Evaluation of Economic Security of Water Resources and Analysis of Influencing Factors

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ABSTRACT

To effectively evaluate the level of economic security of water resources (WES) in China and analyze its influencing factors, a comprehensive evaluation model of WES and a regression analysis model of influencing factors are established based on the panel data of 30 provinces in China from 2011 to 2017. It is found that, first, WES in China presents a fluctuating upward trend. Second, different regions have different economic security levels for their water resources in China, among which WES in the central region is the highest. Third, there is a U-shaped correlation between economic development and WES, and the population, pollution control level, technological innovation have negative impacts on WES. Moreover, this study also finds that with upgrades to the industrial structure and level of human capital, there will be improvements to WES. However, the external coefficient and the investment scale of fixed assets have a negative impact on the economic security of water resources. This is helpful to utilize the water resources and improve the water resource safety management.

KEYWORDS

Economic Security, Fuzzy Comprehensive Evaluation, Influencing Factors, Water Resources

1. INTRODUCTION

At present, the international environment is constantly changing; thus, economic security has become increasingly complex. There has been a significant amount of research on economic security in China and the world. Traditional economic security mainly refers to the security of national natural resources supply and resources transportation channel. With the acceleration of global economic integration, the concept of economic security has gradually changed, placing the ability to resist external economic interference at the forefront while simultaneously placing more emphasis on the stability of market operations, including improvements to the market scale and structure. With the development of the national non-traditional security theory, the theme of security research has gradually become more profound, such that the topics of environmental security, energy security, ecological security, and financial security have begun to attract increasing attention (Sun et al., 2021; Fu et al., 2021). As the material basis of economic and social development, natural resources, directly affect national economic security, are the basic source of human production and life, and are fundamentally guaranteed in

the sustainable development of the national economy (Song et al., 2020; Zhao et al., 2019a; Zhao et al., 2019b). As a type of non-traditional security, economic security from the perspective of natural resource assets has received increased attention from all demographics; however, this issue still requires further research.

Water resource demand is the basic demand for human survival and economic and social development. Within the background of continuous population growth and rapid socio-economic development, water resources security problems, such as water shortages and deterioration of the water ecological environment, have become increasingly prominent and, seriously threatens the security of water resources (Ginkel et al., 2018). Water resources security is an important topic in the field of resource security, as well as an important part of national economic security. Moreover, it is an important basis for national political and economic security, social stability, ecological environment security, and food security, and has a significant impact on the sustainable development of the regional economy, resources, and environment (Xenarios et al., 2021). With the development of industrialization and urbanization, the demand for water resources in various industries is increasing, which aggravates the contradiction between economic development and water resources protection globally. Comprehensively coordinating the relationship between economic development and water resources protection while promoting the security of human society and the water resources system can not only strengthen environmental protection, but also contribute to the construction of an ecological civilization in China and the world (Ako et al., 2010). The connotation of water resources security is diverse, covering many aspects of the economy, environment, society, and ecology, where the economic security of water resources is of great significance. Reasonable evaluation and influencing factor analysis of the economic security level of water resources is conducive for water resources management departments to understand current regional economic security of water resources and the regulation changes. It helps to create development plans that reflect the actual situation, improve the utilization efficiency of water resources, optimize water resources allocation, and holistically improve the economic security level of water resources. The study of economic security of water resources is of great significance to promote the rational use of water resources, realize harmonious development between water resources and economic society, and improve the level of water resources security management.

However, at present, most existing literature focuses on the connotation of water resources security and water resources security evaluation; relatively few studies focus on the economic security of water resources. Thus, evaluating the economic security of water resources and analyzing its influencing factors is of both theoretical and practical significance. The remainder of this paper is organized as follows. Section 2 reviews the relevant literature, Section 3 introduces the research methods and data sources, Section 4 analyzes the evaluation results for the economic security of water resources, Section 5 analyzes the factors influencing the economic security of water resources, and Section 6 provides our research conclusions.

2. LITERATURE REVIEW

2.1 Connotation of Water Resources Security

Earth's resources are limited; therefore, with advancement in industrialization, population growth, and economic development, the issue of resource security has received increasing attention. As a type of valuable strategic resource, water resources have increasingly become the supporting elements of economic growth (Chang and Zhu, 2021). Global changes such as urbanization, population growth, socio-economic changes, changing energy needs and climate change are putting unprecedented pressure on water resources (Mishra et al., 2021). Therefore, security of water resources has gradually become an urgent issue in academic research. There are numerous opinions on the definition of water resources security. Witter and Whiteford (1999) suggested that water resources security refers

to having sufficient water of a certain quality to meet residential demand at an affordable price to maintain human health, safety, and welfare and production capacity. With the increasing prominence of environmental problems, people have realized that the excessive use of water resources will cause irreversible damage to the economy and society. At the Second World Water Resources Forum in 2000, the Global Water Partnership (2000) brought sustainable development issues, such as environmental protection and disaster control, into the scope of water resources security. Water resources security was defined as the ability for all to obtain sufficient water at an affordable price to maintain a clean, healthy, and happy life while ensuring the protection of and improvement to the environment, as well as the protection of vulnerable populations from water-related hazards (Global Water Partnership, 2000). Therefore, water resources security should at least include the following components: meeting basic needs, protecting the ecological environment, reasonable price, and reasonable management and control. With more robust academic research on water resources, the important factors of economic and social development have been included in the field of water resources security, such that the definition of water resources security has become interdisciplinary (Xenarios et al., 2021). In 2007, the United Nations defined water security as the ability of a population to obtain a sufficient quantity and quality of water to meet their livelihood, human well-being, and socio-economic development needs to ensure protection from water pollution and other water-related hazards, as well as to maintain ecosystems in an atmosphere of peace and political stability (UN, 2007). Grey and Sadoff (2007) extended the connotation of water resources security to the availability of an appropriate water quality and quantity required to maintain human health, life, ecology, and production, as well as the level of water-related risks that humans, the environment, and the economy can sustain. Since the 21st century, the U.S. government linked resource security with anti-terrorism, emphasizing the security of the water infrastructure. According to the U.S. Environmental Protection Agency (EPA), water resources security is intended to prevent and control pollution and terrorism (Staudinger et al., 2006). To protect water resources security, ensuring the safety of drinking water and water conservancy facilities through "guns, gates, and guards" is necessary (Staudinger et al., 2006).

2.2 Evaluation of Water Resources Security

Water resources security reflects the fact that the water resources in a country or region in a specific historical development stage can satisfy the needs of the national economy and social sustainable development based on the predictable level of technical, economic, and social development. This definition uses the principle of sustainable development and the condition of maintaining the ecological environmental cycle such that there is a balance between the supply and demand of water resources. The principle of water resources security is that the supply of water resources can meet the reasonable demand for water resources, which involves social security, economic security, ecological security, and other aspects of human production and life (Mishra et al., 2021). Water resources security emphasizes that domestic water is a basic human right; everyone must have the right to safe water utilization. Scientific and objective evaluations of water resources security are an important component of research on water resources security; evaluations are also a basic research object to solve the problem of coordinated development of the economy, society, and ecological environment (Osei et al., 2010; Haider et al. 2015; Yin et al., 2020; Li et al., 2018). According to the characteristics of the water resource system, Van Leeuwen et al. (2012) proposed the concepts of the water resources security index and pressure index, constructing the water resources security evaluation index system. Li et al. (2020) established the evaluation index system for water resources security based on the four dimensions of water supply security, social security, economic security, and ecological security, analyzing the main influencing factors of the water resources security evaluation using a network analysis method. Meanwhile, combined with gray correlation analysis, they evaluated the situation of water resources security in Guizhou Province from 2008 to 2018. Sun et al. (2018) used the DPSIR (driving forces-pressure-state-impact-responses) conceptual model to evaluate the level of water resources security in Guizhou Province from 2005 to 2012, and found that except for droughts

in 2006 and 2011, the water resources in other years had an "overall security" status. Drought has a significant influence on the water security in karst areas; such threats have also been exacerbated by the rapid development of Guizhou's economy, agricultural non-point source pollution, inadequate sewage treatment, and other factors.

2.3 Review

At present, there is relatively little research on the economic security of water resources; existing research mainly focuses on the connotation of water resources security and the evaluation of the water resources security level. Therefore, this study focuses on the evaluation of the level of economic security of water resources, and analyzes the factors influencing the economic security of water resources to provide theoretical support for the long-term development of the economic security of water resources in China. The main contributions of this study are as follows. First, we analyze the level of economic security of water resources in China with a unique research perspective, which enriches the relevant literature on water resources security. Second, based on the entropy method, we establish a fuzzy comprehensive evaluation model and analyze the situation of economic security of water resources in China, which provides a considerably important reference for the healthy development of China's resources economy. Third, based on the calculation of the level of economic security of water resources, we further examine its influencing factors, which provide theoretical support for China to formulate environmental regulation policies.

3. RESEARCH METHODS AND DATA SOURCE

3.1 Fuzzy Comprehensive Evaluation

When evaluating a system or object, there may be many relevant evaluation factors. Thus, a comprehensive evaluation based on multiple factors, instead of just one index, is necessary. If we suppose that $U = \left\{ u_1, u_2, \cdots, u_n \right\}$ is a set of n objects to be evaluated, and $V = \left\{ v_1, v_2, \cdots, v_m \right\}$ is a set of evaluation factors, measuring each evaluation object in U by each factor in V can establish an observation matrix, A, as follows:

$$
A = \begin{bmatrix}
a_{11} & a_{12} & \cdots & a_{1n} \\
a_{21} & a_{22} & \cdots & a_{2n} \\
\cdots & \cdots & \cdots & \cdots \\
a_{m1} & a_{m2} & \cdots & a_{mn}
\end{bmatrix},
\tag{1}
$$

where a_{ij} refers to the index value of the jth evaluation object under the ith evaluation factor. Vector $a_j = \left(a_{1j}, a_{2j}, \cdots, a_{mj} \right)^T \ (j = 1, 2, \cdots, n)$ indicates the evaluation vector of the jth evaluation object to m indices.

To objectively and fairly evaluate each research object, the index value of each evaluation object will usually be dimensionless according to the index attribute; this index will then be weighted, establishing the objective function, followed by the calculation of the maximum or minimum value of the objective function. This is the fuzzy comprehensive evaluation method, whose main steps are as follows:

(1) Establish fuzzy benefit matrix

In this study, the indices for the economic security of water resources were divided into two categories: positive index and negative index. The positive index, also known as the benefit index, states that the value of the index and the evaluation result are in the same direction: the larger the index value, the better the evaluation result. The negative index, also known as the cost index, refers to the negative relationship between the index value and evaluation result: the smaller the index value, the better the evaluation result. Owing to the varying attributes of the different indices and different measurement units, to facilitate analysis and comparison, this study established the fuzzy benefit matrix, B, through non-dimensionalization, transforming all the elements of the matrix into positive indices:

$$B = \left(b_{ij} \right)_{m \times n} \tag{2}$$

$$b_{ij} = \begin{cases} \dfrac{a_{ij} - \min\limits_{j} a_{ij}}{\max\limits_{j} a_{ij} - \min\limits_{j} a_{ij}} & ,\ when\ a_{ij}\ is\ a\ positive\ index \\[4mm] \dfrac{\max\limits_{j} a_{ij} - a_{ij}}{\max\limits_{j} a_{ij} - \min\limits_{j} a_{ij}} & ,\ when\ a_{ij}\ is\ an\ negative\ index \end{cases} . \tag{3}$$

(2) Establish weight vector, $w = \left(w_1, w_2, \cdots, w_m \right)$, for each evaluation index

The determination of the index weight can be divided into the subjective and objective weighting methods. The economic security of water resources involves resources, economy, ecological development, and other aspects. To ensure the objectivity of the evaluation results, we used the entropy method for objective weighting. Information entropy is a measure of the degree of system disorder, and information is a measure of the degree of system order. The absolute values of the two are equal; however, the symbols are opposite. The greater the degree of variation in an index value, the smaller is the information entropy; the greater the amount of information provided by the index, the greater the weight of the index. In contrast, the smaller the variation degree of an index value, the greater the information entropy; the smaller is the amount of information provided by the index, the smaller the weight of the index. Therefore, according to the variation degree of each index, we can use the information entropy tool to calculate the weight of each index.

(3) Establish the comprehensive evaluation model

$$wes_i = 100 \sum_{j=1}^{p} w_j b_{ij} , \tag{4}$$

To better reflect the economic security level of water resources in a region, we use the hundred-mark system to measure it. Where wes_i refers to the level of economic security of water resources in each sample area. The maximum value of wes_i is 100, and the minimum value is 0. The higher the wes_i, the higher is the level of economic security of water resources in the area.

3.2 Panel Data Regression Model

The panel data regression model is usually used to analyze the influencing factors, and the general form is as follows:

$$y_{it} = \alpha_0 + \sum_{i=1}^{n} \alpha_{it} \cdot control_{it} + \varepsilon_{it} , \tag{5}$$

where y_{it} refers to the explained variable and $control_{it}$ and ε_{it} refer to each explanatory variable and the random disturbance term, respectively. Based on the panel data regression model, this study established a regression model for the factors influencing the economic security of water resources in China, as follows:

$$wes_{it} = \alpha_0 + \alpha_1 ln2pgdp + \alpha_3 lnpgdp + \alpha_4 lnps + \alpha_5 pl + \alpha_6 ti$$
$$+ a_7 iis + \alpha_8 irs + \alpha_9 ef + \alpha_{10} fas + \alpha_{11} hc + \varepsilon_{it} \tag{6}$$

where wes_{it} refers to the explained variable, i.e., the level of economic security of water resources; the right side of the equation contains the relevant factors affecting the economic security of water resources; α_i is the to-be-estimated coefficient; ε_{it} indicates the random disturbance term; i refers to area; and t refers to a specific year.

3.3 Index Selection and Data Source

3.3.1 Index System for Economic Security of Water Resources

The principle of the economic security of water resources is whether the supply of water resources can meet the needs of social and economic development. The focus of the evaluation of economic security of water resources is not only limited to the status quo, but should also consider future possibilities. The content of the evaluation is not only the level of economic development, but also the status quo of the resources and environment. The main focus of the evaluation of economic security of water resources is whether the water resources of a country or a region can yield economic benefits, as well as whether it can conform to the needs of the long-term and sustainable development of the economy and society. Water resources security mainly emphasizes two aspects: one is that the quantity and quality of the water resources supply should meet the reasonable needs of human beings; the other is that the water resources supply of a country or a region should meet the requirements of its long-term economic and social development, as well as consider the economic cost and sustainable development ability. Therefore, combined with other studies on the economic security of water resources, we suggest that the connotation of the economic security of water resources should cover the acquisition and utilization of water resources. Thus, we defined the economic security of water resources as the state and ability of a country or region to obtain the required water resources stably, adequately and economically while reasonably developing and utilizing them to ensure the sustainable and healthy development of the economy and improvement to the comprehensive strength. The level of economic security of water resources reflects the stability of the above state or the strength in the ability, including the following four components: 1) Quantity security: the quantity of water resources in a country or a region can fully meet the demands for agricultural, industrial, domestic, and ecological water, among others. 2) Quality safety: the water resources of a country or region can yield high economic and social benefits while producing a low environmental pollution level. 3) Economic cost: the low construction cost of water resources facilities in a country or region. 4) Sustainable development capacity: a country or a region's good water resources development situation, strong sewage treatment capacity, flood control and disaster resistance capacity, and abundant talent reserves. Based on the above mentioned analysis, we comprehensively considered the current situation of the water resources utilization; economic development mode; data availability; and the scientific, systematic, and typical principles of the

evaluation index system (Shi et al., 2017; Song et al., 2020b; Song et al., 2020c), finally establishing an index system for evaluating the economic security of water resources, including four criteria layers (quantity security, quality safety, economic cost, and sustainable development capacity) and 21 indices, as listed in Table 1. Quantity security mainly includes the water supply capacity and water demand. Among them, the storage of surface water and groundwater was selected for the supply capacity, whereas the water demand covers four aspects: agricultural water, industrial water, domestic water, and ecological environment water. Quality safety mainly includes the economic benefits of water resources and the cost of environmental pollution. For the economic benefit, the real GDP and per capita grain production were selected. The environmental cost included the urban sewage discharge, total wastewater discharge, chemical oxygen demand emissions, and pesticide usage. Economic cost mainly includes water saving and water conservancy facilities investments, which are respectively expressed by the total investments in urban water saving measures and completed investments in water conservancy construction. The sustainable development capacity of water resources is mainly measured by three aspects: sewage treatment capacity, flood control capacity, and talent reserve. Among them, the total sewage treatment capacity and urban sewage treatment rate were selected for the sewage treatment capacity; the total number of built reservoirs, length of dikes, and number of sluices were selected for the flood control capacity; and the total number of technical workers and the professional titles of these workers in the water department were selected for the talent reserve. Table 1 lists the attribute of each index.

3.3.2 Index Selection of Influencing Factors

Based on the calculation of the economic security of water resources in provinces and cities in China, we further investigated the factors influencing economic security of water resources. Therefore, in the analysis of the influencing factors, the dependent variable was the economic security level of water resources calculated in this study, expressed as wes. Following the principles of scientificity, operability, independence, and pertinence, this study selected the level of economic development (pgdp), population size (ps), pollution control level (pl), technological innovation level (ti), industrial structure upgrade level (iis), industrial structure rationalization level (irs), external coefficient (ef), fixed asset investment scale (fas), and human capital level (hc) as the influencing factors (Du et al., 2020). The level of economic development is measured by the regional per capita real GDP, where 2010 was used as the base period. To avoid drastic fluctuations in the data and eliminate possible heteroscedasticity, this study logarithmically processed the real per capita GDP, recorded as lnpgdp. Meanwhile, the square term of the economic development level was introduced and recorded as ln2pgdp. The population size was expressed by the year-end number of permanent residents, which was similarly logarithmized and recorded as lnps. The level of pollution control was measured by the proportion of completed investments in industrial pollution control in GDP while the level of technological innovation was measured by the number of patents granted. The industrial structure upgrade index included industrial structure advancement (*iis*) and industrial structure rationalization (*iis*). The index of industrial structure advancement reflects the evolution process of a country's industrial structure from low to high levels according to the general law of economic development. This study used the industrial structure level coefficient to describe the evolution process of the three major industries at a quantity level based on the relative change in the share proportion. The specific calculation formula is $iis_{it} = \sum_{m=1}^{3} y_{imt} \cdot m$, where y_{imt} is the proportion of industry m in area i during year t. The rationalization of the industrial structure reflects the dynamic process of the continuous strengthening of the coordination ability and the continuous improvement in the correlation level among the industries in a country, reflecting the degree of coordination among industries and the effective utilization of resources. This study used the Theil index to measure the rationalization degree of the industrial structure in various provinces and cities. The specific calculation method is

Table 1. Index system for the evaluation of the economic security of water resources

Objective layer	Criterion layer	Sub-criterion layer	Index layer	Index attribute
Economic security of water resources	A1: Quantity security	B1: Supply capacity	C1: Surface water (100 million m³)	Positive
			C2: Underground water (100 million m³)	Positive
		B2: Water demand	C3: Agricultural water (100 million m³)	Negative
			C4: Industrial water (100 million m³)	Negative
			C4: Domestic water (100 million m³)	Negative
			C6: Ecologic environmental water (100 million m³)	Negative
	A2: Quality safety	B3: Economic benefit	C7: Real GDP (CNY 100 million)	Positive
			C8: Grain production per capita (kg)	Positive
		B4: Environmental cost	C9: Urban sewage discharge (10 000 m³)	Negative
			C10: Total wastewater discharge (10000 tons)	Negative
			C11: Chemical oxygen demand emission (10000 tons)	Negative
			C12: Pesticide usage (10 000 tons)	Negative
	A3: Economic cost	B5: Water savings investment	C13: Total investment in urban water saving measures (CNY 10 000)	Negative
		B6: Water conservancy investment	C14: Completed investment of water conservancy construction (CNY 10 000)	Negative
	A4: Sustainable development capacity	B7: Sewage treatment capacity	C15: Total sewage treatment capacity (10 000 m³/day)	Positive
			C16: Urban sewage treatment rate (%)	Positive
		B8: Blood control capacity	C17: Total number of completed reservoirs	Positive
			C18: Dike length (km)	Positive
			C19: Number of sluices	Positive
		B9: Talent reserve	C20: Total number of technical workers in water department (person)	Positive
			C21: Total professional titles of workers in water department (person)	Positive

$$irs_{it} = 1 - \sum_{m=1}^{3} y_{imt} \ln \left(y_{imt} / l_{imt} \right),$$ where y_{imt} is the proportion of industry m in area i during year t and l_{imt} represents the proportion of the employee number in industry m in area i during year t of the number of total employees. The larger the value of the industrial structure rationalization, the more rational the industrial structure in a given region. The external coefficient was measured by the proportion of the total imports and exports in GDP; the scale of investments in fixed assets was

measured by the proportion of investments in fixed assets in GDP; and the level of human capital was measured by the average number of college students per 100 000 people.

3.3.3 Data Source

In the evaluation of the economic security of water resources, considering the index data availability, we used 30 provinces (autonomous regions and municipalities) in China from 2011 to 2017, except for Tibet, Hong Kong, Macao, and Taiwan, as the research objects. The data were obtained from the official website of the China National Bureau of Statistics and the easy professional superior (EPS) data platform. The real GDP was calculated from the GDP index, using 2010 as the base period. In the analysis of the influencing factors, data from 30 provinces (autonomous regions and municipalities) in China, except for Tibet, Hong Kong, Macao, and Taiwan, were collected, using 2011 to 2017 as the research period. The level of economic security of water resources in each province was measured in the previous section. Other data were obtained from the official website of the National Bureau of Statistics of China, the EPS data platform, and the China Statistical Yearbook for the corresponding years.

4. RESULTS OF THE EVALUATION OF ECONOMIC SECURITY OF WATER RESOURCES

4.1 Index Weight

According to Table 2, among the indices for the evaluation of economic security of water resources, the total investments in urban water saving measures, C13 had the largest weight, followed successively by the groundwater supply C2, and the urban sewage treatment rate C16 was the smallest.

4.2 Economic Security of Water Resources

The economic security levels of water resources in each area and the three regions from 2011 to 2017 are described in Table 3 and Figure 1, which indicate that the water resource security level had a fluctuating upward trend from the entire country and three regions' perspectives. This indicates that over time, there has been a gradual improvement in the economic security of water resources in China. Specifically, the level of economic security of water resources of the entire country from 2011 to 2017 increased from 49.22 to 51.68, with a growth rate of 5.01%. The level of economic security of water resources in the eastern region was the lowest among the three regions over the study period, which increased from 47.46 to 49.26 from 2011 and 2017, with a growth rate of 3.79%. The economic security level of the water resources in the central region ranked first among the three regions for many years, which increased from 51.12 to 55.32 from 2011 and 2017, with a growth rate of 8.22%. The level of economic security of water resources in the western region ranked second among the three regions, which increased from 49.60 to 51.47 from 2011 and 2017, with a growth rate of 3.78%. Further observation on the economic security level of the water resources in various areas showed an upward trend in the economic security level of the water resources in most provinces and cities in China, especially in Jiangsu Province, where the economic security level of the water resources increased from 39.89 to 54.74, with an overall growth of 37.22%. Notably, although the economic security level of the water resources in most provinces and cities increased steadily, there were still many provinces and cities, such as Shanghai, Zhejiang, Fujian, Guangdong, Guangxi Zhuang Autonomous Region, Chongqing, and Yunnan, characterized by a decline in the level of economic security of water resources. This was especially evident for Guangdong Province in the eastern region, where the level of economic security of water resources declined from 47.80 to 34.69, with an overall rate of 27.43%.

Table 2. Weight of each index

Index	2011	2012	2013	2014	2015	2016	2017
C1	0.0451	0.0448	0.0459	0.0451	0.0447	0.0449	0.0408
C2	0.0912	0.0900	0.0934	0.0911	0.0928	0.0960	0.0874
C3	0.0422	0.0436	0.0447	0.0445	0.0442	0.0450	0.0407
C4	0.0538	0.0520	0.0559	0.0581	0.0621	0.0662	0.0617
C5	0.0318	0.0340	0.0343	0.0334	0.0349	0.0349	0.0316
C6	0.0480	0.0465	0.0441	0.0381	0.0423	0.0481	0.0495
C7	0.0364	0.0342	0.0347	0.0338	0.0344	0.0349	0.0321
C8	0.0311	0.0306	0.0339	0.0341	0.0355	0.0359	0.0406
C9	0.0438	0.0413	0.0423	0.0401	0.0395	0.0407	0.0376
C10	0.0380	0.0360	0.0371	0.0361	0.0371	0.0383	0.0335
C11	0.0283	0.0268	0.0272	0.0263	0.0271	0.0273	0.0275
C12	0.0453	0.0428	0.0430	0.0416	0.0417	0.0428	0.0390
C13	0.1068	0.1318	0.1161	0.1372	0.1179	0.1020	0.1573
C14	0.0336	0.0318	0.0300	0.0294	0.0262	0.0212	0.0234
C15	0.0443	0.0414	0.0401	0.0400	0.0392	0.0399	0.0374
C16	0.0010	0.0007	0.0005	0.0005	0.0005	0.0002	0.0001
C17	0.0752	0.0742	0.0761	0.0747	0.0758	0.0770	0.0706
C18	0.0605	0.0673	0.0650	0.0608	0.0596	0.0587	0.0519
C19	0.0706	0.0792	0.0821	0.0804	0.0864	0.0891	0.0826
C20	0.0319	0.0306	0.0330	0.0318	0.0344	0.0348	0.0336
C21	0.0409	0.0203	0.0206	0.0229	0.0237	0.0224	0.0211

5. ANALYSIS OF FACTORS INFLUENCING THE ECONOMIC SECURITY OF WATER RESOURCES

5.1 Descriptive Statistics

Table 4 lists the results of the descriptive statistical analysis for each variable. According to Table 4, the mean values of most variables are greater than the standard deviation, which indicates that the degree of data dispersion is not high; the variance expansion factors are significantly less than 10, indicating that there is no multicollinearity between variables. In other words, we can use the existing data for further analysis.

5.2 Unit Root Test

To prevent the occurrence of pseudo regression, we tested the unit root of the explained variable and the core explanatory variable before regression to verify the robustness of the sequence. To ensure the robustness of the unit root test results, the Levin Lin Chu unit root test (LLC) and Fisher type unit root test (Fisher type unit root test) were used in this study, whose results are listed in Tables 5 and 6, respectively. According to the results of the unit root test, whether using the LLC or Fisher tests for the explained or explanatory variables, the original hypothesis of the unit root was rejected at the 5% significance level. Therefore, the variables selected in this study were robust series, which could be used for regression analysis.

Table 3. Level of economic security of water resources for each area of China from 2011 to 2017

Area	2011	2012	2013	2014	2015	2016	2017	Mean value	Ranking
Beijing	44.20	43.55	40.35	39.33	42.33	37.71	46.71	42.03	30
Tianjin	48.95	49.70	48.86	49.63	48.18	47.99	51.22	49.22	14
Hebei Province	54.49	54.22	53.45	54.15	54.13	54.24	55.55	54.32	3
Liaoning Province	46.50	50.14	45.70	47.58	45.48	47.58	52.39	47.91	24
Shanghai	47.71	46.70	44.42	46.94	44.40	43.13	47.48	45.82	28
Jiangsu Province	39.89	44.89	45.06	43.92	48.54	46.62	54.74	46.24	27
Zhejiang Province	51.66	51.05	48.84	50.50	45.20	45.25	47.75	48.61	19
Fujian Province	50.59	48.39	47.00	48.18	46.89	45.94	48.29	47.90	25
Shandong Province	40.80	46.94	42.26	47.08	41.93	45.55	52.70	45.32	29
Guangdong Province	47.80	51.23	50.36	50.57	48.69	42.68	34.69	46.57	26
Hainan Province	49.47	48.81	47.51	48.69	47.17	46.78	50.34	48.40	20
Mean value of eastern region	47.46	48.69	46.71	47.87	46.63	45.77	49.26	47.48	(3)
Shanxi Province	50.62	51.91	50.00	50.52	49.88	50.13	53.36	50.92	10
Jilin Province	49.34	51.92	51.32	52.00	50.34	51.50	55.16	51.66	8
Heilongjiang Province	52.35	56.07	57.53	58.60	56.65	59.01	62.03	57.46	2
Anhui Province	50.98	51.30	48.96	50.72	49.21	48.52	51.71	50.20	12
Jiangxi Province	52.63	53.39	51.83	53.22	51.66	50.81	53.91	52.49	5
Henan Province	49.29	51.78	52.44	53.59	52.34	51.80	53.86	52.16	6
Hubei Province	47.28	50.95	50.11	52.57	50.33	49.16	53.64	50.58	11
Hunan Province	56.44	59.04	57.56	59.03	57.54	57.42	58.85	57.99	1
Mean value of central region	51.12	53.29	52.47	53.78	52.24	52.30	55.32	52.93	(1)
Inner Mongolia autonomous region	50.46	52.14	51.12	52.58	51.23	51.04	53.23	51.69	7
Guangxi Zhuang autonomous region	50.36	49.61	47.14	48.84	46.88	46.13	49.79	48.39	21
Chongqing	50.21	48.16	46.55	48.38	47.56	46.84	50.09	48.26	22
Sichuan Province	48.41	50.83	48.91	50.44	48.69	46.34	50.87	49.21	15
Guizhou Province	45.75	48.88	47.86	48.80	47.74	46.70	49.75	47.92	23
Yunnan Province	51.89	50.30	47.96	50.46	48.06	47.38	50.70	49.54	13
Shaanxi Province	49.45	52.16	50.33	52.71	50.76	50.69	53.20	51.33	9
Gansu Province	48.09	49.09	49.29	50.31	48.47	47.12	51.69	49.15	17
Qinghai Province	50.50	49.58	48.29	49.38	48.18	47.60	50.95	49.21	16
Ningxia Hui autonomous region	51.11	50.40	46.92	48.17	46.64	45.81	51.31	48.62	18
Xinjiang Uygur Autonomous Region	49.31	55.23	52.71	55.39	54.70	54.41	54.57	53.76	4
Mean value of western region	49.60	50.58	48.83	50.49	48.99	48.19	51.47	49.73	(2)
Mean value of entire country	49.22	50.61	49.02	50.41	48.99	48.40	51.68	49.76	

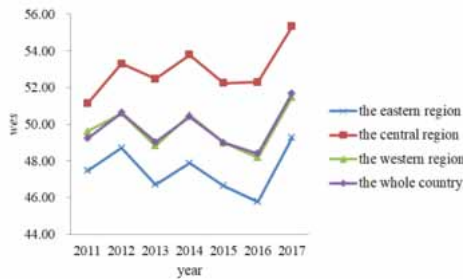**Figure 1. Level of economic security of water resources in China from 2011 to 2017**

Table 4. Descriptive statistics of each variable

Variable	Obs.	Mean	Std. Dev.	Min	Max	VIF
wes	210	49.76	3.94	34.69	62.03	-
lnpgdp	210	10.68	0.44	9.63	11.70	3.84
lnps	210	8.20	0.74	6.34	9.32	1.91
pl	210	0.0013	0.0012	0.0001	0.0099	1.52
ti	210	44301.04	62420.25	502	332652	2.47
iis	210	2.35	0.13	2.17	2.80	4.05
irs	210	0.78	0.14	0.36	0.98	2.63
ef	210	0.28	0.32	0.02	1.55	4.55
fas	210	0.79	0.24	0.24	1.48	2.63
hc	210	2533.09	809.46	1082.15	5612.87	2.63

Table 5. LLC test results

Variable	Adjusted t*	P-value	Result
wes	−12.0675	0.0000	Robust
lnpgdp	−16.2277	0.0000	Robust
lnps	−3.1348	0.0008	Robust
pl	−8.4154	0.0000	Robust
ti	−9.3746	0.0000	Robust
iis	−5.1726	0.0000	Robust
irs	−13.3017	0.0000	Robust
ef	−9.8726	0.0000	Robust
fas	−26.5989	0.0000	Robust
hc	−6.4488	0.0000	Robust

Table 6. Fisher test results

Variable			Statistic	p-value	Result
wes	Inverse chi-squared (60)	P	126.1347	0.0000	Robust
	Inverse normal	Z	−5.4000	0.0000	
	Inverse logit t (154)	L*	−5.3352	0.0000	
	Modified inv. chi-squared Pm	Pm	6.0372	0.0000	
lnpgdp	Inverse chi-squared (60)	P	106.6708	0.0002	Robust
	Inverse normal	Z	−4.1173	0.0000	
	Inverse logit t (154)	L*	−4.0737	0.0000	
	Modified inv. chi-squared Pm	Pm	4.2604	0.0000	
lnps	Inverse chi-squared (60)	P	93.0499	0.0040	Robust
	Inverse normal	Z	−3.0315	0.0012	
	Inverse logit t (154)	L*	−2.9504	0.0018	
	Modified inv. chi-squared Pm	Pm	3.0170	0.0013	
pl	Inverse chi-squared (60)	P	131.1051	0.0000	Robust
	Inverse normal	Z	−5.8665	0.0000	
	Inverse logit t (154)	L*	−5.8836	0.0000	
	Modified inv. chi-squared Pm	Pm	6.4910	0.0000	
ti	Inverse chi-squared (60)	P	88.4569	0.0099	Robust
	Inverse normal	Z	−3.3134	0.0005	
	Inverse logit t (154)	L*	−3.1145	0.0011	
	Modified inv. chi-squared Pm	Pm	2.5977	0.0047	
iis	Inverse chi-squared (60)	P	102.1005	0.0006	Robust
	Inverse normal	Z	−4.3338	0.0000	
	Inverse logit t (154)	L*	−4.1041	0.0000	
	Modified inv. chi-squared Pm	Pm	3.8432	0.0001	
irs	Inverse chi-squared (60)	P	100.8939	0.0008	Robust
	Inverse normal	Z	−4.2420	0.0000	
	Inverse logit t (154)	L*	−4.0207	0.0000	
	Modified inv. chi-squared Pm	Pm	3.7331	0.0001	
ef	Inverse chi-squared (60)	P	92.1771	0.0048	Robust
	Inverse normal	Z	−3.6917	0.0001	
	Inverse logit t (154)	L*	−3.4667	0.0003	
	Modified inv. chi-squared Pm	Pm	2.9374	0.0017	
fas	Inverse chi-squared (60)	P	89.3642	0.0083	Robust
	Inverse normal	Z	−1.6602	0.0484	
	Inverse logit t (154)	L*	−1.5774	0.0584	
	Modified inv. chi-squared Pm	Pm	2.6806	0.0037	
hc	Inverse chi-squared (60)	P	95.9362	0.0022	Robust
	Inverse normal	Z	−2.5626	0.0052	
	Inverse logit t (154)	L*	−2.4042	0.0087	
	Modified inv. chi-squared Pm	Pm	3.2805	0.0005	

5.3 Model Selection and Results Analysis

To analyze the influencing factors, three panel data regression models were established: mixed regression model, random effect model, and fixed effect model. To select a better regression model, several steps are usually required. First, mixed regression and random effect regression were performed, followed by the LM Test. If the results show that the original hypothesis is rejected, then there is a random disturbance term that reflects the individual characteristics in the original model, such that mixed regression should not be used. Then, the fixed effect regression and Hausman test were performed to determine whether to use the random effect model or fixed effect model. If the statistical test results show that the original hypothesis is rejected, the fixed effect model should be used; otherwise, the random effect model should be selected. Finally, if the fixed effect model is selected, the time effect in the model should also be considered to determine whether the two-way FE model should be selected, i.e., to test the joint significance of the annual dummy variables. If the original hypothesis of "no time effect" is rejected, the time effect should be included in the model and the two-way fixed effect model should be chosen.

In this study, the mixed regression and random effect models were first used to analyze the factors influencing the economic security of water resources, followed by the LM Test. The test results showed that the random effect model was better than the mixed regression model. Then, the fixed effect model was used for regression, followed by the Hausman test. The results supported the fixed effect model. Finally, we tested the existence of a time effect; the results showed that the two-way fixed effect model should be used. Accordingly, the two-way fixed effect model was used in this study for analysis. Meanwhile, to obtain more credible research results, we further established a two-way fixed effect model using clustering robust standard errors. The estimated results of the mixed regression, random effect, fixed effect, and two-way fixed effect models are listed in columns (1)–(4) in Table 7.

According to Table 7(4), there was a U-shaped correlation between economic development (*lnpgdp*) and the economic security of water resources, indicating that in the initial stage of economic development, the level of economic security of water resources in a country or region decreases with improvements to the economic development level; when the logarithm of the real per capita GDP is > 9.3155, there is a promoting impact of economic development on the economic security of water resources. This shows that when the economic development of a country or a region is at a low level, it will lead to an increase in the demand for water resources and the discharge of wastewater and sewage, resulting in a low level of economic security of water resources. However, with economic level improvement, people gradually notice problems associated with environmental pollution and resource depletion resulting from economic development, thus changing the traditional concept of economic development, improving environmental protection awareness, and improving the efficiency of resource utilization through technological innovations and other paths, which will improve the level of economic security of water resources. There was a significant negative correlation between the population size (*lnps*) and economic security of water resources. Every 1% increase in the population will lead to an average decrease of 39% in the level of economic security of water resources. This indicates that a country or a region with a large population will inevitably observe an increase in the demand for water resources, which will threaten the quantity security and quality security of water resources, thus reducing the level of economic security of water resources. There was a significant negative correlation between the level of pollution control (*pl*) and the economic security of water resources. Every unit decrease in the level of economic security of water resources will lead to an average increase of 247.4 in the pollution control level. There was a significant negative correlation between technological innovation (*ti*) and the economic security of water resources. Although the value is small, the statistical significance is substantial. It implies that the process of technological development in China significantly hinders the level of economic security of water resources instead of improving it; China should constantly improve its direction of technological progress and protect against the rebound effect of technological innovation. Industrial structure advancement (*iis*) and industrial structure rationalization (*irs*) were both positively correlated with the economic security of

water resources. Every unit increase in the advancement and rationalization of industrial structures increases the level of economic security of water resources by 3.390 and 2.866, respectively. This indicates that the optimization and upgrade of China's industrial structure can promote the economic security of water resources. There was a negative correlation between the external coefficient (*ef*) and the economic security of water resources. Every unit increase of the external coefficient leads to an average decrease of 1.853 in the level of economic security of water resources. This shows that China should be aware of water pollution caused by pollution intensive industries in international trade. There was a negative correlation between the scale of fixed asset investments (*fas*) and the economic security of water resources. Every unit increase in the scale of fixed asset investments will yield a decrease in the average level of economic security of water resources by 1.689. There was a positive correlation between human capital (*hc*) and the economic security of water resources. Every unit increase in human capital level yields an average increase of 0.0006 in the level of economic security of water resources of China. With the increase in human capital, citizen awareness of environmental protection is gradually enhanced, the quantity and quality safety of water resources are guaranteed, and the sustainable development ability of water resources and level of economic security of water resources are improved.

6. CONCLUSIONS AND IMPLICATIONS

The economic security of water resources reflects the comprehensive state of economic development and water resources security of a country or a region. Reasonable analysis of the economic security level of water resources in a country or a region and its influencing factors is of great significance for the government to formulate environmental regulation policies, enhance regional green competitiveness, and realize the win-win situation of economic growth and resource-environmental protection. Based on the data of 30 provinces and cities in China from 2011 to 2017, this study evaluates the economic security level of water resources of each province and city based on the fuzzy comprehensive evaluation method, and empirically tests the influencing factors of economic security of water resources. The results show that the economic security level of water resources in China is fluctuating and rising, and it is gradually improving over time. The economic security level of water resources in three regions of China is different to some extent. In the central region it is the highest, followed by the western region, and the eastern region is the lowest. Further research shows that there is a U-shaped correlation between economic development and the economic security level of water resources, which first decreases and then increases, whereas there is a significant negative correlation between technological innovation and the economic security level of water resources. In addition, this study finds that with the optimization and upgrading of industrial structures and the improvement of human capital level, the economic security level of water resources will also be improved. Based on the aforementioned conclusions, we propose the following suggestions.

First, improve the regional utilization efficiency of water resources and promote regional economic security of water resources. It is found that the low level of water resources economic security in the eastern and western regions is mainly due to the lack of regional water resources and low utilization efficiency of water resources. Therefore, all regions should accelerate the construction of water-saving projects, improve water efficiency, promote the economical and intensive utilization of water resources, and ensure the economic security of regional water resources. Second, increase publicity and develop a green economy. Water pollution has eased to a certain extent with China's increased investment in pollution control; however, there are still several polluted rivers and lakes. The relevant departments should strengthen the publicity of environmental protection, improve the awareness of water resources protection, and promote the green and sustainable development of the economy. Third, accelerate the pace of technological innovation and protect against the rebound effect. In general, the emergence of new technologies can help improve the efficiency of water resources. However, the improvement of utilization efficiency may stimulate the relevant subjects to use more water, resulting

Table 7. Effects of various factors on the economic security of water resources

Variables	(1) OLS wes	(2) RE wes	(3) FE wes	(4) FE_two wes
ln2pgdp	−2.289 (1.695)	−0.396 (1.720)	3.774* (1.856)	3.550 (2.107)
lnpgdp	50.26 (36.09)	13.04 (36.07)	−70.23* (37.89)	−66.14 (42.74)
lnps	0.926 (0.741)	2.233*** (0.769)	−35.01** (16.57)	−39.00** (18.37)
pl	−233.3 (226.1)	−284.5** (120.7)	−385.0*** (97.37)	−247.4** (111.6)
ti	−2.60e−05*** (7.86e−06)	−5.50e−05*** (1.23e−05)	−7.17e−05*** (1.88e−05)	−6.93e−05*** (2.07e−05)
iis	0.0894 (5.403)	1.679 (4.525)	1.242 (5.123)	3.390 (7.409)
irs	4.920 (4.267)	0.431 (5.534)	−2.663 (5.731)	2.866 (5.733)
ef	−6.163* (3.061)	−2.227 (1.653)	0.644 (3.995)	−1.853 (3.529)
fas	−3.191 (2.428)	−2.123* (1.283)	−3.805*** (1.241)	−1.689 (1.193)
hc	−0.000942 (0.000602)	−0.00173** (0.000698)	0.00146 (0.00172)	0.000565 (0.00173)
Constant	−229.0 (197.9)	−57.27 (193.0)	657.6** (272.5)	663.9** (305.4)
Observations	210	210	210	210
R-squared	0.388	0.212	0.311	0.505
Number of ids	30	30	30	30
LM test	[0.0000]			
Hausman test	[0.0001]			
Time-effect test	[0.0000]			

Note: robust standard errors in parentheses; ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$; and P-value is in square brackets.

in waste of resources. It is therefore necessary for governments to consider the rebound effect when formulating policy. Fourth, optimize the industrial structure and enhance the level of human capital. Industrial structure optimization includes two aspects: upgrading and rationalization. Its aim is to realize the coordinated development of the industry and the optimal allocation of resources through industrial adjustment. Furthermore, the promotion of human capital has a positive impact on the economic security of water resources. Further improving the level of human capital and promoting the transformation and upgrading of industrial structures will help promote the high-quality development of a resource-economy.

However, the research on the economic security of water resources in this study must be developed. For example, the water resources economic security evaluation method can be further standardized. The input-output index system can be used for evaluation and analysis, and the results can be mutually verified with fuzzy comprehensive evaluation. In addition, it is also of great significance to introduce

water resources economic security thresholds in different regions and divide them according to the water resources economic security level.

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