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Inspection, Measurement and Interpretation of Club Convergence of Water Use Efficiency in China from 2003 to 2015

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***Abstract*—Based on Quah's (1997) analysis framework about distribution dynamics and using the extended Markov chain model and the spatial Markov chain model, this paper studies the phenomenon of club convergence of total water use, agricultural water use and industrial water use in 31 provinces of mainland China from 2003 to 2015. Firstly, it manages to inspect the club convergence of three types of water use efficiency, then measures the degree of club convergence based on the constructed club convergence index, and finally explains the phenomenon of this kind of club convergence in view of space. The results are as follows. (1) The phenomenon of club convergence exists among the three types of water use. While its convergence degree eases with time, it is still very obvious. For example, the probability that areas with low industrial water use efficiency remain low after 5 year lengths is 0.808, while that is 0.918 when it comes to high-level areas, so it is urgent that the regional water use efficiency effort should be coordinated. (2) The degree of club convergence of industrial water use efficiency is the highest among the three ones, followed by the total water use and then the agricultural water use. More seriously, some areas remain low-level for a long time and they are caught in a "low-level trap", which should be taken great consideration by the government. (3) The phenomenon of club convergence is influenced by spatial factors. On the one hand, when the water use efficiency among areas is different, the local areas tend to be influenced by the adjacent areas to some extent. Simple to say, high-level adjacent areas have positive impact while low-level ones are opposite. On the other hand, there exists a characteristic of agglomeration no matter it is among high-level districts or low-level districts in spatial distribution, so spatial spillover effect follows among different clubs. However, the positive spillover effect in high level clubs is much larger than that in low level clubs, which incurs greater difference between high-low-level clubs so as to promote the phenomenon of club convergence. This is particularly evident in the club convergence of industrial water use in China.**

Keywords*—water use efficiency; club convergence; club convergence index; Markov chain model

I. INTRODUCTION

Guidance on how to strengthen water use control is issued by the Ministry of Water Resources of the People's Republic of China on July 13, 2016, which indicates the importance and urgency of strengthening water use control, and also holds a view that it is prerequisite to promote the cor-development of industrialization, informatization, urbanization, agricultural modernization (4 modernization for short) and to guarantee the sustainable development of China's economy and society. Water resources, as the basic natural resources and strategic economic resources, are the fundamentals for China to achieve "4 modernization". For the recent years, the conflict on the allocation of water use is increasingly intensified among different industries with the rapid development of China. Therefore, it is necessary to strengthen water use control to make use of water more economically and intensively, thus achieving 4 modernization and promoting the society and economy to develop sustainably in China. Above all, it is necessary for people to have insight into the water use efficiency of each industry in every district before the water use is limited. More importantly, what is the difference of water use efficiency in every district? How it changes with time? Does it exist spatial effects? Answers to these questions will help to know the condition of water use of every district. Especially, those areas caught in "low-level traps" can be taken great consideration when inspecting the problem of convergence of water use efficiency from the perspective of dynamics. Therefore, the Chinese government can target its function in controlling water use, and coordinate the development of water use efficiency among districts.

II. LITERATURE REVIEW

Totaling speaking, research into water use efficiency is mainly focused on two aspects: assessment system and influence factors. On the one hand, there are two kinds of indicators when assessing water use efficiency. One is water consumption coefficient acting as the delegate variable of water use efficiency based on ration analytical method. Those coefficients can be divided into two types: economic indicators (e.g. water consumption per ten thousand-yuan GDP) and physical indicators (e.g. water consumption per ton of steel) [1]. For example, Li et al [2], Bao et al [3] and Zang et al [4] all choose water consumption per ten thousand-yuan GDP to analyses the regional differences, influence factors and convergence characteristics of water use efficiency. Another is to measure the efficiency in the framework of total factor productivity in water use. Method to measure the efficiency include parametric method (Stochastic Frontier Analysis) [5] and non-parametric method (Data Envelopment Analysis) [6], [7], [8], [9], [10], [11], [12], [13], [14]. DEA is widely used among scholars when measuring the water use efficiency. For example, Tong et al [6] and Ren et al [7] measure the agricultural water use efficiency in every province of Yangtze river basin and domestic water use efficiency in provincial capital. In another instance, Romano et al [8] compare and study the water use efficiency of India's water industry under the different shareholding structure. In consideration of the pollution during the procedure of producing water resources, the factor of environment is put in the model by many researchers. For instance, Deng et al [9] measures the water use efficiency in every province of China using Slack Based Measure-Data Envelopment Analysis (SBM-DEA) model. Besides, Ma et al [10] and Yang Jian et al [11] do the same.

On the other hand, there are many methods to analyze the influence factors like Tobit Model [6], [7], [9], [10] and Bootstrap Truncated Regression Model [11]. Some important conclusions follow. Firstly, per capita GDP, ratio of the secondary and tertiary industry and per capita education expenditure all have positive effects on the industrial water use efficiency in China. Secondly, farmland irrigation establishment and environmental regulation can positively promote the agricultural water use efficiency in China, whereas it is opposite when water resources are abundant. Thirdly, Qian et al [12] finds that industry structure, demands of import and export and water resources endowment have positive effects. Fourthly, Ren et al [7] indicates that per capita GDP, per capita water resources and ratio of the secondary and tertiary industry have positive effects in terms of urban water use efficiency. What's more, with spatial econometrics springing up, researchers manage to explore the relative influence factors from the point of spatial spillover. For instance, Bao et al [3] analyzes the influence factors of water use efficiency in Henan Province of China, these factors include water resource endowment and its utilization, economic development level, urbanization level, industry structure, agricultural modernization level, informatization level. For another, Chen[13] finds that agricultural water use efficiency is not only affected by the local province's indicators but also influenced by the adjacent provinces' ones when studying the spatial spillover effect of agricultural water use efficiency in 31 provinces of mainland China using Spatial Lag Model (SLM).

However, less scholars focus their study on the convergence of water use efficiency. Although Zang et al [4] makes an empirical research into the strong convergence of provincial water resources of mainland China, and Cheng et al [14] tests the convergence of the industrial water use efficiency in China from 2002 to 2011, they all finished their researches by employing the regression technique presented by Barro et al [15] which is thought to be not rigorous. Obviously, this technique can only inspect whether the subsample tends towards a steady state, but it fails to explore the characteristic of dynamic transformation among different clubs. Furthermore, both of them mainly consider whether each club shows a tendency of club convergence, but this goes against the principle of club convergence. In fact, this paper usually defines club convergence as integrity. First it was divided into different clubs (subsamples) according to the similarity of primary conditions and structure characteristics etc. and then tests the convergence of each club. If there exists a steady state, that is to say, subsamples tend to be the same, the integrity shows a tendency of club convergence. There is a very important method to extend the research of club convergence: Distribution Dynamic Approach (DDA) [16], [17], which is increasingly thought highly of by many scholars. Compared to traditional research methods based on regression, DDA has an outstanding advantage in inspecting the transformation characteristics among different clubs. Therefore, it can prove whether the integrity tends towards convergence from the point of dynamics.

Totally speaking, present papers available about water use efficiency have extradentary academic value, but it can also improve a lot. Firstly, the existing researches mainly center on the measurement of water use efficiency and its regional variations and influence factors, but focus less on the problem of club convergence of water use efficiency. Although there are some scholars who employ regression method, it fails to inspect the transformation characteristics between each club. Secondly, most researches into club convergence of water use efficiency attach great importance to assessment but think lowly of measurement. Rigorously speaking, it is still very hard to measure and compare the convergence degree of different water us efficiency for the lack of efficient measure indicators. Thirdly, the existing research conclusions do not answer well to the problem of club convergence of water use efficiency, especially the explanation from the aspect of spatial adjacency. Therefore, this paper manages to give a more convincing explanation aiming to ease the degree of club convergence of regional water use efficiency in China, especially to provide a new idea and view to help low-level districts to shake off low efficiency.

III. METHOD AND DATA

A. Method

First, in order to dissociate some continuous variables, this paper divides water use efficiency into four types: low level, mid-low level, mid-high level and high level [1] by learning from Zhou et al [21]. Simply speaking, if the transition probability between different kinds is low, then it can be said that there exists a phenomenon that water use efficiency shows a trend of club convergence. When one province changes its type i in year t to type j after d year(s), it can be denoted by virtue of Equation (1).

$$P_{ij}^{k,t+d} = \sum_{t=2003}^{2015-d} n_{ij}^{t,t+d} \Big/ \sum_{t-2003}^{2015-d} n_i^t \qquad (1)$$

n_i^t denotes the total amount of districts whose type is i in year t; $n_{ij}^{t,t+d}$ denotes the total amount of districts whose type changes from i in year t to type j after t plus d years. Also, for any type i and year length d, $\sum_j P_{ij}^{t,t+d} = 1$.

Next, it tends to construct the club convergence index based on transition probability matrix, which can make it possible to take a comprehensive consideration of the convergence degree of each club. And it is also helpful to figure out the numerical value of convergence by averaging the convergence degree of each convergence club. To be concrete, the Equation (2) can calculate the value of the club convergence index.

$$CCI^d = \sum_{i=1}^{k} P_{ii}^{t,t+d} \Big/ k \qquad (2)$$

Finally, it manages to establish spatial Markov chain model to gain deep insight into the trend of club convergence of water use efficiency. This model derives from Markov chain model by introducing "spatial lag" into it. The space factor can be taken good consideration to explore the regional distributed dynamics in this model. That is to say, it is possible to recognize whether the type "transition" in local areas is relative to the type in adjacent areas or not. Here, the spatial weight matrix (W), namely $\sum_{ij} W_{ij} y_j$, is introduced to measure the level of the adjacent, of which W_{ij} is the element of W (i, j = 1, 2, ······, n); y_j denotes the value of district j. As for one matrix like $W_{k\times k}$, k conditional matrices come into being when considering that k spatial lag type(s) is/are regarded as regional transitional condition, which can be written as $P_{ij|\lambda}^{t,t+d}$. Here, it stands for the probability that the regional water use efficiency transfers from i to j after d year (s) in the condition that the water use efficiency of spatial lag (adjacent average) is λ the very year. Then it is possible to explore whether the adjacent areas affect the transformation of water use efficiency of local areas by comparing the relative numerical value of Markov's and spatial Markov's transition probability matrix. For instance, if the Equation that $P_{12}^{t,t+d} > P_{ij}^{t,t+d}$ can be established, it can be figured out that low-level districts are little easier to transfer to mid-low-level districts regardless of space factor if its adjacent area is low-level district. Besides, if the Equation that $P_{ij|\lambda}^{t,t+d} = P_{ij}^{t,t+d}$ is satisfied for any i and j, it means that space factor has no influence on the water use efficiency of local districts. This paper's spatial Markov chain model can explore the spatial spillover effect under different year length [2]. The significance tests of two kinds of Markov transition matrix can be finished by means of Chi-square test statistics which can be figured out by Equation (3).

$$Q = \log\left\{\coprod_{l=1}^{2}\coprod_{i=1}^{k}\coprod_{j=1}^{k}\left[\frac{P_{ij}^{t,t+d}}{P_{ij}^{t,t+d}(l)}\right]^{n_{ij}(l)}\right\} \qquad (3)$$

As for Equation (3), k denotes type; $P_{ij}^{t,t+d}(l)$ denotes probability value of two types of transition matrix when year length is d, and $n_{ij}(l)$ denotes the sum of districts; $P_{ij}^{t,t+d}$ denotes the value of transition probability; Q is Chi-square distributed whose degree of freedom equals the number of k ×(k-1) minus the number of zero probability.

Here, spatial weight is defined by geographical distance in which it is substituted with d_{ij} denoting the distance from district i to district j. Specifically, the formula of measuring spherical distance learns from Han et al [24].

$$W_{ij}\begin{cases}1/d_{ij}^2, (i \neq j)\\ 0, (i = j)\end{cases} \qquad (4)$$

B. Data

The data indicators chosen here include total water consumption, agricultural water consumption, industrial water consumption, provincial GDP as well as other relative agricultural and industrial indicators in China's 31 provinces from 2003 to 2015. Water use efficiency is represented as water consumption per GDP, namely the ratio of GDP to total water consumption. The greater it is, the higher the efficiency is. All the data derive from China Statistic Yearbook and Bulletin on China's Water Resources of each year.

[1] This paper averages the water use efficiency of China's 31 provinces each year, those less than 50% of the average are classified into low-level districts; those between 50% of the average and 100% of the average are classified into mid-low-level districts; those between 100% of the average and 150% of the average are classified into mid-high-level districts; those higher than 150% of the average are classified into high-level districts.

[2] To be concrete, this paper's model is extended to two aspects. One is that year length is introduced when inspecting spatial and non-spatial Markov transition probability matrix. In fact, our model program can compute any year length. Another is that it also works when their matrixes meets the significance test.

IV. Inspection of Club Convergence

Considering the fact that China launches a medium-and long-term plan per five years, this paper analyzes the problem of types transformation based on the variable year length from 1 to 5. We can get the probability transition matrix of China's total water use efficiency, agricultural and industrial water use efficiency under different year length through Equation (1). The results are shown in "Table I" and "Table II".

TABLE I. THE TEST RESULTS OF CLUB CONVERGENCE OF TOTAL WATER USE EFFICIENCY IN CHINA

Year length	Type	n	L	ML	MH	H
1	L	119	**0.950**	0.050	0.000	0.000
	ML	119	0.084	**0.891**	0.025	0.000
	MH	81	0.000	0.086	**0.864**	0.049
	H	53	0.000	0.000	0.113	**0.887**
2	L	112	**0.902**	0.098	0.000	0.000
	ML	107	0.103	**0.841**	0.047	0.009
	MH	72	0.000	0.125	**0.861**	0.014
	H	50	0.000	0.000	0.140	**0.860**
3	L	104	**0.856**	0.144	0.000	0.000
	ML	95	0.126	**0.811**	0.053	0.011
	MH	64	0.000	0.141	**0.828**	0.031
	H	47	0.000	0.000	0.213	**0.787**
4	L	96	**0.802**	0.198	0.000	0.000
	ML	83	0.157	**0.771**	0.072	0.000
	MH	56	0.000	0.161	**0.804**	0.036
	H	44	0.000	0.000	0.273	**0.727**
5	L	88	**0.761**	0.239	0.000	0.000
	ML	72	0.167	**0.750**	0.083	0.000
	MH	47	0.000	0.149	**0.809**	0.043
	H	41	0.000	0.024	0.317	**0.659**

The numerical values in "Table I" denote the probability that water use efficiency rises to higher level or drops to lower level. Especially, each diagonal element represents the probability that the efficiency remains the same next year. If the value gets higher, it can be said that there exists the phenomenon of club convergence. And the higher the probability value is, the more obvious the convergence degree is.

Further analysis shows that, firstly, the value of diagonal elements is about 0.8, the highest of which is 0.950 and the lowest of which is 0.659, obviously higher than all other elements. This indicates that the total water use efficiency in China has somehow a characteristic of club convergence, regional difference has a trend of solidification. Secondly, the phenomenon of convergence is a little eased as the year length changes. For example, the values of probability all decline by 0.189, 0.141, 0.055 and 0.228 when the year length is 5. It manifests that the problem of regional difference is alleviated to some degree, although it is not so satisfactory. Therefore, the present coordinated efforts on regional water use efficiency should be enhanced. Thirdly, the convergence degree is also different within the four types of level clubs. For instance, low-level clubs have a stronger trend of convergence as its probability is 0.950 and 0.902 when the year length is 1 and 2. And it remains the highest among the four types though the value drops a little when the year length is 3. In addition, the convergence degree of low-level clubs is just next to high-level clubs in year length 4 and 5. It reveals that low-level districts tend to be trapped into poor condition for a short time in China while this situation is still hard to be improved in the long run.

After observing the provincial data in China, although the efficiency type in some districts may convert to another type within the research years, some districts still remain unchanged. For instance, the Xinjiang Uygur Autonomous Region, the Ningxia Hui Autonomous Region, the Tibet Autonomous Region, the Guangxi Zhuang Autonomous Region and Gansu Province have been the low-level districts for years; Jilin, Sichuan, Fujian and Jiangsu Province has been mid-low-level clubs; however, Beijing and Tianjin City remain high-level districts all over the research years. It shows that low-level clubs almost all cluster in Chinese western areas, especially in northwest areas. What have in common in these districts are some poor behavior in water use such as large waste, lack of standardability and low GDP from unit water consumption. Therefore, it is imperative that local government should enhance its efforts in promoting the better use of water resources.

TABLE II. THE TEST RESULTS OF CLUB CONVERGENCE OF AGRICULTURAL AND INDUSTRIAL WATER USE EFFICIENCY IN CHINA

Year Length	Type	Agricultural water use efficiency					Industrial water use efficiency				
		n	L	ML	MH	H	n	L	ML	MH	H
1	L	70	**0.943**	0.057	0.000	0.000	154	**0.942**	0.058	0.000	0.000
	ML	123	0.016	**0.911**	0.073	0.000	97	0.113	**0.856**	0.031	0.000
	MH	128	0.000	0.078	**0.891**	0.031	47	0.000	0.106	**0.830**	0.064
	H	51	0.000	0.000	0.078	**0.922**	74	0.000	0.000	0.027	**0.973**
2	L	65	**0.908**	0.092	0.000	0.000	142	**0.894**	0.106	0.000	0.000
	ML	112	0.018	**0.857**	0.125	0.000	87	0.218	**0.736**	0.046	0.000
	MH	117	0.000	0.137	**0.812**	0.051	44	0.000	0.182	**0.727**	0.091
	H	47	0.000	0.000	0.128	**0.872**	68	0.000	0.000	0.029	**0.971**
3	L	60	**0.867**	0.133	0.000	0.000	131	**0.847**	0.145	0.008	0.000
	ML	102	0.029	**0.814**	0.157	0.000	76	0.276	**0.684**	0.039	0.000
	MH	107	0.000	0.168	**0.766**	0.065	41	0.000	0.244	**0.634**	0.122
	H	41	0.000	0.000	0.122	**0.878**	62	0.000	0.000	0.048	**0.952**
4	L	55	**0.818**	0.182	0.000	0.000	117	**0.821**	0.162	0.017	0.000
	ML	93	0.043	**0.774**	0.183	0.000	68	0.324	**0.632**	0.044	0.000
	MH	95	0.000	0.179	**0.747**	0.074	38	0.000	0.342	**0.474**	0.184
	H	36	0.000	0.000	0.111	**0.889**	56	0.000	0.000	0.071	**0.929**
5	L	49	**0.796**	0.204	0.000	0.000	104	**0.808**	0.163	0.029	0.000
	ML	83	0.048	**0.747**	0.193	0.012	59	0.322	**0.661**	0.017	0.000
	MH	84	0.000	0.190	**0.738**	0.071	36	0.000	0.389	**0.417**	0.194
	H	32	0.000	0.000	0.125	**0.875**	49	0.000	0.000	0.082	**0.918**

Obviously, it can be known from "Table II" that each province's agricultural water use efficiency has a trend of club convergence which is also evident to each club. There is no big gap though. Differently, the convergence degree of industrial water use efficiency is larger, and the probability that high-level districts remain high and low-level districts stay low is bigger than other clubs, which means that the competition is quite fierce among mid-level districts. Further researcher reveals that Xinjiang, Ningxia and Tibet remain low-level districts in agricultural water use efficiency; and Guangdong, Guangxi, Jiangsu and Jiangxi Province belong to mid-low-level districts; Zhejiang, Fujian and Hainan Province are mid-high-level districts; Shandong, Henan Province and Chongqing City keep unchanged for their high efficiency. Nevertheless, there are even more districts that each club's industrial water use efficiency has been the same. For example, Guizhou, Guangxi, Jiangxi, Hubei, Hunan and Anhui Province have been the low-level districts; Ningxia, Jilin and Guangdong Province are mid-low-level districts; the Inner Mongolia Autonomous Region is mid-high-level district; and there are five provinces that belong to high-level districts like Liaoning, Hebei, Tianjin, Shandong Province and Beijing City. It can be inferred from the visualized data that it is more obvious in the phenomenon of convergence degree between high-low-level clubs about industrial water use efficiency. Concretely speaking, each club member of three types of water use efficiency is shown in "Table III".

TABLE III. CLUB CONVERGENCE INDEX OF THREE TYPES OF WATER USE EFFICIENCY UNDER DIFFERENT YEAR LENGTH

Types of club convergence	Total water use efficiency	Agricultural water use efficiency	Industrial water use efficiency
L	Ningxia, Sinkiang, Tibet, Guangxi, Gansu	Sinkiang, Ningxia, Tibet	Guizhou, Jiangxi, Hunan, Guangxi, Anhui, Hubei
ML	Jilin, Sichuan, Fujian, Jiangsu	Guangxi, Guangdong, Jiangsu, Jiangxi	Ningxia, Jilin, Guangdong
MH	——	Zhejiang, Fujian, Hainan	Inner Mongolia
H	Beijing, Tianjin	Shandong, Henan, Chongqing	Liaoning, Hebei, Beijing, Shandong, Tianjin

The convergence degree of three types of water use efficiency in virtue of Equation can be accurately measured (2) and figure out their convergence index under different year length. This index can not only precisely measure the value of entire clubs' convergence degree, but in can also conveniently compare the difference of each club's convergence degree. In addition, it is possible to get insight into the variation tendency of the index whose computation can be found in "Table IV". It is clearly shown that all the convergence degree of three types of water use efficiency is smaller and smaller with the year length increases. In other words, time accumulation is important for a low-level district to catch up with a high-level district. More apparently, this phenomenon also exists in the year length 5 as the probability is still quite high, the lowest of which is 0.701. After averaging the probability value at each year length, it can be figured out that the probability of diagonal elements remain high (0.701). Therefore, policy makers should enhance their efforts in coordinating and controlling the regional water use, specially, specific assistance and valid management should be carried out for those districts that have been trapped in low level. Ranking the convergence degree of three types of water use efficiency, it can be known that the industrial water use efficiency is largest, the total water use efficiency follows and the agricultural water use efficiency is smallest. Therefore, it can be easily inferred that the solidification degree of regional disparity of industrial water use efficiency is largest. Low-level districts meet their difficulties in improving water use efficiency so as not to surpass mid-high-level or high-level districts.

TABLE IV. CLUB CONVERGENCE INDEX OF THREE TYPES OF WATER USE EFFICIENCY AT DIFFERENT LENGTHS OF TIME

Year length	Total water use efficiency	Agricultural water use efficiency	Industrial water use efficiency
K=1	0.898	0.917	0.900
K=2	0.866	0.862	0.832
K=3	0.821	0.831	0.779
K=4	0.776	0.807	0.714
K=5	0.745	0.789	0.701

V. SPATIAL EXPLANATION OF CLUB CONVERGENCE

A. *Spatial Correlation Analysis*

This paper first explores the spatial correlation of regional water use efficiency before explaining the phenomenon of club convergence of water use efficiency in China in point of space. Here, it manages to fulfill the test of the spatial agglomeration degree of three types of water use efficiency by means of Moran's Index. The results are shown in "Table V".

TABLE V. THE VALUE OF MORAN'S INDEX OF THREE TYPES OF WATER USE EFFICIENCY

Year	Total water use efficiency		Industrial water use efficiency		Agricultural water use efficiency	
	Moran index	P value	Moran index	P value	Moran index	P value
2003	0.502	0.000	0.528	0.000	1.919	0.055
2004	0.493	0.000	0.537	0.000	1.832	0.067
2005	0.457	0.000	0.534	0.000	1.633	0.103
2006	0.448	0.000	0.541	0.000	1.703	0.089
2007	0.487	0.000	0.536	0.000	1.801	0.072
2008	0.457	0.000	0.562	0.000	1.940	0.052
2009	0.472	0.000	0.559	0.000	1.747	0.081
2010	0.511	0.000	0.566	0.000	1.610	0.107
2011	0.492	0.000	0.561	0.000	1.533	0.125
2012	0.474	0.000	0.555	0.000	1.522	0.128
2013	0.475	0.000	0.552	0.000	1.571	0.116
2014	0.468	0.000	0.539	0.000	1.592	0.111
2015	0.560	0.000	0.107	0.018	1.529	0.126

As is shown in "Table V", the value of Moran's Index is larger in China when it comes to the total water use efficiency and the industrial water use efficiency. The former almost equals 0.5 and the latter is usually greater than 0.5 except in 2015. Besides, they are all statistically significant. It is obvious that there exits the phenomenon of spatial agglomeration in China's total and industrial water use efficiency. However, the value is smaller as to agricultural water use efficiency and it is just statistically significant at 10% significance level before 2009. In addition, the value has been smaller than 0.15 within the research years and the corresponding P value is below 13%, so it is easy to conclude that the phenomenon of spatial agglomeration of agricultural water use efficiency is not so as obvious as the other two types of water use efficiency. Furthermore, the spatial distribution of each province's total water use efficiency and industrial water use efficiency in China shows a characteristic of non-uniform like "high-high agglomeration" and "low-low agglomeration". So, is spatial distribution relative to club convergence? To answer this question, it is necessary to find whether there exists space effect between provincial water use efficiency. Next, this paper will explore whether the adjacency effect exists between water use efficiency by means of spatial Markov Model, so as to analyze the space effect that the adjacent districts with different efficiency level bring to the water use efficiency in local areas.

B. The Results of Spatial Markov Chain

We can get in "Table VI" the results of spatial Markov chain of three types of water use efficiency under different year length. The definite data in the matrix denote the probability that after some years local districts transfer from one kind of efficiency to another one under the influence of different adjacent areas. Among these probability matrixes, the transition matrix of total water use efficiency is figured out in the year length 5, and it is respectively 2 and 4 as to agricultural water use efficiency and industrial water use efficiency[3].

In consideration of the fact that the provincial water use efficiency shows a trend of spatial agglomeration, it is normally seen that the local district is high-level while the adjacent district is low-level as the space factor is explored. So is the circumstance where the adjacent district is high-level while the local district is low-level. To make the results more stable, this paper mainly focuses on studying the space effect under which the adjacent district is mid-low-level while the local is also mid-low-level and the adjacent is mid-high-level while the local is mid-high-level too.

Take the total water use efficiency for example, the probability that one district is still low-level is 0.814, higher than the average 0.796, after 5 year lengths when its adjacent district is also low-level. However, the probability that mid-level districts descend to low-level districts is 0.088 when the local district is mid-low-level while the adjacent districts are low-level. Similarly, the value is 4.8% higher than the average. Besides, these districts get less chance to ascend to higher-level districts as the value of probability is only 0.117, even lower than the average value 0.193. Therefore, we tentatively think low-level districts have some negative influence on local districts. Meanwhile, when the adjacent district is mid-high-level, this paper manages to explore the situation where the adjacent and the local are all mid-high-level while the opposite are all high-level. In the first instance, the probability that local districts descend is 0.125, higher than the average 0.071 but lower than the complete probability value 0.190. For the other instance, the probability that high-level districts stay high-level is 0.907, higher that the complete probability value 0.875. As is shown, local districts are more likely to ascend to higher-level districts than to descend to lower-level ones when the adjacent are high-level districts.

In addition, as for agricultural water use efficiency, this paper just takes the situation into consideration where the adjacent are low-level and mid-low-level while the local are low-level districts, since smaller number of samples will make the analysis results less convincing and stable. When the adjacent is low-level, the local have no chance to transfer to higher-level districts at all as the probability value is 0.000, namely thoroughly trapped into low level. However, the probability increases a little to 0.150, higher than the average 0.093 when the adjacent are mid-low-level districts. That's to say, it is nearly impossible for low-level districts to step forward higher-level districts when their adjacent districts are also low-level. But it is likely to transfer to higher-level districts when the adjacent is high-level. Thus, the adjacent space effect does exist. Furthermore, the probability even rises up to 0.223, far higher than the average 0.051, and it is completely impossible to ascend. However, when the local are mid-low-level while the adjacent are high-level, the probability is 0.161, also higher than the average 0.125. Therefore, adjacent high-level districts have positive influence on local districts.

Similarly, space factor has an influence on the transformation of regional industrial water use efficiency. When the adjacent districts are low-level, local districts are hindered from converting to higher-level districts, while it is opposite when the adjacent is high-level.

[3] To make the analysis more convenient, this paper only explains the results of spatial Markov chain when it is statistically significant in some year length regardless of space factor. The results are nearly the same under different year length.

TABLE VI. THE RESULTS OF TRANSITION PROBABILITY MATRIX OF SPATIAL MARKOV CHAIN OF WATER USE EFFICIENCY IN CHINA

Spatial lag	Type	Total water use efficiency					Agricultural water use efficiency					Industrial water use efficiency				
		n	L	ML	MH	H	n	L	ML	MH	H	n	L	ML	MH	H
Low-level	L	70	0.814	0.186	0.000	0.000	23	1.000	0.000	0.000	0.000	73	0.767	0.206	0.027	0.000
	ML	34	0.088	0.735	0.177	0.000	13	0.000	0.846	0.154	0.000	36	0.389	0.556	0.056	0.000
	MH	8	0.000	0.375	0.625	0.000	23	0.000	0.000	1.000	0.000	7	0.000	0.714	0.286	0.000
	H	0	NaN	NaN	NaN	NaN	0	NaN	NaN	NaN	NaN	0	NaN	NaN	NaN	NaN
Mid-low level	L	15	0.533	0.467	0.000	0.000	40	0.850	0.150	0.000	0.000	34	0.882	0.118	0.000	0.000
	ML	25	0.160	0.840	0.000	0.000	47	0.000	0.872	0.128	0.000	27	0.148	0.815	0.037	0.000
	MH	15	0.000	0.067	0.933	0.000	39	0.000	0.154	0.718	0.128	12	0.000	0.333	0.333	0.333
	H	1	0.000	0.000	1.000	0.000	17	0.000	0.000	0.235	0.765	14	0.000	0.000	0.000	1.000
Mid-high level	L	3	0.667	0.333	0.000	0.000	2	1.000	0.000	0.000	0.000	10	1.000	0.000	0.000	0.000
	ML	12	0.417	0.583	0.000	0.000	21	0.095	0.857	0.048	0.000	5	0.800	0.200	0.000	0.000
	MH	16	0.000	0.125	0.750	0.125	21	0.000	0.000	1.000	0.000	16	0.000	0.250	0.750	0.000
	H	9	0.000	0.000	0.778	0.222	29	0.000	0.000	0.035	0.966	0	NaN	NaN	NaN	NaN
High level	L	0	NaN	NaN	NaN	NaN	0	NaN	NaN	NaN	NaN	0	NaN	NaN	NaN	NaN
	ML	1	0.000	1.000	0.000	0.000	31	0.000	0.839	0.161	0.000	0	NaN	NaN	NaN	NaN
	MH	8	0.000	0.125	0.875	0.000	34	0.000	0.000	0.677	0.233	3	0.000	0.000	0.000	1.000
	H	31	0.000	0.000	0.093	0.907	1	0.000	0.000	1.000	0.000	42	0.000	0.000	0.095	0.905

Totally speaking, there exists space factor in China's water use efficiency, and the efficiency of local areas changes as that of the adjacent is different. However, is the influence significant? This paper tests the difference of spatial and non-spatial Markov chain transition probability matrix by means of Equation (3) under different year length. The results are shown in "Table VII".

TABLE VII. THE TEST RESULTS OF SPATIAL AND NON-SPATIAL MARKOV CHAIN TRANSITION PROBABILITY MATRIX OF WATER USE EFFICIENCY UNDER DIFFERENT YEAR LENGTH

Year length	Total water efficiency				Agricultural water efficiency				Industrial water efficiency			
	Q value	df	χ^2 value	p value	Q value	df	χ^2 value	p value	Q value	df	χ^2 value	p value
1	23.877	30	43.773	0.778	37.269	30	43.773	0.169	14.958	30	43.773	0.990
2	24.370	31	44.985	0.795	51.099	30	43.773	**0.010**	22.578	30	43.773	0.832
3	33.791	31	44.985	0.334	57.912	30	43.773	0.002	34.900	31	44.985	0.288
4	36.479	30	43.773	0.193	65.905	30	43.773	0.000	45.677	31	44.985	**0.043**
5	42.210	31	44.985	**0.086**	70.610	31	44.985	0.000	47.335	31	44.985	0.030

It can be known that there exists space factor in regional water use efficiency. With the year length increases, the difference of spatial and non-spatial Markov chain transition probability matrix of three types of water use efficiency is greater and greater. Of the three types of water use efficiency, agricultural efficiency needs the least time to transfer when being influenced by space factor. It can be greatly significant after mere 2 year lengths. Then the industrial efficiency follows. The total efficiency is the slowest as it is only significant under the significance level of 10%.

All in all, the analysis above can explain to some degree how the space factor affects the club convergence of China's regional water use efficiency. Whether it is better water use experiences or more technology accumulation, learning effect is highly important. And by virtue of effective policies, local districts can learn from adjacent districts about good water policies, thus spatial interaction takes effects. But this effect is more effective when it comes to high-level clubs, considering that high-level clubs have higher water saving and managing technology which makes the communication and learning more gainful. In fact, this phenomenon also explains the difference of the club convergence degree of three kinds of water use efficiency to a certain extent.

VI. CONCLUSION AND SUGGESTION

Using the data of 31 provinces in mainland China from 2003 to 2015 and employing the reciprocal of water consumption per unit of GDP to measure the water use efficiency, this paper studies the club convergence characteristic of total water use, industrial water use and agricultural water use as well as its space factor based on the analysis framework of club convergence under the model of distribution dynamics, extended Markov chain model and spatial Markov chain model. The main conclusions are as follows.

Firstly, the characteristic of club convergence is quite obvious in China's regional water use efficiency. It is nearly impossible for the clubs with same efficiency level to transfer to other clubs with higher or lower efficiency level. Although this phenomenon improves to some extent, the probability that each province still remains in the same club is very high when the year length is 5. Besides, the convergence degree is quite large among the three kinds of water use efficiency. In total, the industrial water use is highest, total water use follows, then it is the agricultural water use.

Secondly, the phenomenon of spatial agglomeration exists in the three kinds of water use efficiency, and total water use and industrial water use is quite obvious. Meanwhile, the space effect is nonnegligible. High-level adjacent districts can be helpful to promote the efficiency of local districts while low-level ones have opposite effects. This space effect can be seen in year length 2, 4 and 5 when it respectively comes to agricultural water use, industrial water use and total water use. More importantly, the difference in year length contributes to explaining the reason why the club convergence degree of industrial water use is largest and that of agricultural water use is smallest.

Based on the conclusions above, to better coordinate the regional water use efficiency, effective measures should be taken to promote more positive space effect. Firstly, more control and assistance should be applied to the members of low-level clubs to pull them out from "low-level traps". For example, the government can strength the control efforts of water use, improve water saving technology and water managing level. Secondly, more communication and learning activities should be encouraged among different clubs to enlarge the space effects. For instance, the member of low-level clubs can also learn from non-adjacent districts so as to achieve the catch-up effect.

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