water

MDPI

Article

Impact of China's Urbanization on Water Use and Energy Consumption: An Econometric Method and Spatiotemporal Analysis

Yan Wang, Weihua Xiao *, Yicheng Wang, Yong Zhao *, Jianhua Wang, Baodeng Hou, Xinyi Song and Xuelei Zhang

State Key Laboratory of Simulation and Regulation of Water Cycle in River Basin, China Institute of Water Resources and Hydropower Research, Beijing 100038, China; wangyan8926@126.com (Y.W.); wangych@iwhr.com (Y.W.); wjh@iwhr.com (J.W.); houbaodeng@163.com (B.H.); 15110192305@163.com (X.S.); 18215106336@163.com (X.Z.)

* Correspondence: xwsen998@163.com(W.X.); zhaoyong@iwhr.com (Y.Z.); Tel.: +86-10-6878-1950 (W.X.)

Received: 8 August 2018; Accepted: 19 September 2018; Published: 25 September 2018

Abstract: As important subsystems of the urban environment, water resources and energy are necessary for normal urban functions and play an important supporting role in urbanization. The rapid development of China's economy is increasingly dependent on these two subsystems. Analyses of the relationship between urbanization and water use or energy consumption have become the focus of attention, but researchers have mainly evaluated the impact on the two subsystems separately without providing an integrated analysis, nor have they revealed the link between water use and energy consumption. We addressed this information gap by using an econometric method to empirically investigate the long-term equilibrium relationships and Granger causal relationships among urbanization, water use, and energy consumption in China, and by conducting a spatiotemporal analysis to identify the trends of water use intensity and energy consumption intensity under the effects of urbanization during 2005–2015. We found long-term equilibrium relationships among urbanization, water use, and energy consumption. Granger causality results reveal the presence of a unidirectional Granger causal relationship running from urbanization to energy consumption and to water use, and bidirectional causality between energy consumption and water use. Moreover, water use intensity and energy consumption intensity decreased significantly under urbanization during the study period.

Keywords: urbanization; water use; energy consumption; cointegration test; Granger causality test; spatiotemporal analysis

1. Introduction

A trend throughout world history has been industrial concentration, labor agglomeration, and the migration of large populations into cities, along with the advancement of industrialization, promoting the urbanization of a country or a region [1]. China's urbanization level had risen at an annual growth rate of more than 1% over the past 20 years [2]. According to the first Macroeconomics Blue Book published by Social Sciences Academic Press, the urbanization rate of China is predicted to be 57.67% in 2020, and 67.81% in 2030 [3]. According to Dhakal [4], China's urban energy consumption accounts for 75% of the total consumption, and the demand for water resources is also increasing. Energy and water resources, as the basic resources of urban economic development, are in high demand for the promotion of urbanization [5]. At the same time, there is a dependency relationship between energy and water resources, which is called the energy–water nexus [6,7]. Energy is consumed in various urban industries in the stages of water supply, use, drainage, and sewage treatment and reuse. Water is needed in many aspects of energy generation: from coal mining and washing, hydro power production, to power plant cooling [8–10]. The relationship between urbanization and water resources utilization or energy consumption, as well as the relationship between water and energy has, therefore, become a focus of scholars.

In recent years, scholars have conducted considerable research on the mechanisms by which urbanization influences total energy consumption and energy efficiency. Scholars have proposed that the advances of urbanization promote economic growth and improve people's living standards, thus increasing the amount of energy consumption [11–14]. Through empirical analysis, scholars have found that the continuous improvement of the urbanization process has led to increased rational industrial transition, improved technology and production infrastructure, optimized allocation, and enhanced the use efficiency of energy resources [15–18]. For example, Poumanyvong and Kaneko empirically researched countries in different stages of development, and found that urbanization reduced energy consumption in low-income countries, but increased energy consumption in middle-income and high-income countries [19]. Shahbaz and Lean assessed the relationships among energy consumption, economic growth, and urbanization, in Tunisia from 1971 to 2008, and confirmed that long-term bidirectional causalities are found between energy consumption and urbanization [14]. Li et al. adopted a stochastic frontier model to evaluate how urbanization affected the energy efficiency in China, and the results revealed that energy efficiency has improved due to the impact of urbanization [20]. Yan used a balanced panel dataset to empirically investigate the impacts of urbanization on China's energy intensity and found that urbanization is responsible for increasing energy efficiency [21]. Additionally, previous studies have investigated the relationship between urbanization and water resources. For example, Sun et al. studied the relationship between urban development and water use in Beijing, and their results indicated that urban development in Beijing has a strong impact on water utilization [22]. Feng et al. conducted a structural decomposition analysis to explore the driving force of the water footprint during the rapid urbanization process of Zhangye city, and concluded that technological innovations and final demand structure adjustments should be prioritized for Zhangye to reduce the water footprint [23]. Although previous studies have studied the impact of urbanization on water use and energy consumption separately, and have ascertained the causal relationship between urbanization and water use or energy consumption, only a few studies have fully identified the spatiotemporal characteristics of water use and energy consumption during the diverse stages of urbanization in China.

With the increasing demand for water and energy and the growing tensions between water and energy departments, the water and energy nexus has become the focus of global research. Gleick first emphasized the interdependence between water and energy and posited that there was a strong balance between the growing water crisis and energy resource conflicts [24]. Sun et al. presented an energy–water nexus in the Beijing–Tianjin–Hebei region, from the perspective of the electricity sector, and found that, while the insufficient water demand of power generation can be mitigated, to a certain degree, through power structure adjustments and technological advancements, the trend towards water shortages cannot be avoided [8]. Wilkinson established a model to calculate the energy intensity and total energy demand of the water system in California, and analyzed the potential role of the effective use of water resources with respect to energy savings [25]. Stillwell et al. reported that, in the United States, producing 1 m^3 surface water requires 0.06 kWh and that extracting 1 m^3 water from a depth of 40 m requires 0.140 kWh [26]. Jiang et al. analyzed the link between domestic water use and energy consumption and synchronous measures of water savings and energy savings in Tianjin City [27]. In the past, scholars have concentrated on the physical linkages of water and energy resources. However, few studies have quantified China's energy–water nexus from an econometrics perspective, and people have paid little attention to estimating the relationships involving three or more variables. This deficiency motivated us to identify the relationships among urbanization, water use, and energy consumption. With varied socioeconomic development phases and natural endowments, a large discrepancy also exists among different provinces regarding urbanization levels in China. Hence, it is important to identify the characteristics of water use and energy consumption at different levels of urbanization according to a spatiotemporal scale. Since the urbanization process experiences comprehensive transformations as a result of social and technological aspects, it is necessary to build a multiple dimension evaluation method to assess the level of urbanization.

In China, water use intensity (WUI: water use per unit of gross domestic product) and energy consumption intensity (ECI: energy consumption per unit of gross domestic product) have been the most important indicators of water and energy security when making policy. China's 13th Five-Year Plan clearly stated that the goals of controlling total water amount and water use intensity should be implemented such that water use intensity will decrease by 23% by 2020 [28]. The goal of controlling energy consumption intensity is also proposed in the 13th Five-Year Plan. In Beijing, for example, energy consumption intensity is to be reduced by 17% from 2016 to 2020 [29]. Since water use intensity and energy consumption intensity are both national policy objectives, we adopt these two indicators to identify the tendency of water use and energy consumption characteristics under the impact of urban development.

This paper, which is based on previous research results, attempts to determine (1) whether there is a long-term equilibrium relationship among urbanization, energy consumption, and water use, and (2) what the spatiotemporal characteristics of water use intensity and energy consumption intensity are, given the different degrees of urbanization in China. To fill these information gaps, we (1) analyze the relationship among urbanization, water use, and energy consumption using a cointegration test and the Granger causality test, (2) build a multiple dimension evaluation method using factor analysis to assess the level of urbanization and to classify the provinces into different urbanization phases, and (3) quantify tendencies of water use intensity (WUI) and energy consumption intensity (ECI) in primary and secondary industries at varied levels of urbanization to create a complete picture of the spatiotemporal characteristics of water use and energy consumption in China (tertiary industries were not included in this study, due to a lack of water use data).

2. Materials and Methods

2.1. Data

The time series data of the total population and the urban population, as well as the GDP (official currency of China) of primary industries (PI) and the secondary industries (SI), along with the energy consumption data and total water use data during the study period, were obtained from the China Statistical Yearbooks [30–40]. The GDP was converted to constant prices (2005 prices) to eliminate the influence of price changes when calculating economic aggregates, and to facilitate a comparison of aggregates over time [41].

2.2. Methodology

2.2.1. Econometric Methodology

We first examine the stationarity of the data to analyze the time series data, so as to avoid a spurious regression [42]. The ADF (augmented Dickey–Fuller test) unit root test proposed by Dickey and Fuller was used to test the stationary status of each variable. If the variables were all stationary at the first difference, the cointegration test was used to examine the long-term equilibrium relationships between and among the variables. The Engle and Granger two-step method was adopted for the cointegration test, and the stationary linear combination is referred to as the cointegration regression equation [43]. The main steps of the cointegration test are as follows:

(1) If k sequences $y_1, y_2, y_3, \ldots, y_k$ are all at the first difference, the regression equation is established:

$$y_{1t} = \beta_2 y_{2t} + \beta_3 y_{3t} + \ldots + \beta_k y_{kt} + u_t, \ \mathrm{t} = 1, 2, \ldots, \mathrm{T}. \tag{1}$$

The residual of model estimation is as follows:

$$\hat{u}_t = y_{1t} - \hat{\beta}_2 y_{2t} - \hat{\beta}_3 y_{3t} - \ldots - \hat{\beta}_k y_{kt},\ \mathrm{t} = 1, 2, \ldots, \mathrm{T}. \quad (2)$$

where β is the index of y in regression equation and $\hat{\beta}$ is the index of the residual value.

(2) Test whether the residual sequence $\hat{u}_t$ is stationary, i.e., whether the sequence contains unit roots, which is usually is determined using the ADF test.

(3) The cointegration relation between the k variables in the regression equation can be determined if the residual sequence is stationary. Otherwise, there is no cointegration relation between or among the k variables.

The Granger causality test is an important causal test method in econometrics [44]. In the case of the time series, the Granger causality of two variables, x and y, is defined as follows. If the prediction result of variable y under the condition of containing the past information of variable x is better than that with only the past information of y, i.e., variable x helps explain the future change of variable y, we consider that variable x is the Granger cause of variable y [45]. The test model is as follows:

$$y_t = a_0 + \sum_{i=1}^{m} a_i y_{t-i} + \sum_{i=1}^{m} b_i x_{t-i} + e_t,\ \mathrm{t} = 1, 2, \ldots, \mathrm{T} \quad (3)$$

where a_0 is the model constant; a_i, b_i are the indexes of y_{t-i}, x_{t-i} (i≠1),respectively and e is the error term. The null hypothesis of the test model is b_i = 0. Under the null hypothesis, variable x is not the Granger cause of variable y. If the original hypothesis is rejected, variable x is the Granger cause of variable y. In the same way, we can test whether variable y is the Granger cause of variable x.

2.2.2. Spatiotemporal Analysis

Spatial Analysis

Based on the varied degrees of urbanization, the spatial scale includes 30 provinces (Tibet, Hong Kong, Macau, and Taiwan were not included, due to data deficiencies) that were classified into three sections, namely, urbanized region, urbanizing region, and under-urbanized region, to support further analysis of the impact of China's different levels of urbanization on water use and energy consumption. We applied factor analysis to classify the various levels of urbanization. The multidimensional classification factors include the urbanization of people, i.e., urban population/total population, the urbanization of technology, i.e., WUI and ECI, and the urbanization of industry structure, i.e., increased contribution of secondary industries and tertiary industries to GDP [46].

Temporal Analysis

To determine the range of the possible trends in the WUI and ECI indicators and their statistical significance during the 2005 to 2015 period, the nonparametric Sen's slope method and Mann–Kendall test were used. Sen's slope was used to verify the range of the possible trends in the statistical sequence [47,48], and the Mann–Kendall test was selected to substantiate the statistical significance [49,50].

2.2.3. Factor Analysis

Factor analysis is a multivariate statistical method used for dimensionality reduction, in which a few comprehensive variables are selected from a multiple-variable index [51,52]. The outcome of the factor analysis is a grouping of variables that improve the correlation of the variables in the group while decreasing the correlation in different groups, thus reasonably explaining the correlation between and among the original variables and reducing dimensionality. The general steps are as follows [53].

N evaluation samples are used as hypotheses, and each sample has P observations. Then, the N × P matrix is constructed.

(1) The data are standardized to eliminate the impact of dimensionality.

$$z = \frac{x_{ij} - \overline{x}_j}{s_j} \ \mathrm{i} = 1, 2, \ldots, \mathrm{n}; \mathrm{j} = 1, 2, \ldots, \mathrm{p} \tag{4}$$

where $\overline{x}_j = \frac{1}{n}\sum_{i=1}^{n} x_{ij}$ represents the mean value of the jth evaluation index and $s_j = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n} (x_{ij} - \overline{x}_j)^2}$ represents the standard deviation of the jth evaluation index.

(2) The common factors are confirmed using the correlation matrix R and corresponding eigenvalues and eigenvectors. The P observations are expressed using the linear combination of common factors $F_1, F_2, \ldots, F_m$.

$$Z = AF + \varepsilon \tag{5}$$

(3) The maximum orthogonal rotation of the factor load is performed. The factor scores are calculated according to the formula

$$F_i = b_{i1}X_1 + b_{i2}X_2 + \ldots b_{ip}X_p \ \mathrm{i} = 1, 2, \ldots, \mathrm{m}; \tag{6}$$

where b_{i1} is the weight coefficient of the ith common factor for the jth evaluation parameter. The weight of each index is calculated using Equation (7).

$$W_{\mathrm{j}} = \frac{\sum_{i=1}^{m} b_{ij}e_i}{\sum_{j=1}^{p}\sum_{i=1}^{m} b_{ij}e_i} \tag{7}$$

(4) The composite score of each sample is calculated as $Y_j = W_j \times Z$.

3. Results

3.1. Results of Cointegration Test and Granger Causality Test

The natural logarithms of urbanization rate (UR, urban population/total population), total water use (WU) and energy consumption (EC) were used to eliminate the heteroscedasticity phenomenon in the time series data. The root tests were performed to test the stationarity of each variable. The results of the ADF unit root test are presented in Table 1, and indicate that all variables are stationary at the first difference and are found to be lnUR ~I (1), lnWU ~I (1), lnEC ~I (1), which can be used for the cointegration test.

The cointegration tests are formed according to the Engle and Granger two-step method. The cointegration regression equations were as follows:

$$\ln \mathrm{WU} = 8.018 + 0.170 \ln \mathrm{UR}, R^2 = 0.960, \tag{7}$$

$$\ln \mathrm{EC} = 4.964 + 1.989 \ln \mathrm{UR}, R^2 = 0.993, \tag{8}$$

$$\ln \mathrm{WU} = 7.633 + 0.080 \ln \mathrm{EC}, R^2 = 0.816, \tag{9}$$

$$\ln \mathrm{EC} = 4.699 + 1.858 \ln \mathrm{WU}, R^2 = 0.857. \tag{10}$$

The residual sequences were also performed using the ADF test. All residual sequences were stationary at a 1% significance level, indicating long-term equilibrium relationships among urbanization, water use, and energy consumption. The cointegration regression Equations (8)–(11), reveal that with a 1% increase in the urbanization rate, total water use increases by 0.17%, and energy consumption increases by 1.989%. This finding suggests that, in China, water use and energy consumption increase with the development of urbanization, and that the increase in the amplitude of energy consumption is greater than that of water. Meanwhile, for an increase of 1% in energy consumption, the total amount of water use increases by 0.08%, and for an increase of 1% in total water use, energy consumption increases by 1.858%. This finding indicates that water use has a positive effect on energy consumption, and that energy consumption has a positive effect on water use. These results indicate that as China's urbanization level increases, a greater demand is placed on water and energy resources.

The Granger test can be used to test the causal relationships between and among these three variables. Table 2 indicates that, with a lag period of one year, urbanization is the Granger cause of water use and energy consumption, whereas water use and energy consumption are not the Granger causes of urbanization. Additionally, there exists a bidirectional Granger causal relationship between water use and energy consumption. These results are in concordance with the results of the cointegration test.

Table 1. Unit root test results.

Variable	ADF Test Value	Critical Value of Significance at 1% Level	Stationary/Nonstationary
lnUR	−1.632	−3.857	Nonstationary
ΔlnUR	−5.172	−4.668	Stationary
lnWU	−2.221	−3.887	Nonstationary
ΔlnWU	−4.998	−4.886	Stationary
lnEC	−2.121	−3.887	Nonstationary
ΔlnEC	−2.991	−2.708	Stationary

Table 2. Results of Granger causality tests.

Null Hypothesis	F Value	*p* Value	Decision	Causal Conclusion
UR does not cause WU	6.083	0.025	Reject	UR causes WU
WU does not cause UR	0.084	0.776	Accept	WU does not cause UR
UR does not cause EC	33.185	0.005	Reject	UR cause EC
EC does not cause UR	1.037	0.324	Accept	EC does not cause UR
WU does not cause EC	47.269	0.004	Reject	WU causes EC
EC does not cause WU	15.508	0.001	Reject	EC causes WU

3.2. Results of Factor Analysis

In this study, factor analysis was used to build the multiple dimension evaluation method. The evaluation index consists of the urbanization of people (urban population/ total population), the urbanization of technology (water use intensity, energy consumption intensity) and the urbanization of industry structure (the added value of the GDP from secondary industries and the added value of the GDP from tertiary industries). The value of each variable in 2015 was selected for the factor analysis. Table 3 indicates that the cumulative contribution rate of the first two principal factors represents 93.125% of the total information. Thus, the first two factors are extracted to analyze the degree of urbanization. The scores and rankings of the degrees of urbanization of 30 provinces in China are presented in Table 4.

The results of the Kolmogorov–Smirnov test showed that the scores of the degrees of urbanization of the 30 provinces obeyed normal distribution characteristics. Based on the Kolmogorov–Smirnov test results, the degrees of urbanization of the whole country are divided into three categories, and the probability of each category was set at 0.33. Hence, a composite score less than ($\mu - 0.44\sigma$) is defined as the under-urbanized region, a composite score greater than ($\mu + 0.44\sigma$) is defined as the urbanized region, and composite scores between the two values are defined as the urbanizing region. The 30 provinces were then classified into one of three regions. (1) The urbanized region consisted of seven provinces, namely, Beijing, Tianjin, Zhejiang, Jiangsu, Shanghai, Guangdong, and Fujian.

(2) The urbanizing region consisted of sixteen provinces, namely, Chongqing, Jilin, Hubei, Hunan, Shaanxi, Liaoning, Shandong, Hainan, Shanxi, Hebei, Henan, Sichuan, Heilongjiang, Jiangxi, Guangxi, and Anhui. (3) The under-urbanized region consisted of seven provinces, namely, Ningxia, Inner Mongolia, Qinghai, Xinjiang, Guizhou, Yunnan, and Gansu. Accordingly, the results indicated that more than half of the provinces were in the urbanizing stage. The level of urbanization, as the most important criterion to classify the regions in China, provides a new perspective for studying the country from a spatial perspective. The varied urbanization degrees in China are presented in Figure 1.

Table 3. The eigenvalues and cumulative contribution rates of the degrees of urbanization.

Component	Eigenvalue	Contribution Rate of Factor Analysis/%	Cumulative Contribution Rate/%
1	3.025	53.134	53.134
2	2.758	39.991	93.125

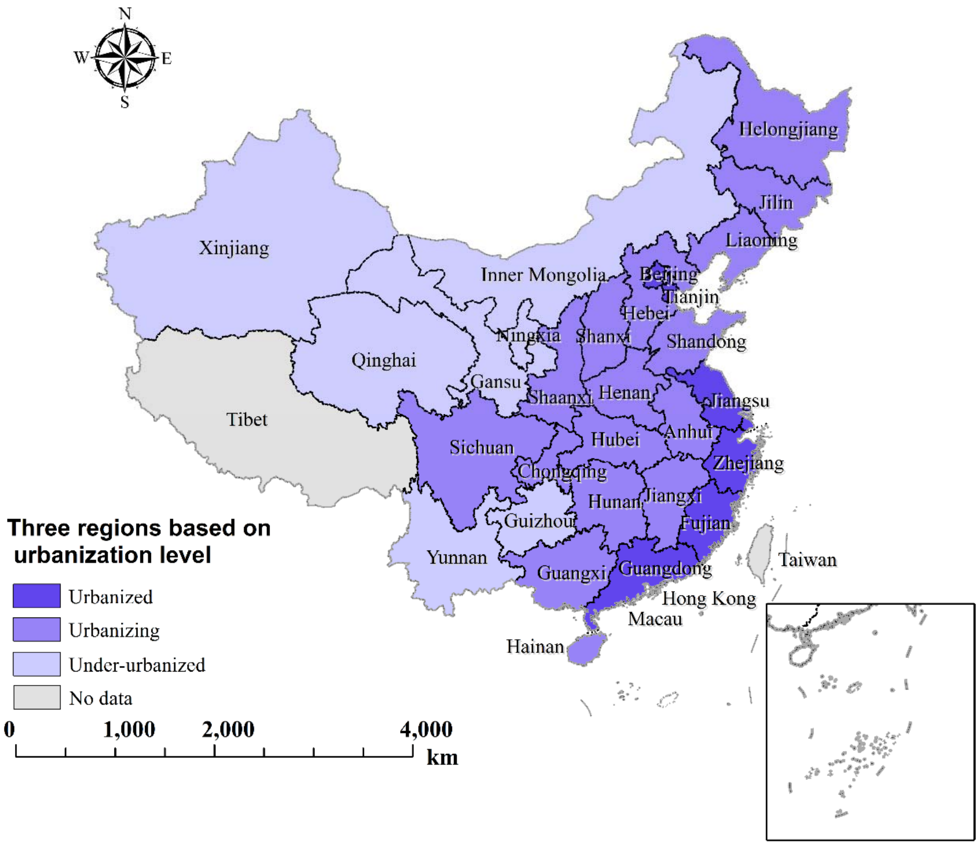

Figure 1. The three regions based on the degrees of urbanization (2015).

Table 4. The scores and rankings of the degrees of urbanization of 30 provinces in China.

Province	F_1	F_2	Composite Score	Ranking	Provinces	F_1	F_2	Composite Score	Ranking
Beijing	2.526	1.162	1.805	1	Shanxi	−0.232	0.144	−0.066	16
Tianjin	2.005	1.156	1.526	2	Hebei	−0.393	0.119	−0.161	17
Zhejiang	1.454	1.097	1.210	3	Henan	−0.343	−0.008	−0.185	18
Jiangsu	1.063	0.996	0.962	4	Sichuan	−0.448	−0.013	−0.243	19
Shanghai	0.939	0.872	0.847	5	Heilongjiang	−0.474	−0.224	−0.341	20
Guangdong	0.600	0.813	0.643	6	Jiangxi	−0.549	−0.121	−0.340	21
Fujian	0.435	0.770	0.538	7	Guangxi	−0.575	−0.130	−0.357	22
Chongqing	0.271	0.483	0.337	8	Anhui	−0.645	−0.063	−0.368	23
Jilin	0.172	0.487	0.286	9	Ningxia	−0.775	−0.414	−0.576	24
Hubei	0.071	0.672	0.306	10	Inner Mongolia	−0.851	−0.539	−0.667	25
Hunan	0.035	0.614	0.264	11	Qinghai	−0.887	−1.019	−0.877	26
Shaanxi	0.011	0.612	0.250	12	Xinjiang	−0.915	−1.353	−1.026	27
Liaoning	−0.055	0.236	0.065	13	Guizhou	−0.930	−1.782	−1.205	28
Shandong	−0.077	0.370	0.107	14	Yunnan	−0.934	−2.190	−1.370	29
Hainan	−0.159	0.179	−0.013	15	Gansu	−1.029	−2.815	−1.670	30

3.3. WUI and ECI Tendencies During Urbanization

3.3.1. WUI Tendency During Urbanization

The results of Sen's slope and the Mann–Kendall test, regarding China's provincial water use intensity (WUI, $m^3/10^4$ RMB) (RMB, official currency of China) during the 2005 to 2015 period, are presented in Figure 2, and data for each industry are available in Tables A1–A3 in Appendix A. At the national scale, the overall WUI showed a significant downward trend during the 2005 to 2015 period, with the total WUI decreasing from 300.72 $m^3/10^4$ RMB to 130.57 $m^3/10^4$ RMB during these eleven years (Table A1). Regarding the WUI values of PI and SI, the WUI values showed the same downward magnitude (PI from 1641.69 $m^3/10^4$ RMB to 632.82 $m^3/10^4$ RMB; SI from 145.91 $m^3/10^4$ RMB to 57.57 $m^3/10^4$ RMB) (Tables A2 and A3). Accordingly, it is concluded that the WUI of PI was the main factor contributing to the total WUI decrease at the national level.

Significant decreasing trends were found in all provinces during the 2005 to 2015 period. Among them, the WUI of urbanized, urbanizing, and under-urbanized regions showed diverse declining trends. The average WUI in urbanized regions decreased from 166.31 $m^3/10^4$ RMB to 58.90 $m^3/10^4$ RMB (Figure 2, Table A1), whereas in urbanizing regions, it decreased from 331.65 $m^3/10^4$ RMB to 125.55 $m^3/10^4$ RMB (Figure 2, Table A1). Similarly, it decreased, on average, in under-urbanized regions, from 826.22 $m^3/10^4$ RMB to 286.58 $m^3/10^4$ RMB (Figure 2, Table A1). More specifically, the average WUI in urbanized regions showed a minimum value, while that in under-urbanized regions was the greatest. The most extreme difference was between Beijing (urbanized region) and Xinjiang (under-urbanized region), where the WUI in the latter showed the highest total provincial WUI during the 2005 to 2015 period and, moreover, the values were 36 to 42 times greater than those of Beijing.

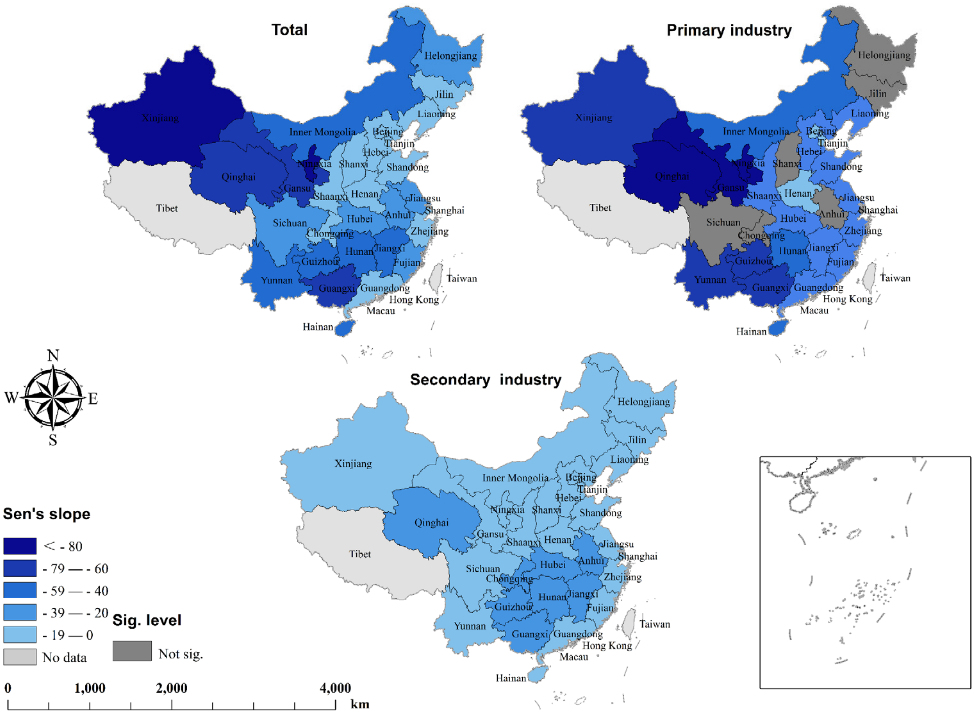

Figure 2. The magnitude of each trend and its statistical significance for China's provincial water use intensity (WUI, $m^3/10^4$ RMB) during the 2005 to 2015 period. Data are available in Tables A1–A3.

From an industrial perspective, the average WUI values of PI and SI in urbanized regions declined from 673.41 $m^3/10^4$ RMB and 132.90 $m^3/10^4$ RMB, to 447.54 $m^3/10^4$ RMB and 45.47 $m^3/10^4$ RMB, respectively (Figure 2, Table A2, Table A3), and the average WUI values of PI and SI in urbanizing regions decreased from 912.21 $m^3/10^4$ RMB and 197.21 $m^3/10^4$ RMB, to 656.47 $m^3/10^4$ RMB and 56.15 $m^3/10^4$ RMB, respectively. The average WUI values of PI and SI in under-urbanized regions decrease from 2840.99 $m^3/10^4$ RMB and 202.55 $m^3/10^4$ RMB, to 1661.6 $m^3/10^4$ RMB and 58.07 $m^3/10^4$ RMB, respectively (Figure 2, Table A2, Table A3). While the WUI of PI decreased the most at both the provincial and national levels, the average WUI values of PI and SI in under-urbanized regions were higher than those in both urbanizing and urbanized regions over the eleven-year period.

3.3.2. ECI Tendency During Urbanization

The results of Sen's slope and the Mann–Kendall test for China's provincial energy consumption intensity (ECI, $t/10^4$ RMB) during the 2005 to 2015 period are presented in Figure 3, and the data for each industry are available in Tables A4–A6 in Appendix A. Across China, the total ECI value decreased significantly, from 1.27 TCE/10^4 RMB (TCE, ton of standard coal equivalent)to 0.92 TCE/10^4 RMB, during the 2005 to 2015 period (Table A4). A significant declining trend of ECI in both PI and SI was detected, with decreases from 0.28 TCE/10^4 RMB to 0.14 TCE/10^4 RMB, and from 1.95 TCE/10^4 RMB to 1.29 TCE/10^4 RMB, respectively (Table A5 to Table A6). Accordingly, it is concluded that the ECI of SI was the key factor contributing to the total downward trend.

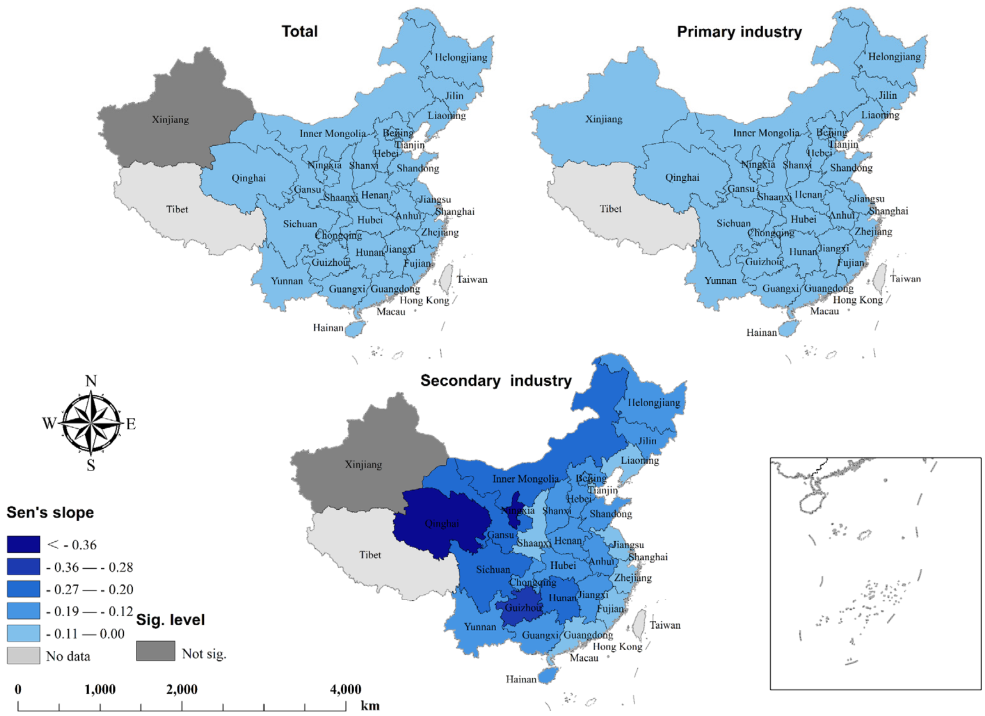

Figure 3. The magnitude of each trend and its statistical significance with respect to China's provincial energy consumption intensity (ECI, $t/10^4$ RMB) during the 2005 to 2015 period. Data are available in Tables A4–A6.

Regarding the total ECI at the provincial scale, a significant declining trend was found in all provinces, except Heilongjiang, Shaanxi, and Xinjiang. The average total ECI decreased from 0.87 TCE/10^4 RMB to 0.52 TCE/10^4 RMB (Figure 3, Table A4) in urbanized regions, and from 1.34 TCE/10^4 RMB to 0.84 TCE/10^4 RMB in urbanizing regions (Figure 3, Table A4). Meanwhile, the average ECI in under-urbanized regions decreased from 2.65 TCE/10^4 RMB to 1.86 TCE/10^4 RMB during the 2005 to 2015 period (Figure 3, Table A4). The average ECI in under-urbanized regions was higher than that in both urbanizing and urbanized regions during the eleven-year period.

Furthermore, a significant downward tendency in the provincial ECI values was detected in PI. The average ECI value of PI dropped from 0.18 TCE/10^4 RMB to 0.08 TCE/10^4 RMB in urbanized regions (Figure 3, Table A5), and from 0.31 TCE/10^4 RMB to 0.13 TCE/10^4 RMB in urbanizing regions (Figure 3, Table A5), while the under-urbanized regions experienced a decrease, on average, from 0.47 TCE/10^4 RMB to 0.24 TCE/10^4 RMB (Figure 3, Table A5) during the same period. Except for Xinjiang (an under-urbanized region), the ECI value of SI showed a significant declining trend. The ECI values of SI decreased, on average, from 1.36 TCE/10^4 RMB to 0.72 TCE/10^4 RMB (Figure 3, Table A6) in urbanized regions and from 2.55 TCE/10^4 RMB to 1.30 TCE/10^4 RMB (Figure 3, Table A6) in urbanizing regions, while the average ECI in under-urbanized regions decreased from 5.26 TCE/10^4 RMB to 2.93 TCE/10^4 RMB during 2005–2015 (Figure 3, Table A6). Therefore, it can be concluded that the ECI of SI were at the dominant position both provincially and nationally, and the average ECI values of PI and SI in urbanized regions showed a minimum value, while those in under-urbanized regions were the largest.

4. Discussion

Based on the empirical study, urbanization had an appreciable impact on water use and energy consumption, and the diverse trends regarding WUI and ECI of PI and SI were identified in the various urbanization regions.

China's total energy consumption grew substantially, from 7.66×10^{10} GJ to 1.25×10^{11} GJ, during the 2005 to 2015 period [30–40], a period when the annual growth rate was approximately 4.60%. Furthermore, total water use gradually increased when the annual growth rate was 0.80%, which is far less than the increase in energy consumption. Additionally, the SI sector consistently accounted for the greatest contribution to energy consumption, with a 67% share in 2015 [40], and the sustained and rapid growth of the national economy contributed by the SI sector was the main driving force for the tremendous increase in energy consumption. The water use by the PI sector was influenced by water-saving technology transformation and engineering construction. Meanwhile, the high-water production lines in the SI sector were gradually eliminated in China. The smooth increasing trend of total water use indicates that China's water-saving reforms had begun to demonstrate early results.

Generally, the urbanization process is a dynamic process that experiences comprehensive transformations with respect to population, technology, industrial structure, regional environment, etc. Based on the connotation of urbanization, the multiple dimension evaluation method not only reflects the change in the nature of a region's population, but also expresses the technological development level and industrial structure evolution of the region. Based on the results of factor analysis, China was divided into three parts, according to the level of urbanization, which takes into consideration the urbanization of people, technology, and industry structure. The results showed that only seven provinces were in a state of high urbanization, and seven provinces were regarded as under-urbanized, while more than half of the provinces were classified as urbanizing. These findings indicated that China's current urbanization process is unbalanced, and that there is a huge gap among the different provinces. The results of the factor analysis also revealed differences in the common geographic classification methods. According to prevailing opinion, provinces in the eastern coastal areas of China are more well developed in the high urbanizing stage than are provinces in the central areas, and the western region is lagging even further behind. However, the present results showed different patterns. For instance, Shandong and Hainan, which are located in the eastern coastal areas of China, are urbanizing regions. More importantly, from the perspective of the factor analysis, we obtained different information with respect to different parts of the country, which can provide more in-depth understanding of the impact of China's urbanization on water use and energy consumption.

China's WUI and ECI decreased consistently during the 2005 to 2015 period. The decreasing tendency at the provincial scale occurred due to technological progress and improving production efficiency [20,21,23]. Considering agriculture as an example, the decrease of WUI in PI was attributed to the innovation of agricultural irrigation and drainage technology, which improved the utilization efficiency of water resources and reduced water use. New crop varieties have also replaced the old high water-consuming varieties and reduced the water demand for crops. Additionally, there was a large disparity in the WUI and ECI among urbanized, urbanizing, and under-urbanized regions. The urbanized regions, such as Beijing, Shanghai, and Guangdong, have transformed into providing high-end services regarding information, finance, and science, for example, while the under-urbanized regions still rely on relatively high water and high energy consumption of SI and PI to drive economic growth.

Water and energy are the basic resources to achieve socioeconomic performance and environmental optimization objectives that influence society in various ways. By now, the policymaking on either optimizing the industrial structure or ensuring water and energy security were isolated from each other. In energy planning, water resources are often assumed to meet energy needs and vice versa. It is urgent for policymakers to conduct a full analysis of macro control policies governing water and energy issues, due to the close connections between the two. The urbanized, urbanizing, and under-urbanized regions showed different characteristics, due to the different stages of urbanization and natural endowments. Therefore, different urbanization strategies should be implemented in different areas.

5. Conclusions

We developed an econometric method to empirically investigate the long-term equilibrium relationships and causal relationships among urbanization, water use, and energy consumption in China; built a multiple dimension evaluation method using factor analysis to assess the degree of urbanization and classify the provinces into different urbanization phases; and performed a spatiotemporal analysis to identify the trends of water use intensity and energy consumption intensity, given the effects of urbanization during the 2005 to 2015 period. The highlights are summarized, as follows.

There exist long-term equilibrium relationships among urbanization, total water use, and energy consumption. With a 1% increase in the urbanization rate, total water use would increase by 0.17%, and energy consumption would increase by 1.989%. Similarly, a 1% increase in energy consumption would result in an increase in total water use of 0.08%, and a 1% increase in total water use would result in an increase in energy consumption of 1.858%. Accordingly, continued urbanization in China will double the pressure on water resources and energy. As a result of the factor analysis, China's 30 provinces were divided into three regions according to urbanization degree, and the results revealed that China's current urbanization process is unbalanced, with huge gaps existing between provinces. Furthermore, China's WUI and ECI of PI and SI revealed a significant decreasing trend, due to technological progress during the urbanization process. These findings further indicate that China has guided its economy toward sustainable growth. Therefore, our results showed a large disparity in the WUI and ECI among urbanized, urbanizing, and under-urbanized regions. Thus, it is important to encourage discretionary practices when formulating and implementing state policies. More specifically, the under-urbanized regions should reduce their dependence on high water and energy-intensive industries, and update their manufacturing sectors, while the urbanizing regions should slow the pace of urbanization and speed up the adjustment of industrial structures, and the urbanized regions should continue innovation-driven development and engage in water-saving, energy-saving, and environmentally friendly development.

In this paper, the econometric methods were used to reveal the internal relationships among urbanization, water use, and energy consumption, providing a new way to study energy and water problems during urbanization. Also, the multiple dimension evaluation method built by factor analysis provides a new perspective to assess the level of urbanization. The methods used and conclusions drawn by this study have important reference value for the authorities concerned, not only in China, but in other countries and regions throughout the world that are facing a similar situation, that is, to adopt the relevant strategies necessary to manage the dilemma during the urbanization process.

Author Contributions: Conceptualization and project administration, W.X. and Z.Y.; methodology and writing the original draft, Y.W.; English editing, Y.W.; validation, J.W.; review and editing, B.H.; software and data curation, X.S. and X.Z.

Funding: This research was financially supported by the National Key Research and Development Program of China (2016YFE0102400) and the National Key Research and Development Program during the 13th Five Year Plan, Ministry of Science and Technology, PRC (2016YFA0601500).

Acknowledgments: The authors are grateful to anonymous reviewers for their detailed comments, which have significantly improved the presentation of this work.

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

Abbreviation

EC	energy consumption
RMB	official currency of China
ECI	energy consumption intensity
SI	secondary industry
GDP	gross domestic product
TCE	tons of coal equivalent
P	significance level
UR	urbanization rate
PI	primary industry
WU	water use
Q	Sen's slope
WUI	water use intensity

Appendix A

Table A1. China's total water use intensity (WUI), Sen's slope (Q), and significance level (P) at provincial and national levels between 2005 and 2015.

Regions	Provinces	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	*Q*	*P*
								($m^3/10^4$ RMB)						
Urbanized region	Beijing	49.50	43.55	38.61	35.66	32.75	29.44	27.82	25.77	24.26	23.30	22.21	−2.47	0.01
	Tianjin	59.12	51.25	45.84	37.05	33.28	27.28	24.06	21.17	19.33	17.82	17.39	−4.17	0.01
	Shanghai	131.15	113.77	100.11	90.94	87.86	80.34	73.20	63.44	62.57	50.27	46.09	−7.52	0.01
	Zhejiang	156.44	136.30	120.42	112.34	94.17	86.39	77.53	71.66	66.27	59.88	53.52	−9.20	0.01
	Guangdong	203.46	177.39	155.48	140.49	128.59	115.74	104.14	93.53	84.73	78.52	72.80	−11.90	0.01
	Jiangsu	279.44	255.68	227.39	201.76	176.50	157.46	142.87	128.85	122.77	115.80	103.70	−17.49	0.01
	Fujian	285.08	248.85	226.43	202.18	183.10	161.56	148.39	127.63	117.71	107.53	96.57	−18.49	0.01
	Average	166.31	146.68	130.61	117.20	105.18	94.03	85.43	76.01	71.09	64.73	58.90	-	-
Urbanizing region	Hainan	479.46	446.72	387.68	352.98	299.63	257.66	230.73	215.53	186.72	179.51	169.41	−33.33	0.01
	Shandong	114.90	107.17	91.23	81.56	72.74	65.50	59.50	53.67	48.14	43.59	40.05	−7.24	0.01
	Shanxi	131.71	124.24	106.21	94.85	88.90	88.42	91.11	81.86	75.56	69.68	69.70	−5.93	0.01
	Liaoning	165.60	153.69	135.19	119.14	105.34	92.81	83.22	74.79	68.75	64.82	62.50	−11.07	0.01
	Henan	186.81	187.40	150.77	146.22	135.41	115.68	105.39	99.68	92.20	73.65	72.40	−11.64	0.01
	Shaanxi	200.22	187.66	157.18	141.51	122.94	106.08	98.00	87.08	79.50	72.96	68.66	−13.16	0.01
	Hebei	201.54	179.68	158.12	138.31	124.90	111.29	101.18	92.01	83.28	78.82	71.65	−12.38	0.01
	Chongqing	205.21	187.81	171.41	160.02	143.53	124.14	107.18	90.13	81.19	70.22	62.10	−15.06	0.01
	Jilin	271.78	247.16	208.50	185.63	174.41	165.61	159.10	140.55	131.44	124.82	117.97	−12.35	0.01
	Sichuan	287.47	256.65	222.95	194.90	183.19	164.01	144.60	135.27	121.24	109.17	113.40	−16.77	0.01
	Hubei	384.48	346.90	302.63	279.23	255.74	227.98	206.34	187.01	165.60	149.17	143.14	−23.12	0.01
	Anhui	388.83	401.74	337.59	343.95	333.68	292.46	258.99	229.47	210.17	176.91	172.63	−25.46	0.01
	Heilongjiang	492.43	463.02	420.86	383.73	366.77	334.45	322.88	298.97	279.57	266.06	245.70	−23.55	0.01
	Hunan	497.93	440.48	378.97	332.06	290.89	256.06	227.91	206.24	1109.17	172.94	158.43	−31.49	0.05
	Jiangxi	512.85	451.48	455.42	401.19	365.37	318.51	310.41	258.03	255.88	228.40	198.45	−29.95	0.01
	Guangxi	785.27	695.02	596.30	528.08	453.41	394.56	351.61	317.27	292.90	269.46	242.55	−52.70	0.01
	Average	331.66	304.80	267.56	242.71	219.80	194.70	178.63	160.47	205.08	134.39	125.55	-	-
Under urbanized region	Yunnan	424.00	374.62	346.02	319.34	283.94	244.28	213.85	195.75	172.18	158.96	146.91	−28.92	0.01
	Inner Mongolia	447.53	384.33	324.76	269.11	237.37	207.10	183.91	164.68	150.16	138.38	131.16	−28.40	0.01
	Guizhou	484.79	441.96	377.49	352.52	311.75	279.32	229.67	212.48	172.35	161.14	148.91	−34.85	0.01
	Qinghai	564.12	523.27	445.54	433.44	329.40	305.57	272.67	213.75	198.40	169.69	159.61	−43.22	0.01
	Gansu	635.84	567.26	505.84	458.03	410.02	370.43	332.11	295.48	264.43	240.02	219.55	−40.24	0.01
	Ningxia	1274.71	1124.40	912.48	846.67	736.74	650.38	590.11	498.62	472.32	426.30	395.23	−81.02	0.01
	Xinjiang	1952.55	1776.14	1596.31	1467.27	1364.19	1243.16	1085.95	1093.01	981.18	882.55	804.72	−111.7	0.01
	Average	826.22	741.71	644.06	592.34	524.77	471.46	415.47	381.97	344.43	311.01	286.58	-	-
China		300.72	274.45	241.24	223.46	206.16	188.12	174.17	162.40	151.73	139.39	130.57	−15.99	0.01

Table A2. China's water use intensity (WUI), Sen's slope (Q), and significance level (P) of primary industry (PI) at provincial and national levels between 2005 and 2015.

Regions	Provinces	2005	2006	2007	2008	2009	2010	2011 ($m^3/10^4$ RMB)	2012	2013	2014	2015	*Q*	*P*
Urbanized Region	Beijing	310.43	293.44	279.51	267.47	256.33	247.94	231.46	204.68	194.00	174.58	153.13	−15.05	0.01
	Tianjin	469.43	448.64	456.78	415.46	397.15	328.51	333.20	327.69	335.98	306.04	320.09	−17.83	0.05
	Shanghai	424.75	419.38	362.76	372.01	376.95	403.07	398.82	420.52	405.20	362.82	311.90	−4.11	0.01
	Zhejiang	623.11	571.66	553.95	521.07	501.28	472.50	443.97	431.60	432.40	409.04	387.17	−22.62	0.01
	Guangdong	1004.95	948.90	910.89	888.01	849.82	808.50	764.78	747.69	717.30	696.97	682.66	−32.64	0.01
	Jiangsu	1036.06	1012.34	974.03	1002.21	1002.05	968.31	941.26	893.31	858.41	821.93	745.78	−28.53	0.01
	Fujian	845.18	809.18	802.83	752.36	729.63	680.80	661.72	597.46	591.05	565.67	532.09	−32.02	0.01
	Average	673.42	643.36	620.11	602.66	587.60	558.52	539.32	517.56	504.91	476.72	447.54	-	-
Urbanizing Region	Hainan	963.64	924.32	834.90	771.36	686.62	643.69	605.95	584.90	512.49	505.51	493.98	−47.82	0.01
	Shandong	517.01	532.84	483.07	453.79	432.36	412.84	381.99	378.02	354.29	334.53	313.71	−20.83	0.01
	Shanxi	651.28	648.87	652.07	610.22	612.13	636.79	684.09	633.64	610.35	561.72	603.82	−5.01	0.00
	Liaoning	645.62	637.89	614.19	572.89	557.06	519.01	486.89	472.30	448.18	432.93	413.12	−24.83	0.01
	Henan	456.11	519.87	429.37	452.39	449.61	391.41	374.77	390.14	391.55	312.60	320.53	−15.56	0.05
	Shaanxi	709.03	718.10	668.30	645.65	610.29	559.34	535.29	522.66	498.58	472.77	450.12	-27.93	0.00
	Hebei	763.59	738.75	705.62	635.60	618.20	596.79	559.64	547.51	510.41	497.65	471.50	−29.21	0.01
	Chongqing	291.58	261.38	246.97	233.46	222.32	218.55	247.58	250.65	233.48	216.19	224.40	−4.54	0.00
	Jilin	787.89	801.32	760.12	712.27	711.51	712.06	749.06	738.37	743.73	718.93	689.38	−7.07	0.00
	Sichuan	602.73	584.42	546.20	517.69	541.35	534.34	516.48	561.46	518.71	521.14	541.81	−4.73	0.00
	Hubei	976.37	934.44	828.17	841.00	836.60	740.18	729.35	717.06	747.90	701.47	676.46	−27.03	0.01
	Anhui	825.79	949.18	809.56	960.52	1006.80	959.40	931.55	827.59	821.81	692.50	732.56	−18.20	0.00
	Heilongjiang	2000.88	1999.69	1979.95	1858.88	1923.54	1903.58	1955.31	1988.81	1978.93	1922.30	1806.89	−8.73	0.00
	Hunan	1326.38	1248.39	1174.27	1111.13	1036.59	975.65	922.95	919.64	930.23	912.68	859.07	−46.73	0.01
	Jiangxi	1131.72	1049.31	1147.79	1077.35	1088.58	1005.44	1097.29	950.77	1025.87	940.39	827.13	−24.69	0.10
	Guangxi	1945.72	1801.86	1601.69	1486.21	1358.92	1294.20	1226.20	1273.85	1209.34	1162.94	1079.08	−68.00	0.01
	Average	912.21	896.91	842.64	808.78	793.28	756.45	750.27	734.84	720.99	681.64	656.47	-	-
Under urbanized region	Yunnan	1179.10	1088.30	1048.24	977.86	915.40	809.35	769.63	778.91	721.71	683.74	653.78	−66.47	0.01
	Inner Mongolia	1625.96	1556.80	1494.30	1314.99	1329.28	1214.84	1159.25	1093.08	1017.78	1025.02	1013.23	-42.65	0.01
	Guizhou	1045.05	1075.90	933.98	925.95	874.45	822.79	807.27	714.03	681.94	668.19	676.09	-60.51	0.01
	Qinghai	1671.30	1671.40	1504.56	1582.49	1455.92	1475.33	1425.36	1297.19	1247.80	1094.34	1035.78	−85.44	0.01
	Gansu	2061.11	1945.81	1905.47	1795.12	1652.33	1575.01	1480.31	1404.14	1388.74	1296.97	1210.75	−282.30	0.01
	Ningxia	5793.19	5403.69	4579.87	4476.68	4006.18	3717.99	3602.51	3168.49	3138.13	2872.62	2779.12	−218.90	0.01
	Xinjiang	6511.21	6234.25	5905.54	5659.24	5452.16	5166.88	4889.24	5255.38	4880.71	4553.47	4264.03	−66.47	0.01
	Average	2840.99	2710.88	2481.71	2390.33	2240.82	2111.74	2019.08	1958.75	1868.12	1742.05	1661.83	-	-
China		1641.70	1571.58	1295.34	1118.50	1089.85	937.22	810.95	762.30	708.76	663.14	632.82	−100.9	0.01

Table A3. China's water use intensity (WUI), Sen's slope (Q), and significance level (P) of secondary industry (SI) at provincial and national levels between 2005 and 2015.

Regions	Provinces	2005	2006	2007	2008	2009	2010	2011 ($m^3/10^4$ RMB)	2012	2013	2014	2015	*Q*	*P*
Urbanized Region	Beijing	39.84	32.87	27.05	24.27	21.98	18.81	17.45	15.85	15.35	14.27	10.32	−2.74	0.01
	Tianjin	23.03	19.47	15.83	12.17	11.78	10.88	9.52	8.41	7.88	7.16	6.48	−1.57	0.01
	Shanghai	201.42	172.47	161.36	146.80	150.04	129.52	118.67	101.57	105.78	83.55	80.57	−12.72	0.01
	Zhejiang	91.57	86.48	76.55	66.59	56.75	54.67	52.19	48.00	42.85	37.86	33.31	−6.16	0.01
	Guangdong	127.64	110.45	98.12	85.53	77.99	69.46	60.64	51.53	47.08	42.70	38.38	−9.47	0.01
	Jiangsu	220.23	201.21	178.09	146.25	120.73	105.27	94.76	85.39	88.46	88.41	81.99	−16.77	0.01
	Fujian	226.60	204.73	188.40	169.71	152.78	136.18	120.38	95.57	83.60	74.98	67.24	−17.62	0.01
	Average	132.90	118.24	106.49	93.05	84.58	74.97	67.66	58.05	55.86	49.85	45.47	-	-
Urbanizing Region	Hainan	179.18	178.34	177.12	176.82	125.31	102.97	98.21	80.46	73.36	66.79	52.12	−15.64	0.01
	Shandong	23.10	20.52	18.97	17.33	15.23	14.68	14.56	12.45	11.57	10.51	10.12	−1.43	0.01
	Shanxi	65.83	62.83	50.33	44.12	33.87	34.32	33.52	32.96	28.80	26.52	25.92	−4.66	0.01
	Liaoning	62.00	59.09	51.89	45.26	37.98	33.97	28.66	24.94	22.78	21.63	20.35	−5.07	0.01
	Henan	93.67	83.78	75.34	65.89	61.02	55.19	49.84	47.64	42.71	34.54	32.01	−6.56	0.01
	Shaanxi	77.73	69.83	52.50	48.86	38.03	34.10	32.16	28.25	25.86	23.76	22.57	−5.48	0.01
	Hebei	54.55	48.42	40.42	36.94	31.43	26.96	26.50	23.33	21.40	19.78	17.36	−3.98	0.01
	Chongqing	254.98	253.65	223.35	212.38	186.28	151.34	113.51	89.43	80.87	65.17	51.81	−23.12	0.01
	Jilin	137.76	119.81	100.92	84.15	88.08	81.99	71.02	63.38	56.96	54.06	44.48	−9.34	0.01
	Sichuan	224.73	192.53	164.00	141.21	129.99	108.50	91.67	67.32	64.18	45.32	52.22	−17.87	0.01
	Hubei	333.04	302.34	287.95	247.88	220.63	213.19	185.95	165.97	113.31	100.39	95.92	−27.12	0.01
	Anhui	368.57	365.11	320.98	281.77	264.51	220.00	179.77	172.17	153.15	131.21	122.14	−29.86	0.01
	Heilongjiang	205.65	188.85	168.74	150.82	129.13	113.43	95.38	67.74	51.74	42.92	34.80	−18.26	0.01
	Hunan	366.64	318.90	270.72	233.58	199.99	178.79	162.73	148.11	128.43	109.27	104.68	−27.10	0.01
	Jiangxi	351.84	298.75	295.13	257.92	195.48	178.35	163.70	140.16	128.49	118.02	108.49	−27.21	0.01
	Guangxi	356.09	308.42	262.33	241.65	214.25	181.92	162.06	127.47	127.33	114.42	103.35	−26.91	0.01
	Average	197.21	179.45	160.04	142.91	123.20	108.11	94.33	80.74	70.68	61.52	56.15	-	-
Under Urbanized Region	Yunnan	157.27	137.43	142.00	125.43	112.06	109.88	92.36	87.16	70.37	62.79	58.08	−11.02	0.01
	Inner Mongolia	89.05	88.73	73.75	71.09	60.04	54.82	48.91	43.12	39.08	29.91	26.38	−6.86	0.01
	Guizhou	397.82	340.34	350.11	343.84	310.27	267.51	203.09	224.54	134.04	122.18	117.11	−33.71	0.01
	Qinghai	306.95	296.88	264.19	248.23	84.92	77.62	71.61	44.98	46.41	34.42	38.55	−24.95	0.01
	Gansu	230.39	201.40	153.31	131.71	118.97	110.24	107.43	95.24	71.33	63.76	58.98	−16.73	0.01
	Ningxia	151.07	130.20	113.67	93.83	90.64	87.48	83.78	77.11	70.66	64.32	60.37	−9.46	0.01
	Xinjiang	85.27	80.52	76.59	71.00	67.31	66.56	66.70	57.77	53.01	49.43	47.02	−4.44	0.01
	Average	202.55	182.21	167.66	155.02	120.60	110.59	96.27	89.99	69.27	60.97	58.07	-	-
China		145.91	134.47	122.03	110.63	99.86	92.22	84.15	75.64	69.18	62.12	57.57	−9.70	0.01

Table A4. China's total energy consumption intensity (ECI), Sen's slope (Q), and significance level (P) at provincial and national levels between 2005 and 2015.

Regions	Provinces	2005	2006	2007	2008	2009	2010	2011 (TCE/10^4 RMB)	2012	2013	2014	2015	*Q*	*P*
Urbanized Region	Beijing	0.79	0.75	0.70	0.64	0.61	0.58	0.54	0.52	0.45	0.42	0.40	−0.04	0.01
	Tianjin	0.90	0.86	0.83	0.76	0.72	0.71	0.68	0.65	0.63	0.59	0.55	−0.03	0.01
	Shanghai	0.85	0.82	0.78	0.74	0.70	0.69	0.64	0.61	0.58	0.54	0.51	−0.03	0.01
	Zhejiang	0.90	0.87	0.83	0.78	0.74	0.72	0.70	0.65	0.62	0.58	0.56	−0.03	0.01
	Guangdong	0.76	0.74	0.71	0.69	0.66	0.66	0.62	0.59	0.53	0.51	0.48	−0.03	0.01
	Jiangsu	0.92	0.88	0.85	0.80	0.76	0.73	0.68	0.65	0.62	0.58	0.55	−0.04	0.01
	Fujian	0.94	0.91	0.88	0.84	0.81	0.73	0.76	0.71	0.69	0.63	0.58	−0.03	0.01
	Average	0.87	0.83	0.80	0.75	0.71	0.69	0.66	0.63	0.59	0.55	0.52	-	-
Urbanizing Region	Hainan	0.89	0.89	0.88	0.85	0.83	0.76	0.80	0.78	0.74	0.73	0.72	−0.02	0.01
	Shandong	1.32	1.27	1.21	1.13	1.07	1.01	0.83	0.79	0.76	0.72	0.69	−0.07	0.01
	Shanxi	2.39	2.35	2.19	2.08	2.04	1.92	1.84	1.76	1.68	1.59	1.84	−0.09	0.01
	Liaoning	1.08	1.05	1.14	1.03	0.99	0.98	0.97	0.94	0.84	0.82	0.79	−0.03	0.01
	Henan	1.38	1.34	1.29	1.22	1.14	1.08	1.06	0.99	0.84	0.81	0.75	−0.07	0.01
	Shaanxi	1.22	1.21	1.17	1.11	1.05	1.01	1.01	0.98	0.94	0.84	0.79	−0.03	0.10
	Hebei	1.98	1.92	1.84	1.72	1.64	1.50	1.52	1.43	1.36	1.20	1.13	−0.09	0.01
	Chongqing	0.93	0.88	0.84	0.95	0.89	0.84	0.81	0.76	0.73	0.58	0.65	−0.04	0.05
	Jilin	1.34	1.30	1.25	1.19	0.94	0.90	0.90	0.80	0.75	0.67	0.59	−0.08	0.01
	Sichuan	1.60	1.55	1.48	1.42	1.34	1.27	1.22	1.13	1.07	0.92	0.85	−0.07	0.01
	Hubei	1.49	1.45	1.39	1.32	1.24	1.19	1.15	1.10	1.06	0.84	0.78	−0.06	0.01
	Anhui	1.22	1.18	1.13	1.07	1.02	0.97	0.93	0.89	0.83	0.78	0.74	−0.05	0.01
	Heilongjiang	0.88	0.88	1.52	1.43	1.21	1.14	1.11	1.06	1.02	0.87	0.84	−0.05	0.10
	Hunan	1.38	1.33	1.36	1.27	1.20	1.17	1.13	1.05	4.98	0.80	0.74	−0.05	0.05
	Jiangxi	1.06	1.02	0.98	0.92	0.88	0.83	0.82	0.77	0.73	0.71	0.68	−0.04	0.01
	Guangxi	1.25	1.22	1.18	1.13	1.06	1.04	0.93	0.89	0.86	0.83	0.79	−0.05	0.01
	Average	1.34	1.30	1.30	1.24	1.16	1.10	1.06	1.01	1.20	0.86	0.84	-	-
Under Urbanized Region	Yunnan	1.74	1.71	1.65	1.57	1.49	1.44	1.39	1.35	1.16	1.11	1.01	−0.07	0.01
	Inner Mongolia	2.47	2.40	2.30	2.14	2.01	1.92	1.87	1.77	1.45	1.39	1.34	−0.12	0.01
	Guizhou	2.96	2.73	2.62	2.45	2.35	2.25	2.17	2.08	1.74	1.64	1.52	−0.14	0.01
	Qinghai	2.96	3.02	2.92	2.76	2.60	2.62	2.61	2.59	2.52	2.49	2.40	−0.06	0.01
	Gansu	2.26	2.20	2.11	2.00	1.86	1.77	1.73	1.66	1.58	1.50	1.39	−0.09	0.01
	Ningxia	4.03	4.00	3.87	3.63	3.37	3.31	3.78	3.52	3.40	3.23	3.19	−0.08	0.05
	Xinjiang	2.11	2.09	2.03	1.96	1.93	1.93	2.06	2.19	2.27	2.26	2.18	0.02	0.00
	Average	2.65	2.59	2.50	2.36	2.23	2.18	2.23	2.17	2.02	1.95	1.86	-	-
China		1.27	1.23	1.16	1.10	1.06	1.02	1.00	0.96	1.02	0.97	0.92	−0.03	0.01

Table A5. China's energy consumption intensity (ECI), Sen's slope (Q), and significance level (P) of primary industry (PI) at provincial and national levels between 2005 and 2015.

Regions	**Provinces**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	***Q***	***P***
								(TCE/10^4 RMB)						
	Beijing	0.21	0.20	0.18	0.16	0.15	0.13	0.12	0.11	0.11	0.10	0.09	−0.02	0.01
	Tianjin	0.22	0.22	0.20	0.16	0.15	0.14	0.13	0.13	0.13	0.12	0.11	−0.01	0.01
	Shanghai	0.14	0.12	0.12	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.07	−0.01	0.01
	Zhejiang	0.14	0.13	0.13	0.12	0.12	0.11	0.11	0.12	0.10	0.10	0.10	−0.01	0.01
Urbanized Region	Guangdong	0.20	0.18	0.15	0.14	0.12	0.21	0.10	0.10	0.09	0.09	0.09	−0.01	0.01
	Jiangsu	0.13	0.12	0.10	0.09	0.08	0.08	0.06	0.06	0.06	0.06	0.06	−0.01	0.01
	Fujian	0.23	0.21	0.13	0.12	0.12	0.05	0.10	0.09	0.08	0.04	0.03	−0.02	0.01
	Average	0.18	0.17	0.14	0.13	0.12	0.11	0.10	0.10	0.09	0.08	0.08	-	-
	Hainan	0.15	0.16	0.16	0.14	0.14	0.15	0.13	0.12	0.10	0.09	0.09	−0.01	0.01
	Shandong	0.10	0.09	0.09	0.08	0.07	0.07	0.05	0.06	0.05	0.05	0.06	−0.01	0.01
	Shanxi	1.14	1.11	0.78	0.73	0.69	0.61	0.55	0.52	0.51	0.39	0.40	−0.08	0.01
	Liaoning	0.16	0.16	0.14	0.12	0.10	0.09	0.08	0.08	0.07	0.07	0.07	−0.01	0.01
	Henan	0.24	0.25	0.21	0.18	0.18	0.17	0.18	0.18	0.14	0.14	0.16	−0.01	0.01
	Shaanxi	0.23	0.29	0.28	0.27	0.26	0.21	0.19	0.17	0.16	0.14	0.12	−0.02	0.01
	Hebei	0.27	0.27	0.23	0.22	0.20	0.18	0.17	0.15	0.13	0.12	0.12	−0.02	0.01
	Chongqing	0.42	0.56	0.46	0.40	0.38	0.38	0.33	0.33	0.32	0.08	0.07	−0.05	0.01
Urbanizing Region	Jilin	0.29	0.29	0.25	0.22	0.11	0.10	0.09	0.08	0.08	0.10	0.11	−0.02	0.01
	Sichuan	0.18	0.20	0.13	0.14	0.13	0.11	0.09	0.09	0.09	0.08	0.08	−0.01	0.01
	Hubei	0.43	0.36	0.31	0.25	0.26	0.20	0.17	0.16	0.16	0.16	0.15	−0.03	0.01
	Anhui	0.15	0.15	0.13	0.13	0.12	0.12	0.10	0.10	0.10	0.09	0.09	−0.01	0.01
	Heilongjiang	0.40	0.37	0.32	0.23	0.25	0.23	0.25	0.26	0.22	0.21	0.22	−0.02	0.01
	Hunan	0.43	0.39	0.35	0.33	0.34	0.36	0.31	0.31	0.23	0.22	0.21	−0.03	0.01
	Jiangxi	0.28	0.29	0.21	0.16	0.14	0.12	0.10	0.08	0.08	0.08	0.07	−0.02	0.01
	Guangxi	0.11	0.11	0.10	0.08	0.07	0.10	0.06	0.06	0.08	0.09	0.09	0.00	0.05
	Average	0.31	0.32	0.26	0.23	0.22	0.20	0.18	0.17	0.16	0.13	0.13	-	-
	Yunnan	0.25	0.23	0.24	0.19	0.19	0.15	0.16	0.14	0.13	0.13	0.15	−0.02	0.01
	Inner Mongolia	0.54	0.53	0.45	0.42	0.49	0.47	0.41	0.36	0.32	0.33	0.35	−0.03	0.01
	Guizhou	0.37	0.36	0.32	0.27	0.28	0.23	0.18	0.14	0.14	0.11	0.10	−0.03	0.01
Under Urbanized Region	Qinghai	0.22	0.22	0.18	0.15	0.17	0.14	0.12	0.11	0.10	0.10	0.11	−0.02	0.01
	Gansu	0.78	0.75	0.63	0.56	0.53	0.42	0.38	0.33	0.30	0.27	0.24	−0.06	0.01
	Ningxia	0.52	0.51	0.49	0.48	0.47	0.42	0.40	0.38	0.35	0.32	0.29	−0.03	0.05
	Xinjiang	0.62	0.64	0.58	0.58	0.55	0.38	0.41	0.40	0.45	0.45	0.45	−0.03	0.01
	Average	0.47	0.46	0.41	0.38	0.38	0.32	0.29	0.27	0.26	0.24	0.24	-	-
China		0.28	0.27	0.22	0.18	0.18	0.16	0.15	0.13	0.15	0.14	0.14	−0.02	0.01

Table A6. China's energy consumption intensity (ECI), Sen's slope (Q), and significance level (P) of secondary industry (SI) at provincial and national levels between 2005 and 2015.

Regions	Provinces	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	*Q*	*P*
								(TCE/10^4 RMB)						
Urbanized Region	Beijing	1.58	1.47	1.31	1.19	1.08	1.01	0.87	0.79	0.62	0.56	0.52	−0.12	0.01
	Tianjin	1.22	1.19	1.12	1.03	0.94	0.95	0.92	0.85	0.83	0.77	0.70	−0.05	0.01
	Shanghai	1.22	1.15	1.10	1.04	1.00	0.94	0.89	0.87	0.84	0.79	0.78	−0.05	0.01
	Zhejiang	1.37	1.29	1.24	1.16	1.10	1.04	0.98	0.93	0.88	0.83	0.79	−0.06	0.01
	Guangdong	1.07	1.03	0.98	0.94	0.91	0.88	0.83	0.78	0.70	0.66	0.62	−0.05	0.01
	Jiangsu	1.51	1.43	1.39	1.28	1.21	1.15	1.06	0.98	0.92	0.87	0.81	−0.08	0.01
	Fujian	1.55	1.49	1.42	1.34	1.28	1.13	1.11	1.02	0.96	0.89	0.83	−0.08	0.01
	Average	1.36	1.29	1.22	1.14	1.07	1.01	0.95	0.89	0.82	0.77	0.72	-	-
Urbanizing Region	Hainan	2.68	2.46	2.30	2.18	2.02	1.83	1.99	1.86	1.79	1.73	1.68	−0.12	0.01
	Shandong	2.09	2.00	1.88	1.75	1.61	1.51	1.27	1.20	1.14	1.08	1.04	−0.12	0.01
	Shanxi	3.88	3.75	3.53	3.30	3.13	2.86	2.69	2.56	2.42	2.37	2.95	−0.19	0.01
	Liaoning	1.82	1.72	1.87	1.63	1.56	1.51	1.48	1.41	1.26	1.21	1.20	−0.07	0.01
	Henan	2.36	2.26	2.14	2.00	1.84	1.64	1.55	1.38	1.18	1.12	1.02	−0.15	0.01
	Shaanxi	1.94	1.87	1.75	1.66	1.52	1.41	1.42	1.39	1.31	1.19	0.98	−0.10	0.01
	Hebei	3.41	3.28	3.13	2.91	2.75	2.46	2.48	2.26	2.15	1.86	1.73	−0.18	0.01
	Chongqing	1.80	1.60	1.47	1.70	1.56	1.39	1.27	1.14	1.07	0.82	0.91	−0.13	0.01
	Jilin	2.46	2.38	2.17	2.04	1.61	1.46	1.46	1.28	1.20	1.06	0.92	−0.17	0.01
	Sichuan	3.43	3.28	2.95	2.74	2.55	2.29	2.05	1.84	1.71	1.48	1.36	−0.23	0.01
	Hubei	2.84	2.74	2.56	2.30	2.09	1.93	1.81	1.71	1.59	1.22	1.11	−0.19	0.01
	Anhui	2.77	2.57	2.35	2.16	1.98	1.77	1.59	1.48	1.30	1.21	1.13	−0.19	0.01
	Heilongjiang	1.17	1.17	2.18	2.10	1.86	1.66	1.39	1.28	1.16	1.04	0.96	−0.16	0.01
	Chongqing	2.97	2.76	2.71	2.51	2.26	2.05	1.87	1.66	1.31	1.20	1.09	−0.21	0.01
	Hunan	2.13	2.01	1.91	1.74	1.61	1.45	1.40	1.29	1.18	1.13	1.06	−0.12	0.01
	Jiangxi	2.90	2.66	2.48	2.27	2.07	1.91	1.65	1.53	1.51	1.39	1.29	−0.19	0.01
	Guangxi	2.68	2.46	2.30	2.18	2.02	1.83	1.99	1.86	1.79	1.73	1.68	−0.12	0.01
	Average	2.55	2.41	2.33	2.19	2.00	1.82	1.73	1.60	1.47	1.34	1.30	-	-
Under Urbanized Region	Yunnan	3.82	3.65	3.43	3.24	3.00	2.79	2.61	2.44	2.07	1.91	1.68	−0.22	0.01
	Inner Mongolia	4.77	4.37	4.0	3.60	3.12	2.86	2.76	2.55	2.14	2.02	1.97	−0.33	0.01
	Guizhou	5.47	5.12	4.99	4.77	4.56	4.19	3.95	3.69	2.76	2.50	2.18	−0.36	0.01
	Qinghai	6.06	6.26	6.04	5.56	5.14	5.04	5.00	4.92	4.76	4.68	4.45	−0.21	0.01
	Gansu	6.72	6.37	5.85	5.65	5.23	4.88	4.62	4.34	4.11	3.88	2.57	−0.37	0.01
	Ningxia	6.39	6.31	5.95	5.61	5.19	4.96	4.81	4.63	4.44	4.28	3.51	−0.30	0.01
	Xinjiang	3.62	3.98	3.90	3.57	3.52	3.58	3.91	4.20	4.35	4.33	4.15	0.00	0.00
	Average	5.26	5.15	4.88	4.57	4.25	4.04	3.95	3.82	3.52	3.37	2.93	-	-
China		1.95	1.89	1.78	1.69	1.61	1.51	1.45	1.37	1.47	1.39	1.29	−0.08	0.01

References

1. Deng, X.; Huang, J.; Rozelle, S.; Uchida, E. Growth, population and industrialization, and urban land expansion of China. *J. Urban Econ.* **2008**, *63*, 96–115. [CrossRef]
2. Fan, J.; Zhang, Y.; Wang, B. The impact of urbanization on residential energy consumption in China: An aggregated and disaggregated analysis. *Renew. Sustain. Energy Rev.* **2017**, *75*, 220–233. [CrossRef]
3. Zhang Ping, L.X. *Report on China's Economic Growth (2009–2010): Urbanization and Economic Growth*; Beijing Social Sciences Academic Press: Beijing, China, 2006. (In Chinese)
4. Dhakal, S. Urban energy use and carbon emissions from cities in China and policy implications. *Energy Policy* **2009**, *37*, 4208–4219. [CrossRef]
5. Lin, G.; Jiang, D.; Duan, R.; Fu, J.; Hao, M. Water use of fossil energy production and supply in China. *Water* **2017**, *9*, 513. [CrossRef]
6. Siddiqi, A.; Anadon, L.D. The water–energy nexus in Middle East and North Africa. *Energy Policy* **2011**, *39*, 4529–4540. [CrossRef]
7. Liu, L.; Hejazi, M.; Patel, P.; Kyle, P.; Davies, E.; Zhou, Y.; Clarke, L.; Edmonds, J. Water demands for electricity generation in the US: Modeling different scenarios for the water–energy nexus. *Technol. Forecast. Social Chang.* **2015**, *94*, 318–334. [CrossRef]
8. Sun, L.; Pan, B.; Gu, A.; Lu, H.; Wang, W. Energy–water nexus analysis in the Beijing–Tianjin–Hebei region: Case of electricity sector. *Renew. Sustain. Energy Rev.* **2018**, *93*, 27–34. [CrossRef]
9. Dai, J.; Wu, S.; Han, G.; Weinberg, J.; Xie, X.; Wu, X.; Song, X.; Jia, B.; Xue, W.; Yang, Q. Water-energy nexus: A review of methods and tools for macro-assessment. *Appl. Energy* **2018**, *210*, 393–408. [CrossRef]
10. Hamiche, A.M.; Stambouli, A.B.; Flazi, S. A review of the water-energy nexus. *Renew. Sustain. Energy Rev.* **2016**, *65*, 319–331. [CrossRef]
11. Al-mulali, U.; Fereidouni, H.G.; Lee, J.Y.M.; Sab, C.N.B.C. Exploring the relationship between urbanization, energy consumption, and CO_2 emission in MENA countries. *Renew. Sustain. Energy Rev.* **2013**, *23*, 107–112. [CrossRef]
12. Zhang, X.; Hu, H.; Zhang, R.; Deng, S. Interactions between China's economy, energy and the air emissions and their policy implications. *Renew. Sustain. Energy Rev.* **2014**, *38*, 624–638. [CrossRef]
13. Madlener, R.; Sunak, Y. Impacts of urbanization on urban structures and energy demand: What can we learn for urban energy planning and urbanization management? *Sustain. Cities Soc.* **2011**, *1*, 45–53. [CrossRef]
14. Shahbaz, M.; Lean, H.H. Does financial development increase energy consumption? The role of industrialization and urbanization in Tunisia. *Energy Policy* **2012**, *40*, 473–479. [CrossRef]
15. Maruotti, A. The impact of urbanization on CO_2 emissions: Evidence from developing countries. *Ecol. Econ.* **2008**, *70*, 1344–1353.
16. Zhang, C.; Lin, Y. Panel estimation for urbanization, energy consumption and CO_2 emissions: A regional analysis in China. *Energy Policy* **2012**, *49*, 488–498. [CrossRef]
17. Howard, B.; Parshall, L.; Thompson, J.; Hammer, S.; Dickinson, J.; Modi, V. Spatial distribution of urban building energy consumption by end use. *Energy Build.* **2012**, *45*, 141–151. [CrossRef]
18. Chen, S.; Chen, B. Urban energy consumption: Different insights from energy flow analysis, input–output analysis and ecological network analysis. *Appl. Energy* **2015**, *138*, 99–107. [CrossRef]
19. Poumanyvong, P.; Kaneko, S. Does urbanization lead to less energy use and lower CO_2 emissions? A cross-country analysis. *Ecol. Econ.* **2010**, *70*, 434–444. [CrossRef]
20. Li, K.; Fang, L.; He, L. How urbanization affects China's energy efficiency: A spatial econometric analysis. *J. Clean. Prod.* **2018**, *200*, 1130–1141. [CrossRef]
21. Yan, H. Provincial energy intensity in China: The role of urbanization. *Energy Policy* **2015**, *86*, 635–650. [CrossRef]
22. Sun, Y.; Lu, C.; Xie, G.; Li, N.; Hu, X. The conjunction between urban development and the utilization of water resources in Beijing. *Resour. Sci.* **2015**, *37*, 1124–1132. (In Chinese)
23. Feng, L.; Chen, B.; Hayat, T.; Alsaedi, A.; Ahmad, B. The driving force of water footprint under the rapid urbanization process: A structural decomposition analysis for Zhangye city in China. *J. Clean. Prod.* **2017**, *163*, S322–S328. [CrossRef]
24. Gleick, P. Water and energy. *Annu. Rev. Energy Env.* **1994**, *19*, 267–299. [CrossRef]

25. Wilkinson, R. *Methodology for Analysis of the Energy Intensity of California's Water Systems and an Assessment of Multiple Potential Benefits Through Integrated Water-Energy Efficiency Measures*; University of California Press: Berkeley, CA, USA, 2000.
26. Stillwell, A.S.; King, C.W.; Webber, M.E. Desalination and Long-Haul Water Transfer as a Water Supply for Dallas, Texas: A Case Study of the Energy-Water Nexus in Texas, 2010. Available online: https://journals.tdl.org/twj/index.php/twj/article/view/1042 (accessed 11 September 2010).
27. Jiang, S.; Wang, J.; Zhao, Y.; Lu, S.; Shi, H.; He, F. Residential water and energy nexus for conservation and management: A case study of Tianjin. *Int. J. Hydrogen Energy* **2016**, *41*, 15919–15929. [CrossRef]
28. National Development and Innovation Committee. *The Thirteen Five-Year Plan for Economic and Social Development of People's Republic of China*; Central Compilation and Translation Press: Beijing, China, 2016.
29. People's Government of Beijing Municipality. *The Thirteen Five-Year Plan for Economic and Social Development of Beijing*; Social Sciences Academic Press: Beijing, China, 2016.
30. National Bureau of Statistics of China. *China Energy Statistical Yearbook 2005*; China Statistic Press: Bejing, China, 2005.
31. National Bureau of Statistics of China. *China Energy Statistical Yearbook 2006*; China Statistic Press: Beijing, China, 2006.
32. National Bureau of Statistics of China. *China Energy Statistical Yearbook 2007*; China Statistic Press: Beijing, China, 2007.
33. National Bureau of Statistics of China. *China Energy Statistical Yearbook 2008*; China Statistic Press: Beijing, China, 2008.
34. National Bureau of Statistics of China. *China Energy Statistical Yearbook 2009*; China Statistic Press: Beijing, China, 2009.
35. National Bureau of Statistics of China. *China Energy Statistical Yearbook 2010*; China Statistic Press: Beijing, China, 2010.
36. National Bureau of Statistics of China. *China Energy Statistical Yearbook 2011*; China Statistic Press: Beijing, China, 2011.
37. National Bureau of Statistics of China. *China Energy Statistical Yearbook 2012*; China Statistic Press: Beijing, China, 2012.
38. National Bureau of Statistics of China. *China Energy Statistical Yearbook 2013*; China Statistic Press: China, Beijing, 2013.
39. National Bureau of Statistics of China. *China Energy Statistical Yearbook 2014*; China Statistic Press: Beijing, China, 2014.
40. National Bureau of Statistics of China. *China Energy Statistical Yearbook 2015*; China Statistic Press: Beijing, China, 2015.
41. World Bank, GDP deflator (annual%), 2015. Available online: https://data.worldbank.org/indicator/ny.gdp.defl.kd.zg (accessed 10 February 2018).
42. Zheng, X. *Panel Data Analysis*; China Renmin University Press: Beijing, China, 2015. (In Chinese)
43. Zhao, X. *Study on the Relationship Between Coal Consumption and Economic Growth in China Based on Co Integration Theory*; Tsinghua University Press: Beijing, China, 2009. (In Chinese)
44. Narayan, P.K.; Smyth, R. Electricity consumption, employment and real income in Australia evidence from multivariate Granger causality tests. *Energy Policy* **2005**, *33*, 1109–1116. [CrossRef]
45. Ghosh, S. Electricity supply, employment and real GDP in India: Evidence from cointegration and Granger-causality tests. *Energy Policy* **2009**, *37*, 2926–2929. [CrossRef]
46. Shahbaz, M.; Loganathan, N.; Muzaffar, A.T.; Ahmed, K.; Ali Jabran, M. How urbanization affects CO_2 emissions in Malaysia? The application of STIRPAT model. *Renew. Sustain. Energy Rev.* **2016**, *57*, 83–93. [CrossRef]
47. Gocic, M.; Trajkovic, S. Analysis of changes in meteorological variables using Mann-Mendall and Sen's slope estimator statistical tests in Serbia. *Glob. Planet. Chang.* **2013**, *100*, 172–182. [CrossRef]
48. Hirsch, R.M.; Slack, J.R.; Smith, R.A. Techniques of trend analysis for monthly water quality data. *Water Resour. Res.* **1982**, *18*, 107–121. [CrossRef]
49. Sridhar, S.I.; Raviraj, A. Statistical trend analysis of rainfall in Amaravathi river basin using Mann-Kendall test S.I. *Curr. World Environ.* **2017**, *12*, 89–96. [CrossRef]

50. Islam, M.S.; Sikder, M.B. Detection of trend in hydrologic variables using non-parametric test: A study on Surma river in northeastern Bangladesh. *J. Sci. Res.* **2017**, *9*, 277. [CrossRef]
51. Georgiades, S.; Frazier, T.; Duku, E. *Factor Analysis*; Springer: New York, NY, USA, 2018.
52. Chen, C.; Lin, Z. Multiple timescale analysis and factor analysis of energy ecological footprint growth in China 1953–2006. *Energy Policy* **2008**, *36*, 1666–1678. [CrossRef]
53. Sovacool, B. A qualitative factor analysis of renewable energy and sustainable energy for all (SE4ALL) in the Asia-Pacific. *Energy Policy* **2013**, *59*, 393–403. [CrossRef]