

## Article

# An Input–Output Analysis of the Water–Energy–Food Nexus Based on the Intensity and Quantity Index System—A Case Study of 30 Provinces in China

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**Abstract:** In the study of the water–energy–food nexus (WEF nexus), the importance of the intensity and quantity index system has been widely recognized. In order to study the impact of WEF on the economy, this paper establishes an intensity index system and a quantity index system, taking account of the impact of environmental pollution. Using a DEA model and China's provincial data from 2019, this paper calculated the efficiency of the WEF nexus with the developed intensity and quantity index systems. The results show that the efficiency is not high in areas with a high economic development level, and efficiency is not the lowest in areas with a relatively low economic development level. When considering environmental pollution, the efficiency of some provinces has increased significantly, indicating that the WEF nexus has not caused environmental damage and is conducive to sustainable economic development. In the two intensity index systems, the efficiency of the production system is significantly lower than that of the consumption system, indicating that there is a serious waste of cultivated land per capita. Compared with the intensity index system, the efficiency of the quantity index system is low, and the polarization is obvious. A high level of GDP does not mean a high level of economic development. There may be a low level of resource utilization technology or environmental pollution underlying it. It is unscientific to evaluate local economic development only by GDP. When evaluating the urban economy and national economy, we should conduct an overall study of WEF and reasonably allocate WEF resources, which will not only help to alleviate the current situation of resource shortage in various countries but also effectively promote the coordinated development of national and regional economies. At the same time, environmental protection should also be taken into account. Compared with the economic development model of developing the economy first and then solving environmental problems, developing and solving at the same time is more conducive to the sustainable development of the national economy.

**Keywords:** input–output analysis; water–food–energy nexus; intensity and quantity; index system; DEA model; efficiency

## 1. Introduction

The role of indicators, index system, or metrics in the governance of the water–energy–food nexus (WEF nexus) attracts great attention in WEF nexus research [1–3]. Developing an effective index system for different countries or regions is critical to avoid the dilemma, which integrated water resource management (IWRM) has faced [4]. An index system has been widely developed in recently nexus modeling work [5], with numerous indicators used [6] and has been performed in governance processes to achieve good nexus governance [3]. In China, a similar index system for a green economy has been put into use since 2016, including both intensity and quantity indicators.

Great advancement has been achieved in China's economy, and its input–output efficiency to achieve sustainable development is quite important. Water, energy, and food (WEF) are critical inputs in urban areas that affect efficient urban development. A holistic

perspective on WEF research has been proposed by Hoff [7] and further developed by Li et al. [8] using Data Envelopment Analysis (DEA) as the background of methodology barriers. Li et al. [8] introduced the DEA method in WEF nexus research, but their research lacked comparison between an intensity and quantity index system, which is improved in this paper. When the contradiction between the supply of and demand for domestic resources is growing, the input–output efficiency of urban resources can be analyzed by combining WEF as a whole, the best input point for promoting urban development can be found, and the three resources of WEF can be allocated reasonably, whether to alleviate the current situation of a domestic resource shortage or to effectively promote different regions. The coordinated development of intereconomics has important theoretical and practical significance.

The WEF nexus was first proposed by Hoff in 2011, and achievements in the theoretical basis, quantified modeling, and governing practices have been made. After summarizing and analyzing the factors affecting the WEF relationship, Lawford et al. [9] put them into several specific cases for analysis, and they think that the WEF framework is conducive to understanding and cooperation between governments. Many scholars believe water is most important among them. As an important natural resource, the water problem must be paid enough attention by governments of all countries to find ways to protect water security, so as to ensure the safety of food and energy and stable economic growth [10]. In Smidt et al.'s [11] study, based on the analysis of the WEF relationship, the main driving factors influencing the current agriculture were separated, the importance of water management was emphasized, and the theoretical basis for solving the water management problems related to the WEF relationship was established. After studying the problems of agricultural water use in the critical transitional period, King and Jaafar [12] made recommendations for adaptive management strategies to maximize synergies using measurements to assign values to the units of WEF stocks and flows. In the context of a lack of water resources, Perrone and Hornberger [13] indicated that tradeoff frontiers (TFs) can be used to balance the water consumption of food and energy, and the social and political constraints were discussed. From the macro level, Rasul and Sharma [14] pointed out that climate change has made it more difficult for developing countries to use the WEF nexus effectively to solve the growing demand for WEF. It is of great significance to understand the interrelationship between water, energy, and food to improve the utilization rate of resources and ensure the security of WEF. From a microscopic point of view, the impact of phosphorus on WEF has not been fully discovered. The lack of phosphorus affects the production of energy and food, while the phosphorus entering the water system will harm ecological security. Sustainable phosphorus management can guarantee the security of energy and food [15].

In terms of methodology, Hussien et al. [16] presented one integrated model based on system dynamics to study the interaction among WEF, which can estimate the demand for WEF and the generated organic waste and wastewater, as well as the impact of family size and climate change. After analyzing a series of articles and books, Albrecht et al. [17] extracted four features of nexus analysis tools and methods and believe that interdisciplinary research methods are needed to meet the challenges brought by the complex resources and development, promoting the development of nexus analysis methods. For decision makers to make optimal decisions, Zhang et al. [18] put forward an integrated modeling approach of WEFO (Water, Energy, and Food security nexus Optimization model) to analyze the social economy of multiple periods and the relationship among various parts of the system quantitatively. Gulati et al. [19] advocated a rethinking of the green economy development and construct a governance framework for the WEF nexus.

From the viewpoint of policy and economics, although scholars in many countries have paid attention to the relationship among WEF, policies in some countries do not reflect the concern of this relationship, and conflict between related resources still exists [20,21]. Conway et al. [22] point out that it is necessary to take economic measures and formulate response policies to ensure the security of WEF. Furthermore, water, energy, and food are closely related. Cross-sector cooperation is needed in infrastructure planning. It will be

a rare opportunity for effective development to take advantage of the potential synergy among sectors [23]. Hellegers et al. [24] point out that the high price of energy leads to the increase in the transportation cost of water resources. In addition, the demands of hydropower, the substitute for other energies, will also change the distribution of water resources, which will affect food production. From the perspective of the basin scale, the framework of WEF assessment was tested in the Douro River Basin of Spain. The rise in energy prices has introduced restrictions to water supply management and may generate new energy and water demands [25].

In addition, in southern Africa, the distribution of resources such as WEF is uneven. Schreine and Baleta [26] suggested that expanding the scope of regional resource integration could improve the recovery capacity of the region, improve the utilization rate of resources, and achieve regional economic growth and sustainable development. Through a case study in Cyprus, Halbe et al. [27] explored the sustainable innovation among the three sectors of WEF by analyzing the framework of the WEF method, which is of great significance to systematically explore the responsibilities of different stakeholders in the innovation process. WEF security has a significant impact on the sustainable development of human beings, especially in today's context of resource scarcity and changing environment. Cross-sector management of WEF as a whole can save costs and also reduce the impact on the environment [28].

DEA evaluates the relative effectiveness of the production possibility set composed of a decision-making unit (DMU) with the help of mathematical programming model. The DEA method regards the decision-making unit as a "black box", without giving the form of the functional relationship between variables and the weight of each index, which is conducive to grasping the input–output efficiency of WEF as a whole; on the other hand, the efficiency evaluation based on multiple outputs is conducive to comprehensively considering the impact of WEF consumption on external subsystems such as economy and environment [29].

## 2. Research Method: DEA Model

DEA is a nonparametric estimation method proposed by Charnes and Cooper [30] in 1978 to estimate the effective production frontier by means of linear programming and actual observation data. The idea of DEA is to take each evaluation object as a decision-making unit (DMU), use all the DMUs to form an evaluated group, then use the comprehensive analysis of input and output ratio to determine the effective production frontier, and, finally, combine the distance between each DMU and the effective production frontier to determine whether each DMU is DEA effective. Although there are many methods that can analyze and evaluate the effectiveness of input–output, when it comes to multiple input and output indicators of the same kind, compared with many other methods that are limited to single output indicators, DEA without a specific form of production function can show the advantages of comprehensive analysis of these indicators. DEA can avoid the dimension unification of indicators, and it does not need to consider the weight of input–output indicators, so it can reduce the subjective evaluation of DMUs to a greater extent, simplify the calculation, and reduce the error to a greater extent. The study of WEF input–output is just a system of multiple input indicators and multiple output indicators, and because the weights among the three input indicators of WEF cannot be effectively determined, DEA can better grasp them as a whole. Therefore, it is appropriate to use the DEA model to analyze the effectiveness of WEF input–output.

Banker and others [31] changed the basic assumption of the  $C^2R$  model fixed scale return to variable scale return without changing other conditions, and then decomposed the technical efficiency of the  $C^2R$  model into pure technical efficiency and scale efficiency. Considering that not every possible set of production is consistent with the assumption of constant return on a fixed scale in reality, and the input variable of WEF is the basic variable and given in advance, this paper chose the  $BC^2$  model with variable return on a scale guided by the input to study the input–output efficiency of WEF.

The input BC<sup>2</sup> model is:

$$\min t_0 = \theta - \varepsilon \left( \sum_{i=1}^m s_i^- + \sum_{j=1}^n s_j^+ \right) \text{ s.t. } \begin{cases} \sum_{r=1}^R \lambda_r X_{ir} + s_i^- = \theta X_{i0}, i = 1, 2, \dots, m \\ \sum_{r=1}^R \lambda_r Y_{jr} - s_j^+ = Y_{j0}, j = 1, 2, \dots, n \\ \sum_{r=1}^R \lambda_r = 1 \\ \lambda_r \geq 0, r = 1, 2, \dots, R \\ s_i^- \geq 0, s_j^+ \geq 0, i = 1, 2, \dots, m, j = 1, 2, \dots, n \end{cases} \quad (1)$$

where  $x_{ir}$  ( $i = 1, 2, \dots, m$ ) indicates the  $i$  number of the  $r$  input indicator of the DMU;  $y_{jr}$  ( $j = 1, 2, \dots, n$ ) indicates the  $j$  number of the  $r$  output indicator of the DMU;  $s_i^-$  indicates the input slack variable;  $s_j^+$  indicates the output slack variable; and  $\lambda$  indicates the weight coefficient.

When  $\theta = 1, s_i^- = s_j^+ = 0$ , the DMU is strongly DEA effective. When  $\theta = 1, s_i^- \neq 0$ , or  $s_j^+ \neq 0$ , the DMU is weakly DEA effective. When  $\theta < 1$ , and  $s_i^- \neq 0, s_j^+ \neq 0$ , the DMU is DEA invalid. When  $\theta$  is larger, the DEA efficiency is higher.

When  $\sum_{r=1}^R \lambda_r = 1$ , the scale efficiency of the DMU does not change. When  $\sum_{r=1}^R \lambda_r < 1$ , the scale efficiency of the DMU increases. The smaller the value is, the larger the increasing trend. This means that increasing a certain amount of input can bring more output, so the input should be increased. When  $\sum_{r=1}^R \lambda_r > 1$ , the scale efficiency of DMU decreases. The smaller the value is, the larger the increasing trend. This means that increasing a certain input will lead to less output. At this time, the input should be reduced.

### 3. Construction of Index System and Selection of Data

This paper offers a comparative study on the input–output efficiency of WEF in different regions of China from the perspective of the total index system and the intensity index. Combined with the specific situation of the WEF input and output, and considering the availability of data, this paper constructed the evaluation index system of WEF input and output, which included two levels: taking the water input, energy input, and food input as the input indexes and taking the economic output and environmental impact (divided into consideration and not considered) as output indexes. At the same time, we replaced the specific input indicators in the intensity indicators to carry out a comparative analysis under the unified perspective. In the total index system, water input was represented by total water consumption, energy input was represented by total energy consumption, and grain input was represented by total grain consumption. In the first intensity index (intensity index 1) system and the second intensity index (intensity index 2) system, water input was represented by per capita water consumption, energy input was also represented by per capita energy consumption, while grain was represented by per capita energy consumption. The food input intensity index 1 was expressed by per capita cultivated land area, and intensity index 2 was expressed by per capita grain consumption expenditure. In order to reduce the impact of the change in the output indicators on the comparative analysis of three groups of input indicators, in these three indicator systems, the economic output was expressed by per capita GDP (gross domestic product), and the environmental impact was expressed by the environmental pollution index. Here, the environmental pollution index referred to the emission of SO<sub>2</sub>, nitrogen oxide, particulate matter, COD (chemical oxygen demand), and industrial solids. The output index was obtained by weighting five factors of the volume of solid waste. The index system of the WEF input and output in 30 provinces of China in 2019 is shown in Table 1.

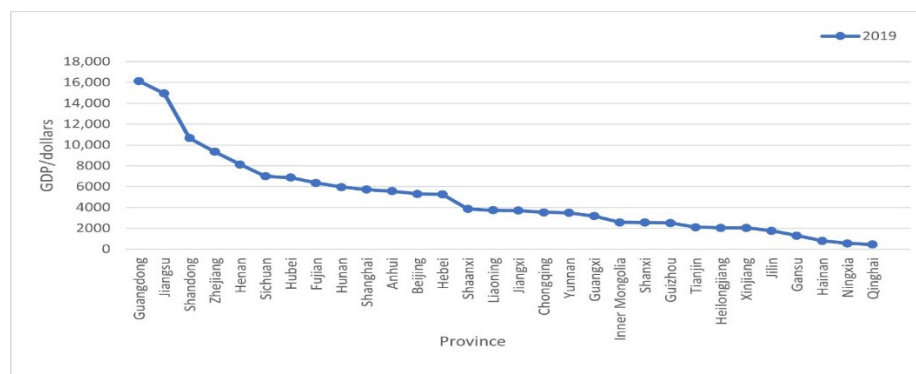
**Table 1.** Input–output index system of the DEA model of WEF.

Categories		Indicators	Codes	Specification	Units
Input	Intensity	Water	Water consumption per capita	X1	$\frac{\text{Total water consumption}}{\text{Total residents}}$ $\text{m}^3 \cdot \text{TR}^{-1}$
		Energy	Energy consumption per GDP	X2	$\frac{\text{Total energy consumption}}{\text{The amount of GDP}}$ $\text{Ton} \cdot \text{USD}^{-1}$
		Production based	Cultivated land area per capita	X3	$\frac{\text{Total amount of cultivated land}}{\text{Total residents}}$ $\text{Hm}^2 \cdot \text{TR}^{-1}$
		Food	Food consumption expenditure per capita	X4	$\frac{\text{Total amount of food consumption expenditure}}{\text{Total residents}}$ $\text{USD} \cdot \text{TR}^{-1}$
	Quantity	Water	Total water consumption	X5	The amount of water consumed in provincial district $\text{m}^3$
		Energy	Total energy consumption	X6	The amount of energy consumed in provincial district $10^4 \text{ Ton}$
		Food	Total expenditure on food consumption	X7	The amount of expenditure on food consumption by all residents in provincial district $10^4 \text{ USD}$
Output	-	Social-economy	GDP per capita	Y1	$\frac{\text{The amount of GDP}}{\text{Total residents}}$ $\text{USD TR}^{-1}$
	-	Environment	Environmental pollution	Y2	f(SO <sub>2</sub> , nitrogen oxide, particulate matter, COD, and industrial solid) -

The data used for each indicator in this paper are from the China Statistical Yearbook 2020 [32] and the China Energy Statistical Yearbook 2020 [33], and some of them are processed.

#### 4. Empirical Analysis

The development level of GDP in China's provinces in 2019 is shown in Figure 1. After processing the index data of 30 provinces in China from 2019, the calculation was carried out with the help of Windeap 2.1 software (Centre for Efficiency and Productive Analysis, the University of Queensland, Australia). According to the seven regions divided by China's geographical regions, we obtained the DEA comprehensive efficiency value (Table 2), pure technical efficiency value and scale efficiency value (Table 3), the average value of various efficiency values in seven regions (Figure 2), and the histogram of efficiency values of each indicator system (Figures 3–5).

**Figure 1.** GDP of China's provinces in 2019.

**Table 2.** Results of comprehensive input–output efficiency of the WEF nexus.

Regions	Provinces	Production Based Intensity		Consumption Based Intensity		Quantity		
		Contains	Does Not Contain	Contains	Does Not Contain	Contains	Does Not Contain	Contains Only
North China	Beijing	1	1	1	1	1	1	0.699
	Tianjin	1	0.586	1	0.586	1	0.808	1
	Hebei	0.243	0.227	0.53	0.512	0.108	0.108	0.049
	Inner Mongolia	0.413	0.264	0.76	0.591	0.254	0.254	0.173
	Shanxi	0.106	0.106	0.636	0.636	0.299	0.299	0.07
East China	Shanghai	0.253	0.225	0.525	0.496	0.184	0.184	0.088
	Shandong	0.368	0.12	1	0.481	0.36	0.341	0.36
	Jiangsu	0.165	0.054	0.805	0.391	0.197	0.188	0.197
	Anhui	0.663	0.65	0.749	0.742	0.64	0.64	0.332
	Zhejiang	0.48	0.48	0.933	0.933	0.217	0.217	0.037
	Fujian	0.522	0.443	0.686	0.623	0.225	0.225	0.149
	Jiangxi	0.302	0.198	0.646	0.497	0.176	0.176	0.092
Central China	Henan	0.44	0.42	0.699	0.684	0.364	0.364	0.155
	Hubei	0.299	0.173	0.74	0.527	0.245	0.245	0.146
	Hunan	0.372	0.372	0.674	0.674	0.118	0.118	0.042
Northeast China	Heilongjiang	0.51	0.269	1	0.696	0.14	0.139	0.104
	Jilin	0.384	0.26	0.842	0.673	0.229	0.229	0.116
	Liaoning	0.313	0.181	0.734	0.515	0.161	0.161	0.096
Southwest China	Sichuan	0.376	0.376	0.52	0.52	0.118	0.118	0.046
	Chongqing	0.271	0.103	0.845	0.441	0.186	0.185	0.168
	Guizhou	0.491	0.168	1	0.41	1	1	1
	Yunnan	0.693	0.364	0.996	0.588	0.452	0.398	0.398
South China	Guangxi	0.365	0.218	0.625	0.446	0.117	0.117	0.089
	Guangdong	0.439	0.183	1	0.584	0.283	0.282	0.237
	Hainan	0.347	0.177	0.799	0.544	0.217	0.216	0.15
Northwest China	Shaanxi	0.569	0.328	1	0.737	0.323	0.323	0.239
	Ningxia	0.346	0.093	0.949	0.373	0.328	0.255	0.328
	Gansu	0.385	0.133	1	0.493	1	1	1
	Qinghai	0.155	0.063	1	0.609	1	1	0.894
	Xinjiang	0.089	0.051	0.738	0.556	0.27	0.27	0.158
Average	—	0.412	0.276	0.814	0.585	0.374	0.362	0.287

‘contains’ indicates that the output index includes two indexes: per capita GDP and environmental pollution index. ‘Does not contain’ indicates that the output index only includes per capita GDP. ‘contains only’ indicates that the output index includes only the environmental pollution index.

**Table 3.** Calculation results of the pure technical efficiency and scale efficiency of WEF input–output in 30 provinces of China in 2019.

Regions	Provinces	Production Based Intensity (Contains)		Consumption Based Intensity (Contains)		Quantity (Contains Only)	
		Pure Technical Efficiency	Scale Efficiency	Pure Technical Efficiency	Scale Efficiency	Pure Technical Efficiency	Scale Efficiency
North China	Beijing	1	1	1	1	1	0.699
	Tianjin	1	1	1	1	1	1
	Hebei	0.756	0.322	0.917	0.577	0.144	0.339
	Shanxi	0.891	0.463	1	0.76	0.345	0.502
	Inner Mongolia	0.251	0.424	0.841	0.756	0.223	0.317
East China	Shanghai	0.608	0.416	0.753	0.697	0.201	0.44
	Jiangsu	0.448	0.821	1	1	0.424	0.848
	Zhejiang	0.244	0.675	0.858	0.938	0.277	0.708
	Anhui	0.679	0.977	0.75	0.999	0.37	0.897
	Fujian	0.637	0.753	1	0.933	0.095	0.387
	Jiangxi	0.673	0.776	0.78	0.88	0.176	0.848
	Shandong	0.557	0.543	0.921	0.701	0.17	0.543
Central China	Henan	0.643	0.685	0.863	0.811	0.219	0.709
	Hubei	0.533	0.561	0.956	0.774	0.259	0.566
	Hunan	0.826	0.45	0.985	0.685	0.116	0.361
Northeast China	Liaoning	0.77	0.662	1	1	0.149	0.695
	Jilin	0.551	0.697	0.924	0.911	0.162	0.714
	Heilongjiang	0.517	0.606	0.902	0.814	0.157	0.611
Southwest China	Chongqing	0.656	0.573	0.802	0.648	0.091	0.508
	Sichuan	0.392	0.69	0.852	0.992	0.239	0.703
	Guizhou	1	0.491	1	1	1	1
	Yunnan	0.777	0.892	1	0.996	0.415	0.957
South China	Guangdong	0.633	0.576	0.81	0.772	0.15	0.598
	Guangxi	0.628	0.698	1	1	0.324	0.732
	Hainan	0.595	0.583	0.913	0.875	0.249	0.601
Northwest China	Shaanxi	0.783	0.726	1	1	0.302	0.792
	Gansu	0.45	0.768	0.964	0.984	0.412	0.797
	Qinghai	0.42	0.917	1	1	1	1
	Ningxia	0.186	0.831	1	1	0.975	0.917
	Xinjiang	0.153	0.579	0.823	0.897	0.245	0.645
Average	—	0.609	0.672	0.92	0.88	0.363	0.681



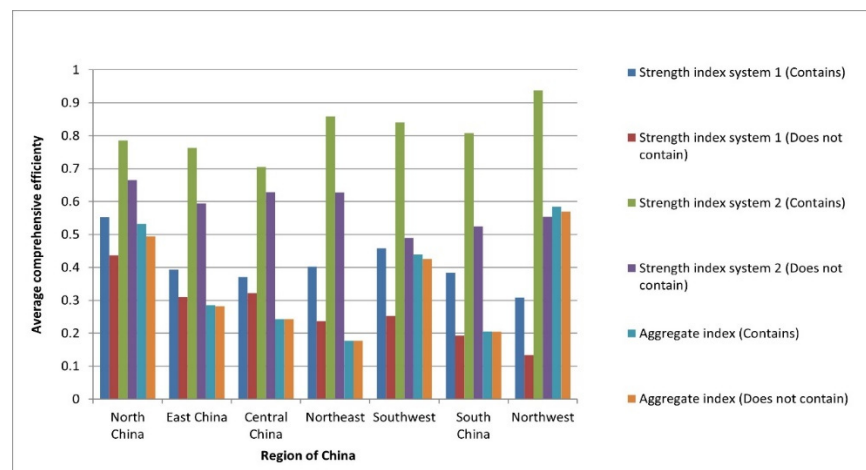


Figure 2. Average comprehensive efficiency of each region.

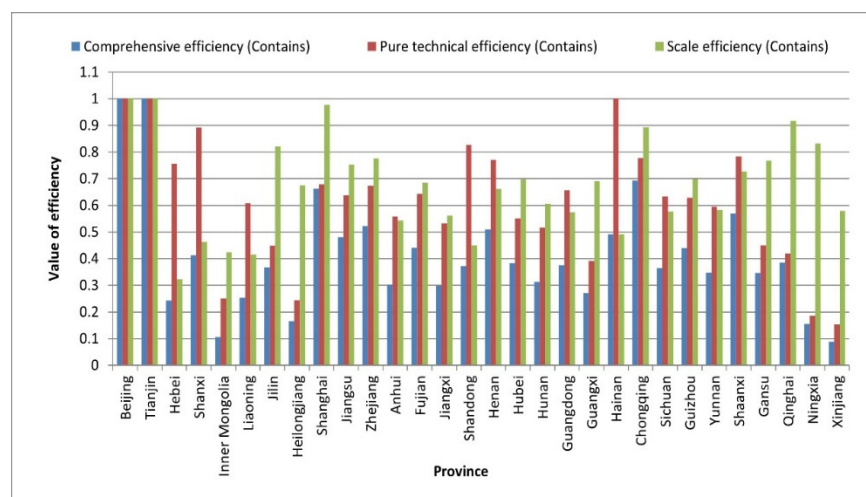


Figure 3. Efficiency values of production based intensity index.

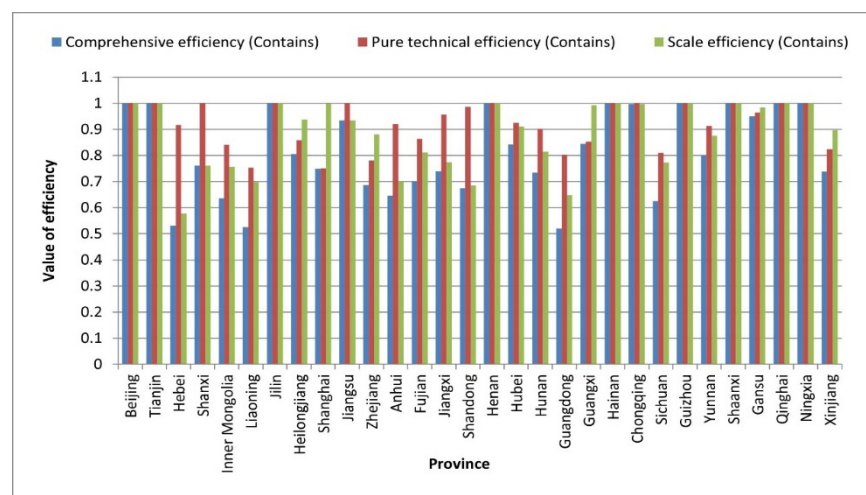


Figure 4. Efficiency values of consumption based intensity index.



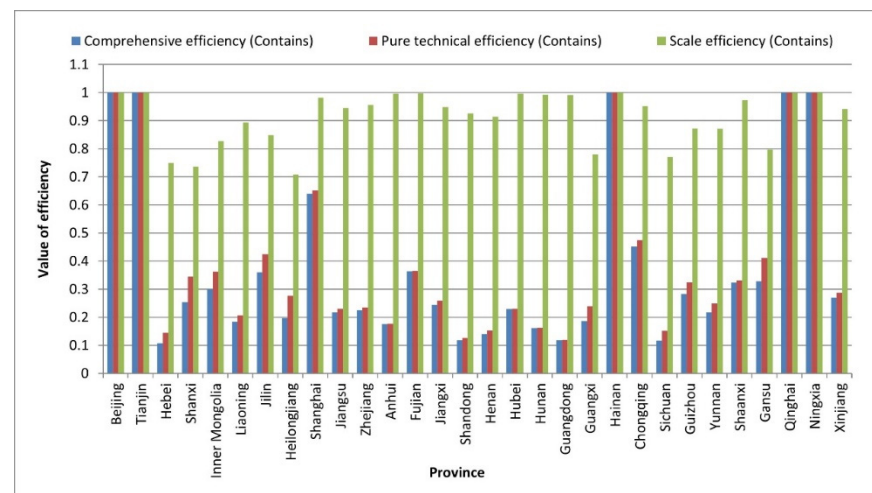


Figure 5. Efficiency values of quantity index.

According to the data in Table 2, in the intensity index system with per capita cultivated land area as the food input index, the two provinces with a comprehensive efficiency value greater than 0.9 were Beijing and Tianjin. The four provinces with the lowest comprehensive efficiency value were Shanxi, Jiangsu, Qinghai, and Xinjiang. The comprehensive efficiency values of these four provinces were all lower than 0.2. In intensity index system 1 (Contains), the WEF input and output in Beijing and Tianjin were effective, while in intensity index system 1 (Does not Contain), only Beijing's WEF input and output were effective. In the intensity index system 1 with per capita food consumption expenditure as the food input index, there were several provinces with effective WEF input–output; on the whole, the comprehensive efficiency of most provinces reached more than 0.5, and there was no province with particularly low input–output efficiency. This shows that China's WEF development policy is based on the overall perspective of national common development, rather than only considering the development of some regions. Although the overall level was not low, there were not many provinces whose efficiency value was above 0.9, and more provinces whose comprehensive efficiency was between 0.5 and 0.75; so, it is still significant to further improve the input–output efficiency of WEF. In intensity index system 2 (Contains), the WEF input and output in nine provinces were effective, while in intensity index system 2 (Does not Contain), only Beijing's WEF input and output were effective.

In the intensity index system, when the output index took environmental impact into account, the comprehensive efficiency values of Beijing, Tianjin, Shanxi, Zhejiang, Hunan, and Sichuan remained the same as when not considering the impact on the environment, which means that for the six provinces in the process of economic creation, the environmental pollution is relatively small. After considering the environmental impact, the efficiency of most provinces was reduced.

Combined with Figure 1 and Table 2, we can see that the input–output level of WEF in regions with a high economic development level was not high, and that in regions with a relatively low economic development level, the input–output level of WEF was not the lowest. That is to say, when evaluating the national economy, we should consider the input–output efficiency of development comprehensively; we should not solely emphasize the economic development of the country ignoring the WEF resources invested, thus causing the waste of domestic resources. Therefore, it is more reliable to use the input–output efficiency to evaluate the utilization of WEF when evaluating the economic development of each province.

Under the index system of consumption based intensity, the input–output of WEF in the eight provinces was invalid, and the efficiency value of Shandong, Guizhou, and Gansu was very low without considering the impact on the environment. When the output index took the impact on the environment into account, the input–output efficiency became

effective. The reason for this gap is that these three provinces pay special attention to the protection of the ecological environment. There is no pollution in the local environment to a large extent. To take Guizhou as an example, when the impact on the environment was not considered, Guizhou's per capita GDP ranked 24th in the country, which belonged to the middle and lower levels. On the surface, Guizhou's economic development level is relatively low, but, in fact, it does not cause damage to the environment, which is conducive to the sustainable development of the economy. In the long run, compared with other provinces, Guizhou does not need to spend as much energy dealing with the environmental damage caused by economic development, which actually brings greater economic advantages. When considering the impact on the environment, Guizhou's WEF input–output was effective, while the input–output of provinces with a high level of economic development was indeed invalid when considering this factor. Therefore, compared with first achieving development and then governing environmental problems, development and prevention at the same time are worth the government's consideration when formulating economic development policies.

After comparing the two index systems of the intensity index, it can be seen that when using the DEA model to analyze the average WEF input–output efficiency in different provinces, the average value changed with the change in input index. Although the overall efficiency value and average efficiency value changed with the change in input index, the provinces on the efficiency frontier, that is to say, the provinces that achieved DEA input–output efficiency, did not become invalid with the change in input index. Provinces with poor comprehensive efficiency may also have higher efficiency in other aspects, such as how Zhejiang's comprehensive efficiency in intensity indicator system 2 was significantly higher than that in intensity indicator system 1. Provinces with comprehensive efficiency in the middle may have good input in some aspects. However, in other aspects, there may be greater waste. For example, the comprehensive efficiency ratio of Ningxia, Gansu, Qinghai, and Xinjiang in intensity index system 1 was significantly lower than that in intensity index system 2, which shows that there is a serious waste problem when taking the per capita cultivated land area as the input index.

In the total amount index system, there were five provinces with effective WEF input–output: Beijing, Tianjin, Guizhou, Gansu, and Qinghai. Compared with these effective provinces, the comprehensive efficiency of other provinces was significantly lower, the overall two-level differentiation was serious, and the average comprehensive efficiency was low. The provinces with effective input–output are mainly located in North China, Southwest China, and Northwest China. Compared to these three regions, the comprehensive efficiency of other regions was significantly lower, and the regional differences were obvious. As shown in Figure 2, the average value of comprehensive efficiency in Northwest China was particularly low under intensity index system 1, which is due to the poor environment in Northwest China and the small cultivated land area, resulting in the low level of per capita cultivated land area. However, the average value of comprehensive efficiency in Northwest China under intensity index system 2 was high because the grain output in this region is small, so it needs to consume the grain supplied by other regions. The quantity index system also reflected this point, so it was biased and lacked objectivity to determine the input–output efficiency of WEF in Northwest China only through intensity index system 1. The large population in Central China and East China made it difficult to measure the input–output efficiency of WEF with per capita GDP as the output index, which does not take population into account. It did not reflect the input–output efficiency of the total index as it used the WEF consumption per capita. Therefore, the two regions have two different ways to measure the intensity index system and the total index system. There is also a huge contrast in law. Southwest China, South China, and Northwest China pay attention to environmental protection. When the impact on the environment was taken into account, the input–output efficiency of WEF was correspondingly improved.

In general, the pure technical efficiency in intensity index system 2 was relatively high, while the pure technical efficiency in the total amount index system had an obvious

two-level differentiation. Except for several provinces with pure technical efficiency, the pure technical efficiency in other provinces was generally low. From the overall point of view of scale efficiency, the overall water body of scale efficiency in intensity index system 2 and the total amount index system was relatively high, but the number of provinces that achieved scale efficiency in the intensity index system was less than that of pure technical efficiency. Pure technical efficiency refers to the ability to obtain an output with a certain amount of resource input. In intensity index system 1, the output of Ningxia and Xinjiang was the lowest with a certain amount of WEF input. This is because these two provinces are located in the Northwest with a small population. Compared with a large number of colleges and universities in the East, these two provinces had the lowest output. Because of the lack of scientific and technological talents and the relatively low level of science and technology, it is necessary for the government to promote welfare policies to introduce advanced talents and technologies to these less educated provinces to further improve their ability to obtain an output. According to Figure 3, in the system of production based on the intensity index, the scale efficiency level was generally high. According to the comprehensive efficiency = pure technical efficiency \* scale efficiency, the ineffectiveness of the comprehensive efficiency of these provinces was largely affected by the low level of pure technical efficiency. As shown in Figure 4, in the system of consumption based on the intensity index, the pure technical efficiency level was very high, the ineffectiveness of the comprehensive efficiency of these provinces was largely affected by the low level of scale efficiency. According to Figure 5, in the total indicator system, the scale efficiency value of each province was higher—much higher than the pure technical efficiency value—which means that in the total indicator system, the reason for the low comprehensive efficiency was the low pure technical efficiency value. In intensity index system 2, the scale efficiency of each province was mostly between 0.7 and 0.9. The most important reason for the inefficiency of the comprehensive efficiency was that the pure technical efficiency is particularly low, and improving the pure technical efficiency is the primary problem to be solved at present.

## 5. Conclusions

This paper studied the impact of the water–energy–food nexus on the economy and calculated the value of efficiency by the DEA method. In terms of the index system, this paper established an intensity index system and quantity index system. In terms of input indicators, it was divided into water input, energy input, and food input. In terms of output indicators, it was divided into economic output and environmental impact output (considered and not considered). The value of efficiency changed with different index systems. Overall, the pure technical efficiency value of most provinces was low, and the technical capacity limited the output capacity of WEF. Most of these regions are located in the western provinces. These provinces should be provided with science and technology and scientific and technological talents to improve the output efficiency.

Although the GDP of some provinces increased rapidly every year, after considering the WEF investment, it is found that there was a certain waste of resources in some areas. In areas with a high economic development level, the input–output level of WEF was not high, and in areas with a low economic development level, the input–output level of WEF was not the lowest. Therefore, simply using GDP growth to measure the economic situation of provinces is unscientific, and resource utilization efficiency should be considered. Only emphasizing the growth rate of national GDP will place the input–output efficiency of WEF resources into an unimportant position. Ignoring the input–output efficiency of WEF resources will result in the waste of domestic resources and make the insufficiency of resources more severe.

In the quantity index system, the polarization was serious on the whole, and the effective provinces were distributed in North China, Southwest China, and Northwest China. Compared with these regions, the efficiency of other regions was significantly lower. In the intensity index system, the output of multiple provinces was effective.

Generally speaking, the comprehensive efficiency of most provinces was high. This shows that China's WEF investment is based on the overall perspective of national common development, rather than only considering the development of some regions. The overall change in these three resources is of great significance to the efficient development of the urban economy, which needs more attention from the international community. The comprehensive calculation of the input–output efficiency of WEF resources can define a correct direction for countries around the world to make full and effective use of the input resources, combine the three resources of WEF as a whole to analyze the input–output efficiency of resources, take effective measures to improve the utilization efficiency of WEF resources, find the best investment point to promote the development of national economy, allocate WEF resources reasonably, and avoid a large amount of waste of resources, thus having a far-reaching impact on alleviating the current situation of national resource tension and effectively promoting the coordinated development of economy between different countries and regions.

Although the overall level was good, the input–output efficiency of WEF still needs to be further improved. After considering the environmental impact, the efficiency values of six provinces did not change, indicating that these provinces pay attention to the ecological environment in the process of economic development, which has a good governance effect on environmental pollution. However, the efficiency value of most provinces decreased after considering the environmental impact. For areas with low economic development, when there is little environmental pollution, it can bring greater economic advantages to the region; that is, the region does not need to spend more effort to deal with the environmental damage caused by environmental development, which is conducive to sustainable economic development. At the same time as considering economic development, environmental protection should also be considered. The development and governance model at the expense of the environment is not the most effective economic development model. As obvious economic achievements are obtained, the environment will be seriously damaged, which will not only take a lot of time and energy to deal with but also will harm people's environment. Production and life affect people's happiness. In particular, the current environmental problems are the focus of attention of all countries in the world. In the development of national economy, we should always consider environmental prevention and control. Only by protecting the environment and creating good environmental conditions for economic development can we achieve the sustainable development of a national economy.

This paper did not collect data over the years to conduct a longitudinal analysis of the trend of time change, which is a limitation of this study but also the motivation for the next in-depth study. This paper was only based on the data of 30 provinces in China. Due to the different economic development and social systems in different countries, the WEF input–output efficiency of a country cannot fully reflect the situation of all countries in the world. Next, we need to combine the development data of each country to carry out a comparative analysis among different countries in the world to further improve the WEF nexus index system.

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