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Exploring the Impacts of Water Resources on Economic Development in Beijing-Tianjin-Hebei Region

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Abstract: Beijing-Tianjin-Hebei region is one of the most developed areas in China with a most rapid rate of economic growth. It is also a well-known region suffering great water scarcity. Water resources scarcity restricts the economic growth of the region at large and economic growth in return aggravates its water shortage. This study investigates the impacts of water resources factors on the regional economic growth to explore the direct influential factors of water resources, using panel data collected from 2004 to 2013. The main results show that: (1) the share of water for agricultural use and annual domestic water use per capita are statistically significant to the regional GDP per capita, with coefficients of 0.86 and 0.32 and (2) thus the impact of water resources on regional economic development is attributable to regional water use structure and domestic water use efficiency. Integrated regional governance of water resources, especially regional policies towards efficient water use and enhanced economic structure optimizing would be effective options for governments to propel the sustainable development of the region.

Keywords: water resources; regional economic development; Beijing-Tianjin-Hebei Region

1. Introduction

Water scarcity is now a worldwide problem to be faced in the twenty-first century that threatens the social and economic development. And it is increasingly becoming a crisis that constrains regional sustainable development in China. North China has been facing water stress of a larger magnitude than other parts of the country due to its limited water resources, large population, rapid economic growth and long-term unsustainable water use.

Beijing-Tianjin-Hebei region is the heart of the circum-Bohai area which lies in the

Haihe River basin in North China, with a population of 110.52 million in 2014 and covers 216 thousand square kilometers. It includes three distinct provincial administrative regions: Beijing the capital and political center of China, Tianjin one of the four municipals directly under the governance of the central government and one of the main economic centers of North China, and Hebei province (including eleven cities) (Fig.1). This region is one of the most developed areas in China with a most rapid rate of economic growth. The total gross domestic product (GDP) of the region is 6647.4 billion yuan in 2014 (National Bureau of Statistics of the PRC, 2014) and its average annual economic growth rate from 2010 to 2014 is 12.6% (Table 1). The region carries 8.1% of the national population and produces 10.4% of the total GDP on a land of less than 2.3% of the national land with less than 0.8% of the national water resources. The integrated and coordinated development of Beijing-Tianjin-Hebei region is an important national strategy of the Chinese government.

It is also a well-known region suffering great water scarcity. The total regional resources has decreased sharply from 28 ~ 29 billion cubic meters in the 1950s to 14 ~ 15 billion cubic meters in the early twenty-first century. The water resources per capita is 118.60 m³, 99.46 m³, 240.57 m³ respectively in Beijing, Tianjin and Hebei in 2013, all below 500 m³ that is defined as absolute scarcity by the United Nations. Water resources scarcity restricts the economic growth of the region at large and fast economic growth in return aggravates its water shortage. Water scarcity has had deleterious impacts on the economy and human welfare.



Fig. 1 Beijing-Tiajin-Hebei region in China
 (Source: revised from *bjreview.com.cn*)

Table 1. Snapshot of Beijing, Tianjin and Hebei in the year of 2014.

	Area (km ²)	Population (million)	GDP (billion CNY)	Total volume of water resources (year 2013, billion m ³)
Beijing	16,410	21.51	2133	2.48
Tianjin	11,919	15.17	1572	1.46
Hebei	188,848	73.84	2942	17.59
Regional overall	217,177	110.52	6647	21.53
China	9,634,057	1,367.82	63646	2795.79
Regional share (%)	2.25	8.08	10.44	0.77

Source: Data on area, population and GDP are obtained from National Bureau of Statistics of the People's Republic of China (<http://data.stats.gov.cn/>). Data on water resources are obtained from the Water Resources Bulletin of China (2013), the Water Resources Bulletin of Beijing (2013), the Water Bulletin Resources of Tianjin (2013), and the Water Resources Bulletin of Hebei Province (2013). The data on total volume of water resources for the year 2014 are not available.

2. A Review on Water Resources Studies of the Region

The relationship between natural resources and economic growth has been examined in recent research (Duarte et al., 2014). Economic variables have significant effects on water demand (Zhou and Tol, 2005). Quite a few studies has explored how economic changes affect water resources. The impacts of urbanization, industrial transformation and/or population growth on water resources have received widely interests and input-output model, decomposition analysis, computable general equilibrium (CGE) model and panel data regression are the most used methods when studying water resources and social economic development (e.g. Watson and Davies, 2011; Jiang, 2014). Some studies specifically focus on the relationship between water use and income (Rock, 2000; Cole, 2004) and some have examined the relationship between regional economic sectors and water use. In the case of the U.S. urban areas, researchers find that higher water use and population growth are associated with greater economic growth per capita (Barbier and Chaudhry, 2014).

There are also a lot of studies that investigates the economic impacts of local water resources projects or water management measures and policies. Qin et al. (2013) assess the effectiveness of three different measures for mitigating the water scarcity in Beijing-Tianjin-Hebei region. The three measures analyzed in their study are reduction in groundwater use, planned water transfer project and water demand management. The effectiveness is assessed by CGE modeling in consideration with impacts on regional GDP, household income and goods trade.

As regarded in areas of China with water scarcity problems, most of the studied areas lie in North China (e.g. Wang et al., 2014; Wang et al., 2014; Zhou and Zhang, 2015). And as the concept of the integration of Beijing-Tianjin-Hebei region being proposed, water resources has become one of the most important study issues for the sustainability

of the regional development. Most studies for this region focus on its water resources carrying capacity and virtual water trade. Some focus on the regional allocation of water resources in market terms. The regional demand and supply of water resources has been analyzed (e.g. Zheng, 2004) or predicted (e.g. Wang, 2014).

Although there are various studies on many aspects of water resources of the region from the social and/or economical perspective, most of them focus on one aspect of water resources, e.g. water use efficiency or water demand, but to take water resource as a whole and to find out the direct influential factors water resources are significant with the change of the regional economy.

3. Data

Six variables are used in the research of Rock (2000) when studying the dewatering of economic growth and empirically testing with the U.S. data: the consumptive use of water per dollar of gross state personal income (and that of water in agriculture, industry and domestic sectors), annual fresh water availability, the share of crop land irrigated, gross personal income per capita, population and a dummy variable for the introduction of environmental regulation, in a log-log OLS estimation for panel data regression. We take it as reference when choosing variables in this study. A panel data regression is conducted throughout the time period from 2004 to 2013. The time frame is chosen due to the limited availability of data on water resources in Hebei province. The data set is created by pooling three-province-level data across ten time periods

3.1 Regional economic development

The dependent variable is GDPPER (in 10 thousand CNY), the GDP per capita, representing the economic development level of the region. GDP is not chosen to account for prosperity because Beijing and Tianjin are not comparable with Hebei in land coverage and population and therefore their total gross production is not comparable. And GDP is a comprehensive indicator of regional productive development level while GDP per capita reflects the affluence and living standard (Li, 2011). Raw data on GDP and population are taken from National Bureau of Statistics of PRC and data on annual GDP per capita of are calculated from annual GDP divided by its corresponding population.

3.2 Water resources

The independent variables include water resources indicators and population (POP, in 10 thousand persons). In this study, we define water resources into three aspects: the availability of water resources, water use structure and water use efficiency (or water use intensity as defined in other studies). Water quality, water price and other aspects of water resources are not considered in this study.

The availability of water resources is represented by total annual volume of water supply or consumed (TQ, in 10 million m³). In China, total annual water consumed equals total annual water supply and the data on this variable is collected from the Water Bulletin of Beijing, Tianjin and Hebei Province separately.

Water use structure is denoted by the share of water for agricultural use (AGRP, in percent).

Water use per unit value of GDP reflects the water use efficiency in production and water use per industrial production value reflects the water use efficiency of the industrial sector (Zhou and Tol, 2005). Water use per ¥10,000 agricultural value added (USEAGR, in m³ per 10,000 CNY), water use per ¥10,000 industrial value added (USEIND, in m³ per 10,000 CNY) and annual per capita domestic water use (USEDOM, in m³ per person) are adopted to denote the water use efficiency. USEAGR is calculated from the annual volume of water for agriculture use divided by the annual agricultural value added. USEIND is calculated in the same way. USEDOM is derived from annual domestic water use divided by population. The data on water use of the three sectors are collected from the Water Resources Bulletin of Beijing, Tianjin and Hebei Province separately while those of the value added of the three sectors are obtained from National Bureau of Statistics of China.

Table 2 shows a descriptive summary of the variables with the means, deviations, minimums and maximums reported.

Table 2. Summary statistics.

Variable	Mean	Std. Dev.	Min	Max
GDPPER	5.07	2.53	1.25	9.76
TQ	84.92	80.59	21.82	204.04
AGRP	0.54	0.18	0.25	0.78
POPU	3362.78	2675.48	1024	7333
USEAGR	932.63	320.91	406.98	1545.33
USEIND	23.64	13.81	8.50	6.02
USEDOM	46.63	24.72	24.25	87

Notes: GDPPER stands for the GDP per capita (in 10 thousand CNY). TQ represents the total annual volume of water supply or consumed (in 10 million m³). AGRP denotes the share of water for agricultural use (in percent). USEAGR, USEIND and USEDOM denotes water use per ¥10,000 agricultural value added (in m³ per 10,000 CNY), water use per ¥10,000 industrial value added (in m³ per 10,000 CNY) and per capita domestic water use (in m³ per person) respectively.

4. Model Specification

The included variables are log-transformed as so in the reference research of Rock (2000). The regression estimation process is taken in Stata 14. Hausman test is conducted to decide whether fixed effects or random effects should be used. And its result indicates that the fixed effects estimator model should be estimated.

The panel data model is a long, static and balanced panel which takes the following equation form:

$$GDPPER_{it} = \beta_0 + \beta_1 TQ_{it} + \beta_2 AGRP_{it} + \beta_3 POPU_{it} + \beta_4 USEAGR_{it} + \beta_5 USEIND_{it} + \beta_6 USEDOM_{it} + \varepsilon_{it} \quad (1)$$

where i ($i=1, 2, 3$) refers to each city/province, t ($t=1, 2, \dots, 10$) refers to the selected years, the dependent and explanatory variables are defined above, and ε_{it} is individual and time-varying disturbing term.

The presence of group-wise heteroskedasticity, within-group autocorrelation and contemporaneous correlation is tested and the results indicate that there is no presence of group-wise heteroskedasticity or contemporaneous correlation, but panel autocorrelation exists within groups, thus Prais-Winsten method is employed with panel corrected standard errors (PCSE) estimator to improve the accuracy of the estimators.

5. Results and discussion

Table 3 provides the estimated coefficients, standard errors and p-values of the panel-corrected standard error estimation results.

Table 3. Panel corrected standard errors (PCSE) regression results.

Independent Variables	Coefficient	Std. error	p-value
TQ	−0.07	0.35	0.840
AGRP	0.86	0.28	0.002
POPU	0.69	0.38	0.070
USEAGR	−0.18	0.16	0.261
USEIND	−0.05	0.03	0.117
USEDOM	0.32	0.12	0.011

Notes: The p-value of F test and the Wald test indicate that the overall model is statistically significant. The model has a good fitness with R-square of 99%.

5.1 The availability of water resources

TQ is not significantly correlated with GDPPER which indicates that the regional economic development is not contributed to increase of the availability of water resources. Though small, the negative coefficient of TQ somewhat suggests that ceteris paribus the regional GDP per capita would not grow with the increase of annual water resources supply. And this is true in the regional reality. The GDP per capita of Beijing-Tianjin-Hebei region grows with a rapid rate while the volume of annual water supply roughly stays steady. The regional economic development do not and cannot rely on its water endowment because the present water scarcity don't allow it and as the regression results show, even if there is larger amount of water supply, per capita economy would not be promised.

This is a meaningful result for this region. As a region with severe water scarcity, the availability of water resources supply is small but it does not significantly affect the regional economy. For decades, the rapid population and economic growth has consumed as many groundwater as possible, much more than the amount that it is supplemented from rainfall and surface water rivers, causing the huge underground funnel of North China Plain. Groundwater provides a majority part of water for agricultural, industrial, households and environmental use in Beijing-Tianjin-Hebei

region, 68% of the total water supply in the year 2013. Although the proportion of groundwater supply is declining during the selected ten years, it is still large especially for Beijing and Hebei province. The proportion is 78%, 81% in 2004 and 55%, 76% in 2013 for Beijing and Hebei respectively. The proportion of groundwater supply is much smaller in Tianjin, from 32% in 2004 to 24% in 2013. The surface water supply in Tianjin is relatively abundant with additional supplement from sea water desalination and transferred water from the Yellow River and Luan River. The amount of desalinated and transferred water of Tianjin is nearly the amount exploited from the underground.

5.2 Water use structure

The variable representing water use structure AGRP is significantly correlated with the dependent variable regional GDP per capita. The coefficient of AGRP is positive and equals 0.86 indicating that for 1 percent of increase in the share of water for agricultural use there will be 0.86% increase in the regional GDP per capita.

The share of water for agricultural use also indicates the industrial structure of how the gross domestic production is constituted. Agriculture is a water-intense sector especially in North China Plain where most of agriculture production is irrigation-related, in which Beijing-Tianjin-Hebei region lies.

The share of water for agricultural use differs in the three provincial administrative areas though it is decreasing in the selected years. Although it is roughly and slightly going down from 2004 to 2013, agricultural use is still the main part of water usage in Tianjin and Hebei, 52% in Tianjin and 72% in Hebei in the year of 2013. The share is 25% in Beijing in 2013, and the its decrease rate of the share of water for agricultural use is relatively faster as the city makes intensive efforts to adjust the industrial structure and to promote sustainable use of water resources. Agricultural production of Beijing only accounts for 0.8% in 2013 (Statistic Bureau of Beijing, 2014).

5.3 Water use efficiency

As the results show, of the three efficiency variables, only USEDOM is significantly correlated to GDPPER. Its coefficient is positive 0.32 implying that 1% increase in domestic water use per capita will result in a 0.32% increase in regional GDP per capita. The per capita domestic water use in Beijing-Tianjin-Hebei in 2013 is 47.1 m³, 86% of the national level and nearly the same as in 2004. However, in reality, the figure would be much greater as the water used by households in rural areas is not all covered by public water supply and not included in the collected data on domestic water use volume while their population is counted in the overall population. Tianjin has the smallest annual per capita domestic water use and thus has the most efficient water use in domestic.

The estimation is based on historical data, which shows the fact of the past but the predicted future trend. Water use efficiency should be controlled under reasonable standard to ensure a sustainable use of water and to restrict water demand which is an important part of water management on the demand side. Higher water use is associated with a higher growth rate in per capita income (Barbier and Chaudhry, 2014) and higher per capita income often goes with higher GDP per capita. Large and increasing

population increased the risk to water supply with it ever-increasing demands for water (Wang et al., 2015).

The other two explanatory variables that represent water use efficiency, water use per ¥10,000 agricultural value added (USEAGR) and water use per ¥10,000 industrial value added (USEIND) are not significant to GDP per capita in the region. Both variables are important indicators of water use efficiency. The more water used per ¥10,000 value added in agriculture or industry, the lower water efficiency it has. The average water use per ¥10,000 agricultural value added is 426.9 m³ in Beijing-Tianjin-Hebei region and that of industry is 15.5 m³. Although the correlation of the two variables are not significant, the negative coefficients indicates that the more water used in ten thousand agriculture or industry production, the less per capita economic growth there would be.

The variable of water use per ¥10,000 industrial value added is a very commonly used indicator of water use efficiency. It indicates the water use efficiency in mining and industrial sectors. The statistic is 15.45 m³ in Beijing-Tianjin-Hebei region in 2013, and 14.86 m³, 8.5 m³, 19.12 m³ for Beijing, Tianjin and Hebei respectively. Tianjin uses less water for industry than Beijing and Hebei though it is highly industrialized. Its water use is efficient due to the early promotion of circular economy and water saving practice (Sha and Liu, 2010). According to the Integrated National Water Resources Planning, by 2020, the national total water use should be controlled to 670 billion cubic meters and the water use per ¥10,000 GDP and per ¥10,000 industrial value added should be decreased to 120 m³ and 65 m³, which is regarded as the national water use efficiency goal. For the whole region, water efficiency is under reasonable level. As Zhou and Tol (2005) estimates, when regional value of industrial production grows the water use per production value declines because technology improvement helps to enhance the water use efficiency and the industries learn by doing.

6. Conclusions

This study uses panel data regression to estimate the impacts of water resources on economic development in Beijing-Tianjin-Hebei region. Rather than taking into consideration of all aspects of water resources, we focus on examining the direct impacts of influential water factors on regional economic development.

The impacts of water resources on economic development in Beijing-Tianjin-Hebei region are attributable to water use structure and water use efficiency, where the share of water for agricultural use and annual per capita domestic water use are statistically correlated with regional GDP per capita. Regional integrated management towards enhanced economic structure optimizing and water use efficiency improvement would be effective ways for solving regional water shortage problems and sustainable economic development.

Due to data limitation, the time framework of this paper is only 10 years. Longer term data would be more efficient. Our future work focuses on the analysis on how the effects of water use efficiency and structure on the economic development in this region function based on multiplier analysis and structural path analysis and further to

investigate optional economic policies and their impacts by CGE modelling.

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