water

Article

The Impact of New Urbanization on Water Ecological Civilization: Based on the Empirical Analysis of Prefecture-Level Cities in Jiangxi, China

Daxue Kan [1,*], Wenqing Yao [2], Lianju Lyu [1] and Weichiao Huang [3]

[1] School of Economics and Trade, Research Center of Water Economics and Management, Nanchang Institute of Technology, Nanchang 330099, China; 2011994310@nit.edu.cn
[2] Business Administration School, Nanchang Institute of Technology, Nanchang 330099, China
[3] Department of Economics, Western Michigan University, Kalamazoo, MI 49008-5330, USA; huang@wmich.edu
* Correspondence: 2011994292@nit.edu.cn

Abstract: This study aims to improve the level of water ecological civilization (WEC) in the urbanization process based on the data of prefecture-level cities in Jiangxi, China, from 2011 to 2020. This paper applies spatial analysis methods such as the natural fracture method, barycenter transfer model, and standard deviation ellipse method to explore the spatiotemporal evolution characteristics of WEC and the impact of new urbanization (NU) on WEC. The NU pilot construction is further regarded as an exogenous impact, and the "net effect" of the NU pilot policy on WEC is tested. The results showed that (1) the spatial distribution pattern of the east–west polarization of WEC was broken, and a spatial distribution pattern of strong in the north and weak in the south was gradually formed. (2) NU contributes to improving the WEC level, among which population, digital, and green urbanization can significantly promote the WEC level, while economic urbanization impedes the improvement of the WEC. This conclusion is still valid following a series of robustness tests. (3) heterogeneity analysis showed that the impact of NU in improving the level of WEC is more evident in cities with scarce water resources, non-resource-based cities, and non-old industrial base cities after the implementation of NU planning. (4) NU's pilot policy can help improve the WEC level in the region and the WEC level in neighboring regions through the spillover effect of policy. Therefore, it is necessary to make use of the superimposed effect of multidimensional urbanization based on urban characteristics, implement differentiated policy, break administrative barriers, make use of the spatial spillover effect of pilot policy, and improve the WEC level.

Keywords: urbanization; water ecological civilization; spatiotemporal evolution; multiperiod difference-in-difference model; Jiangxi, China

check for updates

Citation: Kan, D.; Yao, W.; Lyu, L.; Huang, W. The Impact of New Urbanization on Water Ecological Civilization: Based on the Empirical Analysis of Prefecture-Level Cities in Jiangxi, China. *Water* **2024**, *16*, 331. https://doi.org/10.3390/w16020331

Academic Editors: Rubén Jerves-Cobo and Wout Van Echelpoel

Received: 27 December 2023
Revised: 16 January 2024
Accepted: 17 January 2024
Published: 19 January 2024

1. Introduction

Since the beginning of the 21st century, the rapid development of urbanization in developing countries and the resultant climate change have exacerbated the deterioration of the water ecological environment (WEE), resulting in insufficient water resource supplies and difficulties meeting local basic needs. Similarly, urbanization in China has achieved remarkable results since the country's reform and opening-up. The urbanization rate of permanent residents increased from 17.92% in 1978 to 64.72% in 2021, maintaining steady growth at an average annual rate of 1.06%, higher than the world average in the same period. However, because China has ignored the implications of urbanization for a long time, the process has focused on speed and neglected quality. As a result, the imbalance between water supply and demand is apparent. In China, per capita water resources are only a quarter of the world's, and 24 provinces experience water shortages, accounting for about 77%. The volume of water resources that can be exploited and utilized comprises less than 40% of the total water resources, while the area of a water resource overload zone or critical overload zone accounts for about 53% of the national land area. Furthermore, water resource utilization efficiency is low; China's water consumption per unit of gross domestic product (GDP) is about four times higher than the world average, about ten times that of the United States, and 25 times that of Japan. Additionally, water environment pollution is severe; in 2021, among the 1900 national groundwater-quality monitoring sites, 20.6% were classified as V. In 2022, among the 3641 national surface water monitoring sections, 12.1% were classified as IV–V (i.e., not meeting the standards of a drinking water source). Finally, the water ecological balance is damaged, adversely affecting the improvement of the region's water ecological civilization (WEC) level. WEC aims to integrate the concept of ecological civilization into all aspects of water resource development—utilization, management, allocation, conservation, and protection—to achieve the intensive, safe, and sustainable use of water resources; support the green development of economy and society; and achieve harmonious coexistence between humankind and water, which is an important part of ecological civilization. Water resource conservation and ecological protection are the top priorities and key to WEC construction [1,2]. At the same time, the current urbanization rate of China is lower than that of developed countries, and the urbanization rate of the household registration population in 2021 was only 46.70%. Therefore, combined with the law of the Northam curve and referring to the urbanization development experience of developed countries, China's urbanization will maintain a rapid development trend, which may increase the problems affecting WEC and affect Beautiful China Construction. Therefore, in the process of urbanization, how to promote the construction of WEC, alleviate the imbalance between the supply and demand of water resources, improve the water resource utilization efficiency (WRUE), improve the quality of the water environment, and maintain the balance of water ecology have become problems that the Chinese government must solve urgently. To this end, the Chinese government proposed the concept of "NU" in 2012, which aims to overcome the shortcomings of traditional urbanization that emphasizes speed and ignores quality. NU also attaches importance to the connotation construction of urbanization, strives to improve the urbanization quality, and coordinates the harmonious coexistence of man and nature. Subsequently, in 2017, based on promoting NU, the Chinese government incorporated the concept of green development into the requirements of NU construction, clarifying the importance of vigorously promoting the construction of ecological civilization and a resource-saving and environment-friendly society. In 2022, the Chinese government had even higher requirements for NU, aiming to accelerate the green transformation of the development mode and promote the formation of green and low-carbon production modes and lifestyles. Green environmental protection and intensive development have become important features and inevitable requirements of NU; however, it remains unclear whether NU can adhere to the concept of green development to become the endogenous driving force in promoting the construction of WEC.

Therefore, this paper takes Jiangxi Province, China, as an example. This paper uses the principal component analysis method to measure the status quo of WEC in 11 prefecture-level cities in the province from 2011 to 2020. We then apply spatial analysis methods, such as the natural fracture method, barycenter transfer model, and standard deviation ellipse method, to explore the spatial–temporal evolution characteristics of WEC. The impact of NU on WEC was explored from the four dimensions of population, economic, digital, and green urbanization. The multiperiod difference-in-differences model (MDID; it is a commonly used method to evaluate the effect of policies. Its principle is to evaluate the changes in observed variables under the policy occurrence and no policy occurrence scenarios based on a counterfactual framework) was further used to test the effect of the NU pilot policy on WEC, providing a policy reference for promoting the integration of NU and WEC construction. The study also provides a reference for other developing countries to solve water pollution problems in the process of urbanization.

2. Literature Review

The existing research mainly includes three aspects. (1) The first is the impact of NU on ecological civilization. The literature mainly focuses on the impact of NU on carbon emissions, environmental pollution, and ecological environment quality. Li et al. took the counties around Poyang Lake in China as the research object. Using the spatial Durbin model, they verified that NU is conducive to reducing carbon emission intensity with a pronounced spatial spillover effect [3]. Other studies empirically found that NU and carbon emissions from tourism and industry have nonlinear effects at the industry level. The former has a significant "N-type" curve [4], while the latter shows an inverted "N-type" relationship [5]. Lv and Gao, Cai and Zhang found that NU is conducive to improving environmental pollution in the region; however, a negative spatial spillover effect occurs. Related to the former, findings indicate that population urbanization is the cause of worsening environmental pollution [6]. As for the latter, the authors believe that population urbanization is conducive to the centralized management of pollutant discharge through population aggregation, and population flow promotes the spillover of knowledge and technology and inhibits environmental pollution in local and surrounding areas [7]. With the help of the STIRPAT and spatial metrology models, Xie et al. and He et al. found that NU has a positive spatial spillover effect on urban ecological environment quality [8,9]. Furthermore, Cheng and Wang, Xiao et al., and Yang et al. used the difference-in-difference method (DID) to empirically show that the NU pilot policy is conducive to the development of urban ecological civilization [10–12]. (2) The second aspect is the evaluation of WEC. Scholars have constructed different index systems using the entropy method, principal component analysis method, analytic hierarchy process, and fuzzy comprehensive evaluation method to measure the WEC situation in different regions of China. These regions include provinces, the Yangtze River Economic Belt, the Yellow River basin, pilot cities of WEC, urban agglomerations, provincial capital cities, and prefecture-level cities [13–22]. Most studies show that since the implementation of the WEC pilot policy, the WEC is increasingly improving, and the efficiency of water resource utilization and the quality of the water environment have been significantly improved in pilot cities. Furthermore, the contradiction between water supply and demand and the imbalance of water ecology have been solved in pilot cities, and the spatial distribution pattern of WEC in China is "strong in the east and west, weak in the middle." However, in nonpilot cities, the WRUE is low, the contradiction between water supply and demand is still prominent, the WEE problem is still serious, and the construction of the WEC needs to be strengthened. (3) The final aspect is the impact of urbanization on water resource utilization (WRU). Scholars mainly analyzed the impact of urbanization on the efficiency and quantity of WRU. Kan and Lv and Zeng et al. analyzed the impact of urbanization on WRUE by taking urban agglomerations in China. Their results showed that improving urbanization quality is conducive to improving water resource use efficiency. Improving urbanization level and speed is not conducive to improving WRUE [23,24]. Meinzen-Dick and Appasamy found that since the WRUE of the primary industry was lower than that of the secondary and tertiary industries, urbanization improved WRUE by reducing the proportion of WRU of the primary industry and increasing that of the secondary and tertiary industries [25]. Furthermore, Hai et al. decomposed WRUE into domestic water utilization efficiency, industrial water utilization efficiency, and agricultural water utilization efficiency. They empirically determined that urbanization level has evident heterogeneity in the three types of water utilization efficiency. This result is reflected explicitly in the fact that urbanization is conducive to improving domestic water utilization efficiency but not conducive to improving industrial and agricultural water utilization efficiency [26]. Zhang et al. and Qin et al. studied the effects of urbanization on water resource consumption, determining that population and economic urbanization increased water resource consumption while industrial urbanization decreased water resource consumption [27,28].

The existing studies have provided rich and profound insights for understanding the impact of NU on ecological civilization, evaluating WEC, and evaluating the impact of urbanization on WRU, laying a solid foundation for this study; however, regarding research content, the above literature rarely discusses the impact of NU on WEC. While Kan et al. took the Yangtze River Economic Belt in China as a case to study the coordination of NU and WEC and its driving factors [2], most of the literature only evaluates WEC [19]. Some scholars have conducted studies on the coupling coordination between urbanization and water resources, revealing that this coupling coordination varies across different stages of urbanization. However, overall, there is a tendency for the coupling coordination level between urbanization and water resources to increase in most regions [29–32]. Additionally, the literature has analyzed the impact of changes in water resources on urbanization, indicating that regions with limited water resources tend to adopt a water-saving mode during their urbanization development. Conversely, regions with abundant water resources often witness a higher proportion of water-consuming industries within their industrial structure of urbanization and exhibit lower levels of environmental regulation, leading to more severe water pollution [33–35]. Of particular relevance to this study is the analysis of the impact of changes in water resources in Poyang Lake, Jiangxi, on local urbanization development. Some scholars have found that the changes in water resources in Poyang Lake have influenced urbanization development through factors such as urban population size, infrastructure, industrial arrangement, and the road network [36–38]. Water resource utilization mentioned in the above literature is only one component of WEC. WEC also includes water pollution control, water environment conditions, and water ecological imbalance restoration, so the impact of urbanization on water resource utilization cannot be equated with the impact of urbanization on WEC. Therefore, the possible marginal contributions of this paper are as follows. (1) By differentiating existing analysis methods of WEC by using methods such as the natural fracture method, barycenter transfer model, and standard deviation ellipse method, this paper analyzes the spatiotemporal evolution of WEC in Jiangxi in detail, thereby enriching the existing evaluation literature on WEC. (2) We incorporate digital urbanization into NU's index system and investigate the impact of NU on WEC. This study is the first study in China that provides empirical evidence for the impact of urbanization on WEC at the city level and expands the relevant research on WEC. (3) The NU pilot construction is regarded as an exogenous impact, and the "net effect" of the NU pilot policy on WEC is tested for the first time. This approach provides empirical support for further expanding the scope of the NU pilot project and provides a scientific basis for the national environmental policy to improve and accelerate the construction of WEC.

3. Materials and Methods

3.1. Research Area

Jiangxi is an eastern province of China, stretching from the banks of the Yangtze River in the north to hilly areas further south. Jiangxi covers an area of 167,000 square kilometers, with a population of 45 million, and is divided into 11 cities (Nanchang, Ganzhou, Jiujiang, Fuzhou, Yingtan, Jingdezhen, Pingxiang, Yichun, Xinyu, Ji'an, and Shangrao), as shown in Figure 1. Jiangxi has a warm and humid climate with cold springs and winters, hot summers, and dry autumns; thus, accounting for its four distinct seasons, Jiangxi enjoys a subtropic humid monsoon climate. The annual rainfall averages 1400–1800 mm, and the average temperature is 3–9 °C in January and 27–31 °C in July. Jiangxi is renowned for the natural beauty of its misty mountains and freshwater lakes. The Gan River dominates the landscape, flowing through the length of the province from south to north. It enters Poyang Lake, the largest freshwater lake in China, in the north. The province is surrounded on three sides by mountains and hills, with hilly lands occupying its central part and a vast plain in its northern part. There are more than 2400 rivers of various sizes in Jiangxi Province. The five major waterways are the Ganjiang, Fuhe, Xinjiang, Xiuhe, and Raohe Rivers, all draining into the Poyang Lake; thus, Jiangxi Province is endowed with rich water resources.

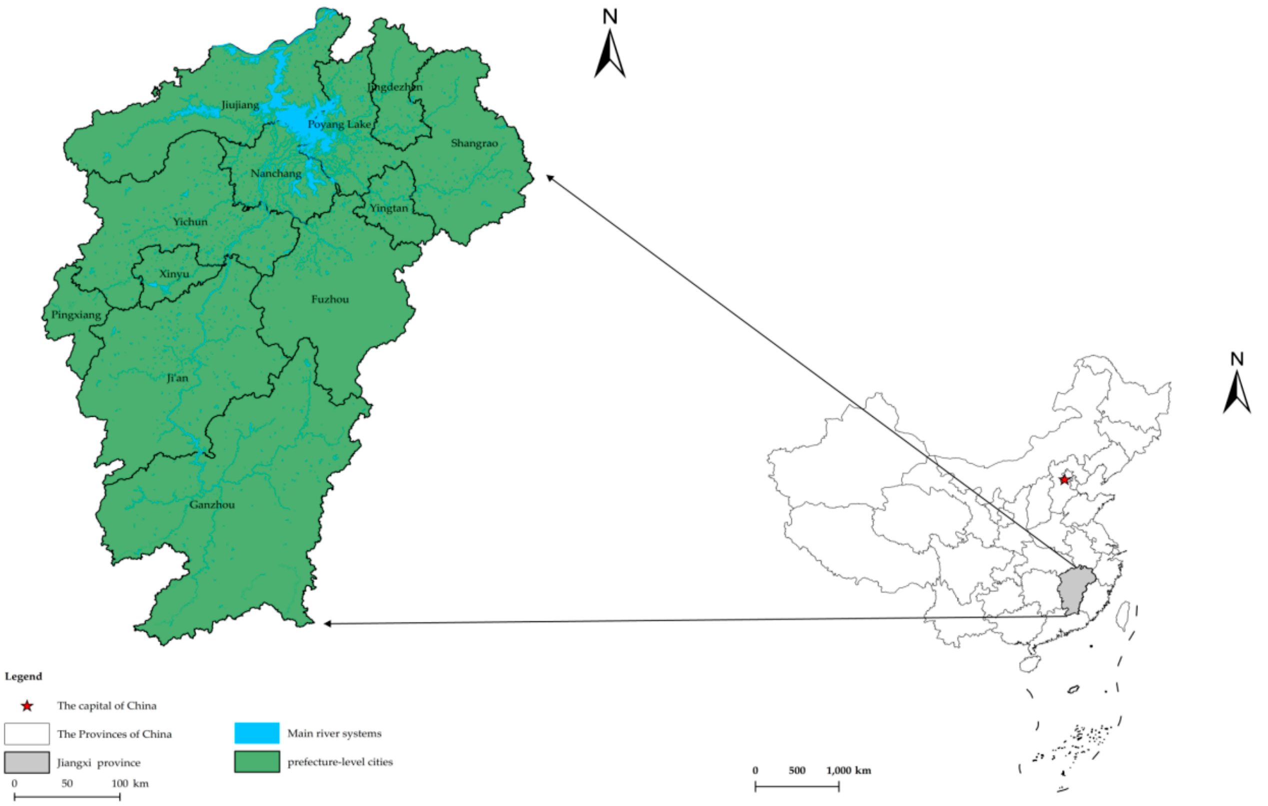

Figure 1. Map of the Jiangxi Province.

3.2. Model Construction

Currently, a minimal number of studies have examined the influencing factors of WEC. This paper refers to the academic research on the impact of urbanization on water resource utilization efficiency and quantity [23,27]. In this paper, WEC is the explained variable, and NU is the explanatory variable. This paper also includes population urbanization (*PUR*), economic urbanization (*EUR*), digital urbanization (*DUR*), green urbanization (*GUR*), and control variables such as human capital (*HUM*), opening-up (*OPE*), and financial support (*FIN*). The following panel data model is constructed:

$$lnWEC_{it} = a_0 + a_1 lnNU_{it} + a_2 lnHUM_{it} + a_3 lnOPE_{it} + a_4 lnFIN_{it} + u_i + \varphi_t + \varepsilon_{it} \tag{1}$$

Among them, *i* represents the 11 cities, and *t* represents the year; the sample period is 2011–2020. u, φ, and ε represent the individual fixed effect, time-fixed effect, and random error term, respectively. We used Stata software (the version number: 17.0) to estimate the model.

To more accurately assess the impact of NU on WEC, this paper takes the NU pilot construction as an exogenous impact and uses an MDID to test the "net effect" of the NU pilot policy on WEC. Specifically, this paper sets the prefecture-level cities successively selected as NU pilot areas in Jiangxi Province from 2014 to 2016 as the experimental group and the other prefecture-level cities as the control group [39], and the following MDID is constructed:

$$lnWEC_{it} = \beta_0 + \beta_1 lnNUS_i \times SSZ_t + \Sigma p_i Control_{it} + v_i + \varepsilon_{it} \tag{2}$$

In model (2), *NUS* is a dummy variable. If city *i* belongs to the NU pilot city, the value is 1; otherwise, it is 0. *SSZ* is also a dummy variable. The value is 0 before the pilot; otherwise, it is 1. *Control* is a series of control variables, as above.

One of the preconditions for using the MDID to evaluate the effect of the NU pilot policy empirically is to satisfy the parallel trend hypothesis. That is, we must satisfy the assumption that the control and experimental groups have the same trend before implementing the NU pilot policy; however, because the difference between the MDID and the DID is that the implementation of the NU pilot policy does not occur centrally in a particular year, we must set the relative time dummy variable of the implementation of the NU pilot policy for each pilot city [40]. In this paper, model (3) is constructed to test the parallel trend hypothesis as follows:

$$lnWEC_{it} = r_0 + \sum_{k=-2}^{k=6} \delta_k NUS_i \times SSZ_{t+k} + r_1 Control_{it} + u_i + \varepsilon_{it} \quad (3)$$

Considering that the research interval of this paper is from 2011 to 2020, the policy year of the first batch of pilot cities for NU is 2014. Some pilot cities do not have the sample value of an extra −3 period. Therefore, the time in other cities before the −3 period was merged into the −3 period. This dummy variable was eliminated to avoid multicollinearity, making the policy −2 period and −1 period the reference years of the parallel trend hypothesis test. Furthermore, due to the lack of data in the six years after the NU pilot policy, the data in the six years after the implementation of the policy were also merged into the sixth period [40].

3.3. Variable Measurement

Considering the connotation of WEC and drawing upon relevant literature [2,13–15], the evaluation indicator system of WEC was constructed based on principles of scientific rigor, comprehensiveness, representativeness, independence, and data availability. The system encompasses three key aspects: pressure, state, and response (PSR).

First, "pressure" is generally used to measure the damage to the quality of the water environment caused by human economic activities, industrialization processes, excessive fertilization, and the economic efficiency and utilization rate of water resources. Contributing factors include the per capita ammonia nitrogen discharge of urban domestic sewage, per capita discharge of chemical oxygen demand of urban domestic sewage, the discharge of chemical oxygen demand per USD 10,000 of the GDP, ammonia nitrogen discharge per USD 10,000 of the GDP, and fertilizer application intensity (fertilizer application intensity measured as agricultural fertilizer application amount/effective irrigation area). The utilization rate was evaluated based on the water consumption per USD 10,000 of the GDP, the development and utilization rate of water resources, the average water consumption per mu of farmland irrigation, and the effective coefficient of farmland irrigation. Generally speaking, the greater the per capita ammonia nitrogen discharge of urban domestic sewage and the per capita discharge of chemical oxygen demand of urban domestic sewage, the worse the water environment quality resulting from human activities. Similarly, a higher discharge of chemical oxygen demand per USD 10,000 of the GDP and ammonia nitrogen discharge per USD 10,000 of the GDP indicates more severe water pollution caused by economic activities. Moreover, an increase in fertilizer application intensity and the amount of agricultural fertilizer applied per unit of effective irrigation area leads to more serious agricultural water pollution and hampers the construction of WEC. Conversely, lower water consumption per USD 10,000 of the GDP, development and utilization rate of water resources, and average water consumption per mu of farmland irrigation along with a higher effective coefficient of farmland irrigation contribute to the greater economic efficiency of water resource utilization and a greater utilization rate of farmland irrigation, and the more conducive they are to the construction of WEC.

Second, "State" refers to the natural endowment of water resources and the supply capacity of water resources under pressure. Water resources can be measured based on the amount of surface water resources and the amount of groundwater resources. The supply capacity was evaluated using the groundwater exploitation coefficient, urban water penetration rate, per capita water resources, blue water quality index, and proportion of fine water quality of state-controlled sections. A greater amount of surface water resources and groundwater water resources indicates a richer natural endowment of water resources. Additionally, a smaller groundwater exploitation coefficient suggests a greater potential for groundwater exploitation. A higher urban water penetration rate and higher per capita water resources indicate a greater exploitable potential of water resources. Furthermore, better quality indicators such as a smaller blue water quality index and a larger proportion of fine water quality of state-controlled sections reflect improved environmental conditions regarding freshwater bodies while also indicating a stronger supply capacity of water resources.

Third, "Response" usually refers to the human contribution in increasing the repeated utilization of water resources and reducing the pressure on water ecology, aiming at improving urban sewage treatment capacity, improving water storage capacity, and maintaining water ecological balance. We evaluated the response using the proportion of investment in water-related affairs in general budget revenue, sewage treatment rate, drainage pipe density in built-up areas, per capita park green area, percentage of forest cover, green coverage rate in built-up areas, proportion of the total wetland area in the land area, proportion of water consumption in the ecological environment, control rates of water and soil losses, and proportion of the water-saving irrigation area. A greater proportion of investment in water-related affairs in general budget revenue, sewage treatment rate, and drainage pipe density in built-up areas indicate a stronger urban sewage treatment capacity. Additionally, a greater per capita park green area, percentage of forest cover, and green coverage rate in built-up areas suggest a stronger water storage capacity. Furthermore, the greater the proportion of the total wetland area in the land area, the proportion of water consumption in the ecological environment, the control rates of water and soil losses, and the proportion of the water-saving irrigation area, the stronger the intensity of measures taken by human beings to maintain water ecological balance.

Table 1 presents the specific WEC indicator system. Positive and reverse indicators exist in the indicator system; therefore, when the principal component analysis was used to measure the score of WEC, the inverse indicator was normalized by the "1/inverse indicator." The larger the value, the higher the WEC level.

Table 1. Indicator system of WEC.

Target Layer	Criterion Layer	Indicator Layer	Dimension	Indicator Attribute
Water ecological civilization	Pressure	Per capita ammonia nitrogen discharge of urban domestic sewage	kg	–
		Per capita the discharge of chemical oxygen demand of urban domestic sewage	kg	–
		The discharge of chemical oxygen demand per USD 10,000 of GDP	kg	–
		Ammonia nitrogen discharge per USD 10,000 of GDP	kg	–
		Fertilizer application intensity	kg/hm^2	–
		The water consumption per USD 10,000 of GDP	m^3	–
		The development and utilization rate of water resources	%	–
		The average water consumption per mu of farmland irrigation	m^3	–
		The effective coefficient of farmland irrigation	–	+
	Status	The amount of surface water resources	m^3	+
		The amount of groundwater resources	m^3	+
		Groundwater exploitation coefficient	–	–
		Urban water penetration rate	%	+
		Per capita water resources	m^3	+
		Blue water quality index	–	–
		Proportion of fine water quality of state-controlled sections	%	+

Table 1. *Cont.*

Target Layer	Criterion Layer	Indicator Layer	Dimension	Indicator Attribute
Water ecological civilization	Response	Proportion of investment in water-related affairs in general budget revenue	%	+
		Sewage treatment rate	%	+
		Drainage pipe density in built-up area	km/km^2	+
		Per capita park green area	m^2	+
		Percentage of forest cover	%	+
		Green coverage rate in built-up area	%	+
		Proportion of the total wetland area in the land area	%	+
		Proportion of water consumption in ecological environment	%	+
		Control rates of water and soil losses	%	+
		Proportion of the water-saving irrigation area	%	+

Note: "+" indicates that positive correlation, and "−" indicates that negative correlation.

This study measures the explanatory variable NU. The NU evaluation indicator system was constructed from four aspects: population urbanization, economic urbanization, digital urbanization, and green urbanization, and it was measured by using principal component analysis. (1) Population urbanization: The NU is "people-oriented" urbanization. The indicators of population urbanization in academic circles currently include the urbanization rate, the urbanization rate of the registered population, the proportion of the nonagricultural population, and the number of students in colleges and universities per 10,000 people. China's unique household registration system makes the current urbanization rate far lower than the current nominal urbanization level, and statistics on the urbanization rate of the registered population in prefecture-level cities of Jiangxi Province are lacking. Therefore, this paper does not use the first two methods to measure population urbanization. Moreover, since the China Statistical Yearbook no longer publishes the nonagricultural population in each province after 2009, some scholars use the employed population in the secondary and tertiary industries/total employed population to measure the proportion of the nonagricultural population [41]. This approach ignores the impact of population flow [42]. The rural migrant population in the employment population of the secondary and tertiary industries may not realize the citizenization of the population, which is contrary to the core meaning of the NU. Therefore, this paper uses the number of students in colleges and universities per 10,000 people to measure population urbanization. Given this indicator's serious lack of data, the number of people with a junior college education or above/the number of permanent residents in the city was used as a proxy variable for the number of students in colleges and universities per 10,000 people. (2) Economic urbanization: As an essential support of NU construction, economic urbanization is measured by using the regional GDP growth rate in this paper. (3) Digital urbanization: Digital technologies, such as big data, cloud computing, the Internet of Things, and virtual reality, have promoted the construction of NU; helped accelerate the realization of urban digitization, intelligence, and informatization; and improved urbanization quality. In this paper, the development status of the regional digital economy is used to measure digital urbanization. The measurement of the regional digital economy is based on the method of Zhao et al., and principal component analysis was used to calculate it [43]. (4) Green urbanization: Green development is critical as a part of NU construction under the "double carbon" goal. This paper adopts urban green technology innovation to measure green urbanization. The measurement of urban green technology innovation refers to the approach of Xu et al., which measured urban green technology innovation by using the number of green invention applications in the current year [44].

Finally, the measurement of the control variable is as follows. (1) Human capital: Improving human capital is conducive to enhancing public awareness of environmental protection, promoting technological innovation of regional environmental governance, and supervising the implementation of government environmental regulations. It is beneficial to the publicity and acceptance of WEC ideas. This paper measures human capital as local financial education expenditure/local general budget expenditure. (2) Opening-up: Jiangxi Province may rely on the advantages of abundant water resources, low labor factor prices, and considerable export market potential to engage in high water consumption in the processing trade of low-value-added labor-intensive products. This situation may result in significant water consumption, which is not conducive to improving WEC. We used gross import and export/GDP to measure opening-up. (3) Financial support: Financial support can broaden the financing channels for water environmental pollution control and WEC construction, attract capital inflow with diversified financial services, improve financing efficiency, and provide strong support for water environmental pollution control and WEC construction. The balance of loans by financial institutions at the end of the year/GDP measures financial support.

3.4. Data

This study measures the digital inclusive financial index in the regional digital economy and the number of green invention applications in the current year. The original data of most of the indicators related to water in WEC come from the Jiangxi Provincial Water Resources Bulletin, Jiangxi Provincial Statistical Yearbook, and Jiangxi Provincial Prefecture-level City Statistical Yearbook. The original data for the remaining indicators in WEC (such as the sewage treatment rate, wastewater treatment facility treatment capacity, drainage pipe density in built-up area, per capita park green area, percentage of forest cover, and green coverage rate in built-up area) and the original data for the indicators to measure population urbanization (the number of people with a junior college education or above and the number of permanent residents in the city) and economic urbanization (GDP growth rate) come from the China Urban Statistical Yearbook and China Urban Construction Statistical Yearbook. The original data of the indicators to measure the control variable come from the China Urban Statistical Yearbook and Jiangxi Provincial Statistical Yearbook. Some missing values were filled with adjacent values. The digital inclusive finance index comes from the Indicator System and Index Compilation of Digital Inclusive Finance published by the Internet Finance Research Center of Peking University [45]. The number of green invention applications comes from the National Intellectual Property Patent Database, coded according to the list of green invention applications and the international classification provided by the World Intellectual Property Organization. The number of green invention applications was added up to the city level. WEC and the regional digital economy were calculated using the principal component analysis method. Specifically, we used SPSS 22.0 to standardize the original data for various indicators of WEC and the regional digital economy in Jiangxi Province to eliminate the impact of different dimensions on the evaluation results. Second, the eigenvalues of the correlation matrix were calculated, and the number of principal components of WEC and regional digital economy were extracted according to the cumulative variance contribution rate $\geq$ 85% and eigenvalue $\geq$ 1 principles, respectively. Then, the eigenvectors of the principal components were calculated, and the linear combinations of the principal components about the original variables were given. The proportion of the variance contribution rate of each principal component in the total variance contribution rate was taken as the weight, and the scores of WEC and the regional digital economy in Jiangxi Province were finally obtained. There were some negative values in the calculated results, so the 0–1 standardization method was used for processing. Furthermore, the calculation formulas of water ecological civilization, population urbanization, and digital urbanization are $\ln(WEC + 1)$, $\ln(PUR + 1)$, and $\ln(DUR + 1)$, respectively. Table 2 presents the descriptive statistical results of the above variables (Supplementary Materials).

Table 2. Descriptive statistics of variables.

Variable	Mean Value	Minimum Value	Median Value	Maximum Value
ln*WEC*	0.239	0.000	0.242	0.697
ln*PUR*	0.889	0.271	0.696	2.517
ln*EUR*	2.168	0.577	2.197	2.694
ln*DUR*	0.289	0.000	0.276	0.693
ln*GUR*	3.837	1.099	3.726	6.958
ln*HUM*	2.860	2.465	2.872	3.352
ln*OPE*	2.652	1.655	2.624	4.180
ln*FIN*	−0.143	−0.951	−0.190	1.012

Note: *WEC*: water ecological civilization, *PUR*: population urbanization, *EUR*: economic urbanization, *DUR*: digital urbanization, *GUR*: green urbanization, *HUM*: human capital, *OPE*: opening-up, *FIN*: financial support.

4. Results

4.1. The Spatiotemporal Evolution of WEC

First, principal component analysis was used to calculate the WEC scores of prefecture-level cities in Jiangxi, and the value of WEC was divided into four regions by using the natural fracture method in ArcGIS software (the version number: 10.7). These regions include the low-level zone [−1.228, −0.110], the medium-level zone [−0.110, 1.008], the medium- and high-level zone [1.008, 2.126], and the high-level zone [2.126, 3.244]. Figure 2 presents the spatial pattern distribution map of WEC in prefecture-level cities of Jiangxi Province in 2011, 2014, 2017, and 2020. Figure 2 indicates that in 2011 and 2014, WEC in all regions of Jiangxi was at low and medium levels, and the spatial pattern distribution of WEC was relatively dispersed. Only the provincial capital city of Nanchang jumped from a low-level zone in 2011 to a medium-level zone in 2014. This result may be because after Nanchang was selected as a national pilot city of WEC, relying on the location advantage of the provincial capital, the WRUE, water pollution control capacity, and water storage capacity were improved by promoting technological progress, improving human capital, promoting industrial upgrading, and promoting factor agglomeration, thus enhancing the WEC level. Although the WEC in all regions of Jiangxi was still at low and medium levels in 2017, remarkable results were achieved in constructing WEC in all regions compared with 2011 and 2014. The spatial distribution of WEC evolved from relatively scattered to centralized contiguity, showing an east–west polarization pattern centered on the provincial capital, Nanchang. The WEC of Shangrao, Fuzhou, Yingtan, and Ganzhou in the east all rose from the low level in 2014 to the medium level in 2017, the WEC of Yichun and Ji'an in the west was always at the low level, and the WEC of Jiujiang was degraded from the medium level in 2014 to the low level in 2017.

In 2020, the east–west polarization pattern of Jiangxi's WEC was broken, forming a distribution pattern with Nanchang and Xinyu as the core and gradually decreasing to the surrounding areas. Among them, the WEC of Nanchang and Xinyu jumped from the medium level to the high level, Yingtan's WEC rose from the medium level to the medium-high level, Jiujiang and Yichun's WEC also rose from the low level to the medium level, and the spatial differences in WEC in different regions of Jiangxi have gradually narrowed. The level of WEC in the neighboring areas centered on Nanchang has been improved because, as a national pilot city of WEC, Nanchang focuses on cultivating public water-saving consciousness in the region, standardizing the utilization of water resources, protecting the water ecosystem, improving the quality of the water environment, and promoting the idea of WEC. Furthermore, through the spatial spillover effect of pilot policies, the pilot city of WEC plays a leading and demonstrating role, provides a construction reference for neighboring regions to improve the level of WEC, and realizes the coordinated development of WEC between pilot cities and neighboring regions.

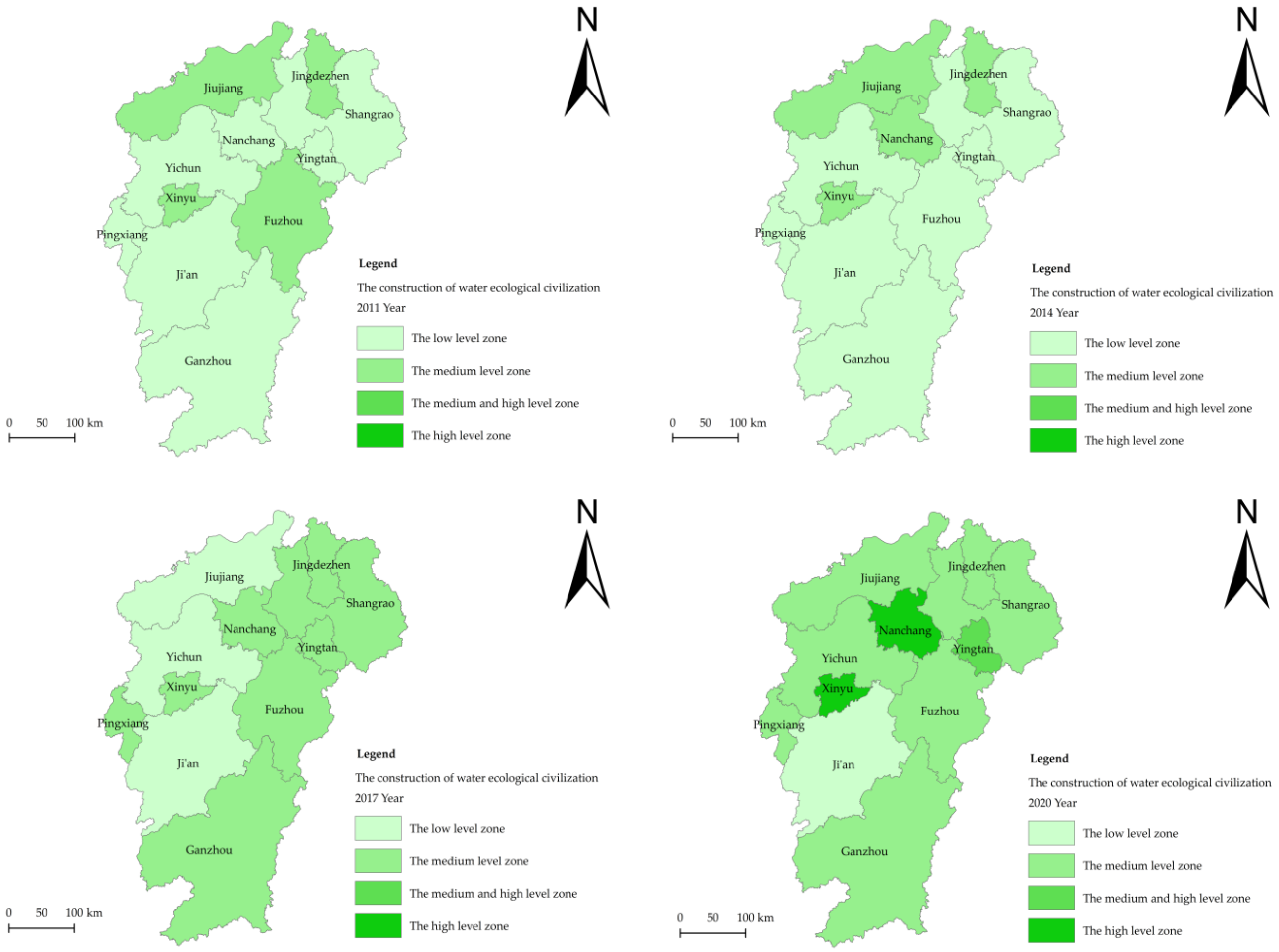

Figure 2. Spatial evolution of WEC in Jiangxi from 2011 to 2020.

Second, the barycenter transfer model and standard deviation ellipse method were used to further explore the spatiotemporal evolution characteristics of WEC in prefecture-level cities of Jiangxi Province to reflect the barycenter transfer and spatial direction of WEC in each region. The results are shown in Figure 3 and Table 3. From the perspective of the barycenter transfer track, the barycenter of WEC in Jiangxi Province from 2011 to 2020 moves at 115°43′ E to 115°52′ E and 28°06′ N to 28°57′ N, first moving in the northeast direction, then moving in the southeast direction, and finally moving in the southwest direction. The above barycenter falls southeast of Yichun City, near the geographical barycenter. On the one hand, this result shows that the WEC of prefecture-level cities in Jiangxi Province is relatively stable in space, showing the spatial distribution characteristics with the average barycenter as the boundary, with the north strong and the south weak. On the other hand, the result shows that after Nanchang, Xinyu, and Pingxiang were selected as national pilot cities of WEC, they improved the level of WEC in the region and actively assisted the surrounding areas in promoting the construction of WEC, especially in neighboring areas. This situation made the barycenter of WEC and the barycenter transfer track show in the southeast of Yichun City. From the standard deviation ellipse parameters, the ellipse area decreased from 61,769.591 km² in 2011 to 60,807.477 km² in 2020, indicating that the WEC in the interior of the ellipse had a strong effect on improving the overall WEC in Jiangxi Province, and the trend of the accumulation of WEC areas was further enhanced. The long and short axes of the ellipse decreased by 5.241 km and increased by 1.376 km, respectively, indicating that the WEC contracted significantly in the direction of northeast to southwest but expanded in the direction of southeast to northwest. The azimuth of the ellipse reversely contracted from 40.482° in 2011 to 38.525° in 2020, indicating that the WEC in southeast Jiangxi Province is improving faster than that in southwest Jiangxi Province, but the northeast–southwest direction still dominates the spatial distribution.

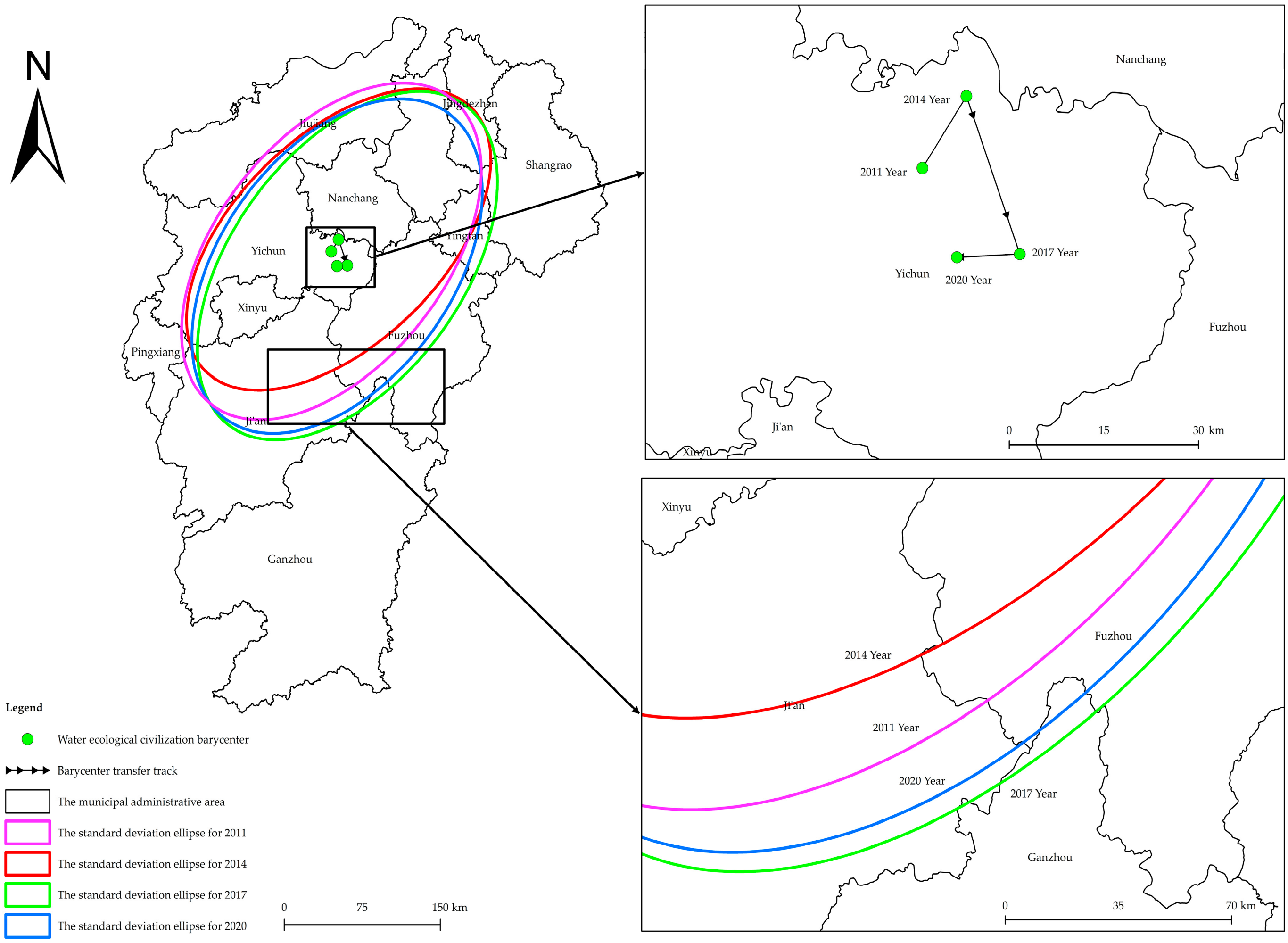

Figure 3. Changes in WEC barycenter and standard deviation ellipse during 2011–2020.

Table 3. The barycenter and standard deviation ellipse parameters of WEC in Jiangxi from 2011 to 2020.

Year	Barycenter Coordinate	Area (km²)	Long Semi-Axis (km)	Short Semi-Axis (km)	Azimuth
2011	115°43′ E 28°14′ N	61,769.591	182.519	107.733	40.482°
2014	115°48′ E 28°19′ N	54,249.125	176.552	97.815	47.679°
2017	115°52′ E 28°57′ N	63,865.832	186.436	109.049	38.587°
2020	115°46′ E 28°06′ N	60,807.477	177.278	109.190	38.525°

4.2. Baseline Regression Analysis

Based on the Hausmann test, this paper selected the individual fixed effect model for the baseline regression. Table 4 shows that the estimated coefficients of population, digital, and green urbanization are all positive and significant at the 1% level. In comparison, the estimated coefficient of economic urbanization is negative and significant at the 1% level, and the sum of positive effects is much higher than the negative effects, indicating that NU is conducive to improving the level of WEC. Specifically, a 1 percentage point increase in population and digital urbanization levels in Jiangxi Province increased WEC by 0.401 and 0.579, respectively. These results indicate that population and digital urbanization are conducive to improving WEC. The reason for the former may be that the agglomeration effect of population urbanization helps to promote knowledge and technology exchange within the city, improve the efficiency of urban innovation, and promote technological innovation in the fields with intensive and efficient use of water resources and water pollution control. Thus, water use efficiency (WUE; it is an important comprehensive index that reflects the effective development, utilization, and management of water resources. The higher it is, the lower the intensity of water resource consumption) and pollution control ability can be improved. The latter may be because digital urbanization helps enterprises achieve green and high-efficiency production, reduce undesirable output while improving WUE, and avoid water resource waste and water pollution. Digital urbanization is also beneficial for the government in monitoring the quality of the water environment in real-time, improving WEE supervision efficiency, and improving WEE governance. Digital urbanization has also promoted the government, enterprises, and the public to strengthen collaborative governance in WEE, create a good atmosphere for WEE protection, and enhance the level of WEC.

Table 4 shows that as green urbanization increased by 1 percentage point, the WEC level increased by 0.071 percentage points. This finding indicates that green urbanization has a positive role in promoting WEC, potentially because green urbanization can help reduce the cost of enterprises in the application of clean technology, encourage enterprises to conduct green production from the source, and promptly treat waste sewage discharge to reduce the impact on water environment quality and promote water ecological restoration. Green urbanization can also enable enterprises to improve WRU efficiency by reusing water resources and reducing water consumption under constant output.

Furthermore, the regression coefficients of explanatory variables in Table 4 show digital urbanization > population urbanization > green urbanization. These results indicate that after digital technology enables NU, it helps digital dividends from the supply and demand sides, releases digital effects, and provides new development opportunities for promoting WEC. On the supply side, digital urbanization can form economies of scale with the help of emerging digital technologies, such as the Internet of Things, big data, and cloud computing; therefore, it can change the extensive economic development model while reducing the dependence on traditional high water consumption and heavy pollution products. On the demand side, digital urbanization helps build green consumption platforms, expand green consumption services, and develop green products. These actions help increase the public's demand for intelligent, intensive, and green life, thus realizing the transformation of enterprises' green production and releasing ecological dividends.

Table 4 shows that as economic urbanization increased by 1 percentage point, the WEC level decreased by 0.178 percentage points. This finding indicates that economic urbanization significantly negatively affects WEC, and Jiangxi Province is still on the left side of the environmental Kuznets curve. The increase in economic urbanization volume leads to increased water resource demand and ecological environment pressure, resulting in a water resource shortage and water ecosystem imbalance. However, economic urbanization provides a financial guarantee for the infrastructure required for digital urbanization and the ecological and environmental protection and green technology research and development expenditure required for green urbanization. Therefore, the negative effect caused by economic urbanization (-0.178) can be "masked" by the positive effect of digital urbanization (0.579) and green urbanization (0.071). Furthermore, the increased economic urbanization volume has helped the region attract high-end talents, high-tech enterprises, research and development capital, and other innovative factors. This situation has helped comprehensively improve the city's innovation capacity and the conversion rate of scientific research achievements related to WUE, pollution reduction, and emission reduction, providing innovation guarantees for constructing WEC. Therefore, this negative effect belongs in an acceptable range in the process of NU.

From the perspective of control variables, both human capital and financial support are conducive to improving the WEC level. When the explanatory variables are digital and green urbanization, the estimated coefficient of human capital passes the significance test. No matter which type of urbanization is the explanatory variable, the estimated coefficient of financial support does not pass the significance test. The reason for the former is that under digital urbanization and green urbanization, human capital is more likely to exert the effect of economies of scale and technological progress, and it is more likely to promote the innovation and diffusion of water-saving technology and water pollution control technology. The latter may be because Jiangxi is in an underdeveloped area with a weak ecological financial foundation and low financing efficiency and has not formed a sound long-term financial support mechanism for constructing WEC. Opening-up has a significant adverse effect on the level of WEC, mainly because Jiangxi is located in the middle reaches of the Yangtze River and does not have an advantageous geographical position in the coastal area. The province mainly exports labor-intensive products with high water consumption and low added value under its abundant water resources and is prone to water-quality-induced water shortages and environmental pollution. Jiangxi must change its traditional foreign trade development mode and leap toward environmental friendliness, resource conservation, and high added value.

Table 4. Baseline regression result.

Variable	Population Urbanization	Economic Urbanization	Digital Urbanization	Green Urbanization	Population Urbanization	Economic Urbanization	Digital Urbanization	Green Urbanization
ln*NUR*	0.381 ***	−0.181 ***	0.567 ***	0.064 ***	0.401 ***	−0.178 ***	0.579 ***	0.071 ***
	(0.103)	(0.040)	(0.096)	(0.015)	(0.102)	(0.037)	(0.096)	(0.015)
ln*HUM*					0.139	0.065	0.201**	0.336 ***
					(0.114)	(0.093)	(0.074)	(0.099)
ln*OPE*					−0.047 **	−0.019	−0.038 **	−0.033 *
					(0.018)	(0.016)	(0.015)	(0.017)
ln*FIN*					0.009	0.002	0.014	0.015
					(0.022)	(0.019)	(0.018)	(0.020)
C	−0.094	0.631	0.080 ***	−0.001 **	−0.375	0.496	−0.389 *	−0.882 **
	(0.091)	(0.087)	(0.028)	(0.060)	(0.359)	(0.308)	(0.214)	(0.330)
Fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.278	0.479	0.399	0.329	0.346	0.491	0.456	0.415
F	13.952	20.421	34.949	16.817	8.321	15.158	19.918	15.674
N	110	110	110	110	110	110	110	110

Note: *, **, and *** indicate that the variable is significant at the level of 10%, 5%, and 1%, respectively.

4.3. Robustness Test

This paper adopted the following four methods to ensure the reliability of the above empirical results. (1) We remeasured the explained variables using the entropy method instead of the principal component analysis method to measure WEC. (2) We eliminated pilot cities for WEC. In estimating the impact of NU on WEC, it is necessary to reference the pilot policy of WEC implemented by the Ministry of Water Resources in 2013, resulting in an overestimation or underestimation. Furthermore, due to the general predisposition and continuity of China's policies, this paper excluded Nanchang, Xinyu, and Pingxiang, which were selected as national pilot cities of WEC after 2013. Furthermore, we deleted the samples of Nanchang, Xinyu, and Pingxiang from 2011 to 2013. (3) We conducted tail reduction and truncation processing. The outliers of WEC were eliminated via a bilateral tail reduction of 1% and bilateral truncation of 1% to avoid the deviation of results caused by outliers in the explained variables. (4) We gradually added control variables. Based on baseline regression, foreign direct investment (ln*FDI*) and per capita road area (ln*SPA*), two control variables that may affect the level of WEC, were added successively (foreign direct investment was measured as the amount of actually utilized foreign investment). Tables 5–7 show that the above four robustness tests all confirm that the conclusions in this paper are reliable, and the estimated coefficients and significance levels of explanatory variables do not differ significantly from the baseline regression results.

Table 5. Estimation results of robustness test (1).

Variable	Remeasure the Explained Variables				Eliminate Pilot Cities for Water Ecological Civilization			
	Population Urbanization	Economic Urbanization	Digital Urbanization	Green Urbanization	Population Urbanization	Economic Urbanization	Digital Urbanization	Green Urbanization
ln*NUR*	0.165 *** (0.043)	−0.079 *** (0.014)	0.262 *** (0.055)	0.031 *** (0.005)	0.445 ** (0.157)	−0.180 *** (0.041)	0.587 *** (0.148)	0.061 ** (0.018)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C	0.200 (0.124)	0.581 *** (0.102)	0.179 * (0.090)	−0.055 (0.098)	−0.367 (0.339)	0.499 * (0.226)	−0.409 (0.254)	−0.712 (0.386)
Fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.349	0.575	0.542	0.518	0.395	0.539	0.496	0.462
F	11.482	9.484	8.273	30.992	46.357	10.229	11.655	13.275
N	110	110	110	110	80	80	80	80

Note: *, **, and *** indicate that the variable is significant at the level of 10%, 5%, and 1%, respectively.

Table 6. Estimation results of robustness test (2).

Variable	Bilateral Tail Reduction 1%				Bilateral Truncation 1%			
	Population Urbanization	Economic Urbanization	Digital Urbanization	Green Urbanization	Population Urbanization	Economic Urbanization	Digital Urbanization	Green Urbanization
ln*NUR*	0.388 *** (0.101)	−0.173 *** (0.037)	0.567 *** (0.093)	0.070 *** (0.015)	0.343 *** (0.082)	−0.156 *** (0.047)	0.509 *** (0.118)	0.065 *** (0.014)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C	−0.372 (0.357)	0.494 (0.306)	−0.386 * (0.212)	−0.877 ** (0.328)	−0.217 (0.306)	0.543 * (0.274)	−0.271 (0.250)	−0.680 * (0.309)
Fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.349	0.495	0.460	0.419	0.321	0.473	0.424	0.427
F	8.393	15.281	20.077	15.810	10.930	6.722	7.557	17.929
N	110	110	110	110	107	107	107	107

Note: *, **, and *** indicate that the variable is significant at the level of 10%, 5%, and 1%, respectively.

Table 7. Estimation results of robustness test (3).

Variable	Add Foreign Direct Investment				Add Foreign Direct Investment and per Capita Road Area			
	Population Urbanization	Economic Urbanization	Digital Urbanization	Green Urbanization	Population Urbanization	Economic Urbanization	Digital Urbanization	Green Urbanization
ln*NUR*	0.328 ** (0.110)	−0.156 *** (0.035)	0.514 *** (0.098)	0.062 *** (0.017)	0.214 * (0.099)	−0.122 *** (0.036)	0.363 *** (0.062)	0.039 ** (0.015)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ln*FDI*	0.147 * (0.071)	0.155 ** (0.057)	0.093 (0.052)	0.078 (0.054)	0.072 (0.069)	0.087 (0.079)	0.051 (0.065)	0.048 (0.051)
ln*SPA*					0.221 ** (0.073)	0.171 ** (0.067)	0.173 ** (0.064)	0.190 ** (0.063)
C	−0.450 (0.301)	0.295 (0.279)	−0.435 * (0.208)	−0.862 ** (0.325)	−0.908 ** (0.367)	−0.226 (0.419)	−0.793 ** (0.326)	−1.092 ** (0.365)
Fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.379	0.530	0.468	0.422	0.499	0.597	0.531	0.498
F	12.286	14.259	16.997	14.098	12.213	17.282	56.798	13.439
N	110	110	110	110	110	110	110	110

Note: *, **, and *** indicate that the variable is significant at the level of 10%, 5%, and 1%, respectively.

4.4. Heterogeneity Analysis

4.4.1. Time Heterogeneity

The development of NU has prominent stage characteristics, from emphasizing speed and neglecting quality to people-oriented transformation. To investigate whether the impact of NU on WEC will be heterogeneous due to the different stages of NU, we took the time (2014) first proposed in the National NU Plan (2014–2020) (from now on referred to as the "Plan") as the boundary and divided the research samples into 2011–2014 and 2015–2020 for testing. The specific results are shown in Table 8. From columns (1) and (2) of Table 8, it can be seen that compared with 2011–2014, NU in 2015–2020 has a significantly greater promoting effect on the level of WEC. The reasons are as follows. On the one hand, the proposal of the plan makes NU construction enter the implementation stage from the exploration stage, which focuses more on improving the quality of urbanization, reducing pollution and carbon in the urbanization process, and protecting the WEE. It focuses on the green, intensive, and safe use and recycling of water resources. Among them, population and green urbanization play an increasingly significant role in promoting WEC through population aggregation and progress in green technology. On the other hand, before the plan's announcement, the infrastructure of digital urbanization was weak, and digital industrialization and digital governance were in the initial stage of development, resulting in the limited effect of digital urbanization on the improvement of the WEC level. With the implementation of planning policies and supporting programs, the digital dividend released by digital urbanization gradually became prominent, and various industries were empowered by digital technology. Furthermore, it has improved the green utilization efficiency of water resources and promoted the level of WEC.

Table 8. Estimation results of heterogeneity.

Variable	Time		Water Resource Endowment		Urban Type			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Year ≤ 2014	Year > 2014	Scarcity	Abundant	Resource-Based City	Non-Resource-Based City	Old Industrial Base	Non-Old Industrial Base
ln*PUR*	0.230 **	0.282 **	0.339 **	0.332 *	0.321 **	0.497 *	0.285 **	0.537 **
	(0.085)	(0.093)	(0.138)	(0.153)	(0.106)	(0.204)	(0.082)	(0.161)
ln*EUR*	−0.015 **	−0.201 ***	−0.167 *	−0.151 ***	−0.153 **	−0.205 **	−0.188 *	−0.164 **
	(0.006)	(0.043)	(0.085)	(0.040)	(0.052)	(0.057)	(0.079)	(0.042)
ln*DUR*	0.097	0.757 ***	0.540 **	0.483 **	0.534 **	0.625 ***	0.490 *	0.620 ***
	(0.086)	(0.148)	(0.172)	(0.149)	(0.156)	(0.118)	(0.181)	(0.132)
ln*GUR*	−0.007	0.082 ***	0.080 **	0.051 ***	0.064 *	0.073 **	0.056	0.085 ***
	(0.011)	(0.017)	(0.031)	(0.016)	(0.023)	(0.022)	(0.030)	(0.019)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	44	66	50	60	50	60	40	70

Note: *, **, and *** indicate that the variable is significant at the level of 10%, 5%, and 1%, respectively.

4.4.2. Water Resource Endowment Heterogeneity

As a key factor in promoting the construction of WEC, water resource endowment affects residents' water consumption habits, enterprises' production mode, and green technology innovation. To investigate whether the impact of NU on WEC is heterogeneous due to different regional water resource endowments, we used the method proposed by Tian et al. to measure regional water resource endowment based on per capita water resources [46]. It divides the index into two equal parts: the first is the region with scarce water resources, and the second is the region with abundant water resources. Columns (3) and (4) of Table 8 show that NU's improvement effect on the WEC level is more significant in areas with scarce water resources. There are two main reasons for this outcome. First, areas with scarce water resources are susceptible to constraints on water resources, and their industrial structure tends to be environmentally friendly and resource-saving. Furthermore, these industries are often based on improving WUE, protecting water environment quality, and maintaining water ecological balance. Second, compared with areas with abundant water resources, environmental regulations are more stringent in areas with scarce water resources. Additionally, they participate more actively in environmental governance investment and green technology progress; therefore, the upgrading effect of NU on WEC is increasingly apparent in such areas.

4.4.3. Urban Type Heterogeneity

This paper draws on the classification criteria proposed by Shi and Li to investigate whether the impact of NU on WEC is heterogeneous due to different city types. We divided the research samples into resource-based and non-resource-based cities and old industrial and non-old industrial bases [47]. Columns (5) to (8) of Table 8 indicate that compared with resource-based cities and old industrial bases, NU has a more prominent role in promoting

WEC in non-resource-based cities and non-old industrial bases. Resource-based cities mainly rely on natural resources to develop corresponding industries, such as ceramics in Jingdezhen, iron and steel in Xinyu, coal in Pingxiang, rare earth minerals in Ganzhou, and lithium ore in Yichun. Most of these industries are polluting or water-consuming, which affects the promotion effect of WEC in the process of NU. Resource-based cities may also be affected by the "resource curse"; their technological innovation level, factor allocation efficiency, and environmental regulation intensity often lag behind non-resource-based cities, restricting the role of NU in promoting water resource utilization efficiency and water pollution control. As a result, the effect of NU on the improvement of WEC is not apparent. Furthermore, the industrial structure of non-old industrial bases may be more rational and advanced than that of old industrial bases. At the same time, the economic vitality of non-old industrial bases is relatively strong, and the degree of marketization is relatively developed, which makes the environmental regulations and environmental quality demands of these areas stricter in the NU construction, forcing enterprises to innovate green technology and apply clean production technology, improve WUE, reduce water pollution discharge, and significantly affect the improvement of the WEC level.

4.5. Further Analysis

Table 9 shows the estimation results of the MDID. The first two columns of the estimation results show that the estimated coefficients of the NU pilot policy are significantly positive regardless of whether the control variables are included. That is, the "net effect" of the NU pilot policy on WEC is positive, indicating that the implementation of the policy has significantly improved the level of WEC. The last column in Table 9 is the estimation result of the spatial Durbin model using inverse distance weights, which again proves the above viewpoint. Furthermore, the spatial correlation coefficient ρ is significantly positive, indicating that the pilot policy has a significant spatial positive spillover effect. That is, the improvement of WEC in selected pilot cities of NU has helped to promote the improvement of WEC in neighboring areas.

Table 9. Estimation results of the MDID.

Variable	Traditional Panel MDID		Spatial Panel MDID
$NUS \times SSZ$	0.143 *** (0.034)	0.145 *** (0.029)	0.059 *** (0.021)
Direct $NUS \times SSZ$			0.075 *** (0.019)
Indirect $NUS \times SSZ$			0.292 *** (0.094)
LM error test			51.175 ***
LM lag test			44.861 ***
ρ			0.503 ***
Control variable	No	Yes	Yes
C	0.212 *** (0.007)	−0.155 (0.394)	
Fixed effect	Yes	Yes	Yes
R^2	0.221	0.263	0.107
F	18.326	11.319	
N	110	110	110

Note: *** indicate that the variable is significant at the level of 1%.

Figure 4 shows the parallel trend hypothesis test results with a 95% confidence interval. The estimated coefficients before the NU pilot policy implementation are insignificant, indicating no significant difference between the experimental and control groups regarding the level of WEC. That is, the pilot policy conforms to the parallel trend hypothesis. Further, it can be seen that NU's pilot policy does not significantly improve the WEC level in the year of implementation but has a certain lag. With the implementation of the pilot policy, the positive estimation coefficient of NU's pilot policy on the level of WEC continues to rise, indicating that NU's pilot policy can promote the improvement of WEC.

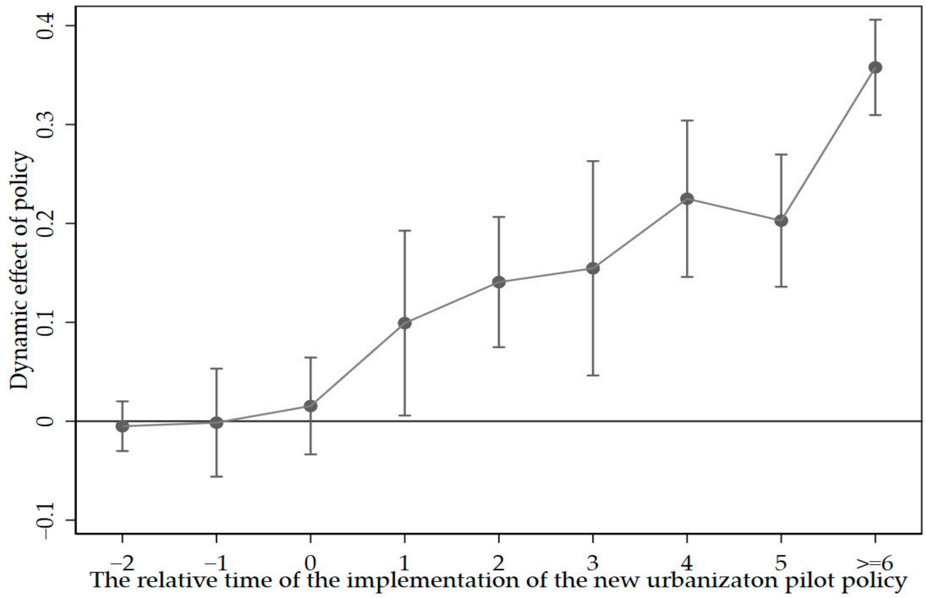

Figure 4. Test results of the parallel trend hypothesis.

5. Discussion

Improving the level of WEC is crucial to alleviating the contradiction between the supply and demand of water resources, protecting the WEE, and maintaining the balance of water ecology in the process of NU. In this paper, based on the data on prefecture-level cities in Jiangxi, China, from 2011 to 2020, we constructed an indicator system. We used the natural fracture method, barycenter transfer model, standard deviation ellipse method, individual fixed effect model, and MDID to study the impact of NU on WEC.

First, regarding the spatiotemporal evolution of WEC, Figures 2 and 3, and Table 3 show that the level of WEC in all regions of Jiangxi has generally improved significantly, the gathering trend of WEC regions has strengthened, and the polarization pattern of WEC in the east and west has gradually broken. Conversely, the spatial distribution pattern is relatively stable in the north and south, showing the average barycenter as the boundary, and the spatial distribution pattern is strong in the north and weak in the south. The reason is that after Nanchang, Xinyu, and Pingxiang were selected as national pilot cities of WEC, they focused on cultivating public water-saving consciousness, standardizing the utilization of water resources, protecting the water ecosystem, improving the quality of the water environment, promoting the idea of WEC, and improving the level of WEC in the regions and actively assisted the surrounding areas in promoting the construction of WEC. They played a leading and demonstrating role and provided a construction reference for neighboring areas to improve the level of WEC. This result is consistent with studies on the level of Jiangxi's WEC [19]. The extant literature found that the level of Jiangxi's WEC shows a fluctuating upward trend and significant urban differences. This result is also similar to the findings of Deng et al. and Su et al. on the level of WEC in China [13,48]. They found that the level of WEC in China continues to rise, with significant differences between different provinces, indicating that the application of the PSR model to construct the indicator system of WEC is reasonable and has a particular reference value.

Second, in terms of the impact of NU on WEC, Tables 4–9 show that NU contributes to the improvement of the WEC level, among which population urbanization, digital urbanization, and green urbanization can significantly promote the improvement of the WEC level, while economic urbanization impedes the improvement of the WEC. This conclusion is still valid following a series of robustness tests. Heterogeneity analysis shows that the impact of NU in improving the level of WEC is more evident in cities with scarce water resources, non-resource-based cities, and non-old industrial base cities after the implementation of NU planning. Further research shows that NU's pilot policy can help improve the WEC level in the region and the WEC level in neighboring regions through the spillover effect of policy. This result contradicts the results of Darko et al. and Margaret et al. [49,50]. They found that NU is not conducive to the quality of the WEE, which not only intensifies the discharge of water pollution but also inhibits the absorption capacity of the water environment. This result is inconsistent with those of Li, Al-Mulali et al., Irfan and Shaw, and Kan et al. [19,51–53]. Li found an anti-N-shaped relationship between NU and the ecological environment in China. That is, NU is not conducive to the quality of the ecological environment in the early stage of the sample, NU is conducive to the quality of the ecological environment in the middle stage of the sample, and NU is not conducive to the quality of the ecological environment in the late stage of the sample. Conversely, Al-Mulali et al. examined 93 countries, Irfan and Shaw investigated South Asian countries, Al-Mulali et al., Irfan and Shaw empirically found an inverted U-shaped relationship between NU and the ecological environment. Similarly, Kan et al. found an inverted U-shaped relationship between NU and the level of WEC. That is, NU is conducive to the level of WEC in the early stage of the sample, but after the level of NU has passed a certain stage of development, NU is not conducive to the level of WEC.

The results of this study can help to improve the level of WEC during the process of promoting NU in Jiangxi Province. Although this study analyzed the impact of NU on WEC in Jiangxi Province, this study also has the following shortcomings. Based on the PSR model, the evaluation indicator system of WEC is constructed only from three aspects: pressure, state, and response. It does not include driving force and impact, and subsequent research will be based on the DPSIR model to construct an evaluation indicator system from five aspects: driving force, pressure, state, impact, and response. Furthermore, the control variables in the constructed panel model do not consider the natural factors that affect the WEC, such as climate change and precipitation. Finally, in the future, it is necessary to empirically study the impact of NU on WEC in other developing countries or regions.

6. Conclusions

According to the above empirical research results and the actual development of NU and WEE in Jiangxi Province, this paper proposes the following suggestions to improve the level of WEC.

First, the province should make use of the superimposed effect of multidimensional urbanization to provide new momentum for Jiangxi to enhance the level of WEC. (1) In promoting the construction of NU, the government should implement a people-oriented concept, accelerate the household registration system reform, promote the citizenization of farmers, improve the quality of population urbanization, and make use of the positive effect of population agglomeration on WEC. (2) Furthermore, the province should continue to implement the "No. 1 project" of the digital economy, tap the potential of digital economy-enabling industries, accelerate the improvement of digital infrastructure construction, broaden the depth and breadth of digital urbanization, promote the high-quality development of digital urbanization, and make use of the positive role of the digital economy on WEC. (3) Additionally, the government should strengthen environmental regulations; formulate green credit policies, subsidy policies, and tax relief policies to guide enterprises to increase capital investment in green research and development projects; improve the level of green technology; promote the progress of clean production technology; promote the conservation development of green urbanization; and make use of the positive impact of green technology innovation on WEC.

Second, the province should implement differentiated policies based on urban characteristics. (1) The government should consider the difference in urban water resource endowment, advocate the establishment of a long-term and effective cross-regional water rights trading system, strive to ensure water demand in areas with scarce water resources in the construction of NU, and continue to make use of the positive effect of NU on WEC. It is necessary to seize the dividends of NU, encourage regions with abundant water resources to accelerate the transformation into environmentally friendly and resource-saving industries, and enhance the region's enthusiasm to participate in environmental governance investment and green technology progress. (2) Furthermore, different city types should be considered. On the one hand, resource-based cities and cities with old industrial bases are encouraged to speed up upgrading their industrial structure, eliminate backward production capacity, and shut down enterprises with high energy, pollution, and water consumption. On the other hand, enterprises in resource-based cities and old industrial base cities should be guided to abandon the dependence on resource advantages, transform and develop into capital-intensive and technology-intensive industries, improve WUE, reduce water pollution, and promote the level of WEC.

Finally, administrative barriers should be eliminated, and the spatial spillover effect of the pilot policy should be exerted. Pilot cities for NU should be used as the benchmark to strengthen the exchange of experience in NU construction, promote practical cooperation between pilot cities and nonpilot cities, break down regional administrative barriers, and promote the cross-regional flow of resources and factors in promoting NU development. This approach can also help improve the resulting factor agglomeration, technological progress, and marketization effects; realize the coordinated development of regional NU; and further exert the positive spatial spillover effect of NU pilot policies on WEC.

This paper improves the analysis of the impact of NU on the level of WEC and enriches the theory of NU and ecological civilization. The results of this study provide a reference for other developing countries and regions similar to Jiangxi Province in China to improve the WEC during the process of NU and achieve the harmonious coexistence of humans and water.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/w16020331/s1.

Author Contributions: Conceptualization, D.K. and L.L.; methodology, W.H.; software, W.Y.; validation, D.K., L.L., W.H. and W.Y.; formal analysis, D.K.; resources, L.L.; data curation, W.Y.; writing—original draft preparation, D.K.; writing—review and editing, W.H.; visualization, L.L.; supervision, W.H.; project administration, L.L.; funding acquisition, D.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Natural Science Foundation of China, grant number 72363022; the Project Supported by Jiangxi Provincial Natural Science Foundation, grant number 20232ACB203024; and the Social Science Foundation of Jiangxi Province, grant numbers 22GL56D and 21JL08D.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Kan, D.; Ye, X.; Lyu, L.; Huang, W. Study on the coupling coordination between new-type urbanization and water ecological environment and its driving factors: Evidence from Jiangxi Province, China. *Int. J. Environ. Res. Public Health* **2022**, *19*, 9998. [CrossRef] [PubMed]
2. Kan, D.; Yao, W.; Liu, X.; Lyu, L.; Huang, W. Study on the coordination of new urbanization and water ecological civilization and its driving factors: Evidence from the Yangtze River Economic Belt, China. *Land* **2023**, *12*, 1191. [CrossRef]
3. Li, S.S.; Liu, Y.B.; Luo, K. Spatial spillover effect of new-type urbanization on carbon emission intensity in counties around the Poyang Lake. *Resour. Sci.* **2022**, *7*, 1449–1462. [CrossRef]
4. Wang, Z.F.; Wang, Q. Threshold effect of new urbanization on tourism carbon emission in Yangtze River Economic Belt. *Resour. Environ. Yangtze Basin* **2022**, *1*, 13–24.
5. Zhang, Y.; Chen, X. Spatial and nonlinear effects of new-type urbanization and technological innovation on industrial carbon dioxide emission in the Yangtze River Delta. *Environ. Sci. Pollut. Res.* **2023**, *11*, 29243–29257. [CrossRef]

6. Lv, Y.J.; Gao, B. The direct impact of new urbanization on environmental pollution and spatial spillover: Taking 108 cities in the Yangtze River Economic Belt as example. *J. Dalian Univ. Technol.* **2021**, *5*, 41–51.
7. Cai, Q.; Zhang, Y. Impact mechanism of new urbanization on environmental pollution: Empirical analysis based on spatial panel model. *Front. Public Health* **2022**, *10*, 2056.
8. Xie, R.; Chen, Y.; Han, F.; Fang, J.Y. Research on influence and time-space effect of new-type urbanization on urban eco-environmental quality. *Manag. Rev.* **2018**, *30*, 230–241.
9. He, G.; Yang, J.W.; Bao, K.Y.; Zhou, Q.T. Analysis for the spatial correlation and the impact of the newly urbanized trend on the regional eco-environment quality. *J. Saf. Environ.* **2020**, *5*, 1958–1966.
10. Cheng, Z.; Wang, L. Can new urbanization improve urban total-factor energy efficiency in China? *Energy* **2023**, *266*, 126494. [CrossRef]
11. Xiao, Y.; Huang, H.; Qian, X.M.; Zhang, L.Y.; An, B.W. Can new-type urbanization reduce urban building carbon emissions? New evidence from China. *Sustain. Cities Soc.* **2023**, *90*, 104410. [CrossRef]
12. Yang, X.; Jia, Z.; Yang, Z. How new-type urbanization pilots reduce carbon emissions: A technology progress paths perspective. *J. Clean. Prod.* **2023**, *401*, 136663. [CrossRef]
13. Deng, Z.B.; Su, C.W.; Zong, S.W.; Song, X.J. Measurement and analysis of China's water ecological civilization construction index. *China Soft Sci.* **2019**, *9*, 82–92.
14. Yu, X.X.; Dai, M.Y.; Sheng, X.M. Spatial and temporal characteristics and optimization path of water ecological civilization construction in Yangtze River Economic Belt. *Yangtze River* **2021**, *52*, 1–6.
15. Zhang, G.X.; Wang, H. Evaluation of water ecological civilization construction in central cities of the Yellow River Basin based on PSR Model. *Ecol. Econ.* **2022**, *38*, 211–216, 222.
16. Zhang, W.J.; Yue, Q.M.; Wen, H.Q.; Xu, X.Y.; Tian, P.; Liu, M.X. Evaluation of water ecologically civilized city construction. *J. Beijing Norm. Univ.* **2020**, *2*, 315–323.
17. Chen, L.; Fang, L.; Li, J. Evaluation of water ecological civilization in Guanzhong urban agglomeration based on principal component analysis. *Water Resour. Dev. Res.* **2018**, *18*, 16–21.
18. Fang, Y.Z.; Chen, Z.H.; Xiong, Y.J. Evaluation of water ecological civilization of Zhongshan city based on AHP-fuzzy comprehensive method. *Acta Sci. Nat. Univ. Sunyatseni* **2021**, *60*, 88–98.
19. Kan, D.; Yao, W.; Lyu, L.; Huang, W. Temporal and spatial difference analysis and impact factors of water ecological civilization level: Evidence from Jiangxi Province, China. *Land* **2022**, *11*, 1459. [CrossRef]
20. Zhao, Z.H.; Peng, Y.L. Evaluation of water ecological civilization city construction in Luoyang City. *Yellow River* **2023**, *45*, 79–80, 82.
21. She, H.; Wang, L.Q.; Li, T.N.; Guo, W.W. Evaluation of water ecological civilization construction of Mudanjiang City based on matter element extension method. *J. Eng. Heilongjiang Univ.* **2019**, *10*, 50–56.
22. Wang, F.Q.; Liu, P.H.; Wei, H.B. Evaluation on the construction effect of water ecological civilization city in Zhengzhou. *J. N. China Univ. Water Resour. Electric Power* **2019**, *40*, 58–63.
23. Kan, D.X.; Lv, L.J. The impact of China's urbanization on water resources utilization. *Urban Probl.* **2018**, *7*, 4–12.
24. Zeng, H.; Yan, C.H.; Huang, W.B.; Lin, Q.Y.; Yu, L.Y.; Qiu, G.Y. A case study on the relationship between urbanization level and water use efficiency in the Pearl River Delta Urban Agglomeration. *Acta Sci. Nat. Univ. Pekin.* **2020**, *3*, 561–570.
25. Meinzen-Dick, R.; Appasamy, P.P. *Urbanization and Intersectoral Competition for Water*; The Woodrow Wilson Institute: Washington, DC, USA, 2012; pp. 27–51.
26. Hai, X.; Li, W.F.; Wang, C.; Zhou, W.Q.; Han, L.J.; Qian, Y.G. Interactions between water use efficiency and urbanization level in the Beijing-Tianjin-Hebei megaregion, China. *Acta Ecol. Sin.* **2018**, *12*, 4245–4256.
27. Zhang, H.Q.; Li, Y.M.; Zhang, C.J. Dynamic effects and regional disparity of population, economy and industrial urbanization on the water consumption. *Ind. Technol. Econ.* **2019**, *1*, 83–90.
28. Qin, T.; Zhang, H.Q.; Tong, J.P.; Ma, J.F. Analysis on threshold effects and dynamic mechanism of water consumption growth in the process of urbanization. *China Pop. Resour. Environ.* **2017**, *5*, 45–53.
29. Hou, L. Coordinated development of urbanization and water resources in Wuhan City. *Yangtze River* **2023**, *54*, 124–130.
30. Qin, Z.W.; Nie, X.Q. Spatial and temporal evolution and drivers of coordinated development of urbanization efficiency and water resources efficiency in the Yangtze River Economic Belt. *Resour. Environ. Yangtze Basin.* **2023**, *32*, 2237–2253.
31. Yang, Y.; Xie, Z.Y. Evaluation on coordination level of water resources utilization and urban development in urban agglomerations in the Yellow River Basin. *Yellow River* **2024**, *46*, 56–60, 108.
32. Chao, J.L.; Li, L.L.; Yang, S.; Lei, T.J.; Zhao, D.Y.; Li, H.J. Coupling and coordination relationship between urbanization and water resources in the Fenhe River Basin. *Sci. Geogr. Sin.* **2022**, *42*, 487–496.
33. Wang, B.; Yang, C. A study on the constraint effect of water resources in the Yangtze River Economic Belt on urbanization. *Macroeconomics* **2019**, *6*, 122–131.
34. Cao, Q.W.; Bao, C.; Gu, C.L.; Guan, W.H. China's urbanization SD modelling and simulation based on water resource constraints. *Geogr. Res.* **2019**, *38*, 167–180.
35. Qin, T.; Zhang, H.Q.; Tong, J.P.; Ma, J.F.; Zhi, Y.L. Water resource constraint on urbanization in Yangtze River Economic Belt. *China Pop. Resour. Environ.* **2018**, *28*, 39–45.
36. Xia, J.; Diao, Y.X.; She, D.X.; Li, M.; Zhang, Y.F.; Ding, W.L.; Yao, C.H.; Liu, Z. Analysis on ecological security and ecological carrying capacity of water resources in the Poyang Lake Basin. *Water Resour. Prot.* **2022**, *38*, 1–8, 24.

37. Fu, C.; Luo, Y.; Pei, W.H.; Deng, J.P.; Wang, L.Z. The response of water resources system to urbanization in Poyang Lake Basin. *China Rural. Water Hydropower* **2021**, *6*, 55–60, 68.
38. Hu, M.H.; Liao, G.X.; Yuan, J.H.; Lu, F.C. The temporal-spatial changes and its influencing factors of regional water use efficiency of Poyang Lake Eco-Economic Zone based on DEA-CCA model. *J. Jiangxi Norm. Univ.* **2018**, *42*, 427–433.
39. Sun, Y.; Yan, K.X. Inference on difference-in-differences average treatment effects: A fixed-b approach. *J. Econom.* **2019**, *2*, 560–588. [CrossRef]
40. Bai, J.H.; Zhang, Y.X.; Bian, Y.C. Does innovation-driven policy increase entrepreneurial activity in cities: Evidence from the National Innovative City Pilot Policy. *China Ind. Econ.* **2022**, *6*, 61–78.
41. Liu, Y.; Zhou, J.J. How do house prices affect urban resident's consumption in China: Promotion or inhibition? *Consum. Econ.* **2019**, *1*, 49–56.
42. Wu, C.Q.; Zhang, S.N. Research on the impact of urbanization and industrial agglomeration on the innovation of the Yangtze River Economic Belt. *J. Hebei Univ. Econ. Trade* **2021**, *5*, 61–69.
43. Zhao, T.; Zhang, Z.; Liang, S.K. Digital economy, entrepreneurship, and high-quality economic development: Empirical evidence from urban China. *Manag. World* **2020**, *10*, 65–76.
44. Xu, L.; Lin, S.Y.; Qian, S.F. The slow-release effect of environmental information disclosure and green technology innovation on the financing constraints. *Secur. Mark. Her.* **2021**, *9*, 23–33.
45. Guo, F.; Wang, J.Y.; Wang, F.; Kong, T.; Zhang, X.; Cheng, Z.Y. Measuring China's digital financial inclusion: Index compilation and spatial characteristics. *China Econ. Quart.* **2020**, *4*, 1401–1418.
46. Tian, G.L.; Zhao, Q.Y.; Wu, Z. Water-saving effects of water right reform under the rural vitalization strategy and its impact on water efficiency. *China Pop. Resour. Environ.* **2022**, *12*, 193–204.
47. Shi, D.; Li, S.L. Emissions trading system and energy use efficiency: Measurements and empirical evidence for cities at and above the prefecture level. *China Ind. Econ.* **2020**, *9*, 5–23.
48. Su, C.W.; Deng, Z.B.; Li, L.P.; Wen, J.X.; Cao, Y.F. Spatial pattern evolution and convergence of water eco-civilization development index in China. *J. Nat. Resour.* **2021**, *36*, 1282–1301. [CrossRef]
49. Darko, G.; Obiri-Yeboah, S.; Takyi, S.A.; Amponsah, O.; Borquaye, L.S.; Amponsah, L.O.; Fosu-Mensah, B.Y. Urbanizing with or without nature: Pollution effects of human activities on water quality of major rivers that drain the Kumasi Metropolis of Ghana. *Environ. Monit. Assess.* **2022**, *194*, 38. [CrossRef]
50. Margaret, Y.O.; Adebayo, O.E.; Ifeanyi, E.O. Urbanization and its effects on land and water resources in Ijebuland, southwestern Nigeria. *Environ. Dev. Sustain.* **2022**, *24*, 592–616.
51. Li, C.G. Study on the spatial spillover effect and threshold effect of urbanization on environmental pollution in China. *Ecol. Econ.* **2021**, *37*, 197–206.
52. Al-Mulali, U.; Weng, W.C.; Sheau-Ting, L. Investigating the environmental Kuznets curve (EKC) hypothesis by utilizing the ecological footprint as an indicator of environmental degradation. *Ecol. Indic.* **2015**, *48*, 315–323. [CrossRef]
53. Irfan, M.; Shaw, K. Modeling the effects of energy consumption and urbanization on environmental pollution in South Asian countries: A nonparametric panel approach. *Qual. Quant. Int. J. Methodol.* **2017**, *51*, 65–78. [CrossRef]