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Ecological Welfare Performance Evaluation and Spatial–Temporal Difference Evolution of Blue Economic Zones: A Case Study of the Blue Economic Zone of Shandong Peninsula

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Abstract: The construction and development of the Blue Economic Zone on the Shandong Peninsula in China was elevated to a national strategy in 2011, and it has achieved year-on-year economic growth, driving the economic development of Shandong Province. However, it has also generated problems, such as a fragile ecological environment, unbalanced regional development, and prominent human–land conflicts. Therefore, on the basis of the idea of green sustainable development, this paper measures the ecological welfare performance of seven prefecture-level cities in the Blue Economic Zone of Shandong Peninsula from 2011 to 2020 using an entropy-weighted model together with the TOPSIS method. It then analyzes their spatial distribution characteristics using the natural breaks method. Our findings show that the overall ecological welfare performance level in the Shandong Peninsula BEZ shows a stable upward trend, and that the ecological welfare performance of each city is similar to that of the divided region. The ecological welfare performance levels of Weifang, Rizhao, and Binzhou are relatively low. Dongying, Weihai, Qingdao, and Yantai form a cluster of cities with high ecological welfare performance. Therefore, for the advancement of the Shandong Peninsula BEZ, the government should the government should reasonably deploy the industrial structure; actively implement industrial transformation; strengthen the synergistic development among cities to achieve complementary advantages, coordinating the growth of rural and urban areas; and improve the social security system to achieve high-quality sustainable development in the Shandong Peninsula BEZ.

Keywords: Blue Economic Zone; ecological welfare performance; TOPSIS model; natural breaks method; spatial and temporal variation; entropy-weighted model

1. Introduction

The new concept of the blue economy was originally proposed by Pauli [1]. It is an economic development model which integrates the marine economy and the green economy under the concept of sustainable development [2] in order to improve social welfare, promote economic development, and protect the ecological environment [3]. In order to implement this model of economic development in the region, the concept of the Blue Economic Zone (BEZ) was born. The BEZ is a new type of coastal economic zone characterized by the marine economy, with the scientific utilization of marine resources as the fundamental approach [4]. Through sea–land coordination, resource integration, economic and cultural integration, and collaborative competition, it enhances comprehensive economic strength and competitiveness. The BEZ can protect the ecological environment while also balancing the development of the marine economy and the land economy, achieving the sustainable development of the blue economy. In 2011, the State Council of China approved the "Development Plan for the Shandong Peninsula BEZ", which officially elevated the BEZ plan to a national strategy and became an important component of China's regional coordinated development strategy [5]. The development intention of the Shandong Peninsula BEZ is to protect the ecological environment while scientifically developing marine resources in order to transform the BEZ's economic development model into a blue economy and ultimately form a blue economic functional zone with strong comprehensive competitiveness.

With its location and industrial advantages, the Shandong Peninsula BEZ has developed into a region with the highest level of industrialization and urbanization, the fastest development, and the highest outward economic orientation in Shandong. From 2011 to 2020, the annual GDP of the Shandong Peninsula BEZ rose from RMB 213.95 billion in 2011 to RMB 366.05 billion in 2020, with an average annual growth rate of 5.5%, while the average annual GDP growth rate of Shandong Province was 4.8%. Since the implementation of the plan, the annual growth rate of the gross domestic product (GDP) of the Shandong Peninsula BEZ has been higher than the average level of Shandong Province, and it has achieved year-on-year economic growth. Thus, the Shandong Peninsula BEZ has been playing a crucial role in the economic development of Shandong Province. However, considering how quickly the blue economy is growing, the scarcity of resources such as water and electricity, water environment and air environment pollution, seawater intrusion, and other ecological pollution problems are still prominent. The ecological environment of the Shandong Peninsula BEZ has to be strengthened further [6,7]. In this regard, during the construction and development of the Shandong Peninsula BEZ, emphasis should be given to ensuring holistic and inclusive ecological welfare, encouraging the integrated development of the regional natural environment and the blue economy, and achieving the BEZ's objectives for sustainable development [8].

Maximizing the level of comprehensive welfare is necessary for sustainable development [9]. Sustainable development pursues the continuous improvement of human welfare within the carrying capacity of a planet. Therefore, maximizing the ecological welfare of residents within the limited carrying capacity of the environment and resources [10] is essential for achieving stable and long-term growth of the Shandong Peninsula BEZ. The relationship between ecological welfare and ecological resource use can be reflected by ecological welfare performance (EWP). EWP is the efficiency of converting ecological consumption into welfare levels, and it is used to measure a nation's or a region's capacity for sustainable development. EWP not only considers the output of GDP, but it also maximizes welfare under the condition of minimizing ecological inputs, which coincides with the pursuit of sustainable development. Therefore, the key to improving the overall welfare of residents in the Shandong Peninsula BEZ is the evaluation and study of the EWP levels of each city in the region.

At present, research on EWP mainly focus on three aspects: EWP study area selection, EWP measurement methods, and the selection of EWP indicators. In terms of research region selection, national and provincial units have always been popular options for EWP research, and cities, as the core carriers of ecological civilization construction, have also won the favor of many scholars. In contrast, few studies have been conducted on the regional level. This may be due to the different development priorities and policies of cities within a given region, which make it difficult to carry out research [11,12]. In terms of the EWP measurement methods, the traditional DEA model is usually used in EWP studies to deal with multi-input and multi-output problems, but it cannot solve the problem of the relaxation of input and output variables and the problem of multiple decision units being effective at the same time [12,13]. In terms of the selection of EWP indicators, most of the existing studies generally built indicator systems from the perspectives of the economy, society, and environment, but the selected indicators tend to be relatively simple and fail to fully reflect the development characteristics of the research objects [14,15].

In response to the above problems, this paper will conduct innovative research on three aspects of EWP, namely, the research object, research method, and index selection. First, based on the concept of sustainable and efficient development, and considering the four dimensions of the economy, society, environment, and resources, an eco-welfare performance index system is constructed in line with the characteristics of urban development in the Shandong Peninsula BEZ. Then, with the Shandong Peninsula BEZ as the research object, an entropy-weighted model together and the technique for order preferences by similarity to an ideal solution (TOPSIS) method are used to measure the EWP levels of seven prefecture-level cities in the Shandong Peninsula BEZ between 2011 and 2020 to discover deficiencies and problems, and thus provide city managers with effective targeted opinions and measures.

The rest of this paper is organized as follows: Part II presents a thorough analysis of the current research literature on EWP by scholars at home and abroad. Part III introduces the materials and research methods used in this study, including the study area and the formula and steps of the research method. It also introduces the EWP evaluation index system of the Shandong Peninsula BEZ and the principles of index selection, and it explains the data sources. Part IV evaluates the EWP levels of seven cities in the Shandong Peninsula BEZ and identifies shortcomings and problems in the development of the cities. Part V summarizes Part IV and proposes targeted policy measures. Part VI summarizes the research content of this paper, points out the remaining shortcomings, and explains possible future research directions.

2. Literature Review

2.1. The Concept of EWP

EWP was originally studied by Daly [16], and it has been used as a tool to assess levels sustainable development by evaluating the social welfare generated per unit of natural resources used, which is expressed as a ratio of services to throughput. Daly [17] emphasizes sustainable development, i.e., throughput should always be kept within the environment's carrying capacity for resources, and he argues that humanity has moved from an "empty world" in which man-made capital is relatively scarce to a "full world" in which natural capital is a limiting factor. However, Daly does not propose indicators that can be quantified and compared in practice. According to Daly's explanation of EWP, it can be defined as a ratio relationship between the value of welfare and the physical quantity of ecological resource consumption which can reflect the degree of decoupling between social welfare and ecological resource consumption.

At present, scholarly research on EWP mainly focuses on three aspects: the EWP measurement method, the selection of EWP indicators, and the study of EWP in countries and provinces.

2.2. EWP Measurement Methods

The current EWP research can be broadly divided into two categories according to their research methods. One method is the ratio approach, and an example of this is the Happy Planet Index (HPI), which was proposed by Common [18] for the measurement national EWP, expressed as happy life expectancy to ecological footprint ratio. The HPI proposed by Marks is expressed as the ratio of years of happy living to per-person ecological footprint [19]. Dietz et al. [20] employed the ratio of life expectancy at birth to ecological footprint per person to measure EWP. Zhang [21] measured the degree of EWP using the ecological footprint to HPI ratio for countries with more than 10 million people.

Even though the single-indicator ratio approach is easy and straightforward to observe, it does not provide a comprehensive and objective representation of the level of EWP, and the assessment results it has produced are not fully convincing. Therefore, a second type of method involving data envelopment analysis (DEA) models and stochastic frontier analysis (SFA) models is gradually being studied and applied to measure EWP. For example, Wang et al. [13] used the super-efficiency slacks-based measurement (SBM) model to measure the EWP of the Yangtze River Economic Belt from 2007 to 2017. Bian et al. [22] used the super-SBM model to measure the EWP levels of 30 provincial capitals in China and discovered that China's EWP levels showed a significant east–west trend. Moreover, the geographic distribution pattern of EWP level as a whole is imbalanced. Using the SFA model, He et al. [23] analyzed the provincial data from 2005 to 2019; the urban EWP of Jiangsu Province was shown to be increasing year by year, and there were spatial differences between urban and rural areas.

2.3. Selected EWP Indicators

The key to choosing EWP indicators is the applicability of the welfare indicator measure. The definition of human welfare is broad, controversial, and can be interpreted from different perspectives. In general, human welfare can be divided into subjective and objective welfare [14]. Objective welfare usually includes personal wealth, education level, and medical facilities; Indicators based on objective welfare reflect the improvement of material level and social attributes or stop loss, such as the Index of Sustainable Economic Welfare (ISEW), the Genuine Progress Indicator (GPI), and other indicators developed based on GDP [24]. In contrast to the pursuit of objective material well-being, subjective well-being focuses on spiritual pursuits and places more importance on personal feelings and perceptions, which are reflected by the two indicators life satisfaction and happiness. The inclusion of only objective or subjective welfare in the indicators would result in a one-sided application of welfare indicators. Therefore, the human development indicator (HDI), which covers both subjective and objective welfare, is the most popular indication. It has three dimensions: education, income, and health. HDI helps improve economic, educational, and medical levels; thus, it can improve human welfare when it is used to measure human welfare [15].

2.4. Research on EWP by Country and Province

In terms of the choice of research subjects for EWP, scholars prefer to conduct studies at the national and provincial levels. For example, Dietz et al. [19] concluded in 2012 that, on a national scale, the connection between per capita GDP and the level of EWP is U-shaped by studying the EWP levels of 58 countries. Common found through a comparative analysis using panel data from 75 countries that countries with good economic levels are actually better at translating ecological impacts into ecological welfare [18]. At the provincial level, Li et al. [25] used a non-expected output SBM model to measure interprovincial EWP in China from 2001 to 2015 and concluded that China's EWP was generally high, but that it showed a declining trend; significant variability was observed among provinces and municipalities. Xia et al. [12] used the Malmquist index and the two-stage DEA model to gauge the extent of EWP in the three provinces of Beijing, Tianjin, and Hebei from 2006 to 2019. They found that cities with high EWP have a positive driving effect on other cities. Most studies on EWP focus on the national and provincial levels; less research has been conducted on EWP at the regional level. China attaches particular importance to the development of strategic regions. Therefore, research at the regional level is necessary.

2.5. Literature Review

(1) In terms of the selection of EWP research areas, most existing studies choose countries and provinces, while research on regions, and especially BEZs, is lacking.

(2) In terms of selecting EWP measurement methods, the DEA method is currently the mainstream choice for measuring EWP level, but it is difficult to solve the problem of multiple decision-making units being effective simultaneously.

(3) In terms of constructing the EWP indicator system, the existing indicator system constructed by the EWP Research Institute fails to reflect the development characteristics of the blue economy, making it difficult to apply to the Shandong Peninsula BEZ.

In response to the shortcomings listed above, this article further optimizes the EWP research area, indicator selection, and measurement method based on previous EWP research results. In the selection of the EWP research area, the seven urban areas involved in the BEZ on the Shandong Peninsula were selected as research objects to expand the study of EWP to the regional level. In the construction of the EWP indicator system, indicators were selected based on the strategic development outline of the Shandong Peninsula BEZ and the development characteristics of various cities in the region so that each indicator would reflect the problems in the development of the Shandong Peninsula BEZ, reflect the importance of the blue economy in BEZ development, and comprehensively evaluate the EWP level of the cities. In the selection of EWP measurement methods, the level of urban EWP is usually comprehensively evaluated through multiple indicators. The selection of an indicator weight determination method directly affects the accuracy of the EWP level measurements, while an entropy weight method can truly and objectively reflect indicator information. The approximate ideal solution ranking method (TOPSIS) can rank by measuring the distance between the evaluation objective and the optimal or worst objective, comprehensively reflecting the contrast between indicators, comprehensively and systematically reflecting the utility of indicator information, and solving the problem of multiple decision-making units being effective at the same time. Based on this, we chose to use the entropy-weighted TOPSIS model to measure the EWP level of the cities to ensure more accurate calculation results.

3. Materials and Methods

3.1. Study Area

The Shandong Peninsula BEZ is located in the key area around the Bohai Sea and Northeast Asia economic circle, covering all the sea areas of Shandong and Qingdao, Dongying, Yantai, Weifang, Weihai, Rizhao, as well as the land areas of Wudi and Zhanhua in Binzhou City. The sea area covers 159,500 square kilometers and the land area covers 64,000 square kilometers. The BEZ has diverse geological and geomorphic structures, numerous bays, rich tourism resources, and a coastline length of 3345 km (which accounts for about 1/6 of the total length of China's coastline). Coastal zone development and utilization activities continue to increase, coastal regional development resource demand is increasing day by day, marine science and technology are developing, and it occupies a significant location with resource advantages. The BEZ of Shandong Peninsula was included in the national development strategy in 2011, becoming one of the national coastal economic zones in China. After the establishment of the Shandong Peninsula BEZ, comprehensive economic strength has been significantly enhanced, the independent innovation ability of marine science and technology has been greatly improved, the quality of the marine and land ecological environments has been significantly improved, the pattern of opening up the marine economy has been continuously improved, the growth rate of foreign trade has been obvious, and the proportion of processing trade in the province's foreign trade turnover has been increasing.

The Shandong Peninsula BEZ is the first BEZ to have been established in China, and it has been upgraded to part of a national strategy, along with the Zhejiang Ocean Development Demonstration Zone and other BEZs approved by the government during the same period. Both the Shandong Peninsula BEZ and the Zhejiang Ocean Development Demonstration Zone have unique geographical advantages: The Shandong Peninsula BEZ connects the old industrial base in Northeast China and the Yangtze River Delta Economic Zone, a connection that can promote the integration, interaction, and integrated development of economic departments in these two regions and drive the economic development of China's hinterland. The Zhejiang Ocean Development Demonstration Zone is located on the north wing of the Hangzhou Bay Industrial Belt and the south wing of the Wentai Coastal Industrial Belt, with convenient transportation and proximity to strategic international shipping channels, which is conducive to regional cooperation at home and abroad. During the rapid development of the blue economy, the Shandong Peninsula BEZ also attached great importance to marine science and technology education, and it has established multiple research institutions and colleges, such as the Ocean Research Institute, which is conducive to enhancing the core competitiveness of marine economic development. It thus provides lessons and and references for the Zhejiang Ocean Development Demonstration Zone.

3.2. Indicator Selection and Data Sources

3.2.1. Indicator Selection

The development plan of the Shandong Peninsula BEZ is based on the coordinated development of the economy, society, and ecology, and the goal of EWP is to achieve the maximum welfare output with the minimum transformation of natural resources and ecological inputs. Therefore, this article aims to ensure that the indicators of each dimension have clear directionality and that the constructed indicator system can reflect the characteristics of the Shandong Peninsula BEZ and of EWP. The ecological dimension was therefore subdivided into two dimensions: ecological resources and ecological environment [26]. Finally, an EWP indicator system containing the characteristics of the Shandong Peninsula BEZ was constructed from the following four dimensions: economy, society, environment, and resources. Details of the selection of the indicators are shown in Table 1.

Table 1. Selection of Shandong Peninsula BEZ EWP indicators.

Tier 1 Indicators	Secondary Indicators	Unit
Social C_1	Employment rate C_{11}	%
	Number of students enrolled in a school with 10,000 students C_{12}	People
	Number of doctors per 10,000 people C_{13}	People
Environment C_2	Industrial solid waste generation per capita C_{21}	t/person
	Industrial wastewater discharge per capita C_{22}	t/person
	Industrial SO_2 emissions per capita C_{23}	Kg/person
Resource C_3	Electricity consumption per capita C_{31}	Kw-h/person
	Water consumption per capita C_{32}	M^3/person
	Built-up area per capita C_{33}	M^2/person
Economy C_4	GDP per capita C_{41}	RMB
	Fixed asset investment C_{42}	Billion
	Disposable income per capita C_{43}	RMB

(1) Economy (C_4)

A city's economic efficiency can be reflected by its rate of economic growth. GDP per capita (C_{41}) [27,28] and disposable income per capita (C_{43}) [29] are used to indicate the material living standards of city residents, and fixed asset investment (C_{42}) is used to synthesize the scale and structure of urban fixed assets [8,30].

(2) Social (C_1)

The selection of social aspects was based on the need for the selected indicators to reflect the level of social welfare. When selecting social welfare indicators, scholars refer to the HDI index of the United Nations Development Program. The corresponding indicators were selected to reflect income, education, and health. In this study, the proportion of students per 10,000 people in school (C_{12}) was used as the indicator for education [31], and the number of doctors per 10,000 population (C_{13}) was used as the indicator for health [29,32]. The fundamental public value of social welfare is that both family and work are essential, and seeking and accepting a job is an important way to achieve a welfare transformation [33]. Thus, employment rate (C_{11}) was chosen as an indicator in this paper.

(3) Resources (C_3)

The Shandong Peninsula BEZ faces resource problems such as human–land tensions, water shortages, and inefficient energy use. This study addresses these problems by selecting the following indicators to represent resource consumption: consumption of water resources, energy, and land resources. Built-up area per person (C_{33}) illustrates the use of land resources [34,35], energy consumption is represented by electricity consumption per capita (C_{31}) [23,36], and water consumption is represented by water consumption per capita (C_{32}) [8,37].

(4) Environment (C_2)

The organic coordination of a city's socioeconomic development needs and ecological interests directly affects the security of the urban ecosystem. Therefore, in the selection of environmental indicators, three waste emissions were chosen to reflect the pressure generated by human economic activities on the regional ecological environment. Solid waste emissions are represented by industrial solid waste creation per capita (C_{21}) [38,39], industrial wastewater emissions per person (C_{22}) indicate emissions of liquid waste [29,40], and industrial SO_2 emissions per capita (C_{23}) represent gaseous waste emissions [29,32].

3.2.2. Data Sources

In this paper, the indicator data of the evaluation system were mainly obtained from the statistical yearbooks and statistical bulletins of the seven prefecture-level cities in the Shandong Peninsula BEZ from previous years, namely, the Shandong Statistical Yearbook, the Shandong National Economic and Social Development Statistical Bulletin, the Shandong Rural Statistical Yearbook, and the Shandong Peninsula BEZ Development Plan. Among them, the Shandong Statistical Yearbook, the Shandong National Economic and Social Development Statistical Bulletin, and the Shandong Rural Statistical Yearbook are issued by Shandong Provincial Bureau of Statistics and the Shandong Provincial government, and the Shandong Peninsula BEZ Development Plan is approved and issued by The State Council. Linear interpolation was used to fill in the missing data for specific years.

3.3. Research Method

3.3.1. Entropy-Weighted Model Together with the TOPSIS Method

The TOPSIS method mainly determines the evaluation index's positive ideal solution and negative ideal solution and then ranks the evaluation objects according to their proximity to the positive ideal solution and the negative ideal solution [41]. The TOPSIS method is often used for multi-objective decision analyses, and it is widely used by scholars because it sets no rigid requirements about the quantity of indicators or the sample size. The determination of weights is critical for the traditional TOPSIS method. Thus, since the setting of the weights is inevitably influenced by subjective factors, they may make the evaluation results uncertain [42].

Entropy is a highly objective evaluation tool that can exclude the influence of personal subjective factors, and it can therefore effectively eliminate the uncertainty involved in the TOPSIS method. Therefore, this paper incorporates the entropy method based on the TOPSIS method, and thereby not only ensures simple and efficient calculations, but also makes the indicator weights objective and ensures the scientific and validity of the conclusions [43]. In this way, the weights of the indicators were determined and the EWP was evaluated. Combinations of entropy-weighted models and the TOPSIS method have been applied by scholars to study supplier selection [44], evaluate the competitive performance of listed companies [45], and comprehensively evaluate road capacity sustainability [46].

- The entropy-weighted model together with the TOPSIS method eco-welfare performance X integrated evaluation model developed in this paper proceeds as follows:
- In this study, the innovation capacity of innovative cities is assumed to be evaluated by j indicators of n cities, and the value of j indicators of i cities is recorded as X_{ij}. The

original data, P_{ij}, are standardized to obtain the standardized matrix after the change, and the characteristic ratio of the indicators of the j cities is calculated as follows:

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (1)$$

The j indicator's entropy value is calculated for the city EWP evaluation index system e_j:

$$e_j = -k\sum_{i=1}^{m} P_{ij} \ln P_{ij} \quad \left(\mathrm{k} = \frac{1}{\ln m}, e_j \in [0,1]\right) \quad (2)$$

The weights are determined using the coefficient of variation, and the weighting factor W_j is calculated as

$$W_j = \frac{1 - e_j}{\sum_{j=1}^{n} (1 - e_j)} \quad (3)$$

With regard to the determination of the TOPSIS model, the same trending process is first implemented for different types of evaluation indicators. Then, the weighted canonical matrix $Z = (P_{ij}W_{ij})m{*}n$ is constructed, the positive and negative ideal solutions are calculated, and the distances from each city sample to the positive and negative ideal points are obtained by combining the Euclidean distance methods D_i^+ and D_i^-:

$$\begin{aligned} D_i^+ &= \sqrt{\sum_{j=1}^{m} W_j (\max z_{ij} - z_{ij})^2} \\ D_i^- &= \sqrt{\sum_{j=1}^{m} W_j (\min z_{ij} - z_{ij})^2} \end{aligned} \quad (4)$$

The relative closeness of the city EWP evaluation value C_i is calculated as follows:

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \quad (5)$$

The EWP evaluation results for each city are ranked according to the magnitude of the C_i value. The magnitude of the C_i value determines the merit of the city EWP. A large C_i value indicates that the city EWP is closer to the positive ideal solution and that it is higher. A small C_i value indicates that the city EWP is closer to the negative ideal solution and that it is lower.

3.3.2. Natural Breaks Method

The natural breaks method adopts the idea of clustering and is based on the univariate classification principle of cluster analysis. When the classification number is determined, data breakpoints between classes are iteratively calculated to minimize and maximize the differences between classes so as to group similar values in the data in the most appropriate way. This method better maintains the statistical characteristics of the data. Unlike other clustering methods, the natural breaks method focuses on class boundaries. Therefore, this method is suitable for solving the turning point of cumulative difference data. In this article, the corresponding values of these turning points can be used for grading the EWP level of the Shandong Peninsula BEZ.

4. Results

An entropy-weighted model was used together with the TOPSIS method to determine the EWP levels of seven prefecture-level cities in the Shandong Peninsula BEZ from 2011 to 2020, and the specific outcomes are displayed in Table 2.

Table 2. EWP levels of seven prefecture-level cities within the Shandong Peninsula BEZ, 2011–2020.

Prefecture-Level City	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Average Value	Ranking
Weifang	0.375	0.380	0.412	0.415	0.418	0.439	0.451	0.464	0.454	0.464	0.427	5
Dongying	0.471	0.501	0.526	0.550	0.563	0.577	0.593	0.601	0.551	0.558	0.549	2
Yantai	0.407	0.414	0.451	0.457	0.475	0.498	0.517	0.535	0.549	0.576	0.488	3
Binzhou	0.345	0.346	0.363	0.347	0.318	0.301	0.325	0.311	0.307	0.326	0.329	7
Qingdao	0.418	0.454	0.504	0.528	0.568	0.601	0.636	0.672	0.709	0.704	0.579	1
Weihai	0.411	0.412	0.433	0.467	0.477	0.485	0.497	0.501	0.500	0.503	0.469	4
Rizhao	0.350	0.357	0.370	0.380	0.391	0.409	0.419	0.451	0.441	0.451	0.402	6
Average value	0.397	0.409	0.437	0.449	0.459	0.473	0.491	0.505	0.501	0.512	0.463	

In terms of time, the overall average annual EWP of the Shandong Peninsula BEZ showed a stable upward trend between 2011 and 2020, rising from 0.397 in 2011 to 0.512 in 2020, an increase of 28.9%. The average EWP of the seven prefecture-level cities in the Shandong Peninsula BEZ across all years was 0.463, with nearly 50% more room for development in the future.

At the city level, Qingdao's annual average EWP reached 0.579 in 2011–2020, which was first among the seven prefecture-level cities, while Binzhou was at the bottom, with an average annual EWP value of only 0.329, which is 43.1% lower than Qingdao's annual average EWP. The cities can be divided into three echelons according to their annual average EWP. The first echelon is 0.5–0.6, and this includes Qingdao and Dongying; the second echelon is 0.4–0.5, and this includes Weifang, Yantai, Weihai, and Rizhao; and the third echelon is less than 0.4, and this includes Binzhou.

In accordance with the unique regional divisions in Shandong, the seven prefecture-level cities can be divided into four regions: Qingdao, Yantai, and Weihai belong to the Jiaodong Peninsula region; Weifang belongs to the Central Lu region; Dongying and Binzhou belong to the Northwest Lu region; and Rizhao belongs to the South Lu region. The average annual EWP values of these four regions are 0.512, 0.427, 0.439, and 0.402, respectively. Ranked from high to low, the four regions appear in the following order: Jiaodong Peninsula, Northwest Lu, Central Lu, and South Lu. This ranking initially reflects the uneven growth of the EWP level of the Shandong Peninsula BEZ at the regional level.

A spatial distribution map of EWP levels in each prefecture-level city within the Shandong Peninsula BEZ was drawn using ArcMap software to enable the visualization of the geographical distribution of EWP levels in each city and the changes generated over time. The spatial distribution map for 2011 was taken as the standard, the EWP levels were classified into four levels using the natural breaks method, with breakpoints of 0.350, 0.418, and 0.500, and the spatial distribution maps for 2014, 2017, and 2020 were analyzed and compared, as is shown in Figure 1.

In 2011, the overall EWP in the Shandong Peninsula BEZ was average, with no cities having a "high" EWP level. The EWP levels of Yantai, Weihai, Weifang, and Qingdao were "higher", that of Dongying was "lower", and those of Binzhou and Rizhao were "low". In 2014, the overall EWP level improved compared with that of 2011, with two cities reaching "high", achieving a zero breakthrough; Qingdao rose from "higher" to "high" and Dongying rose from "lower" to "high". Only Weifang and Rizhao remained at "higher", with Rizhao rising from "low" to "higher" and Yantai and Weihai changing from "higher" to "lower". In 2017, the overall EWP level grew further than in 2014. The number of cities in the "high" level rose to three, among which Yantai rose from "lower" to "high", and Weifang and Rizhao dropped from "higher" to "lower". Only Qingdao and Dongying remained at "high". In 2020, the cities' EWP levels still steadily increased, but they were not much different from those of 2017 as a whole; only Weihai jumped from "lower" to "high".

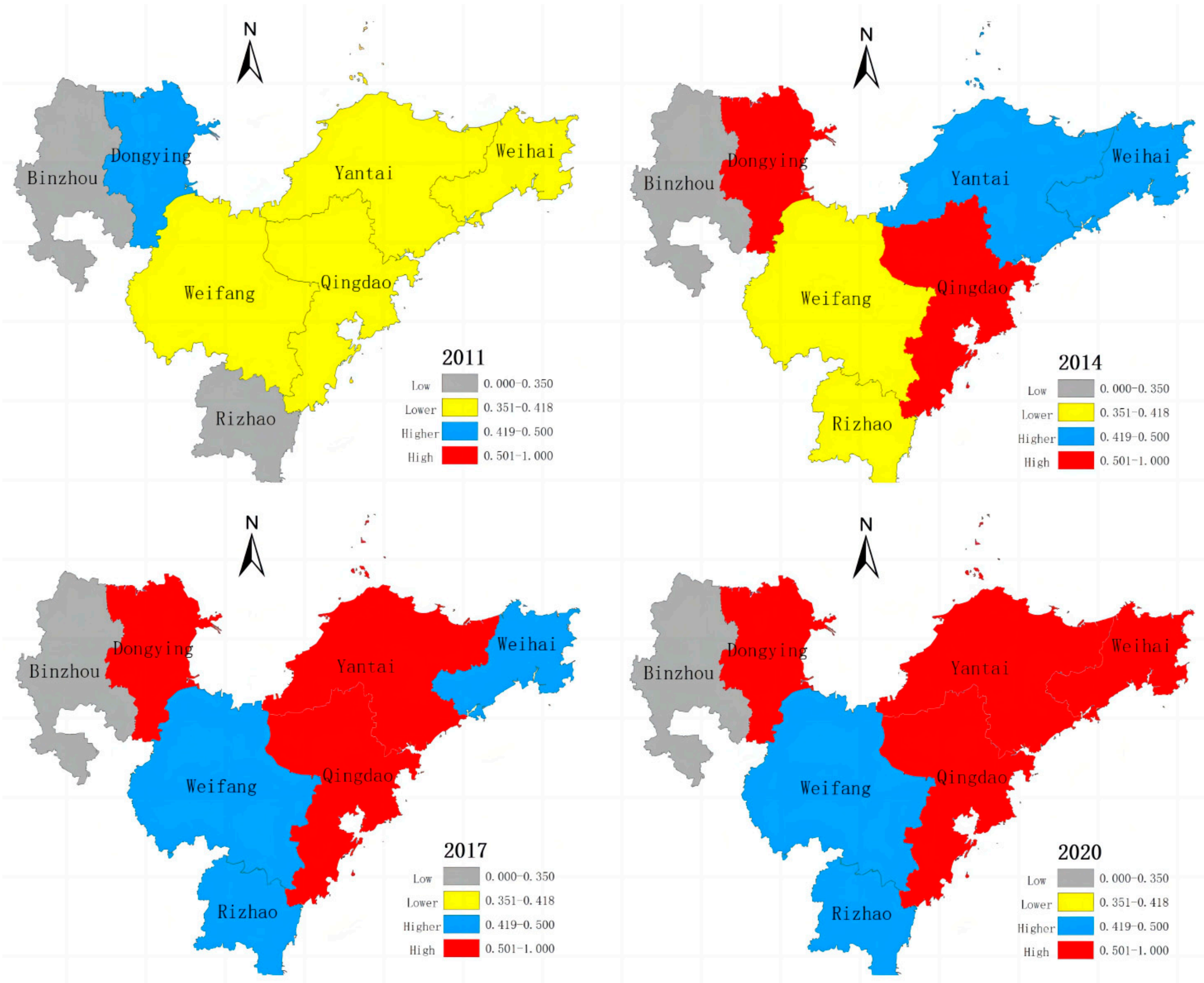

Figure 1. Spatial distribution of EWP levels in the Shandong Peninsula BEZ in 2011, 2014, 2017, and 2020.

A geographic analysis shows that Binzhou, Weifang, and Rizhao, which are located in the west and south of the BEZ, have relatively low EWP levels. In the eastern part of the BEZ, the EWP levels of Weihai, Dongying, Qingdao, and Yantai have been steadily and continuously improving, reaching the "high" level and forming a cluster of cities with highly developed EWP levels. This situation has led to benign interactions among the cities with high EWP levels, promoting the synergistic and efficient development of the region. The only city that has consistently occupied the stable position of "high" or "higher" is Qingdao, which ranks first in average EWP in all years, as is shown in Table 1. Binzhou has been in the "lower" category; its average EWP ranks last for all years, as is shown in Table 1. Qingdao, Yantai, and Weihai are in the same Jiaodong Peninsula region, which shows that different cities in the same region have similar EWP levels.

5. Discussion and Recommendations

5.1. Discussion

In this paper, an entropy-weighted model together with the TOPSIS method was used to measure the EWP levels of seven prefecture-level cities in the Shandong Peninsula BEZ from 2011 to 2020, and the natural breaks method was used to categorize the cities in the region into echelons to clarify the spatial distribution of the EWP levels of cities in different echelons.

Within the study period, the average annual EWP of the seven prefecture-level cities showed a continuous general upward trend, reaching a maximum of 0.512 in 2020, while the overall average EWP level was only 0.463. The overall EWP level was unevenly developed within the region and in 2020 formed a cluster of cities with high levels of development consisting of Dongying, Qingdao, Yantai, and Weihai. Cities within the same division region showed relatively minor differences in their EWP levels. For example, Qingdao, Yantai, and Weihai, which belong to the high-development city cluster, are part of the same Jiaodong Peninsula region.

The data comparison in Table 1 reveals that the EWP levels of Rizhao and Binzhou were lower in every year than the annual average EWP of the Shandong Peninsula BEZ. Among the EWP levels for Weifang, only those for 2018 and 2020 were slightly higher than the annual average EWP of the Shandong Peninsula BEZ. The secondary indicator data of these three cities were further observed to investigate the reasons for this situation, and the results show that, in terms of environment, Binzhou's per capita industrial output for three kinds of wastes was higher than the output of the other cities in the region, thereby indicating that Binzhou needs to further coordinate the connection between urban development and the environment. In terms of the economy, Binzhou, Weifang, and Rizhao's GDP per capita all ranked in the bottom three, while Binzhou and Rizhao's fixed asset investment and per capita disposable income ranked in the bottom two. In terms of resources, Weifang ranked last in terms of built-up area per capita, well below those of the other cities. The city needs to coordinate the growth of rural and urban areas to minimize the disparity between rural and urban development and earnings. At the same time, doing so makes the urban labor force naturally gravitate to rural areas and reduces the tension between urban people and land. In terms of social welfare, Rizhao ranked last in terms of the number of doctors per 10,000 individuals. Thus, the city needs to improve its social security system.

5.2. Recommendations

In light of the conclusions outlined above, the problems encountered in the development of the Shandong Peninsula BEZ can be summarized as follows: a fragile ecological environment, tension between people and land, unbalanced development between regions, and serious brain drain from cities. The following recommendations are made to improve the Shandong Peninsula BEZ's EWP:

(1) Synergistic development and complementary advantages: The western and eastern cities in the Shandong Peninsula BEZ each have their own advantages. The western cities are adjacent to the inland cities, making it more convenient to interact with them and reducing transportation costs. Their populations are smaller than those of the eastern coastal cities, with more natural resources available per capita. The eastern coastal cities can develop transnational trade to attract foreign investment and develop their port cities into international cities. The government should vigorously develop and support high-level city clusters, with Dongying, Weifang, and Yantai as the core, and their development will then radiate outward to drive the development of Binzhou and other cities with low EWP levels. Therefore, the governments of the prefecture-level cities need to make full use of the advantages of their locations in the BEZ, strengthen the interactions between the eastern and western cities, and circulate the talents, capital, industries, and development experience of the two regions. The western cities can expand the international market and attract foreign capital using the advantages of the eastern coast, while the eastern coastal cities can expand their industries to the hinterland and develop the domestic market using the advantages of the western cities adjacent to Jinan. In this way, interregional development can be balanced, thus improving the overall EWP in the Shandong Peninsula BEZ.

(2) Rational deployment of industrial structure and the active implementation of industrial transformation: Binzhou, Rizhao, and other low-level traditional industrial cities should be targeted for industrial adjustment. Binzhou has a diversified industrial structure, a complete industrial chain, and more developed tertiary industries. Subsequent

development should focus on science and technology investment and the development of high-end aluminum, fine chemicals, intelligent textiles, the manufacturing of high-end equipment, innovative information technology, novel materials, and other high-tech businesses. The distribution of Rizhao's industrial structure is too singular; it is still dominated by traditional industries, including the petrochemical and chemical industries, non-metallic mineral products, coking, iron and steel, and other leading industries that require high energy and water consumption and produce heavy pollution. The economic industry is still dominated by production, processing, and manufacturing, while tertiary industry's share of the total industry is too small. Thus, industrial transformation and the growth of high-tech enterprises are urgently needed. Industrial transformation in Rizhao needs to involve the development of secondary industries in the direction of service-oriented manufacturing, and the proportion of tertiary industry needs to increase to attract talent to stay while retaining low-cost labor and promoting the flourishing of the enterprise market.

Dongying, one of the cities with high EWP, is a resource-based city, and at its core is the oil industry. The future development of the city should fully take advantage of its geographical location near the sea to develop and expand the oil industry continuously while taking into account the transformation and upgrading of traditional industries. In the information age, which is marked by network technology, Dongying should accelerate the smart transformation of businesses and complete the construction of an industrial Internet platform so that it can attract high-tech talent while maintaining its advantageous traditional industries. While taking into account industrial development, the Dongying government also needs to adhere to the construction of an ecological civilization, adhere to the green and sustainable development path, and lead the oil industry to green, low-carbon, and intelligent development. The Shandong Peninsula BEZ should take into account the development of the marine industry while vigorously developing the economy so that rich marine resources can be protected and reasonably developed and the carrying capacity of the ecological environment can be improved. Such targeted industrial adjustment can not only break industrial solidification and inject fresh vitality into urban development; it can also promote the coordinated and sustainable growth of the urban economy and the natural environment, reduce the environmental pressure brought about by industrial pollution emissions, and realize the green and sustainable development of the Shandong Peninsula BEZ.

(3) Coordinated urban and rural development and the enhancement of the social security system (corresponding to the problems of brain drain and the tension between people and land): The government should gradually narrow the disparity between urban and rural income to reduce social conflicts, promote urban–rural interaction, and improve urban management regulations. With regard to the problem of insufficient skilled labor resources in the cities, the government needs to formulate relevant policies, such as measures to raise the incomes of residents in rural areas, policies for the introduction of talent, and the provision of financial and site support to enable college students to start their own businesses. This approach can establish a good employment environment, encourage the return of people who have left their homes, and facilitate the inflow of talent. In terms of social security, cities and towns should actively introduce doctors, teachers, and other medical, scientific, and educational talent and send them to the countryside appropriately. The infrastructure in cities, towns, and villages should also be improved to enhance urban innovation and protect livelihoods so that people can devote themselves to urban construction. The above policies can encourage the labor force to stay in rural areas voluntarily and thus solve the problem of the human–land relationship in cities. A generous talent-introduction policy can attract foreign talent and encourage the return of local talent to their hometowns, thus solving the problem of brain drain.

6. Conclusions

To achieve the green and high-quality development of the economy, China established the development of the Shandong Peninsula BEZ as a national strategy. The establishment of the Shandong Peninsula BEZ has promoted the economic development of the cities in the region and has led to an increase in the GDP of Shandong Province. In the course of regional economic development, with the continued over-exploitation and use of ecological resources, problems such as the fragile ecological environment, unbalanced regional development, prominent human–land conflicts, and serious brain drain have emerged. This paper has aimed to find a solution to these problems so that the Shandong Peninsula BEZ can embark on a sustainable development path.

An entropy-weighted model together with the TOPSIS method was employed in this study to calculate the comprehensive EWP levels of seven prefecture-level cities in the Shandong Peninsula BEZ from 2011 to 2020. Their spatial distribution characteristics were analyzed using the natural breaks method.

This article has made the following contributions:

1. Method contribution: This article has integrated an entropy-weighted method based on the TOPSOS model which not only ensures simple and efficient calculations, but also eliminates the influence of personal subjective factors, making the indicator weights objective and ensuring the scientific and effective nature of the conclusions obtained. The natural breakpoint method used in this article enabled us to effectively maintain the statistical characteristics of the data. Combining the entropy-weighted TOPSIS method with the natural breakpoint method enabled us to vividly demonstrate the EWP level of the Shandong Peninsula.

2. Theoretical contribution: An EWP indicator system with the characteristics of Shandong Peninsula BEZ was constructed using four dimensions (economy, society, environment, and resources), providing a reference for relevant research.

3. Management contribution: We proposed countermeasures and suggestions to improve the EWP level of the BEZ in Shandong Peninsula, including (1) coordinated development and complementary advantages; (2) reasonable allocation of industrial structure and the active implementation of industrial transformation; and (3) coordinated urban–rural development and the improvement of the social security system. These countermeasures and suggestions provide valuable references for the establishment of other BEZs.

This study has some limitations which need to be addressed in subsequent studies. The 4 proposed aspects and the 12 indicators were designed to cover all ecological welfare indicators. In future research, we will explore other quantitative and qualitative analysis methods to find more suitable EWP measurement methods, consult with other experts to find more representative blue economic indicators, compare the EWP before and after the establishment of the BEZ, and compare the EWP levels of the BEZ in Shandong Peninsula with those of other BEZs. Moreover, this study takes the Shandong Peninsula BEZ as its research object, and thus the universality of the proposed countermeasures need to be refined further.

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