Plan for Tourism Development" issued by the State Council emphasizes innovation-driven development and accelerating the advancement of smart tourism characterized by digitalization, networking, and intelligence, as well as deepening the integration of "Internet + Tourism." The digital economy has become a crucial engine for the high-quality development of China's tourism industry, serving as a "booster" to enhance the quality of tourism development [3]. Based on panel data from 11 provinces (autonomous regions and municipalities) in western China from 2018 to 2022, this paper employs the DEA-CCR model to examine the impact of digital economy development levels on the high-quality development of the tourism industry in the western region, and to measure the development levels of the digital economy and the high-quality development index of tourism.

II. RESEARCH METHODS AND INDICATOR SELECTION

2.1 Introduction to the DEA-CCR Model.

The DEA-CCR model is a linear programming model expressed as the ratio of outputs to inputs. By comparing the efficiency of a specific unit with the performance of a group of similar units providing the same services, it aims to maximize the efficiency of service units. In this process, some units that achieve 100% efficiency are referred to as relatively efficient units, while others with efficiency scores below 100% are considered inefficient. The rationale for choosing the DEA-CCR model lies in its unique ability to determine the efficiency of decision-making units (DMUs) through relative efficiency evaluation without the need to predefine the form of the production function. The DEA-CCR model can handle multiple input and output variables and avoids the subjectivity of parameter estimation, thereby providing a more objective and accurate efficiency assessment.

The regression equation of the DEA-CCR model is as follows:Assume there are n decision-making units, each with m input indicatorsXj= (x1j, x2j, ⋯, xmj)T, where j=1, 2, ⋯, n, and s output indicators Yj= (x1j, x2j, ⋯xSj)T, The weight vector for inputs is V= (v1, v2, ⋯, vm)T,and the weight vector for outputs is U= (u1, u2, ⋯, um)T. The efficiency value of each decision-making unit can be expressed as:

$$\max U^{t}Y/V^{T}X$$
$$s.t.\,U^{T}Y_{j}/V^{T}X_{j} \leq \ 1, j = 1,2,\ldots,n$$
$$U, V \geq 0.$$

令$T^T = 1/V^T X_O, \mu = UT, \omega = VT$

Subsequently, the linear programming problem can be formulated as follows:

$\max U^T Y_O$

$s.t. \omega X_j - \mu Y_j \geq 0, j = 1,2,\ldots,n$

$\omega^t x = 1,$

$\omega, \mu \geq 0$

Definition 1: If θ <1, the DEA is inefficient.

Definition 2: If θ =1, the DEA is weakly efficient.

Definition 3: If θ >1,and s*+=s*-=0, the DEA is fully efficient.

2.2 **Indicator Selection**

Currently, there is no unified standard for measuring indicators and methods of the digital economy both domestically and internationally. Organizations such as the Organisation for Economic Co-operation and Development (OECD), the European Union, the China Digital Economy Development White Paper (2017), and the Statistical Classification of Digital Economy and Its Core Industries (2021) released by the National Bureau of Statistics have proposed different indicator frameworks for assessing the development level of the digital economy. Therefore, the selection of indicators for this paper draws on extensive authoritative literature, from which we have derived some inspiration. Fu Mengru and Pan Hailan "based their framework on the concepts of innovation, coordination, green development, openness, and sharing, constructing 14 secondary indicators based on previous scholars' research" [3]. Song Guofeng and Zhang Yu "built an indicator evaluation system from three dimensions—digital infrastructure, digital industries, and digital inclusive finance—based on data availability" [4]. Drawing on the research of these scholars, we selected three dimensions—informatization development, internet development, and digital transaction development—along with 12 secondary indicators to construct the digital economy evaluation index system, as shown in Table 1.

Table 1. Digital Economy Evaluation System

Variable	Primary Indicator	Secondary Indicator
Digital Economy	Informatization Development	Fiber-optic cable density (per square kilometer)
		Proportion of informatization employees
		Total telecommunications business revenue (billion yuan)
	Internet Development	Number of domain names (10,000)
		Mobile phone penetration rate (per 100 people)
		Internet broadband access ports (10,000)
		Number of mobile internet users (10,000)
	Digital Transaction Development	Proportion of e-commerce
		E-commerce transaction volume (billion yuan)

2.**Data Sources and Descriptive Statistics**

Considering the availability of data, panel data from 11 provincial-level administrative regions in western China from 2018 to 2022 were used to explore the impact of the digital economy on tourism economic growth. Data on western tourism economic indicators, per capita national income, and per capita tourist arrivals were obtained from the National Bureau of Statistics' statistical bulletins for 2018–2022. Data for the 12 secondary indicators of the digital economy were sourced from the National Bureau of Statistics and the statistical yearbooks of the western provinces. To mitigate the impact of minimal data variations, the data were logarithmically processed in the statistical analysis. Descriptive statistics of the relevant variables are presented in Table 2.

Table 2 Descriptive Statistics of Variables

Variable	Number of Samples	Mean	Maximum	Minimum
Western Tourism Economy Ln(TouE)	55	9.293	10.374	7.478
Per Capita National Income Ln(GDP)	55	10.904	11.396	10.379
Per Capita Tourist Arrivals Ln(TouR)	55	2.350	3.384	1.261
Fiber-Optic Cable Density Ln(FOCD)	55	-2.908	-2.693	-3.588
Proportion of Informatization Employees Ln(POOIE)	55	-4.138	-3.496	-4.590
Total Telecommunications Business Revenue Ln(TeS)	55	6.756	8.926	4.097
Number of Domain Names Ln(NumOfDN)	55	3.216	5.439	0.182
Mobile Phone Penetration Rate Ln(MoPP)	55	4.701	4.852	4.480
Internet Broadband Access Ports Ln(IBAP)	55	7.309	8.811	5.269
Number of Mobile Internet Users Ln(NOMIU)	55	7.666	8.986	5.562
Proportion of E-commerce Ln(POEC)	55	2.271	2.617	1.629
E-commerce Transaction Volume Ln(ECTV)	55	7.075	9.561	4.320

III. EMPIRICAL ANALYSIS

To better understand the impact of the digital economy on the development efficiency of tourism in western China, the DEA-CCR model was employed for regression analysis. The regression results of the DEA-CCR model are presented in Table 3.

Table 3 Efficiency Analysis of Western Provinces

Region	Comprehensive Technical Efficiency	Pure Technical Efficiency	Scale Efficiency
Chongqing	0.999	1.000	0.999
Sichuan	0.988	1.000	0.988
Guizhou	1.000	1.000	1.000
Yunnan	1.000	1.000	1.000
Tibet Autonomous Region	1.000	1.000	1.000
Shanxi	1.000	1.000	1.000
Gansu	1.000	1.000	1.000
Qinghai	0.947	0.951	0.996
Ningxia	0.971	1.000	0.971
Xinjiang	1.000	1.000	1.000
Guangxi	1.000	1.000	1.000

According to the DEA-CCR model, based on the five-year data (2018–2022) collected for the western regions, Table 3 shows that over the past five years, only Qinghai has a pure technical efficiency value not equal to 1, indicating high efficiency in the digital economy and optimal allocation of resources. In other regions, the pure technical efficiency is 1 or close to 1, reflecting relatively ideal pure technical efficiency. Except for Chongqing, Sichuan, Qinghai, and the Ningxia Hui Autonomous Region, the scale efficiency values are below 1, with minimal fluctuations in other years. From the above table, it can be concluded that over the past five years, Chongqing, Qinghai, and Ningxia have experienced decreasing returns to scale, while Sichuan has shown increasing returns to scale. The technical efficiency of most regions is close to 1, indicating effective resource utilization at their current scale. The technical efficiency of Sichuan and Ningxia is below 1, suggesting potential issues in resource allocation, technology application, or management efficiency. The scale efficiency of most regions is close to 1, indicating effective operation at their current scale. The scale efficiency of Qinghai and Ningxia is below 1, suggesting possible diseconomies of scale, where their operational scale may be either too large or too small, leading to reduced efficiency.

Table 4 Analysis of Output Shortfalls in Western Regions

Imput	1	2	3
Chongqing	0.000	0.000	0.000
Sichuan	0.000	0.000	0.000
Guizhou	0.000	0.000	0.000
Yunnan	0.000	0.000	0.000
Tibet Autonomous Region	0.000	0.000	0.000
Shanxi	0.000	0.000	0.000
Gansu	0.000	0.000	0.000
Qinghai	0.000	0.412	1.177
Ningxia	0.000	0.000	0.000
Xinjiang	0.000	0.000	0.000
Guangxi	0.000	0.000	0.000

Table 4 shows the output shortfalls of 11 regions across three secondary indicators. A value of 0 in the table indicates that the current output has reached the optimal level. Using the DEA-CCR model, we also analyzed the average output shortfalls of the 11 regions, which are 0.000, 0.037, and 0.107, respectively. From the table, it can be observed that Qinghai Province has potential for improvement in both per capita tourism income and per capita tourist arrivals. We can leverage the role of the digital economy to enhance the potential of tourism services and product output.

Table 5 Input Analysis of Western Regions

Firminput:	1	2	3	4	5	6	7	8
Chongqing	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sichuan	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Guizhou	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Yunnan	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Tibet	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Shanxi	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Gansu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Qinghai	0.000	-0.352	0.049	0.215	0.001	0.000	0.255	0.237

Ningxia	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Xinjiang	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Guangxi	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 5 shows that Qinghai has negative values in certain input aspects, such as total telecommunications business revenue, number of domain names, mobile phone penetration rate, and e-commerce transaction volume. This indicates redundancy in these inputs in Qinghai Province [4], suggesting that excessive investment in the digital economy may have led to potential surplus. Specifically, the investment in regional informatization personnel exceeds the minimum level required to generate the same output.

Table 6 Comparative Analysis of Regions

Region	Comprehensive Technical Efficiency	Pure Technical Efficiency	Scale Efficiency
Chongqing	0.999	1.000	0.999
Sichuan	0.988	1.000	0.988
Qinghai	0.947	0.951	0.996
Ningxia	0.971	1.000	0.971

Through comparative analysis, it is found that both Chongqing and Sichuan have pure technical efficiency values of 1.000, but their comprehensive technical efficiency values are 0.999 and 0.988, respectively, primarily influenced by scale efficiency. Chongqing's scale efficiency is 0.999, while Sichuan's is 0.988, indicating that these two regions exhibit certain inefficiencies in scale. Adjustments to their operational scale are needed to improve overall efficiency.

By comparing Qinghai and Ningxia, Qinghai's pure technical efficiency is 0.951, and its scale efficiency is 0.996, while Ningxia's pure technical efficiency is 1.000, and its scale efficiency is 0.971. Qinghai requires improvements in both technical and scale efficiency, whereas Ningxia primarily needs to focus on adjustments in scale efficiency.

In the DEA-CCR model analysis of the 11 regions, except for Chongqing, Sichuan, Qinghai, and Ningxia, all other regions are operating on the efficiency frontier at their current scale. Chongqing and Sichuan have technical efficiency values below 1.000 and scale efficiency values below 1.000, indicating that the scale of the digital economy in these regions is insufficient.

Regarding technical efficiency, most regions (Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Xinjiang, and Guangxi) have a technical efficiency of 1.000, indicating that these regions are fully efficient in their production processes. The technical efficiency of Chongqing and Sichuan is also close to 1.000, while Qinghai (0.951) has a relatively lower technical efficiency, suggesting a certain degree of inefficiency in its production process. This implies that the region's output is lower compared to the best-practice regions (i.e., those with an efficiency of 1). The lower technical efficiency in Qinghai may reflect the impact of the digital economy on operational efficiency. Qinghai may need to improve efficiency through technological upgrades or management optimization.

In terms of scale efficiency, most regions (Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Xinjiang, and Guangxi) have a scale efficiency of 1.000, indicating that these regions have achieved optimal scale. The scale efficiency of Chongqing and Sichuan is close to 1.000, while Qinghai and Ningxia have relatively lower scale efficiency, suggesting a certain degree of inefficiency in their operational scale. Ningxia's scale efficiency value of 0.971 indicates lower scale efficiency and the presence of inefficiencies in scale.

In terms of output and input adjustments, Qinghai needs to adjust its outputs and inputs to improve efficiency. Qinghai should increase certain outputs and reduce certain inputs to enhance efficiency. Both Qinghai and Ningxia exhibit output shortfalls, while Chongqing and Sichuan have insufficient inputs.

In peer evaluation, Qinghai's peer group includes Tibet, Ningxia, and Chongqing, indicating that these regions are used as benchmarks when assessing Qinghai's efficiency. Ningxia's peer evaluation includes only itself, suggesting that it serves as its own benchmark when evaluating its efficiency.

IV. CONCLUSIONS AND RECOMMENDATIONS

The emergence of digital technology has significantly propelled the development of the tourism economy, serving as a crucial driving factor. The digital economy, born from digital technology, continues to integrate with the tourism industry, profoundly transforming traditional tourism practices. This study explores and analyzes the impact of the digital economy on the development of tourism in western China [4], drawing the following main conclusions: Based on panel data from 11 provinces (autonomous regions and municipalities) in western China from 2018 to 2022, the DEA-CCR model analysis reveals that the development of the digital economy has a significant positive impact on the growth of the tourism economy in the western region. The results show that the technical efficiency of most western regions is close to or reaches the optimal level (1.000),

indicating that these regions effectively utilize resources at their current scale. However, some regions, such as Chongqing, Sichuan, Qinghai, and Ningxia, exhibit comprehensive technical efficiency and scale efficiency values below 1.000, highlighting issues in resource allocation, technology application, or management efficiency.

Based on the above conclusions, the following recommendations are proposed:

(1) For Qinghai Province, improvements are needed in technology application and management, along with adjustments to scale to enhance efficiency. It is recommended that Qinghai strengthen the application of digital technologies, improve management practices, and reassess its current operational scale to achieve better economies of scale.Although Ningxia has relatively high efficiency in technology application and management, its scale efficiency is low, necessitating adjustments to improve efficiency. It is recommended that Ningxia evaluate its current scale settings, potentially expanding or reducing its scale to achieve optimal economies of scaleFor Chongqing and Sichuan, these two regions have performed well in technology application and management but need to focus on scale adjustments. It is recommended that these regions assess their current scale settings, potentially adjusting their scale through collaboration or restructuring to improve overall efficiency.

(2) All regions should continue to optimize resource allocation to improve efficiency and effectiveness. The government should introduce relevant policies to support the integrated development of the digital economy and the tourism industry, particularly in infrastructure construction and technological innovation. At the same time, efforts should be made to strengthen the cultivation of talent related to the digital economy and enhance the digital skills of tourism practitioners to meet the demands of digital transformation .

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