Empirical Research on Utilization and Protection of Water Resources in China

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Abstract: This paper takes much emphasis on issues of water in China by statistic data and methods and analyzes impaction of economy and population on water utilization and water protection. China is a country not only short of water but also uneven distribution of water. Meanwhile, population, industry and agriculture are in large demand for water. Rapid development of economy and society make burden of water systems heavier and water pollution occurs more frequently than before. Industry and agriculture use over 85% of water and the situation of water utilization will keep for a long time. Waste water, a kind of by-product of industrial production, is a main pollutant, threatening water safe in all country. Effective measures taken to protect water and abate pollution are increasing investment in the treatment of industrial water pollution and facilities for treatment of waste water.

Key words: water resources, water demand and supply, water pollution

1. Introduction

China, as a country with large population, is facing an urgent problem about copping with water scarcity. Since 2000, per capita water resources in China have decreased gradually. Water resources in 2009 are 1816.2cu.m/person, less than 1/4 of world average. China is a country not only short of water but also uneven distribution of water. Population, industry and agriculture are in large demand for water. Moreover, water pollution is threatening water safe in all country. Urgent status of waters resources has effect the development of society and economy. This research focuses on analyzing situation of water utilization and protection and finding out impaction of economy and population on those.

2. Regional Water Resources Distribution

2.1 Method to Measure Regional Differences of Water Resources Distributions

American statistician Max Otto Lorenz put forwarded Lorenz curve for describing the unbalanced degree of income and wealth allocation, in 1905. Italy economist Corrado Geordie designed Geordie Coefficient on the base of Lorenz curve for measuring degree of income gap. Lorenz curve and Geordie Coefficient can be used to research fairness of resources distribution, such as water, energy and education and medical.

Many methods are proposed to measure Geordie coefficient, including formula method and curvilinear regression integration method. Formula method can be divided into two types, according to original data whether grouped or not.

With the un-grouped data on amount of everyone's resource, Geordie coefficient can be calculated as formula 1.

$$G = \frac{1}{NW_n} \sum_{i=2}^{n} \sum_{j=1}^{i-1} (Q_i - Q_j) \qquad \text{Formula 1}$$

W_i is amount of n people's resource; Q_i is amount of exon I people's resource after sorting by amount of everyone's resource from low to high.

If all research objects are sorted by amount of everyone's resource from low to high and divided into different group, Geordie coefficient can be calculated as formula 2.

$$G = 1 - \sum_{i=1}^{n} p_i (2Q_i - W_i) = 1 - \sum_{i=1}^{n} p_i (2\sum_{k=1}^{i} W_k - W_i) \qquad \text{Formula 2}$$

p_i is proportion of every group people in all people; W_i proportion of every group resource; Q_i is accumulated proportion of every group resource

Curvilinear regression integration method is estimating Lorenz curve with observed values and then calculating integral $\int_0^1 f(x)dx$. According to Geordie coefficient formula G=A/B, G equal to $1 - 2\int_0^1 f(x)dx$.

There are two reasons to adopt curvilinear regression integration method for calculating Geordie coefficient. First, formula method is suitable for studying one type resource allocation in population; second, formula method is simple but not exact, different grouping has different result. In contrast, curvilinear regression integration method is more exact suitable for calculating Geordie coefficient of water resources distributions.

2.2 Water resources Distribution in China are Unbalanced.

With the information of population and water resources of 31provinces in2009, this paper builds reasonable model to estimate Lorenz curve with curvilinear regression integration method and calculates Geordie coefficient.

Scatter Figure 1 shows that x (accumulated percent of population) and y(accumulated percent of water recourses) have curve correlation. Cubic curve model is more suitable among other curve models. Cubic curve model can be written as following:

$$y = b_0 + b_1 x + b_2 x^2 + b_3 x^3 \qquad \text{Formula 3}$$

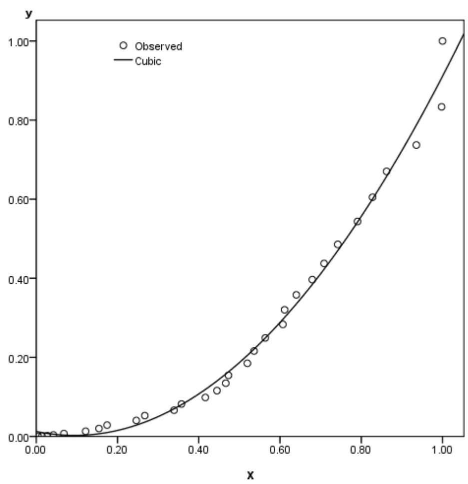

Figure 1 scatter between accumulated percent of population and water resources

Table1 shows that goodness of fit of Cubic curve model is 0.99 and significance of F-statistics equals to 0.00. This model is significant at 0.05 and can be used to estimate Lorenz Curve.

Table 1 Estimation of Cubic curve model

Parameter Estimates	Constant	b1	b2	b3
	0.01	-0.21	1.13	-0.02
Model Summary	R Square	F	Sig.	
	0.99	987.45	0	

With cubic curve model to fit Lorenz Curve, it is necessary to calculate $\int_0^1 (b_0 + b_1 x + b_2 x^2 + b_3 x^3)dx$ for Geordie coefficient. According to integral principle, the results are as follows:

$$\int_0^1 (b_0 + b_1 x + b_2 x^2 + b_3 x^3)dx = (b_0 x + \frac{1}{2} b_1 x^2 + \frac{1}{3} b_2 x^3 + \frac{1}{4} b_3 x^4)\Big|_0^1$$ Formula 4

$$= b_0 + \frac{1}{2} b_1 + \frac{1}{3} b_2 + \frac{1}{4} b_3$$

$$G = 1 - 2(b_0 + \frac{1}{2} b_1 + \frac{1}{3} b_2 + \frac{1}{4} b_3)$$ Formula 5

Putting the estimated value of b_0, b_1, b_2 and b_3 into formula 5, Geordie coefficient equals to 0.44, which means the water resources distributions are serious inequality. Prosperous cities and provinces with large population cost more water resources than backward areas, but water resources are in shortage. Graph2 shows that water resources in area of Yangtze River are more than 2000cu.m/person; however, water resources in area of yellow river basin are less than 1000cu.m/person. Water resources in Beijing and Tanking, as prospers cities in China, are 126.61cu.m/person and 126.79cu.m/person separately, not yet reaching 1/10 of the national average.

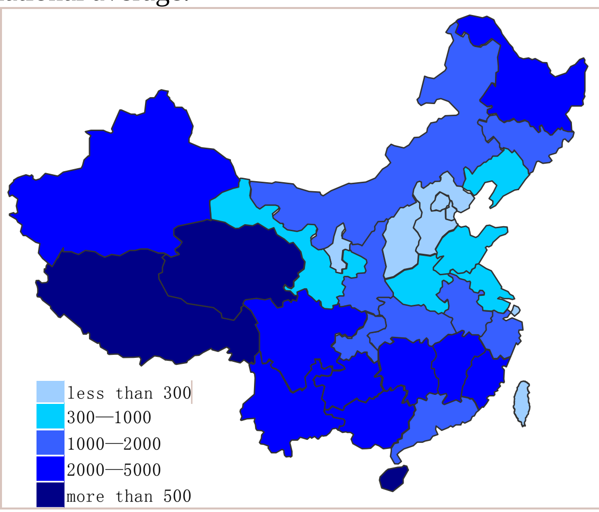

Figure 2 distribution of Per Capita Water Resources in 2009 (unit: cu.m/person)

3. Water Utilization

Figure 3 show that water utilization is gradually growing from 2003 to 2009. Average growth rate of water utilization is about 1.92%.

Stable-increasing water utilization has close relationship to development of industry and agriculture. Figure 4 show more than 85% of water supply is used by agricultural and industrial production; less than 15% is used for daily life and ecological protection. This paper is coming up with researching quantity of demand for water in four accepts.

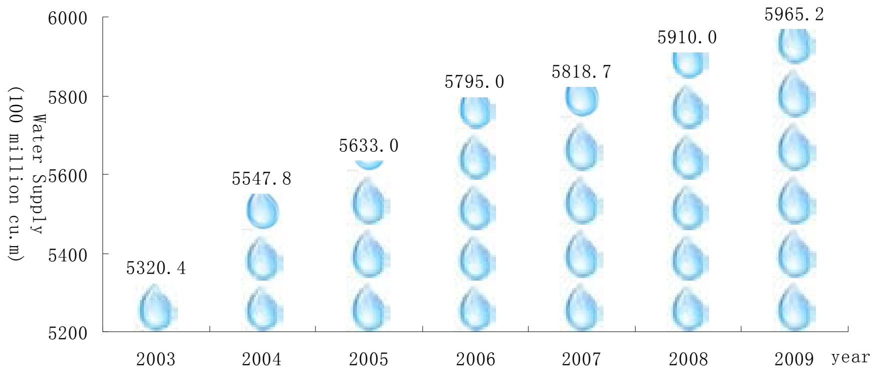

Figure3 water utilization from 2003 to 2009

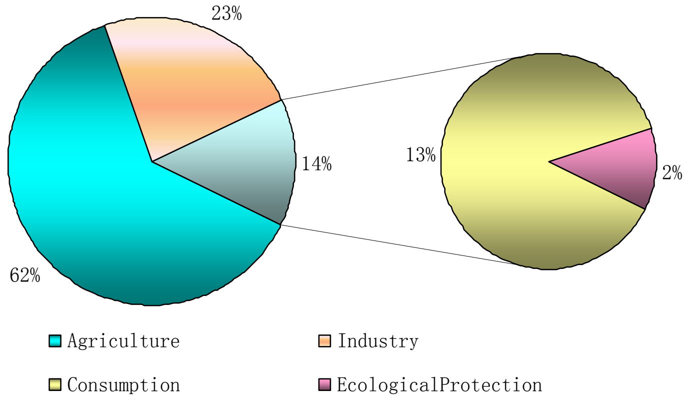

***Figure* 4 pie graph of water utilization**

3.1water utilization by industrial production

Water utilization by industrial production has close relationship with industrial output value. With the data of gross industrial output value and water utilization by industrial production from 2000 to 2009, a model can be built to descript relationship of relative change between them. Avoiding building wrong regression model, it is important to test whether $\ln y_1$ (y_1 water utilization for industrial production) and $\ln x_1$ (x_1 gross industrial output value) have co-integration relationship or not.

Table2 Augmented Dickey-Fuller test statistic

Statistic	$\Delta^2 \ln y_1$	$\Delta^2 \ln x_1$
t-Statistic	-2.15	-2.84
Prob.	0.04	0.01
Test critical values	5% level	-2.01
	10% level	-1.60

Table2 show that statistical values of ADF test are less than critical values with significance level of 5%. So the second order difference is stationary, i.e. they are integrated of order two.

For $\Delta^2 \ln y_1$ ~I(2) , $\Delta^2 \ln x_1$ ~I(2), model of $\ln y_1$ and $\ln x_1$ can be built as formula(6):

$$\ln y_1 = \alpha + \beta \ln x_1 + u_t \qquad \text{Formula 6}$$

Estimated results as following:

$$\ln y_1 = 5.39 + 0.14 \ln x_1 + \hat{u}_t$$ Formula 7

P-value (0.01) (0.00)

$R^2 = 0.95$

Based on the regression estimation, u_t can be written as:

$$\hat{u}_t = \ln y_1 - 5.39 - 0.14 \ln x_1$$ Formula8

Table3 Augmented Dickey-Fuller test statistic

test statistic	t-Statistic	Prob.*
	-3.90	0.00
Test critical values	1% level	-2.89
	5% level	-1.99
	10% level	-1.60

Result of unit root test about $\hat{u}_t$ is in table 3. The statistical values of ADF test equals to -1.80, less than less than critical values with significance level of 10%, so $\hat{u}_t$ is stationary. It can draw a conclusion that $\ln y_1$ and $\ln x_1$ have co-integration relationship.

The relationship between water utilization and industrial production in the long run is that if gross industrial output value increase 1%, the cost of water will increase 0.14%. According to the trend of industrial production, forecasting model (Formula 9) can be used to predict gross industrial output value after 2009.

$$x_{1t} = \alpha x_{1t-1} + \beta t$$ Formula 9

Estimated results as following:

$$x_{1t} = 13654.73 x_{1t-1} + 0.81t$$ Formula 10

P-value (0.00) (0.00)

$R^2 = 0.99$

Residual error of forecasting model is stable and no autocorrelation. Predictive value of industrial production in 2010 is 528090.3 (100 million yuan). Put the predictive value x_1 into Formula (7), water utilization in 2010 (y_1) is 1447.04(100 million cu.m).

3.2water utilization by agricultural production

Water utilization by agricultural production has close relationship with agricultural output value. With the data of gross agricultural output value x_2 and water utilization by agricultural production y_2 from 2003 to 2009, a model can be built to descript relationship of relative change between them. For $\ln x_2$ and $\ln y_2$ are not integrated, so they haven't co-integration relationship. Adding time variable t into model can avoid pseudo-regression.

Estimated results as following:

$$\ln y_2 = -0.05t + 0.86 \ln x_2$$ Formula 11

P-value (0.00) (0.00)

$R^2 = 0.45$ DW=2.21

If gross agricultural output value increases 1%, water utilization by agricultural production will increase 0.86%. According to the trend of agricultural production, forecasting model (Formula 12) can be used to predict gross agricultural output value after 2009.

$$x_{2t} = 1.06 x_{2t-1}$$ Formula 12

P-value (0.00)

$R^2 = 0.93$

Residual error of forecasting model is stable and no autocorrelation. Predictive value of agricultural output value in 2010 is 22330.63 (100 million yuan). Put the predictive value x_2 into Formula (11), water utilization in 2010 (y_2) is 3721.116 (100 million cu.m).

3.3water utilization by living consumption

Although living consumption only accounts for less than 13% of water utilization, it played an important role in maintaining social stability. With the increasing of population, quality of living consumption is keeping growth.

With the data of total population x_3 and water utilization by living consumption y_3 from 2000 to 2009, a model can be built to descript relationship of relative change between them. For $\ln x_3$ and $\ln y_3$ are not integrated, so they haven't co-integration relationship. Adding time variable t into model can avoid pseudo-regression.

Estimated results as following:

$$\ln y_3 = 0.025t + 0.54 \ln x_3 \qquad \text{Formula 13}$$

P-value (0.00) (0.00)

$R^2 = 0.99$ DW=1.52

If total population increases 1%, water utilization by living consumption will increase 0.54%. According to increasing trend of population, forecasting model (Formula 13) can be used to predict total population after 2009.

$$x_{3t} = 5269.66 + 10.97 x_{3t-1} \qquad \text{Formula14}$$

P-value (0.00) (0.00)

$R^2 = 0.99$

Residual error of forecasting model is stable and no autocorrelation. Predictive value of agricultural output value in 2010 is 134097.8 (10000 persons). Put the predictive value x_3 into Formula (13), water utilization in 2010 (y_3) is 753.76(100 million cu.m).

3.4water utilization by Ecological Protection

Water utilization by ecological protection only accounts for less than 2% of water utilization, but it plays an un-neglected role in replenishment water and urban environment.

Because many factors affect quality of water utilization by ecological protection, it is unreasonable to add all variables into model. Time is a best variable to stand for total effect caused by many factors. Forecasting model for Water utilization by ecological protection is estimated as followings:

$$\ln y_4 = 4.32 + 0.06t \qquad \text{Formula 15}$$

P-value (0.00) (0.00)

$R^2 = 0.78$ DW=2.3

Residual error of forecasting model is stable and no autocorrelation. Average growth rate of Predictive water utilization by ecological protection is 6% annually. Predictive value of water utilization by ecological protection in 2010 is 121.52(100 million cu.m).

3.5total water utilization in 2010

According to the above analysis, total water use in 2010 is 6043.44(100 million cu.m). Water use by agriculture still takes first place of, which is about 3721.12(100 million cu.m). Water use by industry is second place, about 1447.04(100 million cu.m), Water use by living consumption and ecological protection are 753.76(100 million cu.m) and 121.52(100 million cu.m) separately.

4. Water pollution and protection

4.1Situation of water pollution

Since 2000, number of water pollution has decreased rapidly. Water pollution accidents happen 116 times in 2009, which is only about 1/10 of that in 2000. As for the water pollution among 31 regions, Anhui, Chongqing, Gansu and Hubei are four regions in which water pollution happen over 10 times, far more than others.

Water pollution in sea area is becoming serious. Figure 5 show that a proportion of heavily polluted area in 2009 is 8% more than in 2007; a proportion of moderately polluted area is 8% more than in 2007. Recently, marine pollution accident occurs more frequently than ever. For example, petrochina oil pipeline explosion is a big tragedy for environment. Tons of oil discharge into sea, and 500000 sq.km sea areas are polluted.

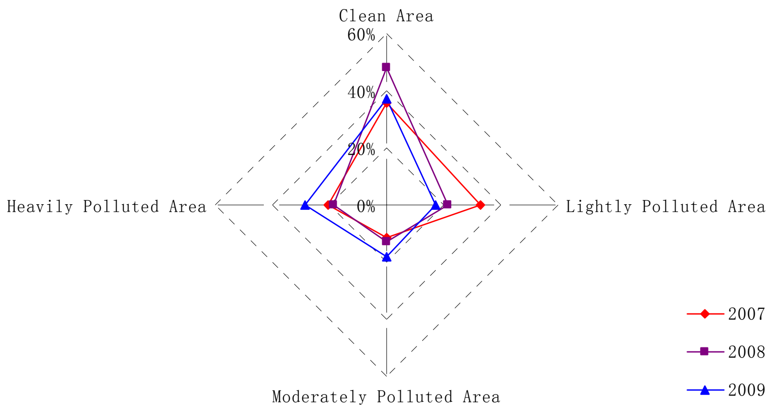

Figure 5 seawater quality in offshore area

4.2.waste water discharge

Total volume of waste water discharged is increasing gradually. It is 589(100 million tons) in 2009, which is 1.4 times as much as that in 2000. Waste water is consisted of industrial discharge and household and service discharge. Household and service discharge accounts for over 50% of waste water.

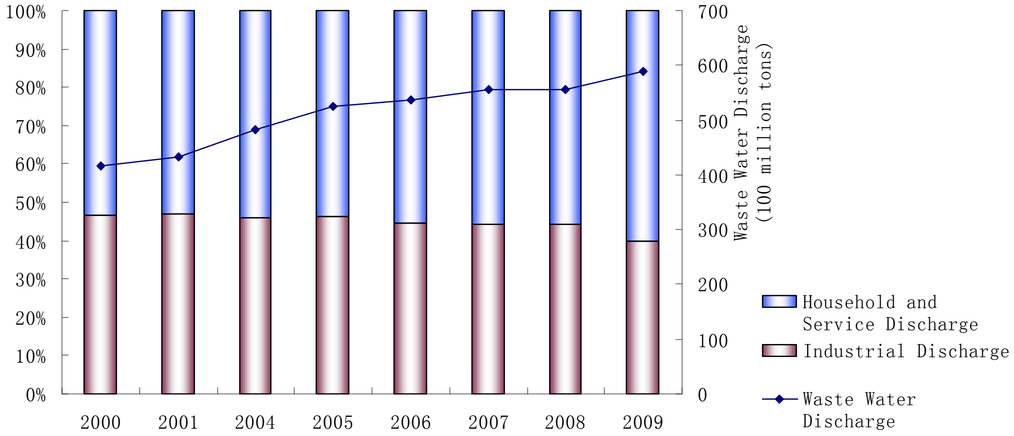

Figure 6 total volume and composition of waste water discharge

A scale of economy and population directly affect local waste water discharged. In 2007, Eastern is developed region with large population, in which total volume of waste water discharged is 2745271(10000 tons), accounting nearly half of all country; Western is backward region with few population, in which total volume of waste water discharged is 1179085 (10000 tons), accounting about 20%.

To make further research on the impaction of economy and population on waste water discharged, a model is built with data of gross industrial output value(z_1), water use(z_2), population(z_3) and total volume of waste water discharged (y)in 2009 among 31 regions.

Because Spearman's correlations between z_1, z_2 and z_3 are close to 1, to eliminate multicollinearity in a model, explanatory variables are changed into different forms like $\ln(\frac{z_1}{z_3})$, $\ln(z_2)$.

Estimated results as following:

$$\ln y = 8.59 + 0.46\ln(\frac{z_1}{z_3}) + 0.71\ln z_2 \qquad \text{Formula 16}$$

P-value (0.00) (0.00) (0.00)

$R^2 = 0.90$ DW=2.3

Because coefficients of two explanatory variables are positive, increasing in per capital gross industrial output value and water use lead to more waste water discharged. When per capital gross industrial output value increase 1%, total volume of waste water discharged increase 0.46%; when water use increase 1%, total volume of waste water discharged increase 0.71%.

4.3*Treatment for Water pollution*

From above analysis, it clearly sees that more and more waste water will be discharged in the future. How to take measures to abate water pollution and treat waste water is becoming an urgent issue.

Industrial Waste Water is a key object to monitor in treating water pollution. Proportion of industrial waste water meeting discharge standards grows year by year. It's 94.2% in 2009, 17.9% more than that in 2000. However, proportion of industrial waste water meeting discharge standards in many regions, especially Western, are far less than the average level. Figure 7 show that proportion of Central, Eastern and South is over 90%, higher than others. Qinghai and Tibet are two of lowest regions in China which are less than 60%, however, they are also two regions abundant in water resource. Such low proportion of industrial waste water meeting discharge standards in these regions will threat water safe in all country. It is urgent to take effective measures to treat water pollution and raise proportion.

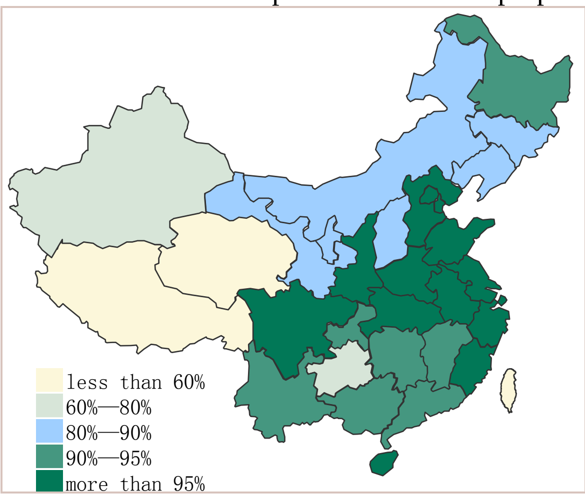

Figure 7 distributions of proportion of industrial waste water meeting discharge standards in China

Investment in the treatment of industrial water pollution and facilities for treatment of waste water are both useful for abating water pollution. With data of Investment in the treatment of industrial water pollution (q_1), number of facilities for treatment of waste water (q_2) and proportion of industrial waste water meeting discharge standards (p) of 31 regions in 2009, a model is built as following:

$$p = \alpha_0 + \alpha_1 \ln q_1 + \alpha_2 \ln q_2 \qquad \text{Formula 17}$$

Because coefficient α_1 isn't significant at 0.05, model is changed into formula (18).

$$p = \alpha_0 + \alpha_2 \ln q_2 \qquad \text{Formula 18}$$

Estimated results as following

$$p = 0.52 + 0.05 \ln q_2 \qquad \text{Formula 19}$$

P-value (0.00) (0.01)

$$R^2 = 0.23$$

The coefficient α_2 is positive means that the more facilities for treatment of waste water, the more proportion of industrial waste water meeting discharge standards. When number of facilities for treatment of waste water increases 1%, proportion of that increases 0.05%.

5. Conclusions

China is a country not only shot of water resources but also unbalanced of water distributions. Geordie coefficient equals to 0.44, which means the water resources distributions are serious inequality. Prosperous regions are more short of water than backward regions. Agriculture and industry are two main demands for water. With the development of economy and population, water utilization by agriculture and industry keeps growing, which call for adopting effective measures to save water. Water pollution is anther problems facing in China. Industrial waste water has become a main pollutant, threatening water safe in all country. It can protect water and abate pollution by increasing investment in the treatment of industrial water pollution and facilities for treatment of waste water.

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