sustainability

MDPI

Article

Domestic Water Consumption and Its Influencing Factors in the Yellow River Basin Based on Logarithmic Mean Divisia Index and Decoupling Theory

Tongtong Zhao * and Bo Shao

Institute of Science and Technology for Development of Shandong, Qilu University of Technology (Shandong Academy of Sciences), Jinan 250014, China
* Correspondence: zhaott@sdas.org; Tel.: +81-531-82605744

Abstract: In recent decades, water resources shortage has become a global problem, and it is critical to analyse the trend of domestic water consumption and its influencing factors to optimise water resource management, promote the construction of a water-saving society, and realise the sustainable development of resources and the environment. We chose the Yellow River Basin as the study area and analysed the temporal and spatial characteristics of domestic water using water-use data, identified its influencing factors by Logarithmic Mean Divisia Index, and analysed its relationship with economic development based on the decoupling theory. In this study, we found that: (1) Domestic water consumption increased in the Yellow River Basin between 2006 and 2020, with provinces primarily located south of the river. (2) Technical and economic effects were the major factors leading to changes in domestic water use. The technical effect is the major factor inhibiting the increase, whereas the economic effect encourages the increase in domestic water consumption. (3) In the Yellow River Basin, weak decoupling was achieved between domestic water consumption and economic growth, with domestic water consumption at a slower rate than the economic growth rate.

Keywords: domestic water consumption; influencing factor; logarithmic mean divisia index; decoupling theory; the Yellow River Basin

check for updates

Citation: Zhao, T.; Shao, B. Domestic Water Consumption and Its Influencing Factors in the Yellow River Basin Based on Logarithmic Mean Divisia Index and Decoupling Theory. *Sustainability* **2022**, *14*, 16866. https://doi.org/10.3390/su142416866

Academic Editor: Elena Cristina Rada

Received: 8 November 2022
Accepted: 13 December 2022
Published: 15 December 2022

1. Introduction

Water is a finite and non-replaceable resource called the foundation of life, societies, and economies [1]. As an important natural resource, water is a basic human need for drinking and supporting sanitation and hygiene, sustaining life and health, and essential to life and health [2–4]. Water is also essential for socio-economic activities, including industrial production, ecological security, economic activities, and regional development; therefore, it is an important strategic economic resource. This natural resource is irreplaceable and critical for economic development, ecological systems, and national security [2,5–7].

Water resources are also related to the level of sustainable development, as they are crucial to sustainable development. The services provided by water resources underpin economic growth, poverty reduction, and environmental sustainability. It plays a crucial role in three main aspects of sustainable development: human well-being, economic growth, and environmental health [8]. However, in recent decades, global climate change and economic and population growth have exacerbated the water resources supply–demand gap. The water crisis has become the main bottleneck for sustainable development in water-deficient areas, and water scarcity has emerged as a global issue that is receiving increased attention [9,10]. Therefore, it is critical to study the trends, structures, and influencing factors of water use to solve water-resource crises and support economic and social development [11–13].

China has some of the largest water resources in the world; however, the population base is large, and the per capita water resources comprise only one-fourth of the world's average. Thus, China is one country that is seriously short of water worldwide. The seasonal and geographic spatial distribution of water resources is extremely uneven due to geographical location and climate conditions. Moreover, with the rapid development of modern industry and the accelerating urbanisation process, the demand for water resources will continue to increase for some time, and the contradiction between the supply and demand for water resources will become more prominent [14]. Therefore, water resources have become an important factor that affecting the sustainable development of economy and society in China [15].

According to their usage, the water use in a region can be divided into four categories, including agricultural, industrial, ecological, and domestic. Domestic water use accounts for a significant portion of total water use in China. Whether or not it is safe is closely related to the daily life of the residents, and it has a direct impact on the life quality of the residents. In 2020, total water consumption in China was 5812.9×10^8 m^3, of which 863.1×10^8 m^3 was domestic water, accounting for 14.8% of the total water consumption, whereas this proportion was 12.6% in 2009, showing an increase of nearly 2%. Therefore, analysing the temporal and spatial characteristic of domestic water consumption over time and identifying the factors influencing the change in domestic water consumption can provide a basis for estimating water-saving potential. This ensures performing well in developing an operational plan for water use, which is critical for optimising water-use management, promoting sustainable development, and building a comprehensive water-saving social environment in the future.

Scholars have conducted many studies on the driving factors of water resource consumption, water-consumption structure, water demand management, and water behaviour [2,7,12,13,15–19] with diverse research methods, including productive water [11], domestic water [4,20–22], and agricultural water [10]. Existing research shows that economic and social development, technological advancement, population growth, and water conservation are the main social driving factors affecting water-use structure, while climate change is the main natural driving factor and is likely to exacerbate water pressure and accelerate water shortages [23,24], especially in agricultural water [25,26]. Urbanisation, economic development, and population growth have promoted an increase in water consumption [27], while technological advancement and industrial structure changes have inhibited the increase [28]. Agricultural water is determined by climate change including temperature and wind speed, moreover the change in land type is also an important factor that affect the agricultural water consumption [25]. Industrial water consumption is primarily determined by economic growth, industrial structural adjustments, and technological progress. Existing studies on domestic water use mainly focus on household domestic water use and its influencing factors at the micro level [7,19,21,29–33]. Research data were always obtained through questionnaire survey, water-use diary, field observation and interview [34]. Fan L et al. [29] investigated 247 households in eight villages to identify the driving factors that affect domestic water use in the Wei River Basin, China, and the results showed that the domestic consumption was significantly correlated with water supply pattern. Janine Garcia et al. [30] used 108 questionnaires to identify the factors that affect water consumption in households in Brazil. Omvir and Sushila [33] used questionnaires and interviews to explore the pattern of domestic water consumption in a village in India. There are only a few studies that focus on the variation characteristics and influencing factors of domestic water use in a specific region from a meso or macro perspective [22,35–38]. It has been discovered that domestic water consumption and water quotas in urban and rural areas have constantly increased in recent years. The level of economic and social development, water-consumption conditions, and public facility construction are the main factors affecting the change of domestic water consumption. In the Yangtze River Economic Belt, urbanisation and population growth have led to an increase in residential domestic water consumption [38].

Since the beginning of the 21st century, China's water conservancy industry has developed rapidly. China has built the largest number of water conservancy and hydropower projects in the world [39], providing strong support for the sustained, rapid and healthy development of the national economy, social stability and improvement of the people's living standards. Moreover, the rural drinking water safety project has been implemented in the vast rural areas to ensure the rural water consumption. Water consumption and water structure had changed significantly in this period. To supplement existing research finding, considering the time span and availability of data, we chose the Yellow River Basin as the study area for analysing water-use characteristics using data from 2006 to 2020. Based on LMDI (Logarithmic Mean Divisia Index) and the decoupling theory, this study identified the influencing factors of domestic water-use change in the Yellow River Basin and its relationship with economic development to provide a scientific reference for optimising water-resource management and building a water-saving society in the future in the Yellow River Basin.

2. Materials and Methods

2.1. Study Area

The Yellow River flows west to east through China, passing through nine provinces and regions, including Qinghai, Sichuan, Gansu, Ningxia, Inner Mongolia, Shaanxi, Shanxi, Henan, and Shandong. It is an important ecological security barrier and economic belt in China and plays a very important role in the economy, social development, and ecological security of China.

The total water resource in the Yellow River Basin accounts for 2.6% of the total water resources in China, and the per capita water resource is 905 m^3, accounting for one-third of the national per capita water resources. The annual average precipitation is 446 mm, accounting for only 41.8% of the Yangtze River Basin, and the annual average runoff is 535×10^8 m^3, accounting for only 6% of the Yangtze River Basin. These characteristics of the Yellow River have led to a shortage of water resources, frequent flood and drought disasters, ecological damage to water resources, and other ecological problems in the Yellow River basin. These determine the long-term nature and complexity of the Yellow River governance and ecological civilisation construction.

In recent years, significant progress has been made in the management and development of the Yellow River, including preventing soil erosion, eliminating downstream flooding, and rationally utilising water resources. In 2019, China proposed the Yellow River Conservation and Development as an important national strategy, which led to the implementation of a slew of major ecological restoration and construction projects. The protection and governance of the Yellow River have entered a new historical stage by insisting on determining the city, land, people, and production by water and exploring a new way of high-quality development with regional characteristics.

Due to missing data and changes in statistical calibre, and data availability and systematisation, nine provinces in the Yellow River Basin were selected as the study area. The Yellow River Basin spans the eastern and western regions of China. There were significant differences in economic level and domestic water consumption. Therefore, analysing the differences within the region and the main influencing factors leading to these differences is of great significance for managing and protecting water resources in the Yellow River Basin.

2.2. Methods

2.2.1. Logarithmic Mean Divisia Index (LMDI)

It is very important to evaluate potential drivers or decisive factors to analyse and understand the changes in socio-economic indicators such as the economy, environment, and employment, among others. The factor analysis approach is widely used in the field of resources and the environment because it not only lists the influencing factors of research objectives but also calculates their overall contribution. The structure decomposition approach (SDA) and index decomposition approach (IDA) are common factor decomposition methods that require a complete input-output table [40]. Therefore, the demand for data is high, and IDA employs time series and cross-sectional data, which have a wide range of data processing capacities. IDA includes the Laspeyres Index Decomposition, Divisia Index Decomposition, and the Logarithmic Mean Divisia Index (LMDI). LMDI was used by Ang for the first time to make decomposition analysis [41–43], which has no unexplained residual after decomposition and is easy to calculate and explain; therefore, it is widely used in many fields, such as energy consumption and carbon emission.

In this study, the LMDI model was used to decompose the driving factors of changes in domestic water consumption, including population change, economic development level, and technological and structural factors. This was done to explore the driving effect and internal mechanisms of different factors on changes in the trend of domestic water consumption.

According to the equation of kaya, domestic water is decomposed as follows:

$$DW = \frac{DW}{TW} \times \frac{TW}{GDP} \times \frac{GDP}{P} \times P \quad (1)$$

where DW is domestic water consumption, TW is the total quantity of water consumption, GDP is the gross regional product, P is the population of a region, and represents the population effect on domestic water use; we define $S = \frac{DW}{TW}$, is the structural factor, use the proportion of domestic water consumption in total water consumption to indicate; $T = \frac{TW}{GDP}$, is the technological factor, expressed by the volume of water resources consumed per unit GDP; $E = \frac{GDP}{P}$, which means that GDP per capita represents an economic factor. Thus, Equation (1) can be further expressed as

$$DW = S \times T \times E \times P \quad (2)$$

We define DW_0 and DW_t as the domestic water consumption at the beginning and end of the period, respectively, and ΔDW represents the change in domestic water use during this period. Therefore, the equation can be expressed as:

$$\Delta DW = DW_t - DW_0 = \Delta S + \Delta T + \Delta E + \Delta P \quad (3)$$

where ΔS, ΔT, ΔE, ΔP represent the structure, technology, economy, and population effects on domestic water use, respectively. The sum of these four effects over a certain period is the change in domestic water consumption. If the effect is positive within a certain period, it lead to an increase in domestic water consumption and promoted the increase of domestic water consumption; otherwise, it had an inhibitory effect on the increase in domestic water consumption.

According to the LMDI decomposition model, the driving factor can be expressed as follows in Equations (4)–(7), where S_0 and S_t, T_0 and T_t, E_0 and E_t, P_0 and P_t represent, respectively, the value of S, T, E, P at the beginning and the end of the period.

$$\Delta \mathrm{S} = \left(\frac{DW_t - DW_0}{\ln DW_t - \ln DW_0}\right) \ln(S_t/\mathrm{S}_0) \quad (4)$$

$$\Delta T = \left(\frac{DW_t - DW_0}{\ln DW_t - \ln DW_0}\right) \ln(T_t/T_0) \quad (5)$$

$$\Delta E = \left(\frac{DW_t - DW_0}{\ln DW_t - \ln DW_0}\right) \ln(E_t/E_0) \quad (6)$$

$$\Delta P = \left(\frac{DW_t - DW_0}{\ln DW_t - \ln DW_0}\right) \ln(P_t/P_0) \quad (7)$$

2.2.2. Decoupling Theory

The term "decoupling" first appeared in physics to describe the relationship between two things, from existence to absence. At the end of the 20th century, the Organisation for Economic Co-operation and Development (OECD) introduced decoupling into agricultural policy research and gradually extended it to the environment and other fields. It is regarded as a basic theory that blocks the connection between economic growth, resource consumption, and environmental pollution. Economic growth should not be at the expense of resource consumption or environmental pollution, and the two should be decoupled.

According to the environmental Kuznets curve (EKC) hypothesis, economic development generally leads to the increase of environmental pollution pressure and natural resource consumption. However, by implementing some effective policies and adopting new technologies, achieving the same or even faster economic growth while reducing environmental pressure and resource consumption is possible. This process is known as decoupling. Decoupling theory can not only explain the relationship between economic development and natural resource consumption, it can also specify the degree of decoupling. Different scholars have provided different definitions of the decoupling index. For the first time, Tapio proposed that the decoupling index can be expressed as elasticity values, taking the proportion of resource consumption or increase caused by a 1% rise or fall in the economy as an indicator of decoupling and distinguishing between decoupling, coupling, and negative decoupling. These are further broken down into weak, strong, and expansive/recessive degrees of decoupling, emphasising the absolute increase or decrease of the variables. Strong decoupling is ideal for achieving low-carbon economic development. Therefore, strong negative decoupling is the most unfavourable state [44]. When the economy continues to grow, the lower the GDP elasticity of energy carbon emissions, the higher the degree of decoupling.

Using the Tapio decoupling index, this study constructed a decoupling model of domestic water consumption and economic growth [45]: $e(DW,\ GDP) = \frac{\Delta DW/DW}{\Delta GDP/GDP}$, and the decoupling state was judged according to ΔDW, ΔGDP, and $e(DW,\ GDP)$, as shown in Table 1.

Table 1. The degrees of coupling and decoupling.

	Degrees	**Δ*DW***	**Δ*GDP***	***e* (*DW*, *GDP*)**
Negative decoupling	Expansive negative decoupling	>0	>0	$e > 1.2$
	Weak negative decoupling	<0	<0	$0 < e < 0.8$
	Strong negative decoupling	>0	<0	$e < 0$
Decoupling	Recessive decoupling	<0	<0	$e > 1.2$
	Weak decoupling	>0	>0	$0 < e < 0.8$
	Strong decoupling	<0	>0	$e < 0$
Coupling	Expansive coupling	>0	>0	$0.8 < e < 1.2$
	Recessive coupling	<0	<0	$0.8 < e < 1.2$

2.3. Data Sources

In this current study, government statistical data were used to analyse the trend of domestic water use and its influencing factors between 2006 and 2020. Population, socioeconomic, and water quantity data were collected from the China Statistical Yearbook (2007–2021), China Water Resources Bulletin (2006–2020), and the statistical yearbooks of the nine provinces in the Yellow River Basin. Domestic water includes water for urban and rural residents and urban and rural public facilities (including water for the tertiary and construction industries).

In this study, DW represents domestic water consumption (10^8 m^3), TW represents water consumption (10^8 m^3), PDW represents the proportion of domestic water consumption to total water consumption (%), and LPCD indicates the litres of domestic water consumption per capita per day (L).

2.4. Statistical Analyses

We recorded and sorted all data for analyses by using Microsoft Excel 2010; statistical analyses were performed using the software SPSS 20.0. Additionally, we used ArcGIS 10.2 to show the spatial distribution of the changes in DW in the Yellow River Basin.

3. Results and Discussion

3.1. The Trend and Temporal and Spatial Characteristics of Domestic Water Use

3.1.1. Descriptive Statistics of DW in the Year 2006 and 2020

We counted the data on domestic water consumption in nine provinces in 2006 and 2020 using the SPSS Software (Table 2). The results showed that MIN, MAX, and MEAN all increased from 2006 to 2020, indicating that domestic water consumption increased overall.

Table 2. Descriptive statistics of DW in 2006, 2020.

Year	MIN	MAX	MEAN	SD.
2006	1.76	34.57	16.65	13.13
2020	3.00	53.60	21.70	18.42

In addition, the SD of domestic water consumption among the nine provinces in 2006 was 13.13, whereas it was 18.42 in 2020. The gap among provinces also showed an increasing trend.

3.1.2. The Temporal Trend

In 2006, the Yellow River Basin TW was 1222 × 10^8 m^3, and the DW was 150 × 10^8 m^3, accounting for 12.26% of the TW. In 2020, the TW increased to 1258 × 10^8 m^3, and the DW increased to 195.3 × 10^8 m^3, accounting for 15.52% of the TW. From 2006 to 2020, the proportion of domestic water consumption in the total water consumption in the Yellow River Basin increased by 3.26%, showing an overall growth trend (Figure 1). Therefore, the litres of domestic water consumption per capita per day (LPCD) increased by 24.70% from 102.27 L to 126.97 L, with an annual average growth rate of approximately 1.61%, considerably reducing the gap with the minimum water quantity recommended by the World Health Organization (150 L/day per capita) [46].

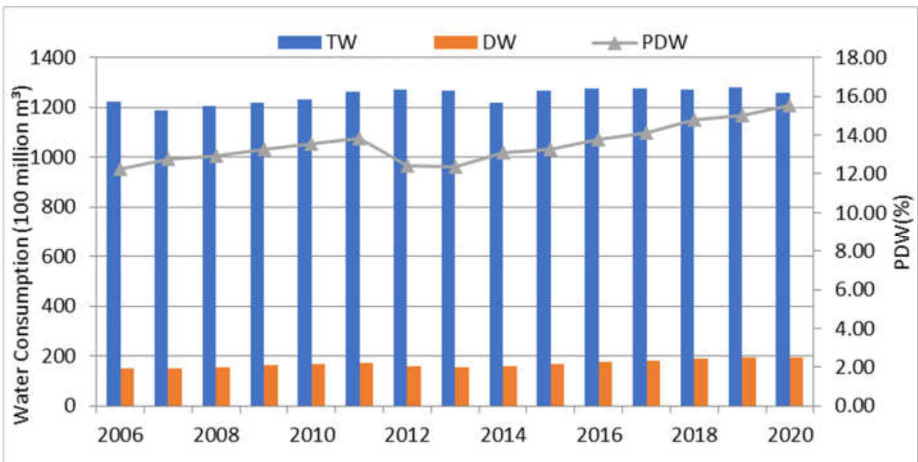

Figure 1. Water consumption in the Yellow River Basin during 2006–2020.

The proportion of domestic water consumption in total water consumption (PDW) increased continuously before 2011; however, it decreased in 2012 (Figure 1). This is because China revised the Water Law in 2009, and a series of policies ranging from the central to the local level have repeatedly emphasised the need to strengthen water conservation management, improve water-use efficiency, and ensure water safety. Nonetheless, after

2012, the PDW began to rise annually, and in 2017, it exceeded that of 2011, rising to 15.52% in 2020.

The litres of domestic water consumption LPCD can be used to characterise the domestic water-use intensity and thus reflect the efficiency of residential water use (Figure 2). After reaching peaking in 2011, per capita domestic water consumption in the Yellow River Basin fell in 2012; however, it began to rise the year after 2014, indicating an overall upward trend. In 2020, the LPCD reached 126.97 L.

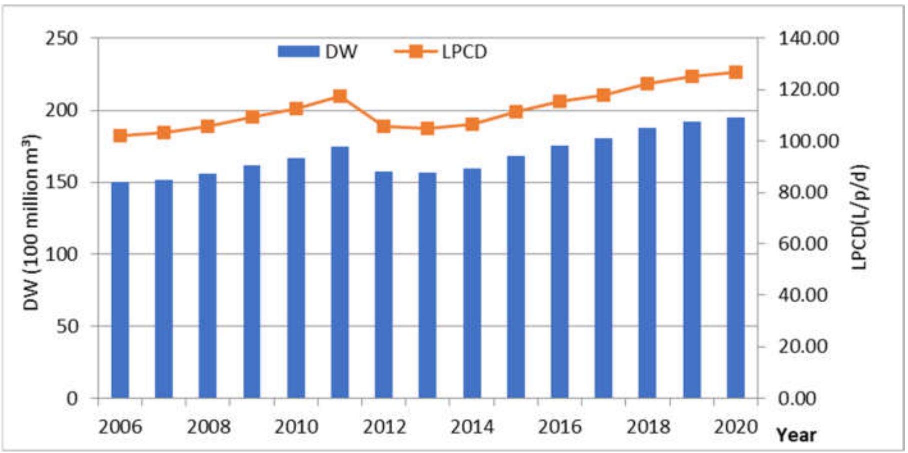

Figure 2. The trend of LPCD from 2006 to 2020.

3.1.3. The Spatial Distribution

Between 2006 and 2020, DW in the Yellow River Basin increased by 45.48 $\times$ 10^8 m^3 (Table 3). Domestic water consumption varies in the nine provinces, with only Inner Mongolia and Qinghai domestic experiencing decreases of -1.53×10^8 m^3 and -0.24×10^8 m^3, respectively. Domestic water consumption in the other seven provinces increased to varying degrees, with Sichuan experiencing the biggest growth at 19.41 $\times$ 10^8 m^3.

Table 3. The TW and DW in nine provinces in 2006 and 2020.

Province	2006		2020		Changes in Domestic Water
	TW	DW	TW	DW	
Gansu	122.3	9.1	109.90	9.30	0.18
Henan	227.0	34.6	237.10	43.10	8.53
Inner Mongolia	178.7	13.1	194.40	11.60	−1.53
Ningxia	77.6	1.8	70.20	3.70	1.94
Qinghai	32.2	3.2	24.30	3.00	−0.24
Shandong	225.8	31.3	222.50	37.50	6.23
Shanxi	59.3	9.3	72.80	14.60	5.33
Shaanxi	84.1	13.3	90.60	18.90	5.63
Sichuan	215.1	34.2	236.90	53.60	19.41
The Yellow River Basin	1222	150	1258.70	195.30	45.48

ArcGis 10.2 was used to spatially show the changes in domestic water use in the Yellow River Basin (Figure 3). The provinces with increased domestic water consumption are mainly located south of the Yellow River, including Sichuan, Henan, Shandong, and Shaanxi.

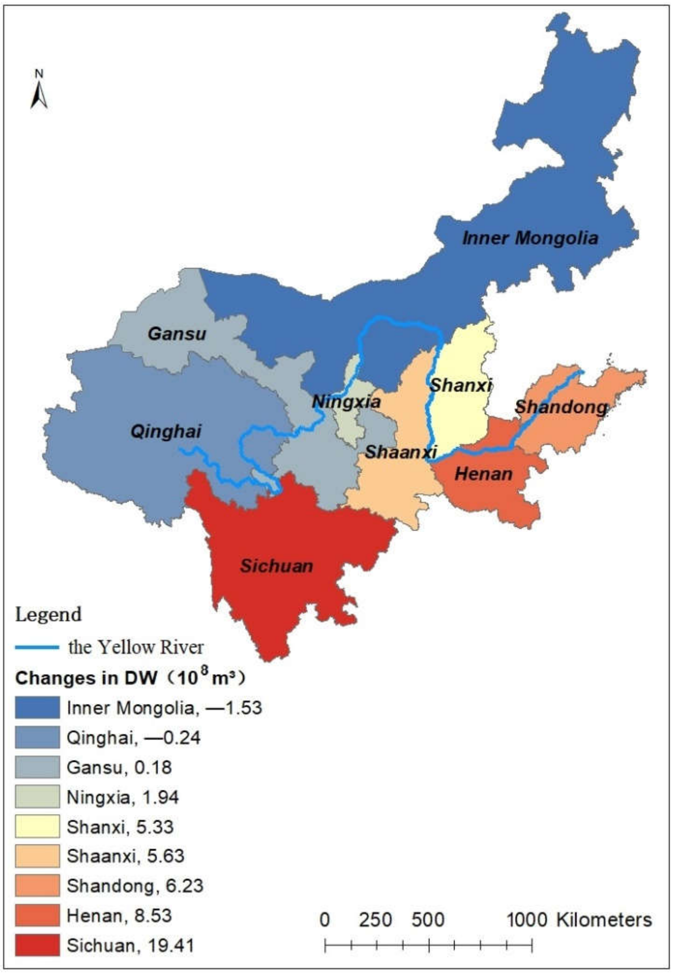

Figure 3. The spatial distribution of domestic water-use change.

3.2. Driving Factors

The LMDI model was used to decompose the factors influencing changes in domestic water consumption, and the contributions of the structure, economy, technology, and population effects were explored. Table 4 shows the final decomposition results.

Table 4. Decomposition table of four effects on domestic water use.

Province	ΔS	ΔT	ΔE	ΔP	ΔDW
Shaanxi	4.44	−26.76	27.04	0.91	5.63
Gansu	1.17	−13.66	13.05	−0.38	0.18
Qinghai	0.64	−5.69	4.57	0.25	−0.24
Ningxia	2.20	−4.72	4.00	0.46	1.94
Shanxi	2.92	−12.99	15.00	0.39	5.33
Inner Mongolia	−2.57	−14.86	15.87	0.03	−1.53
Shandong	6.74	−41.57	38.05	3.02	6.23
Henan	6.84	−55.63	55.12	2.20	8.53
Sichuan	15.25	−70.41	73.52	1.05	19.41
Yellow River Basin	40.42	−239.84	236.52	8.36	45.48

Table 4 shows that the technology effect is negative among the driving factors for the change in Yellow River domestic water consumption between 2006 and 2020, whereas the economic, structural, and population effects are positive, indicating that the continuous improvement and upgrading of technology has effectively suppressed the increase in domestic water consumption. In contrast, economic development, water-consumption structure optimisation, and population growth have promoted an increase in domestic water consumption. In absolute terms, the absolute value of the technology effect was the largest (239.84×10^8 m^3), followed by the economic effect (236.52×10^8 m^3), structural effect (40.42×10^8 m^3), and population effect (8.36×10^8 m^3). The contribution rates of technology, economy, structure, and population to the change in domestic water consumption were −527%, 520%, 89%, and 18%, respectively. It was observed that the technical and economic effects are the main driving factors behind the change in domestic water consumption. The technical effect is the main factor inhibiting the increase in domestic water consumption, while the main factor promoting the increase in domestic water consumption is the economic effect.

By analysing the structural effects of different provinces, it was found that in most provinces in the Yellow River Basin, the proportion of tertiary industry and domestic water consumption in total water consumption increased due to continuous adjustment and optimisation of industrial structures. Thus, the optimisation of industrial structures leads to an increase in domestic water consumption. However, in Inner Mongolia, the structural effect negatively affected domestic water consumption. This is because the primary and secondary industries are the main industries in Inner Mongolia, and the tertiary industry has not improved. In addition, water resources are scarce, the population density in Inner Mongolia is low, and the proportion of domestic water consumption in total water consumption is relatively low. Further analysis showed that Sichuan Province had the greatest structural effect, followed by Shandong and Henan provinces.

In terms of technical effect, all nine provinces had negative values, indicating that technology advancements further improved water-use efficiency and largely inhibited the increase in domestic water consumption. This was the main factor influencing the change in domestic water consumption. In fact, the Chinese government issued the "Outline of Water-saving Technology in China", which covers all aspects of society, such as agriculture, industry, and urban life, and promotes the development and application of water-saving technology, improves the efficiency and benefits of water use, and promotes the sustainable utilisation of water resources.

In addition, we vigorously encourage rational water use and conservation in society, strengthening the awareness of water conservation among residents, and actively promoting and popularising water-saving technologies and appliances.

However, the standard deviation of the technology effect of the nine provinces in the Yellow River Basin was 23.42, and there were significant differences in the technology effects of various provinces. Among them, Sichuan (-70.41×10^8 m^3), Henan (-55.63×10^8 m^3), Shandong (-41.57×10^8 m^3), and Shaanxi (-26.76×10^8 m^3) ranked as the top four, with absolute values greater than 25×10^8 m^3. The absolute values of the technology in the other five provinces were less than 15×10^8 m^3. Ningxia had the smallest technology effect, only 4.72×10^8 m^3. The gap between Ningxia and Sichuan Province was 65.69×10^8 m^3. This shows that there are still significant differences in water-saving technology between the provinces. In the future, there is a need to further promote excellent water-saving technology, compensate for the technological shortcomings of underdeveloped provinces, and close the gap between different provinces.

In terms of economic impact, the nine provinces in the Yellow River basin were all positive, indicating that as economic development levels improved between 2006 and 2020, domestic water consumption increased, and per capita GDP was the direct driving force for the increased domestic water consumption. The reason for this is that as economic development levels improved, the urban scale expanded further, the income of residents increased, household water appliances increased, and the living and hygiene habits of residents changed, which eventually resulted in increased water consumption. Meanwhile, the growing domestic service and catering industries increase domestic water demand. The standard deviation of economic effects among the nine provinces in the Yellow River Basin was calculated to be 23.90, indicating significant differences among different provinces and the difference between the maximum and the minimum is 69.52×10^8 m^3. Sichuan, Henan, Shandong, and Shaanxi have a large economic impact, and these four provinces have a high level of economic development in the Yellow River basin. In contrast, the economic effects in Gansu, Shanxi, Inner Mongolia, Qinghai, and Ningxia were minor and consistent with the regional economic development level. Comparing the economic effects of different provinces, it is easy to see that the situation is similar to the technological effect. Sichuan is the largest, and Ningxia is the smallest, demonstrating that economic development and technological progress complement each other to some extent.

In terms of the population effect, except for Gansu, which was negative, the other eight provinces were positive. Due to the influence of the economic development level and location, the population decrease in Gansu Province between 2006 and 2020 directly led to a decrease in domestic water demand and consumption. Shandong had the largest population effect among the other eight provinces, owing to its location in eastern China. As its economic conditions and geographical location are superior to those of other provinces, the population aggregation effect is relatively evident, and the population growth directly led to an increase in domestic water consumption. However, the impact of the population change on water consumption was not evident in general.

3.3. Degrees of Decoupling between Domestic Water Use and Economic

Decomposing the factors influencing changes in domestic water consumption reveals that the economic effect is the main factor driving an increase in domestic water consumption. Therefore, the Tapio decoupling theory was applied to analyse the reaction between the degree of domestic water consumption and economic growth. According to Table 1, the degree of decoupling between domestic water consumption and the economy of provinces in the Yellow River Basin between 2006 and 2020 was obtained, as shown in Table 5.

Table 5. The degree of decoupling between domestic water consumption and economy.

Province	ΔDW	ΔGDP	e (DW, GDP)	Degree of Decoupling
Shaanxi	5.63	21,658.12	0.09	Weak decoupling
Gansu	0.18	6740.00	0.01	Weak decoupling
Qinghai	−0.24	2364.34	−0.02	Strong decoupling
Ningxia	1.94	3209.79	0.24	Weak decoupling
Shanxi	5.33	12,899.39	0.21	Weak decoupling
Inner Mongolia	−1.53	12,568.34	−0.04	Strong decoupling
Shandong	6.23	51,051.64	0.09	Weak decoupling
Henan	8.53	42,501.10	0.07	Weak decoupling
Sichuan	19.41	39,960.95	0.12	Weak decoupling
Yellow River Basin	45.48	192,953.67	0.10	Weak decoupling

Table 5 shows that nine provinces in the Yellow River Basin achieved decoupling between domestic water consumption and economic growth, that is, the growth rate of domestic water consumption is lower than the economic growth rate. Specifically, compared with rapid economic growth, the growth rate of domestic water consumption was lower or not evident, and the growth rates of the two differed. The relationship between domestic water consumption and economic development in Inner Mongolia and Qinghai is strongly decoupling, which is the ideal state for achieving positive economic growth and negative growth of domestic water consumption. The relationship in the other seven provinces is weakly decoupling, showing evident differences in the degree of decoupling between domestic water consumption and economic growth. The decoupling index of Ningxia and Shanxi was >0.2, and the degree of economic decoupling was relatively low. The decoupling indices of Gansu, Shaanxi, Shandong, and Henan were <0.1, and the economic decoupling level was relatively high. These provinces have large populations, high levels of economic development, and low dependences on natural resources for economic development. In general, the economic decoupling index of the Yellow River basin between 2006 and 2020 was 0.1, indicating that in recent years, provinces along the Yellow

River have prioritised water conservation, constantly improved policies and regulations on water resources management, increased the efficiency of water-resource development and utilisation, and achieved decoupling of domestic water use from economic growth.

4. Conclusions

The results of this study show that between 2006 and 2020, domestic water consumption increased in the Yellow River Basin, with the provinces primarily located in the south of the river. During this period, the economy of China developed rapidly, incomes of residents increased significantly, household water facilities and equipment improved, and living habits of residents changed. The regions with better economic development show greater domestic water use, such as Henan, Shandong, Sichuan, and Shaanxi. These provinces are located to the south of the river. Based on the LMDI, among the driving factors for the change in domestic water consumption of the Yellow River between 2006 and 2020, the technology effect was negative, while the economic, structural, and population effects were positive. According to the contribution rate of domestic water-use change, technical and economic effects are the main driving factors, and the main inhibitor is the technical effect. In contrast, the economic effect is the main factor promoting the increase in domestic water consumption. Based on the decoupling model, further analysis found that the decoupling between domestic water consumption and economic growth in the Yellow River Basin means that the domestic water-consumption growth rate was < 1 compared with the economic growth rate; however, the current decoupling is weak. The relationship between domestic water consumption and economic development in Inner Mongolia and Qinghai is strongly decoupling, and the relationship in the other seven provinces is weakly decoupling. It can be seen that provinces with smaller populations and lower levels of economic development had a higher degree of decoupling, while provinces with larger populations and higher levels of economic development had a lower degree of decoupling.

It is of far-reaching historical and strategic significance to promote ecological protection and high-quality development in the Yellow River Basin. Protecting the ecological environment of the Yellow River Basin and promoting the high-quality economic development are necessary to coordinate the relationship between water and sediment and alleviate the contradiction between supply and demand of water resources. As water resources constitute the biggest rigid constraint, we should give priority to water conservation, comprehensively promote the construction of a water-saving society, rationally plan the development of the population, cities and industries, coordinate the optimization of water-use structures for ecology, production, and living, deepen the reform of the water-use system, improve water-resource management systems, and continuously improve the efficiency of water-resource utilization [47].

From the perspective of the Yellow River basin, in order to realize ecological protection and high-quality economic development in the basin, and realize strong decoupling of domestic water consumption and economic development, it should consider the influence degree of water-use structure, technical level, population effect, and economic effect on water-resource utilization. Additionally, it is necessary to optimise water resource management, improve water resource utilisation efficiency, and fundamentally reduce domestic water consumption. According to the results, the decoupling between domestic water consumption and economic growth in the Yellow River Basin is weak, and the increase of domestic water consumption needs to be further controlled in order to achieve strong decoupling. According to the LMDI analysis results, technology is the main factor to restrain the increase of domestic water consumption. Therefore, the key to control the increase of domestic water consumption is to improve the level of technical means, especially the technology to improve the utilisation efficiency of water resources and water saving. Therefore, firstly, the whole basin should give priority to water saving, refine and implement the measures of determining city, place, people and production by water, implement the double control of total water consumption and intensity, establish the total water-consumption control system covering the whole basin, fully implement water consumption plan management and accurate measurement, improve the water intake licensing system, and comprehensively and scientifically allocate the whole basin's water resources to improve the efficiency of water use. Secondly, it should improve the technical system of water-saving projects, develop water-saving products, popularise water-saving equipment and appliances, upgrade old water supply networks, improve centralised water supply and water-saving supporting facilities in rural areas, and introduce metering fees where conditions permit. Water-efficient technologies have the potential to reduce water demands and ease some of the water shortages [47]. Thirdly, we should strengthen water-saving education and publicity, strengthen the popularisation of water resources, raise residents' awareness of water conservation, and reduce domestic water consumption from the micro level of users.

From the perspective of provinces, they should adapt to local conditions, perform reasonable planning according to the decoupling of water consumption and economy, and allocate water resources scientifically and reasonably by taking all water users and stakeholders into consideration comprehensively [48]. According to the results, Qinghai and Inner Mongolia should continue to keep the strong decoupling of the economy and domestic water consumption, try their best to develop the economy, increase residents' income, and further improve people's livelihood on the basis of controlling the consumption of water resources. The other seven provinces should control domestic water consumption and strive to realize the transition from weak decoupling to strong decoupling. Provinces with small technological effect such as Ningxia, Qinghai, and Gansu should learn from Sichuan to continuously improve the efficiency of comprehensive utilisation of water resources and the level of water-saving technology. In addition, provinces should strengthen cooperation, coordinate the allocation of water resources between regions, strengthen exchanges between governments and enterprises, encourage social capital to enter the field of water-saving, jointly explore new modes of water-saving, and build a water-saving society.

In this study, the trend and driving factors of domestic water use in the Yellow River Basin were analysed by using official statistical data, and the decoupling relationship between domestic water-use change and economic development was analysed. The research angle was relatively macro, and the micro water-use behavior was not studied enough. Due to limited data acquisition, this study did not distinguish between urban and rural domestic water use in the Yellow River Basin. However, there are differences in the trend of domestic water use between urban and rural areas. In the future, we can comprehensively consider the level of economic development, living characteristics, water-consumption habits, population proportion, and other factors to carry out in-depth analysis about urban and rural domestic water consumption within a region.

Author Contributions: Conceptualization, T.Z.; methodology, T.Z. and B.S.; data collection, T.Z.; investigation, T.Z.; resources, B.S.; writing—original draft preparation, T.Z.; writing—review and editing, T.Z.; visualization, T.Z.; supervision, B.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Youth Fund Project of the Shandong Academy of Sciences (No. 2020QN0027).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Publicly available datasets were analyzed in this study. These data are available at http://www.mwr.gov.cn/sj/ (accessed on 10 March 2022).

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

References

1. United Nations. *The United Nations World Water Development Report 2021: Valuing Water*; UNESCO: Paris, France, 2021.
2. Strauch, A.M.; Almedom, A.M. Traditional water resource management and water quality in rural Tanzania. *Hum. Eco.* **2011**, *39*, 93–106. [CrossRef]

3. Bain, R.E.; Wright, J.A.; Christenson, E.; Bartram, J.K. Rural: Urban inequalities in post 2015 targets and indicators for drinking-water. *Sci. Total Environ.* **2014**, *490*, 509–513. [CrossRef] [PubMed]
4. Galaitsi, S.E.; Huber-Lee, A.; Vogel, R.M.; Naumova, E.N. Using water insecurity to predict domestic water demand in the Palestinian West Bank. *Water Int.* **2015**, *40*, 614–634. [CrossRef]
5. Sokile, C.S.; Kashaigili, J.J.; Kadigi, R.M.J. Towards an integrated water resource management in Tanzania: The role of appropriate institutional framework in Rufiji Basin. *Phys. Chem. Earth Parts A B C* **2003**, *28*, 1015–1023. [CrossRef]
6. Franks, T.; Lankford, B.; Mdemu, M. Managing water amongst competing uses: The Usangu wetland in Tanzania. *Irrig. Drain.* **2004**, *53*, 277–286. [CrossRef]
7. Fan, L.; Liu, G.; Wang, F.; Geissen, V.; Ritsema, C.J.; Tong, Y. Water use patterns and conservation in households of Wei River Basin, China. *Resour. Conserv. Recy.* **2013**, *74*, 45–53. [CrossRef]
8. WWAP (United Nations World Water Assessment Programme). *The United Nations World Water Development Report 2015: Water for a Sustainable World*; UNESCO: Paris, France, 2015.
9. Wang, J.L.; Huang, Y.; Yan, T.J.; Sun, T. Growing water scarcity, food security and government responses in China. *Glob. Food Sec.* **2017**, *14*, 9–17. [CrossRef]
10. Jovanovic, N.; Pereira, L.S.; Paredes, P.; Pôças, I.; Cantore, V.; Todorovic, M. A review of strategies, methods and technologies to reduce non-beneficial consumptive water use on farms considering the FAO56 methods. *Agric. Water Manag.* **2020**, *239*, 106267. [CrossRef]
11. Lyu, W.; Chen, Y.; Yu, Z.; Yao, W.; Liu, H. Decomposing drivers of changes in productive and domestic water use based on the logarithmic mean Divisia index method: A regional comparison in Northern China. *Water Policy* **2021**, *23*, 310–326. [CrossRef]
12. Wang, S.; Li, R. Toward the coordinated sustainable development of urban water resource use and economic growth: An empirical analysis of Tianjin City, China. *Sustainability* **2018**, *10*, 1323. [CrossRef]
13. Brown, T.C.; Mahat, V.; Ramirez, J.A. Adaptation to future water shortages in the United States caused by population growth and climate change. *Earths Future* **2019**, *7*, 219–234. [CrossRef]
14. Qiao, Z.; Wu, L.; Yang, Z. Prediction of water consumption in 31 provinces of China based on FGM (1,1) model. *Clean-Soil Air Water* **2022**, *50*, 202200052. [CrossRef]
15. Zhang, C.; Wu, Y.; Pang, Q.; Shi, C. Driving effect of spatial-temporal differences in water use in the Yangtze River economic zone from the perspective of production and domestic. *Resour. Environ. Yangtze Basin* **2019**, *28*, 2806–2816. [CrossRef]
16. Omarova, A.; Tussupova, K.; Hjorth, P.; Kalishev, M.; Dosmagambetova, R. Water supply challenges in rural areas: A case study from Central Kazakhstan. *Int. J. Environ. Res. Public Health* **2019**, *16*, 688. [CrossRef] [PubMed]
17. Gc, R.K.; Ranganathan, S.; Hall, R.P. Does rural water system design matter? *A study of productive use of water in rural Nepal. Water* **2019**, *11*, 1978. [CrossRef]
18. Fan, L.; Gai, L.; Tong, Y.; Li, R. Urban water consumption and its influencing factors in China: Evidence from 286 cities. *J. Cleaner Prod.* **2017**, *166*, 124–133. [CrossRef]
19. Curtis, V.; Dreibelbis, R.; Buxton, H.; Izang, N.; Adekunle, D.; Aunger, R. Behaviour settings theory applied to domestic water use in Nigeria: A new conceptual tool for the study of routine behaviour. *Soc. Sci. Med.* **2019**, *235*, 112398. [CrossRef]
20. Chowdhury, T. *Determinants of Domestic Water Use by Rural Households: A Case Study from Sunderbans, India*; State University of New York College of Environmental Science and Forestry: New York, NY, USA, 2013.
21. Fan, L.; Liu, G.; Wang, F.; Ritsema, C.J.; Geissen, V. Domestic water consumption under intermittent and continuous modes of water supply. *Water Resour. Manag.* **2014**, *28*, 853–865. [CrossRef]
22. Guo, B.; Chen, Y.; Shen, Y.; Li, W.; Wu, C. Spatially explicit estimation of domestic water use in the arid region of northwestern China: 1985–2009. *Hydrol. Sci. J.* **2013**, *58*, 162–176. [CrossRef]
23. Li, T.; Hasegawa, T.; Yin, X.; Zhu, Y.; Boote, K.; Adam, M.; Bregaglio, S.; Buis, S.; Confalonieri, R.; Fumoto, T.; et al. Uncertainties in predicting rice yield by current crop models under a wide range of climatic conditions. *Glob. Change Biol.* **2015**, *21*, 1328–1341. [CrossRef]
24. Wang, W.; Zou, S.; Shao, Q.; Xing, W.; Chen, X.; Jiao, X.; Luo, Y.; Yong, B.; Yu, Z. The analytical derivation of multiple elasticities of runoff to climate change and catchment characteristics alteration. *J. Hydrol.* **2016**, *541*, 1042–1056. [CrossRef]
25. Zhang, Q.; Yue, C.; Li, Y.; Hu, X. Effects of climate and land use change on agricultural water consumption in Baicheng County. *Sustainability* **2022**, *14*, 13746. [CrossRef]
26. Arunrat, N.; Sereenonchai, S.; Chaowiwat, W.; Wang, C. Climate change impact on major crop yield and water footprint under CMIP6 climate projections in repeated drought and flood areas in Thailand. *Sci. Total Environ.* **2022**, *807*, 150741. [CrossRef]
27. Wang, X.; Zhang, J.; Shahid, S.; Bi, S.; Yu, Y.; He, R.; Zhang, X. Demand control and quota management strategy for sustainable water use in China. *Environ. Earth Sci.* **2015**, *73*, 7403–7413. [CrossRef]
28. Yao, L.; Zhang, H.; Zhang, C.; Zhang, W. Driving effects of spatial differences of water consumption based on LMDI model construction and data description. *Cluster Compu.* **2019**, *22*, 6315–6334. [CrossRef]
29. Fan, L.; Liu, G.; Wang, F.; Geissen, V.; Ritsema, C.J. Factors affecting domestic water consumption in rural households upon access to improved water supply: Insights from the Wei River Basin, China. *PLoS ONE* **2013**, *8*, e71977. [CrossRef]
30. Garcia, J.; Salfer, L.R.; Kalbusch, A.; Henning, E. Identifying the drivers of water consumption in single-family households in Joinville, Southern Brazil. *Water* **2019**, *11*, 1990. [CrossRef]

31. Villar-Navascués, R.A.; Pérez-Morales, A. Factors affecting domestic water consumption on the Spanish Mediterranean coastline. *Prof. Geogr.* **2018**, *70*, 513–525. [CrossRef]
32. Wu, Z.; McKay, J.; Hemphill, E. Roles of levies for sustainable domestic water consumption. *Water Resour. Manag.* **2011**, *25*, 929–940. [CrossRef]
33. Singh, O.; Turkiya, S. A survey of household domestic water consumption patterns in rural semi-arid village, India. *Geo. J* **2013**, *78*, 777–790. [CrossRef]
34. Tamason, C.C.; Bessias, S.; Villada, A.; Tulsiani, S.M.; Ensink, J.H.; Gurley, E.S.; Mackie Jensen, P.K. Measuring domestic water use: A systematic review of methodologies that measure unmetered water use in low-income settings. *Trop. Med. Int. Health* **2016**, *21*, 1389–1402. [CrossRef] [PubMed]
35. Morote, Á.-F.; Hernández, M.; Rico, A.-M. Causes of domestic water consumption trends in the city of Alicante: Exploring the links between the housing bubble, the types of housing and the socio-economic factors. *Water* **2016**, *8*, 374. [CrossRef]
36. Tapio, P. Towards a theory of decoupling: Degrees of decoupling in the EU and the case of road traffic in Finland between 1970 and 2001. *Transp. Policy* **2005**, *12*, 137–151. [CrossRef]
37. Nie, Z.; Wu, M.; Ma, H. Affecting factors for domestic water use in China based on LMDI and decoupling theory. *J. Econ. Water Resour.* **2019**, *37*, 11–15.
38. Zhao, C.; Deng, J.; Zhang, C.; Zhang, Z. Study on the center of gravity movement and driving effect of residents domestic water use in the Yangtze River Economic Belt. *Resour. Environ. Yangtze Basin* **2021**, *30*, 827–838.
39. Jia, J. A technical review of hydro-project development in China. *Engineering* **2016**, *2*, 302–312. [CrossRef]
40. Zhao, C.; Chen, B. Driving force analysis of the agricultural water footprint in China based on the LMDI method. *Environ. Sci. Technol.* **2014**, *48*, 12723–12731. [CrossRef]
41. Ang, B.W. Decomposition analysis for policymaking in energy: Which is the preferred method? *Energy Policy* **2004**, *32*, 1131–1139. [CrossRef]
42. Ang, B.W. The LMDI approach to decomposition analysis: A practical guide. *Energy Policy* **2005**, *33*, 867–871. [CrossRef]
43. Ang, B.W. LMDI decomposition approach: A guide for implementation. *Energy Policy* **2015**, *86*, 233–238. [CrossRef]
44. Wang, S.; Li, C.; Yang, L. Decoupling effect and forecasting of economic growth and energy structure under the peak constraint of carbon emissions in China. *Environ. Sci. Pollut. Res.* **2018**, *25*, 25255–25268. [CrossRef] [PubMed]
45. Wang, Q.; Zhao, M.; Li, R.; Su, M. Decomposition and decoupling analysis of carbon emissions from economic growth: A comparative study of China and the United States. *J. Cleaner Prod.* **2018**, *197*, 178–184. [CrossRef]
46. Bun, S.; Sek, S.; Oeurng, C.; Fujii, M.; Ham, P.; Painmanakul, P. A survey of household water use and groundwater quality index assessment in a rural community of Cambodia. *Sustainability* **2021**, *13*, 10071. [CrossRef]
47. Liu, B.; Speed, R. Water resources management in the People's Republic of China. *Int. J. Water Resour. Develop.* **2009**, *25*, 193–208. [CrossRef]
48. Ponok, N.; Arunrat, N.; Pumijumnong, N.; Hamasaki, H.; Sereenonchai, S. Challenges of water policy involvement of the community in the East Coast River Basin of Thailand. *Water* **2021**, *13*, 3395. [CrossRef]