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Effect of IBWT on water consumption and pollution **Can inter-basin water transfer affect water consumption and pollution?** **Lessons from China's South-North Water Transfer Project**

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Abstract

Inter-basin water transfer has become a means by which countries around the world solve the problem of water shortage. Moreover, inter-basin water transfers may also stimulate stronger controls over water pollution control in water-receiving areas. However, most existing literature fails to examine the impacts of inter-basin water transfers on **water consumption** and pollution from the perspective of the complex entanglement between human activities and environmental change. In order to respond to this research gap, this study establishes an improved human-environment model that considers the impacts of inter-basin water transfer, and uses data about China's South-North Water Transfer Project to empirically study the temporal and spatial effects of inter-basin water transfers. **The results show that inter-basin water transfer not only fails to improve water consumption in water-receiving cities, but also further restricts residents' water use due to the high water price caused by this project.** Furthermore, inter-basin water transfers also fail to reduce water pollution in water-receiving cities – levels of water pollution depend more on external environmental policies. These results have some implications for understanding the inter-basin water transfers in authoritarian states: although inter-basin water transfers do not **affect water consumption** and pollution, authoritarian states can maintain and consolidate their political legitimacy by gaining public trust through inter-basin water transfers.

Keywords: *Authoritarian state; Inter-basin water transfers; South-North Water Transfer Project; Water consumption; Water pollution*

1 Introduction

The increasing demand for water caused by population growth and/or socio-economic development has made the contradiction between demand and the finite quantity of water available increasingly prominent. The spatial and temporal distribution of water resources is uneven in many countries, prompting a search for ways of overcoming water shortages. Inter-basin water transfer (IBWT) is one means of redistributing water resources across national, regional, and urban boundaries to meet the growing demand for water in agriculture, industry, and the household sector (Matete & Hassan, 2006). Many IBWT projects have been implemented around the world. By 2015, there were more than 160 IBWT projects built or under construction (Zhuang, 2016), distributed in 20 countries, including the United States (Howitt & Hanak, 2005), Canada (Desbiens, 2004), Australia (Griffin, 2003), India (Verma, Kampman, van der Zaag, & Hoekstra, 2009) and China (Sheng, Webber, & Han, 2018). At the same time, water-deficient regions are also subject to increasing water pollution, which in turn aggravates water shortages (Jiang, 2009). Therefore, water pollution control has become a prerequisite for IBWT; otherwise, the transferred water itself becomes contaminated (Wei, Yang, Abbaspour, Mousavi, & Gnauck, 2010). In this sense, IBWTs may spur controls over water pollution, improving water quality in

the water-receiving area.

However, do IBWTs affect water consumption and pollution in particular places and over time? The complex entanglements between IBWT as a human activity and its environmental impacts have received relatively little attention in the existing literature. Only a few papers have noted the correlation between IBWT as a human activity and environmental change (Barnett, Rogers, Webber, Finlayson, & Wang, 2015; Roman, 2017). Unfortunately, these studies fail to account for the environmental impacts of human activities other than IBWT. Moreover, studies of the environmental impacts of human activities focus on population factors, economic factors and technological factors (Zhao, Chen, Hayat, Alsaedi, & Ahmad, 2014), without considering IBWT.

In response to this gap, this study proposes a model of the human-environment system to contribute to our understanding of IBWTs' impacts on water consumption and pollution in theory and practice. China's South-North Water Transfer Project (SNWTP) provides a case for examining the environmental impacts of both IBWTs and other human activities. This study reviews China's SNWTP from the perspective of its environmental impacts and explores the SNWTP's effects on water consumption and pollution through this model. The evidence supports several political and economic arguments. First, the IBWT not only fails to improve water consumption in water-receiving cities, but also further restricts residents' water use due to the high water price caused by this project. Second, the IBWT also fails to control water pollution in the water-receiving cities, since controls on water pollution depend more on external

environmental policies. Although the IBWT does not affect water consumption and pollution, authoritarian states can maintain and consolidate their political legitimacy by gaining public trust through the IBWT.

2 Theoretical frameworks

Recent decades have witnessed a deeper understanding of the complex relationship between water consumption, pollution, and human activities. Demographic factors are often regarded as an important factor affecting water consumption and pollution. An increase in the total population may lead to a rise in water consumption, and higher levels of water pollution (C. Zhang et al., 2017; Zhao et al., 2014). However, the increase in population size may also improve the efficiency with which public infrastructure is used, thereby reducing the consumption of resources and the emission of pollutants (H. Chen, Jia, & Lau, 2008; Brant Liddle, 2004). Brantley Liddle (2014) argued that population size might have a more significant impact on resource consumption than urbanization and other demographic factors. To the best of our knowledge, the impacts of population size on water consumption and pollution are still uncertain, especially in IBWTs.

Just as the role of demographic factors in IBWT is complicated, so too are the impacts of economic factors on water consumption and pollution. Theoretical and empirical studies have amply demonstrated that there is an inverted U-shaped environmental Kuznets curve (EKC) between income levels and water pollution (Orubu & Omotor, 2011). However, it is still unclear

whether such an inverted U-shaped relationship exists between water consumption and income levels. Duarte, Pinilla, and Serrano (2013) found that the relationship between water consumption and income levels is non-linear, with an inverted U-shape that has distinct downward branches. However, Katz (2015) argued that the inverted U-shape relationship between water consumption and income levels is highly dependent on the choice of data sets and statistical techniques. Such studies do not test whether the EKC appears in IBWTs. Moreover, the relationship between water consumption, pollution, and income levels within an IBWT has not been scientifically studied in the literature.

Technology is also identified as an essential factor affecting water consumption and pollution. Increasing water demand and open market competition drive technological innovation, resulting in reduced water consumption through water-saving, recycling, and reuse (Cheng, Hu, & Zhao, 2009). However, improvements in water-use efficiency may also reduce the cost of water use, leading to an increase in water consumption rather than a decrease – the rebound effect (Berbel, Gutiérrez-Martín, Rodríguez-Díaz, Camacho, & Montesinos, 2015). Therefore, existing studies of this rebound effect are contradictory. Some argue that the rebound effect is real, but its magnitude is small (Graveline, Majone, Van Duinen, & Ansink, 2014); while others argue that the rebound effect is ambiguous and uncertain (Gómez & Pérez-Blanco, 2014). In addition, the efficiency of water use may rise with industrial restructuring: when an industrial structure is transformed from heavy industry to high-tech and knowledge-based industries, water-use efficiency may rise and industrial wastewater discharge decrease (Zhou & Tol, 2005). In other

words, innovations in water-saving technologies and wastewater treatment technologies can improve water-use efficiency, water recycling and reuse, thereby reducing pollutant emissions (Hu & Cheng, 2013). However, current studies on the effects of technology on water consumption and pollution within IBWTs are scarce, and the magnitude of these effects is not accurately measured.

Historical water-use habits and behaviors may also affect current water consumption and pollution (H. H. Zhang & Brown, 2005). Water consumption and pollution behaviors depend on the local awareness of water-saving and environmental protection, which can contribute to current decisions on water use and pollution control (Jorgensen, Graymore, & O'Toole, 2009). Therefore, water-use efficiency can be raised by changing people's values, attitudes, and behaviors towards water (Jianguo Liu & Yang, 2012). However, water-use habits and behaviors are often overlooked in the existing literature on the environmental impacts of human activities; only a few studies have noted the impacts of historical water-use habits and behaviors on water consumption and pollution (Gregory & Leo, 2003; Jorgensen et al., 2009). It is still unclear whether water-use habits can affect water consumption and pollution in an IBWT.

Furthermore, an IBWT may itself directly affect water consumption and pollution. An IBWT enables water-receiving areas to obtain more water resources, thereby **increasing water consumption** and accelerating water exchange, resulting in increased water consumption and improved water quality (Zhuang, 2016). However, an IBWT may also spread pollutants. For example, the Michigan Water Transfer Project is controversial for its long history of exposure to

various pollutants (Rasmussen, Schrank, & Williams, 2014). Overall, the temporal and spatial effects of IBWTs' environmental impacts have surprisingly received little attention. Therefore, this study expands existing models of the human-environment system to explore and scientifically assess the possible environmental impacts of various human activities in IBWT.

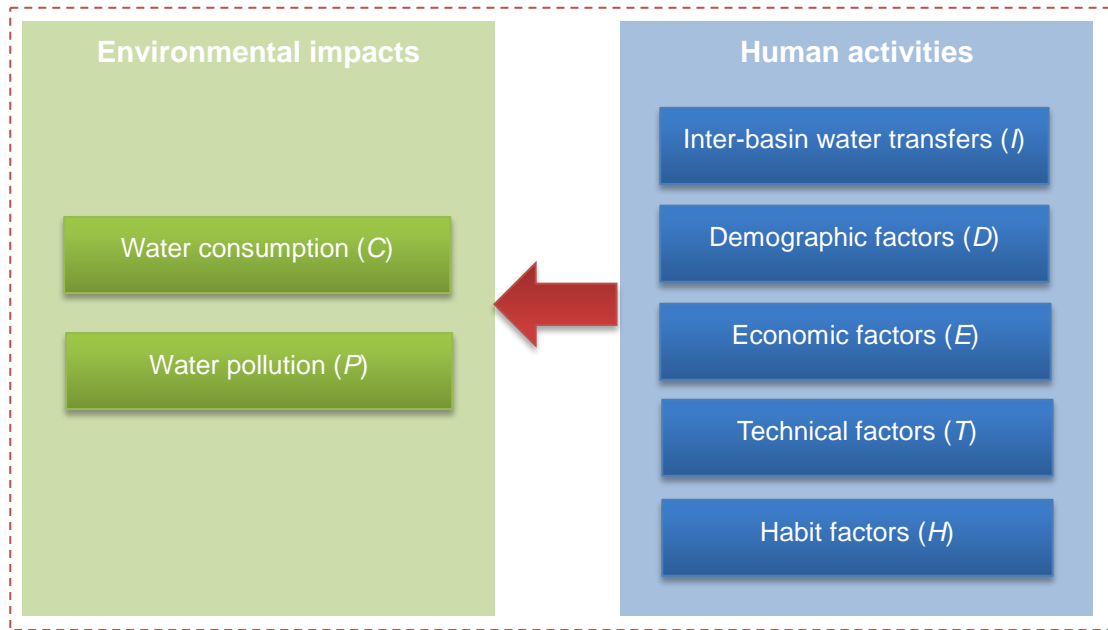


Fig. 1 The improved model of a human-environment system with an IBWT

This improved human-environment system can be stated as follows:

$$C = f_1(I, D, E, T, H) \quad (1)$$

and

$$P = f_2(I, D, E, T, H) \quad (2)$$

where C and P represent water consumption and pollution, respectively; I , D , E , T , and H

represent IBWT, demographic factors, economic factors, technical factors, and habit factors. The left sides of Equations (1) and (2) describe the environmental impacts, while the right sides describe human activities. The resulting model of a human-environment system is shown in Figure 1, which includes five human activities and two environmental impacts.

3 Methods

3.1 Study area

China's SNWTP transfers water from the Yangtze River towards the north and northwest through two routes in the east and middle of China. The eastern route (ER) transfers water by extending the Yangtze River Water Transfer Project in Jiangsu to the north via the Beijing-Hangzhou Great Canal and existing rivers in the Huai River and Hai River Basins (Sheng & Webber, 2017). The middle route (MR) draws water from the Danjiangkou Reservoir in the middle and upper reaches of the Han River and delivers water to Beijing and Tianjin through a newly constructed canal.

The first phases of the eastern and middle routes began construction in December 2002 and December 2003 respectively, and were completed in December 2013 and December 2014, respectively. The two routes can provide 27.8 billion cubic meters of freshwater per year from the Yangtze River Basin to the North China Plain. The total length of the routes is nearly 2 900 km (Ministry of Water Resources, 2002), costing over 240 billion yuan (People's Daily, 2014). It is one of the largest and most ambitious megaprojects in the world (Pohlner, 2016).

The SNWTP involves seven provinces or municipalities: Beijing, Tianjin, Hebei, Henan,

Hubei, Shandong, and Jiangsu. Hubei is the location of the Danjiangkou Reservoir, the water source of the middle route, and is not one of the SNWTP's water-receiving areas. Therefore, the study area includes only six provinces or municipalities (excluding Hubei), comprising 40 water-receiving cities and 20 non-water-receiving cities (Figure 2). The first phase of the middle route serves Beijing, Tianjin, Hebei, and Henan, while the first phase of the eastern route involves only Jiangsu and Shandong. Since the water-use policies of the cities within any one province are almost the same, the SNWTP's environmental effects can be revealed by comparing the differences in water consumption and pollution between water-receiving and non-water-receiving cities. Moreover, in order to study the SNWTP's temporal effects on water consumption and pollution, this study relies on data for the years between 2003 (when construction began) and 2016 (the latest data available).

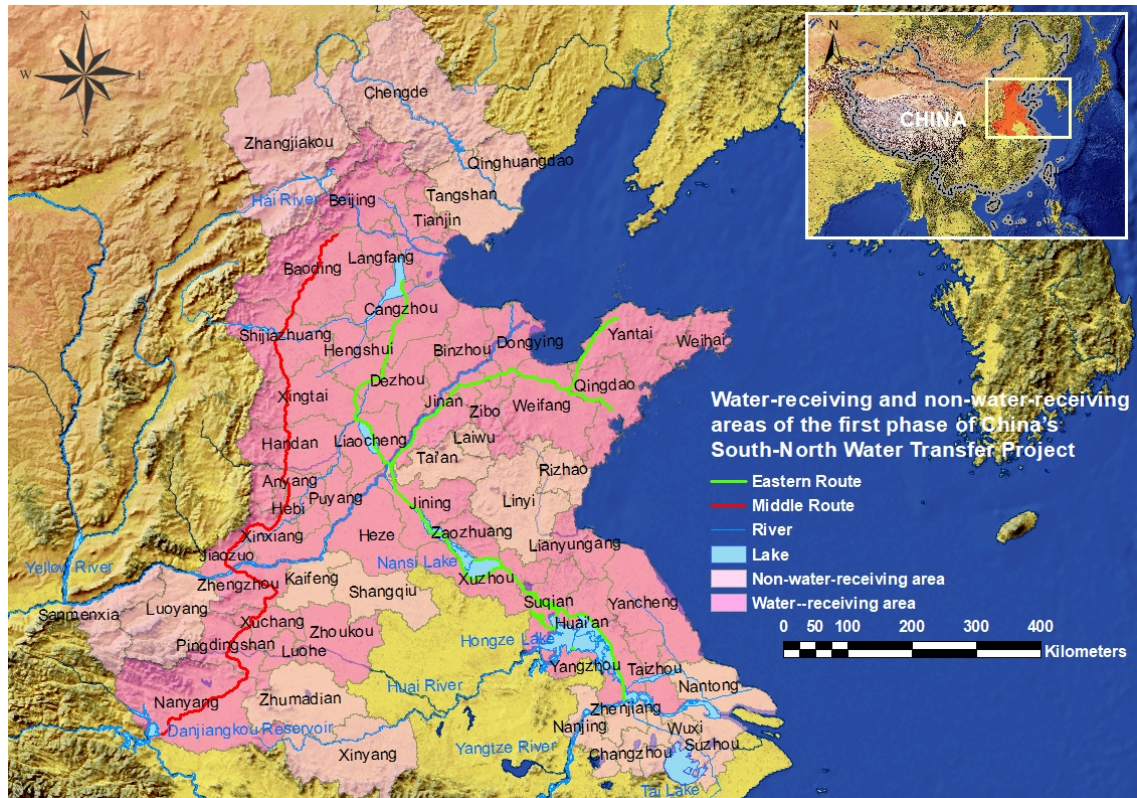


Fig. 2 The water-receiving and non-water-receiving areas of the first phase of China's SNWTP

3.2 Model specification

Total water consumption (*consumption*) and total industrial wastewater discharge (*pollution*) are the two dependent variables that summarize the SNWTP's effects on water consumption and pollution, respectively. Since water consumption is often highly correlated with wastewater discharge (Fu, Butler, & Khu, 2009), and industrial wastewater discharge is the primary source of water pollution (Huang, Wang, Lou, Zhou, & Wu, 2010), endogeneity issues are avoided by following Y. Liu, Zhou, and Wu (2015) and selecting total industrial wastewater discharge as the measure of water pollution.

City type (*city*) and year type (*year*) are the independent variables chosen to measure the SNWTP's temporal and spatial effects, respectively. If a city is a water-receiving city, the value of *city* = 1; otherwise, it is 0. The spatial effects of the SNWTP can be measured by comparing the differences in water consumption and pollution between the two groups of cities in the SNWTP. Similarly, if a year is after the SNWTP began to transfer water, *year* = 1; otherwise, it is 0.

Moreover, an interaction term – city type and year type (*city*year*) – is used to examine whether the SNWTP has affected water consumption and pollution differently in the water-receiving and non-water-receiving cities. If the coefficient of the interaction term is significant, then after the SNWTP began operating water consumption (or pollution) in the water-receiving cities altered significantly more than in non-water-receiving cities; if the coefficient is not significantly different from zero, then water consumption (or pollution) in both kinds of the city changed at similar rates before and after the SNWTP began operating.

Population, economy, and technology are three critical independent variables that are often considered in traditional human-environment systems. The total population (*pop*) is chosen as an independent variable that describes the effects of demographic factors. Moreover, GDP per capita (*gdppc*) is employed as an independent variable to describe the impacts of economic factors. The quadratic term of GDP per capita is also selected as an independent variable to verify whether economic factors have an EKC relationship with water consumption and pollution. Following the studies of York, Rosa, and Dietz (2003) and Y. Liu et al. (2015), the proportion of tertiary industry

output (*terind*) and water-use intensity (*intensity*) are taken to measure the effects of technical factors. The proportion of tertiary industry output reflects technological progress caused by the upgrading of industrial structure, which will affect water consumption and industrial wastewater discharge (Zhou & Tol, 2005). Water-use intensity is the water consumption per unit of GDP, which reflects technological progress in water use (Wu, Jin, & Zhao, 2010). Since there is a high correlation between water-use intensity and per capita water consumption, this variable is excluded when modeling per capita water consumption, and only used to model total industrial wastewater discharge.

First-order lag terms for water consumption and pollution (*consumption*_{*i,t-1*} and *pollution*_{*i,t-1*}) are employed to measure the impacts of habits on water consumption and pollution, respectively. Historical water-use and pollution control habits and behaviors can affect people's awareness of water-saving and environmental protection, which in turn affects current decisions about water use and pollution control (Jorgensen et al., 2009). Therefore, historical water consumption and pollution can reflect the habits and patterns of water use and pollution control, which in turn will affect current water consumption and pollution.

Finally, the econometric models incorporating IBWT are as follows:

$$\begin{aligned} consumption_{it} = & \alpha_0 + \alpha_1 \cdot consumption_{i,t-1} + \alpha_2 \cdot city_{it} + \alpha_3 \cdot year_{it} + \alpha_4 \cdot city_{it} \cdot \\ & year_{it} + \alpha_5 \cdot pop_{it} + \alpha_6 \cdot gdppc_{it} + \alpha_7 \cdot gdppc_{it}^2 + \alpha_8 \cdot terind_{it} + \varepsilon_{1it} \end{aligned} \quad (3)$$

and

$$\begin{aligned}
pollution_{it} = & \beta_0 + \beta_1 \cdot pollution_{i,t-1} + \beta_2 \cdot city_{it} + \beta_3 \cdot year_{it} + \beta_4 \cdot city_{it} \cdot \\
& year_{it} + \beta_5 \cdot pop_{it} + \beta_6 \cdot gdppc_{it} + \beta_7 \cdot gdppc_{it}^2 + \beta_8 \cdot terind_{it} + \beta_9 \cdot intensity_{it} + \\
& \varepsilon_{2it}
\end{aligned} \tag{4}$$

where i ($i=1, 2, \dots, 60$) represents the city; t ($t=2002, 2003, \dots, 2016$) represents the year; α_0 and β_0 are the constant terms; α_k ($k=1, 2, \dots, 7$) and β_l ($l=1, 2, \dots, 8$) represent the coefficients of the k -th and l -th independent variables in Equations (3) and (4), respectively; and ε_{1it} and ε_{2it} represent the random error terms that are assumed to be normally distributed.

Equations (3) and (4) contain lagged dependent variables, so there is a correlation between the independent variables and random errors, resulting in endogeneity issues. Thus, using standard random effect or fixed-effect models may produce inconsistent estimates of parameters (Greene, 2017). Arellano and Bond (1991) proposed the Generalized Method of Moments (GMM) to solve this problem, including differential GMM (DIF-GMM) and system GMM (SYS-GMM). DIF-GMM can provide consistent and more effective estimates, but the weak instruments used in the estimation of DIF-GMM can easily lead to bias in estimation. Therefore, Arellano and Bover (1995) and Blundell and Bond (1998) proposed SYS-GMM to overcome this problem. Compared with the DIF-GMM, this method has smaller standard deviations and higher effectiveness.

Moreover, reverse causality may also lead to endogeneity issues when estimating the IBWT's effects on water consumption and pollution. Because cities with more water consumption are more likely to lack water, they are more likely to be included in the SNWTP's

water receiving area, causing reverse causality. Therefore, we use the two-step SYS- GMM to estimate the parameters in Equations (3) and (4) to ensure that the results are not driven by reverse causality.

3.3 Data

This study uses a balanced panel dataset of 60 cities in six provinces or municipalities (Beijing, Tianjin, Hebei, Henan, Shandong, and Jiangsu) for the period 2003-2016. **The data are collected from the *China Urban Statistical Yearbook* and *China Urban Construction Statistical Yearbook*.**

Table 1 summarizes these variables; their annual average rate of growth across the 60 cities is shown in Figure 3.

Table 1

Summary of the variables

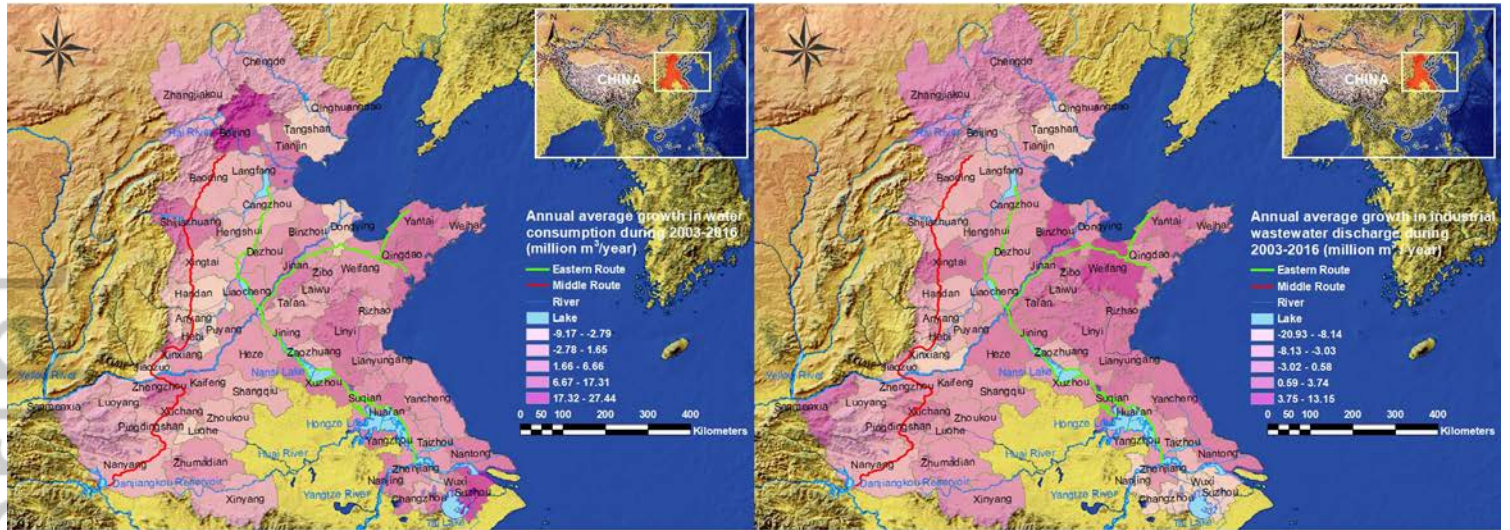
Variables	Descriptions	Unit	No. of Obs.	Mean	Std. Dev.	Min	Max
Dependent variables							
<i>consumption</i>	Total water consumption	10 million m ³	840	17.80	26.43	1.289	189.4
<i>pollution</i>	Total industrial wastewater discharge	10 million m ³	840	11.36	10.36	0.670	77.68

Independent variables

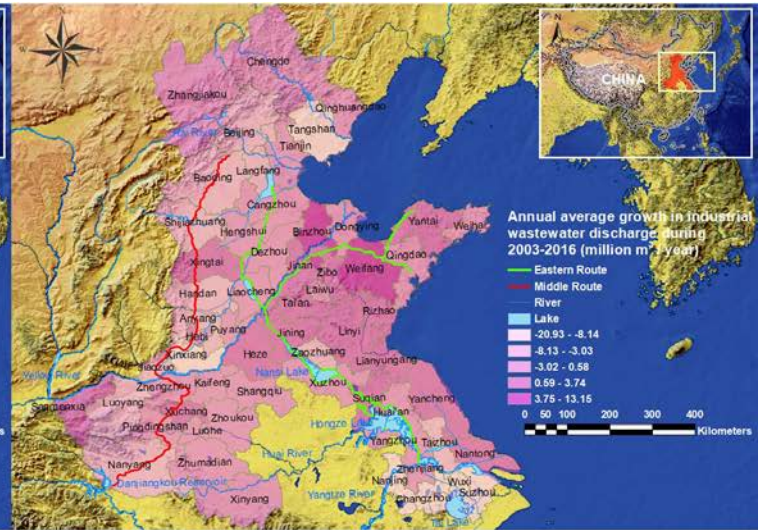
Variables	Descriptions	Unit	No. of Obs.	Mean	Std. Dev.	Min	Max
<i>city</i>	City type (0 = non-water-receiving city; 1 = water-receiving city)		840	0.667	0.472	0	1
<i>year</i>	Year type (0 = non-water-receiving year; 1 = water-receiving year)		840	0.112	0.315	0	1
<i>pop</i>	Total population	million people	840	6.133	2.749	1.239	13.54
<i>gdppc</i>	GDP per capita	10,000 yuan/ person	840	4.085	3.721	0.332	22.99
<i>terind</i>	Proportion of tertiary industry output	%	840	35.70	9.22	13.60	80.20
<i>intensity</i>	Water-use intensity	m ³ /10,000 yuan	840	8.613	7.606	1.139	75.95

According to Figure 3 (a), the cities with the fastest annual increase in total water consumption are concentrated in China's Yangtze River Delta and Bohai Rim regions, which are the regions with the most developed economies and fastest GDP growth in China (see Figure 3

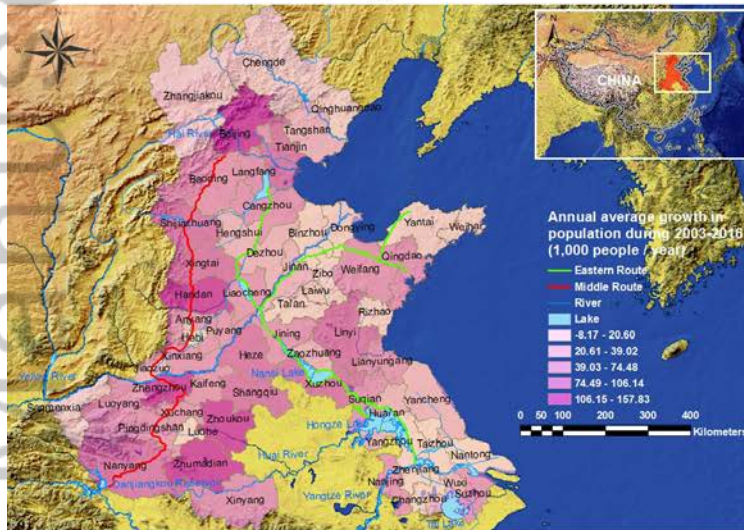
(d)). Figure 3 (b) shows that the five cities with the fastest growth in annual industrial wastewater discharge (Binzhou, Weifang, Zibo, Heze, and Linyi) are all concentrated in Shandong. However, the five cities with the fastest population growth (Beijing, Handan, Zhoukou, Zhumadian, and Zhengzhou) are all located along the middle route (see Figure 3 (c)). According to Figure 3 (e), the annual average growth in water intensity in 60 cities are all negative, indicating that water-use efficiency in these cities has been improving. Finally, Figure 3 (f) shows that cities with higher annual growth in the proportion of tertiary industry output are also concentrated in China's Yangtze River Delta and Bohai Rim, indicating that the proportion of tertiary industry output is positively correlated with water consumption.



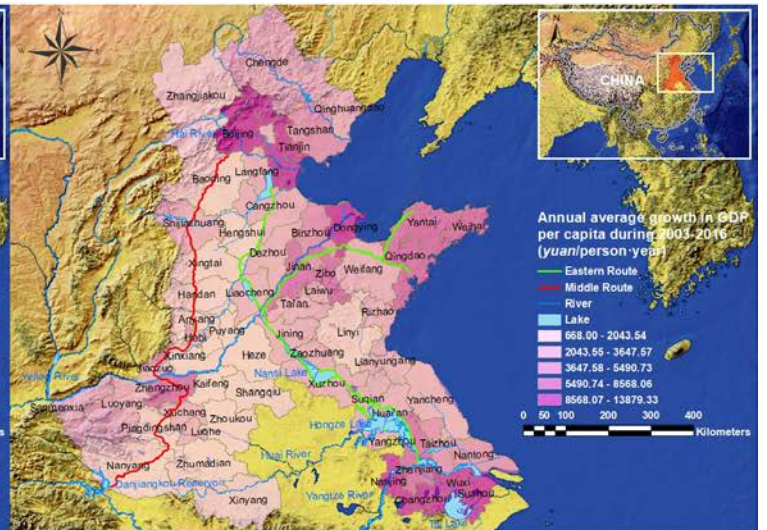
(a)



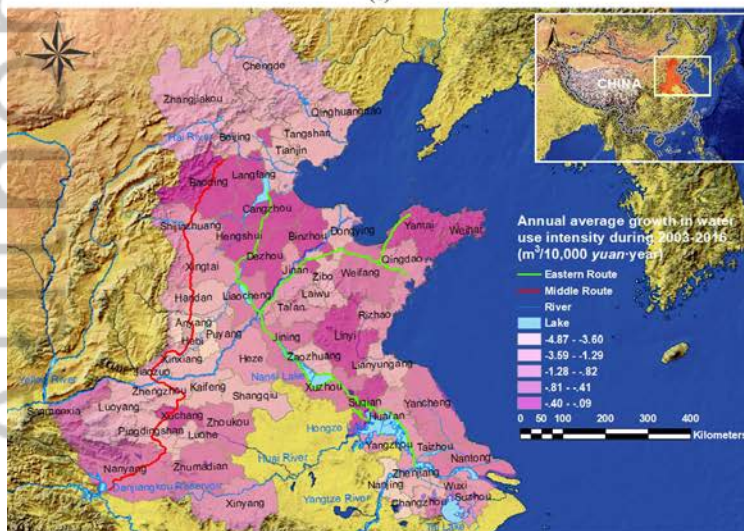
(b)



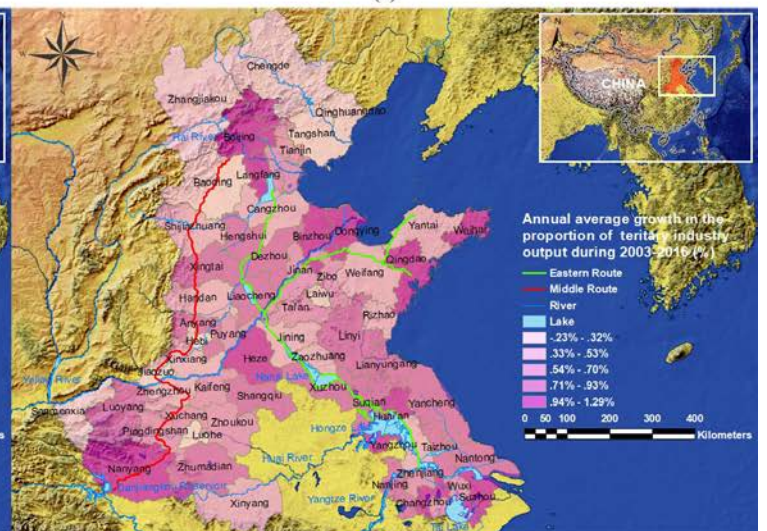
(c)



(d)



(e)



(f)

Fig. 3 Annual average growth in (a) water consumption, (b) industrial wastewater discharge, (c) population, (d) GDP per capita, (e) water-use intensity, and (f) the proportion of tertiary industry output during 2003-2016

4 Results

4.1 Empirical results

Water consumption and industrial wastewater discharges in 60 cities during 2003-2016 were estimated by using Stata 15. The results are shown in Tables 2 and 3. Models 1 and 2 are for consumption; Models 3 and 4 are for water pollution. Models 2 and 4 include an interaction term (*city*year*), whereas Models 1 and 3 do not include this interaction term.

Table 2 The results of the water consumption models

Models	(1)	(2)
<i>consumption</i> _{<i>i, t-1</i>}	0.9501*** (0.0158)	0.9499*** (0.0159)
<i>city</i>	0.1282 (0.2364)	0.0924 (0.3019)
<i>year</i>	-1.0778* (0.5511)	-1.2087** (0.5431)

Models	(1)	(2)
<i>city*year</i>		0.1820 (0.7409)
<i>pop</i>	0.1433*** (0.0447)	0.1450*** (0.0450)
<i>gdppc</i>	0.2124** (0.0981)	0.2070** (0.1013)
<i>gdppc</i> ²	-0.0010 (0.0068)	-0.0007 (0.0073)
<i>terind</i>	11.8415*** (3.2293)	11.8929*** (3.2026)
Constant	-4.6130*** (1.0426)	-4.6049*** (1.0548)
Hansen test (<i>p</i> -value)	0.1927	0.1959
AR (2) (<i>p</i> -value)	0.0575	0.0572
Observations	780	780

Note: robust standard error in parentheses; *, **, and *** represent significant at 10%, 5% and 1% levels, respectively.

Table 3 The results of the water pollution models

Models	(3)	(4)
<i>pollution</i> _{<i>i, t-1</i>}	0.8722*** (0.0612)	0.8745*** (0.0614)
<i>city</i>	-0.3095 (0.2497)	-0.2350 (0.2896)
<i>year</i>	-1.4028*** (0.3400)	-1.2031** (0.5163)
<i>city*year</i>		-0.2652 (0.5041)
<i>pop</i>	0.1311* (0.0695)	0.1274* (0.0680)
<i>gdppc</i>	0.3006*** (0.1159)	0.3059*** (0.1165)
<i>gdppc</i> ²	-0.0085** (0.0035)	-0.0089** (0.0036)
<i>terind</i>	-3.5125* (2.0731)	-3.5791* (2.0720)
<i>intensity</i>	0.0484* (0.0242)	0.0491* (0.0242)

Models	(3)	(4)
	(0.0293)	(0.0293)
Constant	0.8176 (0.6643)	0.7548 (0.6697)
Hansen test (<i>p</i> -value)	0.2452	0.2728
AR (2) (<i>p</i> -value)	0.8099	0.8022
Observations	772	772

Note: robust standard error in parentheses; *, **, and *** represent significant at 10%, 5% and 1% levels, respectively.

According to Tables 2 and 3, the *p*-values of the Hansen tests of all models demonstrate that we cannot reject the null hypothesis, that is, the overidentifying restrictions. The *p*-values of the AR (2) tests show that residual errors do not present significant second-order autocorrelation, indicating that the instrumental variables used in the SYS-GMM models effectively solve the endogeneity issues among the independent variables.

None of the coefficients of city type (*city*) is significant, implying that there is no significant difference in total water consumption and total industrial wastewater discharge between the water-receiving cities and non-water-receiving cities in the SNWTP. In other words, whether cities receive water from the SNWTP or not has no significant effect on water consumption and

pollution. However, the coefficients of the year type (*year*) in all models are significantly negative. Total water consumption and total industrial wastewater discharge in the water-receiving cities and non-water-receiving cities both show a significant decline after the SNWTP's operation. The coefficients of the interaction terms (*city*year*) in Models 2 and 4 are not significant, demonstrating that the interactions between city type and year type do not have significant impacts on total water consumption and total industrial wastewater discharge. In other words, when the SNWTP began operation, water consumption and pollution in water-receiving cities did not change significantly differently than in non-water-receiving cities. Taken together, the results imply that there is no significant difference in water consumption and pollution between water-receiving and non-water-receiving cities before or after the SNWTP began operation. The inclusion of an interaction term does not change the sign and significance of the coefficients of other variables.

The coefficients of the total population in all models are significant. Differences in the total population are directly associated with changes in total water consumption and total industrial wastewater discharge. It demonstrates that an increase in population leads to increased water consumption and more water pollution, and this effect is far greater than the reverse impact of increases in the efficiency of the use of public infrastructure.

According to Tables 2 and 3, the coefficients of GDP per capita (*gdppc*) in all models are significantly positive. However, the coefficients of *gdppc*² are significantly negative in Models 3 and 4, but not in Models 1 and 2. There is a significant inverted U-shaped EKC relationship

between income levels and water pollution in the six provinces or municipalities. The value of the inflection point of the EKC curve in Model 3 is 171,853 *yuan*/person: the total industrial wastewater discharge continues to increase until city GDP per capita reaches 171,853 *yuan*/person, and thereafter total industrial wastewater discharge in these cities gradually declines. There is no such relationship between income levels and water consumption – effectively, the higher a city’s GDP, the higher its water consumption. The inverted U-shaped EKC relationship between water consumption and income levels is apparently not universal but depends on the choice of datasets and statistical techniques.

The coefficients of the proportion of tertiary industry output (*tertind*) are significantly positive in both Models 1 and 2, which suggests that the technological upgrading of industrial structure is positively related to total water consumption. The coefficients of *tertind* are significantly negative in Models 3 and 4, indicating that industrial structure upgrading is negatively correlated with water pollution. The coefficients of water-use intensity (*intensity*) in Models 3 and 4 are significantly positive, which means that increasing water intensity of production is associated with increased water pollution.

The coefficients of lagged total water consumption (*consumption_{i,t-1}*) are significantly positive, indicating that historical water-use habits are positively correlated with current total water consumption. Similarly, the coefficients of lagged industrial wastewater discharge (*pollution_{i,t-1}*) are also significantly positive, demonstrating that historical pollution control habits are also positively correlated with current water pollution. The results suggest that

historical water-use and pollution control habits affect current decisions on water use and pollution control.

4.2 Robustness checks

The above results indicate that the technological upgrading of industrial structure is positively related to water consumption and negatively correlated with water pollution. To check the robustness, the proportion of tertiary industry output (*terind*) was replaced by the proportion of second industry output (*secind*). The results are shown in Appendix A.

The results demonstrate that cities with higher proportions of output in secondary industry are associated with lower water consumption and higher industrial wastewater discharge. Since *secind* is negatively correlated with *terind*, the results verify from the opposite side that the upgrading of industrial structure is positively correlated with water consumption, and negatively correlated with total industrial wastewater discharge. The coefficient estimates for the other independent variables in Appendix A are the same as those in Tables 2 and 3, respectively, indicating that the empirical results are robust.

Moreover, the results indicate that none of the coefficients of city type (*city*) is significant, while the coefficients of the year type (*year*) in all models are significantly negative. In addition, the results also demonstrate that the coefficients of the interaction terms (*city*year*) are not significant. To check the robustness, the feasible generalized least square (FGLS) regression is employed to address both serial correlation and cross-sectional dependence in the panel data

(Reed & Ye, 2011). The results of robustness check by using FGLS are also shown in Appendix A. The results are consistent with the results in Tables 2 and 3. Thus, the results are again proven to be robust.

Finally, as IBWT can increase the amount of water available in the water-receiving area, it may cause the population to grow in the water-receiving areas after the operation of IBWT (Flörke, Schneider, & McDonald, 2018). Then, population growth may lead to an increase in total water consumption and total water pollution. However, the above results demonstrate that the interactions between city type and year type do not have significant impacts on total water consumption and total industrial wastewater discharge. To check the robustness, the variables of per capita water consumption (*pccons*) and per capita industrial wastewater discharge (*pcpoll*) are used to replace the total water consumption (*consumption*) and total industrial wastewater discharge (*pollution*) to examine the impacts of IBWT on per capita water consumption and water pollution. Meanwhile, the population density (*popden*) is used to replace the total population (*pop*) to eliminate the impacts of population size on per capita water consumption and water pollution. The results are shown in Appendix A.

The results are entirely consistent with the results in Tables 2 and 3, demonstrating that there is no significant difference in per capita water consumption and per capita pollution between water-receiving and non-water-receiving cities before or after the SNWTP began operation. The results also indicate that the effects of the SNWTP on per capita variables in Appendix A are consistent with the effects on the total variables in Tables 2 and 3. Thus, the empirical results are

robust. It is worth noting that the coefficients of population density are not significant in all models, indicating that population density does not have a significant impact on per capita water consumption and per capita water pollution. Moreover, the results indicate that the estimates of other independent variables are robust.

4.3 Mediation analysis

The results in Table 3 show that water pollution in all cities has significantly decreased after water delivery. However, the reduction of water pollution may also be caused by environmental regulation policies caused by the SNWTP's water delivery, rather than the direct impact of the project itself (Z. Chen, Kahn, Liu, & Wang, 2018). Therefore, it is necessary to examine whether the year type (*year*) can affect water pollution by altering environmental policies. We employ the mediation analysis proposed by Baron and Kenny (1986) to test the mediation effect of the environmental policies by using the intensity of the environmental regulations (*regulation*) as the mediator. The sewage treatment rate is considered to be a good proxy to reflect the intensity of environmental regulation: an increase in the intensity of the environmental regulations can increase sewage treatment investment, thereby improving the sewage treatment rate; and vice versa (Y.-T. Chen & Chen, 2014). The results of the mediation analysis are shown in Appendix B.

The results of the mediation analysis demonstrate that the SNWTP's water delivery has increased the intensity of the environmental regulations, resulting in a downward trend in water

pollution. Therefore, the year type affects water pollution through the mediation of the intensity of the environmental regulations. This result suggests that improvements in water quality were caused by changes in environmental policies (themselves caused by water delivery) rather than the SNWTP itself.

5 Discussion

The first principal result of this paper is the fact that all cities, regardless of whether they receive SNWTP water or not, show similar levels of water consumption (in relation to the other independent variables). The coefficients for city type (*city*) are not significant: on average, for given values of the other independent variables, water consumption in water-receiving cities is not different from that in non-water-receiving cities. All coefficients of year type (*year*) are significantly negative: in both water-receiving and non-water-receiving cities, water consumption declined after the SNWTP began operation. The coefficients of the interaction terms (*city*year*) are not significant, demonstrating that, when the SNWTP began operation, water consumption in water-receiving cities did not change significantly differently than in non-water-receiving cities.

In other words, the cities that receive water from the SNWTP have, indeed, received additional water, but that has not translated into additional consumption (for given values of the other independent variables). On the contrary, after receiving water from the SNWTP, water consumption in all cities declined. This may occur due to the “two-part water pricing” system that was implemented in the six provinces or municipalities in 2014, whereby a basic water price

corresponds to fixed costs, while a metered water price corresponds to variable costs and profits (National Development and Reform Commission, 2014a, 2014b). Regardless of whether or not water is received, all 60 cities implemented the new water pricing system. The price of transferred water not only needs to compensate for the costs of the SNWTP's operation but also needs to repay the loans for construction. Since the price of transferred water is much higher than the original water price, the newly transferred water is stored in reservoirs rather than sent to water consumers in water-receiving areas (China Economic Weekly, 2014). High water prices not only cover the costs of water supply but also limit the demand for water, providing incentives for saving water (Jiang, 2009). The high water price caused by the SNWTP restricts residents' water use so that the water that has been transferred at a huge cost does not translate into increased water consumption in the water receiving cities. It seems likely that other IBWTs can also only provide water at huge costs, which, if they translate into high prices, will restrain demand for the "new" water.

The design of the routes for the SNWTP reflected a variety of considerations, including appropriate offtake points from the Yangtze River basin and geological factors such as relief. However, an overarching concern was to supply water to cities in which the demand for water was thought to exceed supply. Therefore, for given values of the other independent variables, non-water-receiving cities were likely on average to have higher levels of supply relative to demand than water-receiving cities. **The fact that water consumption is not significantly different in the two types of cities implies that it is indeed possible to alleviate water shortages by**

increasing the water supply to the water-receiving cities through constructing an IBWT. On the one hand, the supply of water has increased, while on the other hand, the demand for water has been limited by high water prices, which makes the water deficit of the water-receiving cities seem to be alleviated on the surface. However, the high-price water transferred from a long distance is not used for consumption of residents or production of enterprises, but only stored in reservoirs. Therefore, an IBWT like the SNWTP only alleviated the water shortage on the surface, but failed to substantially improve the welfare of residents.

The results also demonstrate that all cities, regardless of whether they receive SNWTP water or not, show similar levels of industrial wastewater discharge (in relation to the other independent variables). The coefficients for city type (*city*) are not significant, implying that, for given values of the other independent variables, there is no significant difference in industrial wastewater discharge between the water-receiving cities and non-water-receiving cities in the SNWTP. In other words, whether cities receive water from the SNWTP or not does not affect water pollution.

However, the coefficients of year type (*year*) are all significantly negative: water industrial wastewater discharge in water-receiving cities and non-water-receiving cities, both declines after the SNWTP began to operate. As the results of the mediation analysis show, the changes in environmental policies caused by water delivery, rather than the SNWTP itself, improve the water quality. Water pollution in all cities has significantly decreased after water delivery, in response to the revision of the Environmental Protection Law in 2014 and the implementation of the Regulation on Urban Drainage and Sewage Treatment (State Council, 2014a) and the Regulations

on Water Supply and Water Use for SNWTP (State Council, 2014b) to strictly control industrial wastewater discharge. At the same time, China incorporated pollution control performance into the official performance assessment (General Office of the CPC Central Committee, 2015; General Office of the State Council, 2013), so that official career promotion is linked to water pollution control (Sheng et al., 2018). These measures apply to all cities, whether receiving water from the SNWTP or not.

The coefficients of the interaction terms (*city*year*) are not significant, demonstrating that when the SNWTP began operation, water pollution in water-receiving cities did not change significantly differently than in non-water-receiving cities. Taken together, the results imply that, for given values of the other independent variables, there is no significant difference in water pollution between water-receiving and non-water-receiving cities before or after the SNWTP began operation. This is despite the fact that the government has issued a series of pollution control plans for both the eastern and middle routes (State Council, 2003, 2006) to address water pollution in the SNWTP. These plans appear to have been ineffective. For example, a large amount of sewage was still directly discharged into the Danjiangkou Reservoir while the middle route was about to be completed (China Central Television, 2013). In other words, the SNWTP itself has not affected water pollution flows in the cities along its routes; rates of wastewater discharge are falling in response to general pollution control measures rather than to campaigns associates with the SNWTP.

Finally, we note that these results have some implications for understanding IBWTs in

authoritarian states. The results show that IBWT has not improved water consumption, nor has it contributed to reductions in water pollution. Then why should China spend vast sums of money on building this megaproject? The primary goal of the Communist Party of China is to maintain political stability and achieve sustained political legitimacy (Tsang, 2009). Therefore, the state's top priority is to deal with various threats, and a perceived shortage of water is one of them. The purpose of China's IBWT is to persuade the Chinese people that the government is working on their behalf and therefore has the authority to govern (Zhu, 2011). The SNWTP itself is a symbol of this political legitimacy, symbolizing the authority of the state (Webber, Crow-Miller, & Rogers, 2017). Indeed, there is a broad and long historical connection between political legitimacy and water resource control (Mukerji, 2003). In particular, megaprojects, including IBWTs, dams, and other river control projects, are often a manifestation of political legitimacy, establishing a ruling group's power over another group, or consolidating an already powerful regime (Crow-Miller, 2015). Although China's SNWTP has not improved the welfare of residents, it has apparently alleviated the water shortage. The high-priced water transferred over a long distance is not used for consumption but is stored in reservoirs to increase the water supply. The stored water became a form of propaganda, which allowed authoritarian states to convince people that the water shortage they were worried about had been resolved. As for whether the transferred water is really used to improve water consumption, it is no longer important. Therefore, the test of China's construction of the SNWTP is not whether the project itself can really solve water shortage, but whether it can convince the public that IBWTs can solve environmental problems

(Moore, 2014), to maintain and consolidate its political legitimacy.

6 Conclusion

In many parts of the world, the demand for water exceeds its supply. Even in countries with abundant water, water demand in many regions far exceeds the water supply (Matete & Hassan, 2006). Various countries have built IBWTs so that the supply of water can meet the growing water demand across national, regional, and urban boundaries. IBWTs are often accompanied by water pollution controls to prevent the transferred water from being polluted again (Junguo Liu et al., 2013). However, the impact of IBWTs on the environment is still controversial; in particular, whether IBWTs really affect water consumption and pollution is still unclear. Therefore, it is necessary to understand the drivers of water consumption and pollution in IBWTs to assess their environmental impacts. Given this consideration, this paper examines one IBWT's impacts on water consumption and pollution – China's SNWTP. Our findings contribute to a deeper understanding of IBWTs' environmental impacts and their role in human-environment systems.

The main contributions of this study can be summarized as follows: First, a model of a human-environment system has been proposed to examine the environmental impacts of an IBWT and other human activities. Second, an IBWT's temporal and spatial effects have been revealed empirically by using the panel dataset from China's SNWTP. Third, the robustness of the IBWT's temporal and spatial effects has been checked, which solidly confirms our findings. Our findings demonstrate that the IBWT does not improve water consumption in the water

receiving cities, and the high-water price caused by the IBWT restricts the residents' water use. Also, the IBWT does not resolve water pollution in water-receiving cities, since its impact on water pollution depends more on external environmental policies. Finally, these findings have some implications for understanding the IBWT in authoritarian states. Although the IBWT does not affect **water consumption** and pollution, authoritarian states can maintain and consolidate their political legitimacy by building the IBWT to gain public trust. Pollution and high-water prices may make the IBWT economically and socially unsustainable (Barnett et al., 2015); however, the control of water resources, including the IBWT, is a critical way for authoritarian states to obtain political legitimacy (Mukerji, 2003).

Appendix A. The results of the robustness checks

To check the robustness, the proportion of tertiary industry output (*terind*) was replaced by the proportion of second industry output (*secind*). A summary of the variables used in the robustness checks is shown in Table A.1, and the results are shown in Tables A.2 and A.3.

Table A.1

Summary of the variables for robustness checks

Variables	Descriptions	Units	Obs.	Mean	Std. Dev.	Min	Max
<i>pccons</i>	Per capita water consumption	m ³ /person	840	29.73	32.96	1.469	216.2
<i>pcpoll</i>	Per capita industrial	m ³ /person	836	20.95	19.14	0.767	127.9

Variables	Descriptions	Units	Obs.	Mean	Std. Dev.	Min	Max
	wastewater discharge						
Independent variables							
<i>popden</i>	Population density	100,000 person/km ²	840	66.58	32.49	8.659	772.6
<i>secind</i>	Proportion of second industry output	%	840	0.524	0.0852	0.193	0.823

Table A.2

The results of the robustness checks for the water consumption models (dependent variable: *consumption*)

Model	(A.1)	(A.2)
<i>consumption</i> _{<i>i, t-1</i>}	0.9755*** (0.0135)	0.9534*** (0.0108)
<i>city</i>	0.1268 (0.1903)	0.0976 (0.3456)
<i>year</i>	-0.5871* (0.3335)	-0.9453* (0.5522)
<i>city*year</i>		0.2332 (0.6512)

Model	(A.1)	(A.2)
<i>pop</i>	0.1210*** (0.0453)	0.1685** (0.0712)
<i>gdppc</i>	0.4148*** (0.1278)	0.5719*** (0.2231)
<i>gdppc</i> ²	-0.0111 (0.0075)	-0.0145 (0.0106)
<i>secind</i>	-4.7586*** (1.6712)	-5.4507** (2.4600)
Constant	1.1878 (0.9028)	1.1261 (0.9065)
Observations	780	780
Hensen test (<i>p</i> -value)	0.1653	0.1761
AR (2) (<i>p</i> -value)	0.0564	0.0562

Note: robust standard error in parentheses; *, **, and *** represent significant at 10%, 5% and 1% levels, respectively.

Table A.3

The results of the robustness checks for the water pollution models (dependent variable: *pollution*)

Model	(A.3)	(A.4)
<i>pollution</i> _{<i>i, t-1</i>}	0.8511*** (0.0690)	0.8522*** (0.0692)
<i>city</i>	-0.5948 (0.5855)	-0.5701 (0.5406)
<i>year</i>	-1.2963*** (0.3466)	-1.2482** (0.5466)
<i>city*year</i>		-0.0621 (0.5318)
<i>pop</i>	0.2041** (0.0855)	0.2019** (0.0877)
<i>gdppc</i>	0.2046** (0.0847)	0.2045** (0.0857)
<i>gdppc</i> ²	-0.0037* (0.0017)	-0.0037* (0.0018)
<i>intensity</i>	0.0513* (0.0309)	0.0514* (0.0306)
<i>secind</i>	6.2940** (2.5015)	6.2903** (2.5050)

Model	(A.3)	(A.4)
Constant	-3.5451** (1.4970)	-3.5653** (1.4959)
Observations	772	772
Hensen test (<i>p</i> -value)	0.2685	0.2747
AR (2) (<i>p</i> -value)	0.8179	0.8156

Note: robust standard error in parentheses; *, **, and *** represent significant at 10%, 5% and 1% levels, respectively.

Moreover, to check the robustness, the feasible generalized least square (FGLS) regression is employed to address both serial correlation and cross-sectional dependence in the panel. The results are shown in Tables A.4 and A.5.

Table A.4

The results of the robustness checks for the water consumption models by using FGLS

Models	(A.5)	(A.6)
<i>consumption</i> _{<i>i, t-1</i>}		0.4288*** (0.0570)
<i>city</i>	0.3277 (0.9547)	7.5978 (7.8581)

Models	(A.5)	(A.6)
<i>year</i>	-1.8616** (0.7632)	-1.3812** (0.6267)
<i>city*year</i>	0.8990 (0.8867)	0.3858 (0.7305)
<i>pop</i>	0.9336*** (0.1779)	1.1266 (0.7617)
<i>gdppc</i>	0.6110* (0.3126)	-0.2288 (0.2759)
<i>gdppc²</i>	0.0678 (0.0609)	0.0301 (0.0382)
<i>terind</i>	31.9288*** (5.4992)	17.1185* (8.9558)
Constant	-9.0637*** (2.0653)	-9.5219 (7.9088)
Observations	840	780

Note: robust standard error in parentheses; *, **, and *** represent significant at 10%, 5% and 1% levels, respectively.

Table A.5

The results of the robustness checks for the water pollution models by using FGLS

Models	(A.7)	(A.8)
<i>pollution</i> _{<i>i, t-1</i>}		0.6756*** (0.0274)
<i>city</i>	2.6036 (1.9915)	-0.9209 (0.8403)
<i>year</i>	-0.5682* (0.2990)	-0.7065*** (0.2292)
<i>city*year</i>	0.1229 (0.3311)	0.0865 (0.2461)
<i>pop</i>	0.2368* (0.1526)	-0.2921 (0.2037)
<i>gdppc</i>	0.8537*** (0.1384)	0.3353*** (0.1018)
<i>gdppc</i> ²	-0.0457 (0.0486)	-0.0169 (0.0155)
<i>terind</i>	-10.5978*** (2.4380)	-4.1576** (1.9572)

Models	(A.7)	(A.8)
<i>intensity</i>	0.0401** (0.0191)	0.0586*** (0.0158)
Constant	5.5145** (2.3503)	5.1438** (1.7320)
Observations	840	780

Note: robust standard error in parentheses; *, **, and *** represent significant at 10%, 5% and 1% levels, respectively.

Finally, to check robustness, the variables of per capita water consumption (*pccons*) and per capita industrial wastewater discharge (*pcpoll*) are used to replace total water consumption (*consumption*) and total industrial wastewater discharge (*pollution*). Meanwhile, population density (*popden*) is used to replace total population (*pop*). The results are shown in Tables A.6 and A.7.

Table A.6

The results of the robustness checks for the water consumption models (dependent variable: *pccons*)

Models	(A.9)	(A.10)
$pccons_{i,t-1}$	0.8832***	0.8836***

Models	(A.9)	(A.10)
	(0.0293)	(0.0291)
<i>city</i>	-0.9090 (0.4573)	-1.0433 (0.5493)
<i>year</i>	-2.3623*** (0.6674)	-2.7011*** (0.9075)
<i>city*year</i>		0.5563 (0.9169)
<i>popden</i>	0.0155 (0.0110)	0.0155 (0.0111)
<i>gdppc</i>	0.0640*** (0.0195)	0.0622*** (0.0190)
<i>gdppc²</i>	-0.0000 (0.0001)	-0.0000 (0.0001)
<i>terind</i>	17.6355*** (2.8057)	17.5457*** (2.8200)
Constant	-5.2435*** (0.9977)	-5.0791*** (0.9572)
Observations	780	780

Models	(A.9)	(A.10)
Hensen test (p -value)	0.1984	0.2129
AR (2) (p -value)	0.1536	0.1538

Note: robust standard error in parentheses; *, **, and *** represent significant at 10%, 5% and 1% levels, respectively.

Table A.7

The results of the robustness checks for the water pollution models (dependent variable: $pcpoll$)

	(A.11)	(A.12)
$pcpoll_{i,t-1}$	0.8208*** (0.0519)	0.8186*** (0.0526)
$city$	-1.0077 (0.5946)	-1.3023 (0.7754)
$year$	-2.1728*** (0.5203)	-2.9469*** (1.0923)
$city*year$		1.1256 (1.0595)
$popden$	-0.0025 (0.0038)	-0.0022 (0.0033)

	(A.11)	(A.12)
<i>gdppc</i>	0.0950*** (0.0298)	0.0934*** (0.0295)
<i>gdppc</i> ²	-0.0003** (0.0001)	-0.0002** (0.0001)
<i>terind</i>	-14.9459*** (4.5643)	-15.2383*** (4.7397)
<i>intensity</i>	0.1671*** (0.0565)	0.1666*** (0.0561)
Constant	5.4524*** (1.6257)	5.7955*** (1.8573)
Observations	772	772
Hensen test (<i>p</i> -value)	0.3165	0.3167
AR (2) (<i>p</i> -value)	0.3652	0.3723

Note: robust standard error in parentheses; *, **, and *** represent significant at 10%, 5% and 1% levels, respectively.

Appendix B. The results of the mediation analysis

We employ the mediation analysis proposed by Baron and Kenny (1986) to test the mediation effect of the environmental regulation policies by using the intensity of the environmental

regulations (*regulation*) as the mediator. The equations for the mediation analysis are as

follows:

$$\begin{aligned} \text{pollution}_{it} = & \beta_0 + \beta_1 \cdot \text{pollution}_{i,t-1} + \beta_2 \cdot \text{city}_{it} + \beta_3 \cdot \text{year}_{it} + \beta_4 \cdot \text{city}_{it} \cdot \\ & \text{year}_{it} + \beta_5 \cdot \text{pop}_{it} + \beta_6 \cdot \text{gdppc}_{it} + \beta_7 \cdot \text{gdppc}_{it}^2 + \beta_8 \cdot \text{terind}_{it} + \beta_9 \cdot \text{intensity}_{it} + \\ & \varepsilon_{2it} \end{aligned} \quad (\text{B.1})$$

$$\begin{aligned} \text{regulation}_{it} = & \gamma_0 + \gamma_1 \cdot \text{regulation}_{i,t-1} + \gamma_2 \cdot \text{city}_{it} + \gamma_3 \cdot \text{year}_{it} + \gamma_4 \cdot \text{city}_{it} \cdot \\ & \text{year}_{it} + \gamma_5 \cdot \text{pop}_{it} + \gamma_6 \cdot \text{gdppc}_{it} + \gamma_7 \cdot \text{gdppc}_{it}^2 + \gamma_8 \cdot \text{terind}_{it} + \gamma_9 \cdot \text{intensity}_{it} + \\ & \varepsilon_{2it} \end{aligned} \quad (\text{B.2})$$

$$\begin{aligned} \text{pollution}_{it} = & \theta_0 + \theta_1 \cdot \text{pollution}_{i,t-1} + \theta_2 \cdot \text{regulation}_{it} + \theta_3 \cdot \text{city}_{it} + \theta_4 \cdot \text{year}_{it} + \\ & \theta_5 \cdot \text{city}_{it} \cdot \text{year}_{it} + \theta_6 \cdot \text{pop}_{it} + \theta_7 \cdot \text{gdppc}_{it} + \theta_8 \cdot \text{gdppc}_{it}^2 + \theta_9 \cdot \text{terind}_{it} + \theta_{10} \cdot \\ & \text{intensity}_{it} + \varepsilon_{3it} \end{aligned} \quad (\text{B.3})$$

The following three steps are used to investigate the mediation effect of the intensity of environmental regulation:

Step 1: The coefficient of the year type (β_3) in Eq. (B.1) needs to be checked. A significant coefficient indicates that there may be a mediation effect; and vice versa.

Step 2: The coefficient of the year type (γ_3) in Eq. (B.2) and the coefficient of the *regulation* (θ_2) in Eq. (B.3) need to be checked. If both coefficients are significant, there is a significant mediation effect; if at least one coefficient is insignificant, then the test of Step 3 is required.

Step 3: The null hypothesis ($H_0: \gamma_3 \times \theta_2 = 0$) is tested by using the Bootstrap approach. If the

null hypothesis is rejected, there is a significant mediation effect; and vice versa.

The data for the mediation analysis comes from the *China City Construction Statistical Yearbook*. The results are shown in Table B.1.

Table B.1

The results of mediation test

Models	(B.1)	(B.2)	(B.3)
	<i>pollution_{it}</i>	<i>regulation_{it}</i>	<i>pollution_{it}</i>
<i>pollution_{i, t-1}</i>	0.8745*** (0.0614)		0.8713*** (0.0612)
<i>regulation_{i, t-1}</i>		0.0996** (0.0454)	
<i>regulation_{it}</i>			-1.6833* (0.8676)
<i>city</i>	-0.2350 (0.2896)	-0.0281 (0.0203)	-0.3274 (0.2898)
<i>year</i>	-1.2031** (0.5163)	0.0473** (0.0195)	-1.1486** (0.5045)
<i>city*year</i>	-0.2652 (0.5041)	-0.0170 (0.0282)	-0.2366 (0.4792)

	(B.1)	(B.2)	(B.3)
Models			
	<i>pollution_{it}</i>	<i>regulation_{it}</i>	<i>pollution_{it}</i>
<i>pop</i>	0.1274*	0.0010	0.1341*
	(0.0680)	(0.0042)	(0.0719)
<i>gdppc</i>	0.3059***	0.0360***	0.3911***
	(0.1165)	(0.0121)	(0.1215)
<i>gdppc²</i>	-0.0089**	-0.0019***	-0.0127***
	(0.0036)	(0.0006)	(0.0043)
<i>terind</i>	-3.5791*	0.0730	-3.9162
	(2.0720)	(0.1557)	(2.3949)
<i>intensity</i>	0.0491*	-0.0108***	0.0311
	(0.0293)	(0.0021)	(0.0354)
Constant	0.7548	0.6829***	2.1564**
	(0.6697)	(0.0512)	(1.0013)
Hensen test (<i>p</i> -value)	0.2728	0.1811	0.2862
AR (2) (<i>p</i> -value)	0.8022	0.9352	0.7744
Observations	772	780	772

Note: robust standard error in parentheses; *, **, and *** represent significant at 10%, 5% and 1% levels, respectively.

The results of Step 1 are shown in Model B.1 in Table B.1. The coefficient for *year* (β_3) is significantly negative, which means that there may be a mediation effect in the impact of year type on water pollution. The results of Step 2 in Model B.2 show that the effect of year type on the mediation variable (*regulation*) is significant, indicating that the intensity of the environmental regulations is significantly enhanced after water delivery. In addition, the results of Step 2 in Model B.3 show that the coefficient of *regulation* is also significant, indicating that the mediation effect is significant. This result means that the SNWTP's water delivery has increased the intensity of the environmental regulations, resulting in a downward trend in water pollution.

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Response to reviewers' comments

Thanks for inviting us to submit a revised draft of our manuscript entitled, "Can inter-basin water transfer affect water consumption and pollution? Lessons from China's South-North Water Transfer Project" to *Environmental Policy and Governance*. We appreciate the time and effort the editor and the reviewer has dedicated to providing insightful feedback on ways to strengthen our paper. We now resubmit our article for further consideration. We have incorporated changes that reflect the detailed suggestions the reviewers have provided. We also hope that these changes satisfactorily address all the issues and concerns the reviewer has noted.

To facilitate review of our revisions, we have marked the changes with red in the resubmitted paper and make a point-by-point response to the questions and comments delivered in the editor's letter dated 18 April 2020.

EDITOR COMMENTS:

1. We note that your paper is currently just at our (newly revised) word limit of 10,000 words, and that the referee feels that the text would benefit from being tightened up. We would therefore ask that you certainly do not exceed our word limit in the next iteration of the paper, and indeed that you seek to revise the word count downwards as far as possible.
 - **RESPONSE:** We have thoroughly revised the paper so that the total number of words does not exceed 10,000.

REVIEWER 1 COMMENTS:

1. The paper presents 10 tables. I do not think that all of them need to be included. I suggest to summarize the section on robustness checks and drop tables 9 to 12.
 - **RESPONSE:** We have rewritten the section of robustness checks and moved the results to Appendix A.
2. Model specification: I am not convinced that water shortage can be properly measured as negatively correlated with water consumption in the case of IBWT. In theory, IBWT can improve water access at the same level of consumption through efficiency in water distribution by reducing leakages. It seems reasonable to assume that the building of new water facilities empirically produces this kind of results. The fact that water consumption remains unchanged (does not increase) is not necessarily negative, and may indeed reflect better water access. I encourage to develop this discussion, and to distinguish between water consumption and water shortage in the interpretations of the results.
 - **RESPONSE:** We appreciate this valuable comment. We have realized that water consumption and water shortage are completely different issues. We have changed the subject to the impact of IBWT on water consumption and pollution.

We argue that the IBWT not only fails to improve water consumption in water-receiving cities, but also further restricts residents' water use due to the high water price caused by this project. We have added an explanation in the discussion section to argue that IBWT like the SNWTP only alleviated the water shortage on the surface, but failed to substantially improve the welfare of residents.

3. Still in the model, it is unclear why IBWT in itself would reduce water pollution, other than transferring cleaner water to local consumers. There is no reason to think that this would deter local industries to discharge pollutants (quite the opposite actually). The search for an empirical relation between IBWT and local pollution discharge seems speculative. The argument is, however, crucial to claim that IBWT fails to meet its purpose. Explain why there would be such a positive relation, and show some past evidence if we have any.
 - **RESPONSE:** We have added a mediation analysis in the results section and Appendix B. The results of the mediation analysis demonstrate that the SNWTP's water delivery has increased the intensity of the environmental regulations, resulting in a downward trend in water pollution. Therefore, the year type affects water pollution through the mediator of the intensity of the environmental regulations. It suggests that the changes in environmental policies caused by water delivery, rather than the SNWTP itself, improve the water quality.
4. Finally on the conclusion and interpretation of the authoritarian state in China: Assuming we show that IBWT fails to alleviate water shortage and has no impact on water pollution, this does not mean that the project's motivation is exclusively ideological. IBWT serves the propaganda and probably the legitimacy of the Chinese regime, this is true. IBWT may be poorly effective or ineffective in fulfilling its policy objective, this may also be true. It remains dubious however to assume that Chinese policymakers plan a policy failure in advance for purely ideological reasons. Propaganda is more effective with policy success than with policy fiasco, and therefore cannot be explained by the later.
 - **RESPONSE:** We have added an explanation in the discussion section to argue that although China's SNWTP has not improved the welfare of residents, it has apparently alleviated the water shortage. The high-priced water transferred from a long distance is not used for consumption but is stored in the reservoir to increase the water supply. The stored water became a form of propaganda, which allowed authoritarian states to convince people that the water shortage they were worried about had been resolved. As for whether the transferred water is really used to improve water consumption, it is no longer important. Therefore, the purpose of China's construction of the SNWTP is not whether the project itself can really solve water shortage, but to convince the public that IBWTs can solve environmental problems (Moore, 2014), to maintain and consolidate its political legitimacy.

CONCLUDING REMARKS: Again, thanks for allowing us to strengthen our manuscript with the reviewer's valuable comments and queries. We tried to incorporate the feedback faithfully.