The measure of poverty alleviation efficiency of tourism and spatiotemporal differentiation in Southwest China according to DEA-malmquist approach

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Abstract. To describe the pro-poor tourism efficiency and spatial-temporal features, this paper uses Data Envelopment Analysis (DEA), Malmquist index and ArcGIS to analyze the data of Southwest China from 2012 to 2019. The results show that there are significant regional differences in the efficiency of targeted poverty alleviation of tourism in Southwest China, and the efficiency value increases from Sichuan to the surrounding areas, and the overall pattern is "high in the middle and low in the surrounding areas"; the tourism industry in some regions is in the stage of transformation and development, and the carrying capacity of tourism resources is insufficient; The overall efficiency of poverty alleviation in Southwest China is on the rise. Tourism income in Guizhou has a weak driving force to increase the income of the poor. This paper shows the overall evolution of the poverty alleviation efficiency of tourism in Southwest China under the promotion of economic development and government in the past 10 years driven, and empirically demonstrates the poverty alleviation efficiency of Southwest China promoted by the government to win the battle of poverty alleviation in 2020. It provides a perspective and method to analyze the efficiency of government-driven tourism poverty alleviation.

1. Introduction

In Southwest China, there are many natural and cultural heritages, many of which are tourist attractions, which provide powerful conditions for the inheritance of regional culture and play a bridge role. Due to historical, geographical, and other reasons, the infrastructure construction in some parts of the southwest is relatively backward, and the economic and social development is relatively backward. Poverty is still a problem that needs to be solved urgently. The tourism industry has developed rapidly and has gradually become an important pillar industry to drive the economic development of Southwest China [1].

Tourism poverty alleviation refers to a way of tourism development that can promote poverty alleviation. It emphasizes that in the process of tourism development, the tourism income of the poor must be greater than the cost they pay. To ensure the full implementation of the poverty alleviation in 2020, general secretary Xi Jinping made important instructions for tackling poverty alleviation and put forward the strategy of "precision poverty alleviation", requiring precise measures to improve the
efficiency of poverty alleviation [2]. As an important part of China's poverty alleviation strategy, tourism targeted poverty alleviation is an important way to implement targeted poverty alleviation and development in many poor areas in China [3]. The analysis and evaluation of the efficiency of targeted poverty alleviation through tourism is helpful to measure the implementation effect of targeted Poverty Alleviation Policies among regions and within regions and provide support for the implementation of targeted Poverty Alleviation Policies [4]. The research perspective also began to shift from the poor areas to the poor population and evaluated the satisfaction of tourism poverty alleviation [5]. In recent years, scholars have broken the traditional thinking pattern of qualitative research and introduced quantitative research methods to measure the poverty alleviation efficiency of tourism [6]. The literature on the evaluation of poverty alleviation efficiency of tourism has been published in recent three years, mainly focusing on the measurement method of poverty alleviation efficiency [7], the construction of evaluation model [8], and spatial differentiation [9].

This paper attempts to establish a scientific index system, using data envelopment analysis (DEA) to measure the poverty alleviation efficiency of tourism in Southwest China from 2012 to 2018, analyze their time evolution path, and study regional differentiation, to provide a character reference for similar regions to reduce poverty and become rich in tourism in the future.

2. Research methods and data sources

2.1. Research methods

2.1.1. Packet analysis method (DEA). Data envelopment analysis (DEA) is a quantitative analysis method to study the relative effectiveness of multiple decision-making units (DMU) with the same type of multiple inputs and outputs [10]. The evaluation process of tourism poverty alleviation efficiency in Southwest China is to find the best production frontier of DEA, then compare and analyze the production possibility set of tourism poverty alleviation between the regions, and finally obtain the relative efficiency of each DMU. This paper adopts the specific formula of input-oriented mode with fixed output and different input combinations.

As follows:

\[
\begin{align*}
\min \theta & \\
\text{s. t.} \sum_{j=1}^{n} \lambda_j y_{rj} + S_i^- = \theta x_{i0} \\
\sum_{j=1}^{n} \theta_j y_{rj} - S_i^+ = \theta y_{r0} \\
\lambda_j & \geq 0, j=1,2,\ldots,n \\
\theta & \text{ unconstrained, } S_i^- \geq 0, S_i^+ \geq 0
\end{align*}
\]

(1)

Formula (1), \(x_{ij}, y_{ri}\) refers to the input and output values of the i and r columns of the j decision unit, \(x_{i0}\) and \(y_{r0}\) represent the corresponding input and output values of decision unit, \(\theta\) (0 \(\leq\) \(\theta\) \(\leq\) 1) is the total efficiency value of DMU, \(\lambda_j\) is the weight variable of a linear combination of DMU. \(S^-\) and \(S^+\) refer to the effective relaxation variables for DEA respectively.

When \(\theta\) \(\neq\) 1, \(S_i^-\) and \(S_i^+\) are 0, the DEA of the DMU is effective; When \(\theta\) is 1, but \(S_i^-\) and \(S_i^+\) have at least one non-zero value, it means that the DEA of the DMU is weak efficiency. When \(\theta\) is not 1, the DMU is an invalid unit of DEA.

2.1.2. Malmquist index. The Malmquist index is a two-way index used to compare the production technology of two economies. In 1994, Rolf Fare, a professor at Oregon State University, proposed that the Malmquist index could be applied from the theoretical index to an empirical index and used it for the first time to analyze the efficiency of the cross-period production.

In the model of CCR, the Malmquist exponential expression for the t to t+1 period is:
\[ MI(y_{t+1}, x_{t+1}) = \frac{d^{t+1}(x_{t+1}y_{t+1})}{d^{t}(x_{t}y_{t})} \times \left[ \frac{d^{t}(x_{t+1}y_{t+1})}{d^{t}(x_{t}y_{t})} \times \frac{d^{t+1}(x_{t}y_{t})}{d^{t+1}(x_{t+1}y_{t+1})} \right]^{1/2} \] (2)

If \( MI > 1 \), it indicates an increase in the level of tourism precision poverty reduction efficiency, if \( MI = 1 \), the level of tourism precision poverty reduction efficiency is unchanged, and if \( MI < 1 \), it indicates that the level of precision poverty alleviation efficiency of tourism has decreased. Formula (3) is decomposed from (1).

\[ MI(y_{t+1}, x_{t+1}, y_{t}, x_{t}) = \left[ \frac{d^{t}(x_{t+1}y_{t+1})}{d^{t}(x_{t}y_{t})} \times \frac{d^{t+1}(x_{t}y_{t})}{d^{t+1}(x_{t+1}y_{t+1})} \right]^{1/2} \] (3)

\( \frac{d^{t+1}(x_{t+1}y_{t+1})}{d^{t}(x_{t}y_{t})} \) is the rate of Change in Technical Efficiency (EFFCH), \( \frac{d^{t+1}(x_{t+1}y_{t+1})}{d^{t+1}(x_{t}y_{t})} \) is the rate of Technological Progress (TECHCH). EFFCH can continue to be broken down into pure technical efficiency change rates (PECH) and scale efficiency change rates (SECH). EFFCH (CRS) > 1 indicates that the efficiency of tourism precision poverty alleviation is improved during the t-period to the t-1 period. EFFCH (CRS) = 1, indicating that the efficiency of the precise poverty alleviation of tourism has not changed at this stage, and EFFCH (CRS) < 1, it indicates that the efficiency of precision poverty alleviation in tourism during the period is reduced. The values of the Technological Progress Rate (TECHCH), total factor productivity (TFPCH), the Pure Technology Efficiency Rate (PECH), and the Scale Efficiency Change Rate (SECH), also have corresponding meanings.

2.2. Data sources and indicator selection

2.2.1. Data source. The basic data needed for the study are the input-output and driving factors of tourism poverty alleviation of five provinces (autonomous region) in Southwest China from 2012 to 2019. Including the annual total tourism income, the annual total number of tourists received the total income of rural residents, the total disposable income of urban residents, and the GDP. The data are from the statistical yearbook Southwest China, statistical bulletin, China Rural Poverty Monitoring Report and China rural poverty alleviation and development outline (2011-2020), The State Council Bulletin of the people's Republic of China, China's Rural Statistical Yearbook, the statistical data of provincial and municipal tourism bureaus, poverty alleviation offices and statistical bureaus.

2.2.2. Indicator selection. The efficiency of tourism poverty alleviation is a reflection of the degree of poverty reduction by tourism, which can effectively reflect the situation of poverty alleviation through tourism and the promotion degree of tourism to regional economic development. Given previous studies, this paper measures the efficiency of poverty alleviation through the ratio of tourism economic income and tourism driving capacity. (1) To follow the representativeness of the evaluation and the availability of data, the evaluation system of tourism poverty alleviation efficiency is constructed by selecting indicators from two aspects of tourism input and output. The tourism economic income is represented by the comprehensive tourism income per capita T1, the driving capacity of tourism is represented by the number of tourists per capita T2; Output indicators of tourism poverty alleviation is represented by the per capita net income of rural residents C1, the per capita disposable income C2 and GDP per capita of urban residents C3, and the proportion of the poverty-stricken population is represented by C4, as shown in Table 1.

| The indicator type. | Evaluation indicators. | Variable. | Description of the indicator. | The formula for measuring. |
|---------------------|------------------------|-----------|--------------------------------|---------------------------|
| Output.             | The per capita net income of rural residents. C1 | Reflects the economic situation of farmers. | Total income/total rural population of rural residents. |
3. Empirical analysis

3.1. Analysis of the efficiency of tourism poverty alleviation

3.1.1. Comprehensive efficiency analysis. Using the model of DEA, take advantage of DEAP2.1 to calculate the comprehensive efficiency of tourism in the Southwest region from the year 2012 to 2019, as shown in Table 1. According to the overall data, the efficiency of tourism precision poverty alleviation in southwest China is at the medium and high level, The average comprehensive efficiency of targeted poverty alleviation in Southwest China is 90.8% from the year 2012 to 2019. There are differences in the overall efficiency of tourism poverty alleviation between provinces, of which the comprehensive efficiency of Guizhou Province has been lower than the regional average. Yunnan Province's comprehensive efficiency of tourism poverty alleviation has increased significantly, the efficiency values from 2012 to 2014 are below the average. But the efficiency exceeds the average rapidly in the year of 2015. The average comprehensive efficiency of poverty alleviation by tourism in Chongqing province and Sichuan province has always been at a high level. From the perspective of time change trend, the comprehensive efficiency of tourism poverty alleviation in Tibet Autonomous Region fluctuated slightly from 2012 to 2014, and decreased slightly in 2014, with a decrease rate of 3.4%. In conclusion, the poverty alleviation efficiency of tourism in Guizhou Province in Southwest China still needs to be strengthened.

Table 2. Southwest Region Comprehensive Efficiency of Tourism Poverty Reduction from 2012 to 2019.

| Province.          | 2012   | 2013   | 2014   | 2015   | 2016   | 2017   | 2018   | 2019   | Average. |
|--------------------|--------|--------|--------|--------|--------|--------|--------|--------|----------|
| Chongqing.         | 0.942  | 1      | 1      | 1      | 1      | 0.999  | 1      | 1      | 0.992    |
| Sichuan Province.  | 1      | 0.975  | 1      | 0.973  | 0.995  | 1      | 0.982  | 1      | 0.99     |
| Guizhou Province.  | 0.612  | 0.617  | 0.686  | 0.751  | 0.756  | 0.757  | 0.764  | 0.749  | 0.712    |
| Yunnan Province.   | 0.752  | 0.789  | 0.849  | 0.959  | 0.971  | 0.997  | 1      | 1      | 0.915    |
| Tibet autonomous region. | 0.863  | 0.915  | 0.881  | 0.886  | 0.949  | 0.971  | 0.988  | 1      | 0.931    |
| Average.           | 0.833  | 0.859  | 0.883  | 0.913  | 0.934  | 0.944  | 0.946  | 0.949  | 0.908    |

3.1.2. Analysis of tourism poverty reduction efficiency change. Based on the model of the DEA and Malmquist index, the dynamic change index of tourism poverty alleviation efficiency of provinces (autonomous prefectures) in Southwest China from 2012 to 2019 is calculated by using deap2.1 (Table 3). From the perspective of time evolution, the efficiency of tourism poverty alleviation also showed a
To improve the efficiency of targeted poverty alleviation through tourism, secondly, the matching of tourism resources carrying capacity in Southwest China needs to be further improved. The per capita number of tourists received are used as input indicators for optimization analysis, which are respectively expressed by $S_1^0$ and $S_2^0$ (the results are shown in Table 4). First, in the year of 2014, the per capita tourism income of Guizhou Province and Yunnan Province should be reduced by 0.024 million yuan and 0.013 million yuan respectively to improve the efficiency of targeted poverty alleviation through tourism. Secondly, the matching of tourism resources carrying capacity in Southwest China needs to be further improved. By the year 2014, the per capita number of tourists received by Guizhou Province and Tibet Autonomous Prefecture should be reduced by 0.22 person times and 0.612 person times to make the targeted poverty alleviation efficiency of tourism better.

Table 3. Comprehensive efficiency change index of tourism poverty alleviation in Southwest China from 2012 to 2019.

| Year   | Chongqing Province. | Sichuan Province. | Guizhou Province. | Yunnan Province. | Tibet autonomous region. |
|--------|---------------------|-------------------|-------------------|------------------|-------------------------|
| 2012-2013 | 1.427              | 0.788             | 1.011             | 1.361            | 1.433                   |
| 2013-2014 | 1                  | 1.121             | 1.451             | 1.592            | 1.293                   |
| 2014-2015 | 1                  | 0.921             | 1.684             | 1.886            | 1.019                   |
| 2015-2016 | 1                  | 1.012             | 1.113             | 1.340            | 1.887                   |
| 2016-2017 | 0.916              | 1.019             | 1.012             | 1.358            | 1.287                   |
| 2017-2018 | 1                  | 0.837             | 1.201             | 1.007            | 1.102                   |
| 2018-2019 | 0.815              | 1.311             | 0.822             | 1                | 1.008                   |
| The mean | 1.022              | 1.001             | 1.184             | 1.363            | 1.289                   |

3.1.3. Optimization of input index of tourism poverty alleviation. Optimization of the DEA model mainly studies the target value of DEA effective input in the areas. This value can reflect the input and output redundancy and optimization direction of each DMU. On the premise of keeping the output unchanged, this paper calculates the input redundancy of targeted poverty alleviation in five provinces (autonomous region) in Southwest China. The per capita tourism income and the per capita number of tourists received are used as input indicators for optimization analysis, which are respectively expressed by $S_1^0$ and $S_2^0$ (the results are shown in Table 4). First, in the year of 2014, the per capita tourism income of Guizhou Province and Yunnan Province should be reduced by 0.024 million yuan and 0.013 million yuan respectively to improve the efficiency of targeted poverty alleviation through tourism. Secondly, the matching of tourism resources carrying capacity in Southwest China needs to be further improved. By the year 2014, the per capita number of tourists received by Guizhou Province and Tibet Autonomous Prefecture should be reduced by 0.22 person times and 0.612 person times to make the targeted poverty alleviation efficiency of tourism better.

Table 4. The optimization target value of the tourism poverty reduction input target for the southwest region for 2012-2019.

| Province   | Year | Per capita tourism income. $S_1^0$ | The number of visitors per capita. $S_2^0$ | Year | Per capita tourism income. | The number of visitors per capita. $S_2^0$ |
|------------|------|----------------------------------|---------------------------------|------|----------------------------|---------------------------------|
| Chongqing. | 12   | 0.380                            | 0.000                           | 16   | 0.660                      | 6.619                           |
| Sichuan.   | 12   | 0.304                            | 0.000                           | 16   | 0.757                      | 4.368                           |
| Guizhou.   | 12   | 0.412                            | 0.000                           | 16   | 0.995                      | 4.906                           |
| Yunnan.    | 12   | 0.280                            | 0.000                           | 16   | 0.692                      | 3.675                           |
| Tibet.     | 12   | 0.320                            | 0.000                           | 16   | 0.864                      | 2.868                           |
| Chongqing. | 13   | 0.497                            | 0.000                           | 17   | 0.779                      | 8.683                           |
| Sichuan.   | 13   | 0.407                            | 0.000                           | 17   | 0.932                      | 5.494                           |
| Guizhou.   | 13   | 0.533                            | -0.290                          | 17   | 1.414                      | 6.143                           |
| Yunnan.    | 13   | 0.365                            | 0.000                           | 17   | 1.053                      | 4.397                           |
| Tibet.     | 13   | 0.410                            | 0.000                           | 17   | 0.999                      | 3.436                           |
| Chongqing. | 14   | 0.596                            | 0.000                           | 18   | 0.975                      | 10.392                          |
| Sichuan.   | 14   | 0.478                            | 0.000                           | 18   | 1.074                      | 6.070                           |
| Guizhou.   | 14   | 0.676                            | -0.240                          | 18   | 1.987                      | 7.642                           |
### 4. Spatial and temporal differentiation characteristics of tourism poverty alleviation efficiency

According to different regions, Southwest China can be divided into Chongqing, Sichuan, Guizhou, Yunnan, and Tibet Autonomous Region. Taking the average comprehensive efficiency of tourism poverty alleviation in Yunnan Province from 2012 to 2019 as the classification standard, the natural fracture method is used to scientifically reflect the spatial and temporal differentiation of poverty alleviation efficiency of tourism in Southwest China with the ArcGIS software. (Fig. 3). It can be seen from Figure 3 that there are significant regional differences in the efficiency of tourism poverty alleviation in Southwest China, and the efficiency value increases from Sichuan to the surrounding areas from 2012 to 2017, showing the overall pattern of "high in the middle and low in the surrounding areas", and the efficiency value is relatively stable from 2018 to 2019. From 2012 to 2019, the efficiency of tourism poverty alleviation in Guizhou Province is lower than that in the surrounding provinces of Southwest China, which is suitable for its economic development level. It can be inferred that economic development helps to improve the efficiency of poverty alleviation through tourism, which in turn helps to accelerate the local economic and social development. Also, through the analysis, we can find that the poverty alleviation efficiency of tourism in some areas of Southwest China does not match the level of economic development or tourism development.

| Region  | Year | Efficency | Change | Efficiency | Year | Efficency | Change | Efficiency | Year | Efficency | Change | Efficiency |
|---------|------|-----------|--------|------------|------|-----------|--------|------------|------|-----------|--------|------------|
| Yunnan. | 14   | 0.450     | -0.130 | 5.344      | 18   | 1.441     | 5.344  | -0.420     |
| Tibet.  | 14   | 0.528     | 0.000  | 4.138      | 18   | 1.125     | 4.138  | -0.205     |
| Chongqing. | 15   | 0.593     | -0.141 | 10.340     | 19   | 1.276     | 10.340 | 0.000     |
| Sichuan. | 15   | 0.600     | 0.000  | 6.663      | 19   | 1.212     | 6.663  | -0.225     |
| Guizhou. | 15   | 0.825     | 0.000  | 9.160      | 19   | 2.630     | 9.160  | 0.000     |
| Yunnan. | 15   | 0.565     | 0.000  | 6.173      | 19   | 1.850     | 6.173  | -0.106     |
| Tibet.  | 15   | 0.628     | 0.000  | 4.884      | 19   | 1.424     | 4.884  | -0.209     |

**Figure 1.** Southwestern Region 2012-2019 Tourism Poverty Reduction Efficiency Map.

### 5. Conclusions

Based on the statistical data of five provinces (autonomous regions) in Southwest China from 2012 to 2019, this paper uses the DEA model and Malmquist index to measure the efficiency and change of targeted poverty alleviation through tourism. The results are as follows: first, the efficiency of tourism targeted poverty alleviation in Southwest China is quite different. Second, the overall efficiency of poverty alleviation by tourism in Southwest China is on the rise, and Guizhou's tourism income has a weak driving force to improve the income of the poor. The results of the DEA analysis show that the per capita tourism income in some areas must be reduced to make the efficiency of targeted poverty alleviation better. It shows that the increase of per capita tourism income cannot effectively promote the
income of local poor people, and there is a deviation in the accurate identification of tourism poverty alleviation. Third, the matching of tourism resources carrying capacity in Southwest China needs to be further improved. Some areas need to reduce the per capita tourist reception to make the targeted poverty alleviation efficiency of tourism better. The results show that with the in-depth development of tourism targeted poverty alleviation, some scenic spots in Southwest China have some problems such as overload of bearing capacity, especially transportation, accommodation, catering, and other tourism facilities that are difficult to meet the growing tourism demands.

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