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Research on the Economic Development Quality of 40 Asian Countries and Regions Based on Entropy Weighted TOPSIS and K-means Clustering

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Abstract: *This paper aims to construct an evaluation index system for the economic development quality and conducts comprehensive evaluation and cluster analysis on 40 countries and regions in Asia using Entropy Weighted TOPSIS and K-means clustering algorithms. The research findings indicate that Singapore ranks first in the economic development quality in Asia, followed closely by South Korea and Hong Kong, China. Countries and regions such as China, Hong Kong, Macao, Mongolia, South Korea, and Japan demonstrate excellent performance in high-quality economic development. On the other hand, countries and regions like Laos, Cambodia, Myanmar, Indonesia, Nepal, and Bhutan show moderate economic development quality. However, countries and regions such as Brunei, Iran, Jordan, Saudi Arabia, Bahrain, Qatar, UAE, and Oman exhibit relatively lower economic development quality.*

Keywords: *Asian Economy; Economic Development Quality; Entropy Weighted TOPSIS; K-means Clustering*

1. Introduction

Asia is one of the most dynamic and diverse regions in the global economy, and the quality of its economic development has a significant impact on global economic and social stability and growth. Today, economic growth rate is no longer the sole indicator to measure regional economic performance; rather, the development quality is the key criterion to assess whether the regional economic growth meets the needs of the people and fosters sustainable urban development. However, there are issues of imbalances, inadequacy, and unsustainability in the economic development quality among Asian countries. These problems not only affect the economic and social progress within Asia but also have negative implications for global economic development. Therefore, studying the economic development quality of Asian countries holds vital significance in gaining deeper insights into the current status and problems of Asian economic development, exploring suitable development paths for Asian countries, enhancing the quality of economic development in Asia, and promoting global economic and social stability.

In terms of theoretical research, Rosenstein-Rodan argues that investment is the primary driving force for economic development, and rapid growth occurs when the economy is in a state of disequilibrium[1]. Kuznets emphasizes that measuring regional economic development should consider four aspects: equal educational opportunities, environmental quality, the impact of financial crises, and fair and competitive market economy[2]. Zheng Yaoqun and Ge Xing construct an index system for comprehensively evaluating high-quality economic development based on the new development concept[3]. Zhu Zongyou and Zhang Jilong point out that the five development philosophies provide theoretical guidance for achieving high-quality economic development[4]. Ren Baoping emphasizes that high-quality economic development represents the optimal manifestation of economic progress, encompassing not only an increase in economic output but also an improvement in economic quality and optimization of economic structure[5].

In empirical analysis, Meng Weihua uses a comprehensive qualitative and quantitative approach to study the industrial structure adjustment and economic growth in China's central region from 1978 to 2006. The results indicate a mutually reinforcing relationship between the region's industrial structure and economic growth[6]. Guo Wei and colleagues study the issue of high-quality regional economic development using China's provinces as research subjects, and their findings suggest that most provinces

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(including autonomous regions and municipalities) in China exhibit a fluctuating upward trend in high-quality economic development, while economic development quality gradually decreases from southeast to northwest with spatial agglomeration patterns[7]. Wu Yanrong evaluates the economic development quality of Xi'an city from the perspectives of effectiveness, coordination, and green development, concluding that the optimization and reform of industrial structure play a crucial role in Xi'an city's economic development quality[8].

In summary, existing research has provided abundant evaluations and comparisons of economic development quality among provinces and cities. However, there is a lack of research on the evaluation and comparison of economic development quality among countries.

2. Research Method

2.1. Entropy Weighted TOPSIS Evaluation

The entropy weight method is an objective approach for assigning weights, which determines the weights of various indicators by evaluating the degree of dispersion of the indicators. A larger degree of dispersion indicates a greater amount of information contained in the indicator, resulting in a higher corresponding weight. Conversely, a smaller degree of dispersion leads to a lower weight. On the other hand, the Technique for Order of Preference by Similarity to Ideal Solution(TOPSIS) is a comprehensive comparison and selection analysis method proposed by Huang and Yoon in 1981. It is applicable to multiple indicators and multiple alternatives, and it does not have any special requirements or restrictions regarding the number of samples, data distribution, or number of indicators. The Entropy Weighted TOPSIS method combines the entropy weight method with the TOPSIS method for comprehensive analysis. Firstly, it employs the entropy weight method to determine the weights of each evaluation indicator. Then, it uses the TOPSIS method to approximate the ideal solution and determine the ranking order of the evaluation objects. This approach not only ensures the proximity of the evaluation objects to the ideal target but also effectively eliminates the influence of subjective factors, thereby enhancing the reliability and scientificity of the evaluation results[9].

2.2. K-means Clustering

Cluster analysis is an essential component of data mining, and the K-means clustering algorithm, as a fundamental partitioning method, is an unsupervised machine learning approach. It possesses advantages such as efficiency, ease of understanding, and implementation, making it widely applicable to various data types and widely used in different domains[10].

3. Empirical Analysis of the Economic Development Quality of 40 Asian Countries and Regions

3.1. Data Collection and Processing

This paper draws on the ideas of existing ideas[11] regarding the selection of indicators for economic development quality levels. Following the principles of systematicity, data availability, and authenticity, an evaluation framework consisting of five primary indicators is established, including Effectiveness, Safety, Innovation, Greenness, and Coordination, along with fifteen secondary indicators. The detailed construction is presented in Table 1. All the indicator data in this paper are sourced from the latest statistics of the World Bank. After excluding countries and regions with certain data gaps, a total of 40 countries and regions are included in the data collection, as shown in Table 2.

In the data processing stage, a normalization method is applied to handle different types of indicators, including type I (larger values indicate higher economic development quality), type II (smaller values indicate higher economic development quality), and type III (values close to a specific target indicate higher economic development quality). For type I indicators, the larger the values, the better the economic development quality. Thus, equation (1) is used for normalization[12], ensuring comparability and analysis within the same scale range. Conversely, for type II indicators, the smaller the values, the better the economic development quality. For this type of indicators, equation (2) is utilized for normalization[12] to unify the value range for ease of comparison and evaluation. Among all the indicators, only the percentage of female labor force is considered a type III indicator with an optimal value of 50. For this indicator, equation (3) is employed for normalization to bring its value close to the target value, facilitating comprehensive evaluation.

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Table 1: The comprehensive evaluation index system for economic development quality

Primary Indicators	Secondary Indicators	Unit	Type
Effectiveness	GDP growth rate	Percentage(%)	I
	Per capita GDP growth rate	Percentage(%)	I
	Total savings as a percentage of GDP	Percentage(%)	I
	Industrial value-added as a percentage of GDP	Percentage(%)	I
Safety	Annual inflation rate	Percentage(%)	II
	Fiscal balance ratio	Percentage(%)	II
Innovation	Per capita intellectual property expenditure	USD per person	I
	Proportion of education expenditure to GDP	Percentage(%)	I
	Higher education enrollment rate	Percentage(%)	I
	Percentage of manufactured exports of high-tech exports	Percentage(%)	I
Greenness	Per capita carbon dioxide emissions	Tons per person	II
	Percentage of renewable energy consumption in final energy consumption	Percentage(%)	I
	Primary energy intensity level	Tons of standard coal per ten thousand USD	II
Coordination	Urbanization rate	Percentage(%)	I
	Percentage of female labor force participation	Percentage(%)	III

Table 2: The 40 countries and regions collecting data

East Asia	Southeast Asia	South Asia	Central Asia	West Asia
China; Hong Kong, China; Macao, China; Mongolia; South Korea; Japan	Philippines; Vietnam; Laos; Cambodia; Myanmar; Thailand; Malaysia; Brunei; Singapore; Indonesia	Nepal; Bhutan; Bangladesh; India; Pakistan; Sri Lanka; Maldives	Kazakhstan; Kyrgyzstan; Tajikistan; Uzbekistan	Iran; Jordan; Lebanon; Israel; Saudi Arabia; Bahrain; Qatar; United Arab Emirates(UAE); Oman; Armenia; Azerbaijan; Türkiye; Cyprus

$$\widetilde{x_{ij}} = \frac{x_{ij} - \min\limits_{i} x_{ij}}{\max\limits_{i} x_{ij} - \min\limits_{i} x_{ij}} \tag{1}$$

$$\widetilde{x_{ij}} = \frac{\max\limits_{i} x_{ij} - x_{ij}}{\max\limits_{i} x_{ij} - \min\limits_{i} x_{ij}} \tag{2}$$

$$\widetilde{x_{ij}} = \frac{\widehat{x_{ij}} - \min\limits_{i} \widehat{x_{ij}}}{\max\limits_{i} \widehat{x_{ij}} - \min\limits_{i} \widehat{x_{ij}}},\ \widehat{x_{ij}} = 1 - \frac{|x_{ij} - x_{best}|}{\max\limits_{i} \{|x_{ij} - x_{best}|\}} \tag{3}$$

3.2. The Economic Development Quality Ranking Based on Entropy Weighted TOPSIS

Based on the normalized data and the calculations according to equations (1) to (3), the weights for GDP growth rate, per capita GDP growth rate, total savings as a percentage of GDP, industrial value-added as a percentage of GDP, annual inflation rate, fiscal balance ratio, per capita intellectual property expenditure, proportion of education expenditure to GDP, higher education enrollment rate, percentage of manufactured exports of high-tech exports, per capita carbon dioxide emissions, percentage of renewable energy consumption in final energy consumption, primary energy intensity level, urbanization rate, and percentage of female labor force are determined as 0.0128, 0.0124, 0.0155, 0.0274, 0.0058,

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0.0172, 0.4262, 0.0437, 0.0578, 0.1378, 0.0103, 0.1404, 0.0145, 0.0394, and 0.0389, respectively.

Using the calculated weights, the weighted standardization matrix is constructed for TOPSIS evaluation. The comprehensive evaluation index of the 40 countries and regions is calculated, and the ranking is presented in Table 3.

Table 3: Score and rank of the 40 countries and regions collecting data

Country (Region)	Score	Rank	Country (Region)	Score	Rank	Country (Region)	Score	Rank
Singapore	0.1189	1	China	0.0237	15	Oman	0.0179	29
South Korea	0.0437	2	Myanmar	0.0235	16	Qatar	0.0174	30
Hong Kong	0.0399	3	Cambodia	0.0233	17	Indonesia	0.0174	31
Philippines	0.0328	4	Thailand	0.0228	18	Azerbaijan	0.0171	32
Bhutan	0.0319	5	Sri Lanka	0.0220	19	UAE	0.0171	33
Israel	0.0300	6	Saudi Arabia	0.0217	20	Armenia	0.0170	34
Macao	0.0291	7	Tajikistan	0.0213	21	Bahrain	0.0162	35
Nepal	0.0289	8	Türkiye	0.0211	22	Bangladesh	0.0157	36
Malaysia	0.0288	9	Kyrgyzstan	0.0210	23	Jordan	0.0150	37
Cyprus	0.0278	10	Mongolia	0.0210	24	Iran	0.0150	38
Vietnam	0.0260	11	Maldives	0.0201	25	Uzbekistan	0.0144	39
Laos	0.0244	12	India	0.0187	26	Lebanon	0.0125	40
Kazakhstan	0.0240	13	Pakistan	0.0186	27			
Japan	0.0240	14	Brunei	0.0186	28			

According to the analysis from Table 3, Singapore performs exceptionally well in regional economic development quality, obtaining the highest score and ranking first. This indicates that Singapore has achieved significant accomplishments in economic development, making it a country that best balances effectiveness, safety, innovation, greenness, and coordination in the path of economic development in Asia. South Korea, Hong Kong, the Philippines, and Bhutan closely follow with scores slightly lower than Singapore, highlighting their notable economic development quality. South Korea has made remarkable progress in technology, manufacturing, and exports, establishing itself as one of Asia's economic powerhouses. As an international financial and business center, Hong Kong plays a crucial role in finance, trade, and services. The Philippines is an important economic player in Southeast Asia, while Bhutan benefits from its focus on sustainable development and ecotourism[13].

In terms of regions, East Asian countries and regions demonstrate outstanding economic development quality, with Singapore, South Korea, and Hong Kong ranking high. Central Asian and Southeast Asian countries and regions achieve a moderate level of overall economic development quality, with some countries such as the Philippines, Vietnam, and Thailand exhibiting high-quality economic development. South Asian countries and regions rank in the middle to lower levels of Asia, with except for Bhutan, leaving room for improvement in their overall economic development quality. Economic development in West Asian countries is relatively dispersed, with Turkey ranking the highest in the region. However, many countries in this region still have a lower economic development quality, indicating a need for improvement.

3.3. The Classification of Economic Development Quality Based on K-Means Clustering

Table 4: Quality level of economic development in 40 countries and regions in Asia

Classification	1 (Moderate)	2 (Higher)	3 (Lower)
Country(Region)	Cambodia; Myanmar; Indonesia; Nepal; Bhutan; Bangladesh; India; Pakistan Lanka; Maldives; Kyrgyzstan; Laos; Tajikistan; Sri; Uzbekistan; Lebanon; Azerbaijan	Hong Kong, China; Macao, China; Mongolia; South Korea; Japan; China; Philippines; Vietnam; Thailand; Malaysia; Singapore; Cyprus; Kazakhstan; Israel; Armenia; Türkiye	Brunei; Iran; Jordan; Saudi Arabia; Bahrain; Qatar; United Arab Emirates; Oman

The K-means clustering algorithm is used to cluster and classify the economic development quality of 40 countries and regions in Asia into three categories (Higher, Moderate, Lower). The Euclidean distance is employed as the clustering method with a maximum of 20 iterations. The clustering results

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are shown in Tables 4 to 6.

Table 5: Analysis of Variance

Indicators	Clustering		SER		F	Sig.
	MS	DF	MS	DF		
GDP growth rate	0.0106	2	0.0183	37	0.5803	0.5647
Per capita GDP growth rate	0.0094	2	0.0183	37	0.5137	0.6025
Total savings as a percentage of GDP	0.0099	2	0.0414	37	0.2400	0.7878
Industrial value-added as a percentage of GDP	0.3141	2	0.0377	37	8.3212	0.0010
Annual inflation rate	0.0284	2	0.0263	37	1.0830	0.3491
Fiscal balance ratio	0.0214	2	0.0440	37	0.4868	0.6184
Per capita intellectual property expenditure	0.0472	2	0.0240	37	1.9710	0.1537
Proportion of education expenditure to GDP	0.0194	2	0.0650	37	0.2989	0.7434
Higher education enrollment rate	0.9805	2	0.0408	37	24.0332	0.0000
Percentage of manufactured exports of high-tech exports	0.7769	2	0.0359	37	21.6607	0.0000
Per capita carbon dioxide emissions	0.5422	2	0.0200	37	27.0592	0.0000
Percentage of renewable energy consumption in final energy consumption	0.3427	2	0.0503	37	6.8125	0.0030
Primary energy intensity level	0.1955	2	0.0341	37	5.7276	0.0068
Urbanization rate	1.0978	2	0.0435	37	25.2209	0.0000
Percentage of female labor force participation	1.3126	2	0.0410	37	32.0458	0.0000

Table 6: The distance between the final cluster centers

Clustering	1 (Moderate)	2 (Higher)	3 (Lower)
1 (Moderate)	-	0.844	1.035
2 (Higher)	0.844	-	1.035
3 (Lower)	1.035	1.035	-

Table 4 represents the distribution of economic development quality levels among 40 countries and regions. From the overall situation of the selected 15 indicators, countries such as China, Hong Kong, Macao, Japan maintain high-quality economic development. Countries such as Laos, Cambodia, Myanmar, Indonesia, Nepal, and Bhutan, have moderate economic development quality. Brunei, Iran, Jordan, Saudi Arabia, Bahrain, Qatar, UAE, and Oman are countries with relatively lower economic development quality. Table 5 is the analysis of variance table, which indicates that indicators such as the percentage of industrial value-added to GDP, higher education enrollment rate, high-tech exports as a percentage of manufactured exports, per capita carbon dioxide emissions, the proportion of renewable energy consumption in final energy consumption, primary energy intensity, urbanization rate, and the percentage of female labor force make significant contributions to the classification, while the contributions of other indicators are relatively weak. Since the clustering is chosen to maximize the differences between cases in different clusters, the F-test is used for descriptive purposes only. The significance level is not adjusted for this purpose, so it cannot be interpreted as a test for the hypothesis of "equal cluster means."

Table 6 provides the distances between the final cluster centers. The distance between the "Moderate" and "Higher" economic development quality is 0.844, indicating that countries and regions with moderate economic development quality can relatively easily achieve a higher level with efforts. The distance between the "Lower" and "Higher" and the distance between the "Lower" and "Moderate" are both 1.035, indicating that countries with lower economic development quality must exert greater efforts to move up one level, but with corresponding efforts, it is relatively easy for them to directly reach the "Higher" level, skipping the "Moderate" level.

4. Conclusion and Suggestions

The results of Entropy Weighted TOPSIS show that Singapore ranks first in the economic development quality among Asian countries and regions, with the highest score. The next in rank are South Korea and Hong Kong, ranking second and third, respectively. The Philippines and Bhutan rank fourth and fifth, respectively. Other countries and regions with relatively high scores include Israel, Macao, Nepal, Malaysia, and China. The cluster analysis divides Asian countries and regions into three groups. The first group includes China, Hong Kong, Macao, Mongolia, South Korea, Japan, and other countries and regions that exhibit excellent performance in high-quality economic development. The second group consists of countries and regions such as Laos, Cambodia, Myanmar, Indonesia, Nepal, and Bhutan, which have moderate economic development quality. The third group includes countries and regions like Brunei, Iran, Jordan, Saudi Arabia, Bahrain, Qatar, UAE, and Oman, which have relatively

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lower economic development quality.

According to the Entropy Weighted TOPSIS analysis, Singapore performs the best in terms of economic development quality, ranking first. The cluster analysis also places Singapore in the group of high-quality economic development, further confirming its leading position in the Asian region's economic development. South Korea and Hong Kong rank second and third in the entropy-weighted TOPSIS and are also classified into the high-quality economic development group by the cluster analysis, indicating significant achievements in economic development and their vital role in the Asian region. On the other hand, countries like Brunei, Iran, Jordan, etc., are shown to have lower economic development quality in both the entropy-weighted TOPSIS and cluster analysis, suggesting that these countries may need to take measures to improve their economic development to enhance their competitiveness in the Asian region. Overall, the consistent results from Entropy Weighted TOPSIS and cluster analysis indicate that Singapore, South Korea, and Hong Kong are at the forefront of economic development quality in the Asian region, while some countries need further efforts to elevate their economic development level.

For countries and regions that perform well in economic development quality, such as Singapore, South Korea, and Hong Kong, it is essential to continue strengthening innovation capabilities, technology research and development, and industrial upgrading to maintain their competitive advantage while also focusing on sustainable development and social fairness. For countries and regions with moderate economic development quality, like Laos, Cambodia, Myanmar, etc., it is recommended to enhance infrastructure construction, education, and skill training to increase productivity and competitiveness, and at the same time, diversify the economic structure and reduce reliance on a single industry. For countries and regions with lower economic development quality, such as Brunei, Iran, Jordan, it is advised to intensify economic structural adjustment and reform. Encourage innovation and entrepreneurship, cultivate emerging industries, enhance economic diversity and competitiveness, strengthen governance capacity, improve the business environment, and attract foreign and domestic investment. For all countries and regions, regardless of their economic development quality, it is crucial to prioritize sustainable development, emphasizing environmental protection, resource management, and climate change response, to promote green economic development. Furthermore, all countries need to further strengthen regional cooperation and economic integration, facilitate trade liberalization and connectivity, and elevate the overall economic development level in the entire Asian region.

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