

## Study on Club Convergence of Per Capita Water Resources Distribution in China—Based on Extended Markov Chain Model (Postprint)

**Authors:** Zhou Di, Zhou Fengnian, Liang Weijie

**Date:** 2018-10-23T00:00:00+00:00

### Abstract

Investigating the “club convergence” phenomenon underlying regional water resource imbalances holds important theoretical and practical significance for water resource regulation and balanced allocation of water resources. Based on per capita water resource data from 31 provinces (municipalities and autonomous regions) in China from 2004–2015, this paper employs an extended Markov chain model to examine the club convergence phenomenon in China’s inter-provincial water resource distribution across different time horizons and analyzes its temporal characteristics. The results show that even with a 5-year time accumulation, significant club convergence persists in China’s per capita water resources, with the distribution of water resources in high-level and low-level regions being highly entrenched, and the degree of club convergence has been deteriorating since 2008, indicating that current regional water resource regulation in China needs to be further strengthened. Finally, the paper classifies various regions based on factors such as the club type each region’s per capita water resources belonged to in each year of the study period and the frequency of type transitions, to provide support and reference for regional water resource regulation.

### Full Text

### Preamble

**ChinaXiv Cooperative Journal**

doi:10.12118/j.issn.1000-6060.2018.04.24

**ARID LAND GEOGRAPHY**

**Authors:** ZHOU Di<sup>1</sup>, ZHOU Feng-nian<sup>2</sup>, ZHONG Shao-jun<sup>3</sup>

**Affiliations:** <sup>1</sup> School of International Trade & Economics, Guangdong University of Foreign Studies, Guangzhou 510006, Guangdong, China

<sup>2</sup> Changjiang River Estuary Bureau of Hydrological and Water Resources Survey, Changjiang River Estuary Water Environment Monitoring Center, Shanghai 200136, China

<sup>3</sup> College of Mathematics and Statistics, Hubei University of Science and Technology, Xianning 437100, Hubei, China

## Abstract

Studying the phenomenon of “club convergence” behind the imbalance of regional water resources is of great theoretical and practical significance to the regulation and balanced allocation of water resources. This paper examines the “club convergence” of interprovincial water resource distribution in China across different time spans, analyzing its temporal characteristics using an extended Markov chain model based on per capita water resource data from 31 provinces (including municipalities directly under the central government and autonomous regions) in China from 2004 to 2015. The results show that an obvious phenomenon of “club convergence” exists for per capita water resources in China, with the distribution pattern becoming highly solidified in both high and low resource areas after five years. Since 2008, the trend of “club convergence” has begun to grow in the direction of deterioration. Therefore, the coordination of regional water resources needs to be further strengthened. Finally, the paper classifies regions according to club type and transfer frequency of per capita water resources during the investigation period to provide support and reference for regional water resources regulation.

**Keywords:** water resources; club convergence; Markov chain model; water resources regulation

## 1. Introduction

The uneven spatial distribution of water resources in China has long been a critical constraint on regional sustainable development. Research on water resource distribution patterns has increasingly focused on the phenomenon of “club convergence,” where regions with similar water resource endowments cluster together and exhibit persistent disparities from other groups. Previous studies have applied various methods including cloud models [5], GIS spatial analysis [5-7], and other spatial information technologies to investigate water resource distribution and security issues. Understanding the club convergence phenomenon is essential for developing effective water resource allocation policies and promoting coordinated regional development. This study employs an extended Markov chain approach to analyze the temporal dynamics of per capita water resource distribution across Chinese provinces.

## 1.1 Data and Methods

The study utilizes per capita water resource data classified into four categories based on national standards: (1) Abundant:  $>3000$  m<sup>3</sup> per capita; (2) Relatively abundant: 1000-3000 m<sup>3</sup>; (3) Relatively scarce: 500-1000 m<sup>3</sup>; and (4) Scarce:  $<500$  m<sup>3</sup>. The Markov chain model is employed to analyze transition probabilities between these categories over time. The model calculates transition probabilities using the formula:

$$n_{ij}(\lambda) = -2 \log \Pi_{ij}(\lambda)$$

where  $n_{ij}(\lambda)$  represents the transition count from state  $i$  to state  $j$  at time  $\lambda$ , and  $P_{ij}(\lambda)$  denotes the transition probability matrix. The extended Markov chain approach allows for analysis of both the probability and speed of transitions between water resource categories.

**Table 1. Standard scale of water resources per capita**

Level	Per capita water resources (m <sup>3</sup> )	Classification
1	$>3000$	Abundant
2	1000-3000	Relatively abundant
3	500-1000	Relatively scarce
4	$<500$	Scarce

## 1.2 Data Source

The analysis covers 31 provincial-level regions in China from 2004 to 2015. Data on total water resources and permanent population were obtained from the China Water Resources Bulletin and China Statistical Yearbook. Per capita water resources were calculated by dividing total water resources by permanent population. The 12-year study period provides sufficient data to capture both short-term fluctuations and long-term trends in water resource distribution patterns.

## 3. Results

### 3.1 Spatial Distribution Patterns

The spatial analysis reveals significant clustering of water resource endowments. Regions with abundant per capita water resources are predominantly located in southern and southwestern China, while scarce regions concentrate in northern and eastern coastal areas. The Markov transition probability matrix (Table 2) demonstrates strong state dependence, with diagonal elements exceeding 0.7 for all categories, indicating high stability within each water resource level.

**Table 2. Markov transition probability matrix of per capita water resources at different time spans**

Initial State	Abundant	Relatively Abundant	Relatively Scarce	Scarce
Abundant	0.937	0.063	0.000	0.000
Relatively Abundant	0.111	0.716	0.173	0.000
Relatively Scarce	0.000	0.250	0.481	0.269
Scarce	0.000	0.043	0.186	0.771

The results indicate that 73.9% of regions maintain their initial water resource classification over time, confirming the club convergence phenomenon. Only 26.1% of regions experience transitions, with most moving to adjacent categories rather than jumping multiple levels.

### 3.2 Temporal Characteristics

Temporal analysis identifies 2008 as a critical turning point. Before 2008, transition probabilities between water resource categories showed modest fluidity. After 2008, the diagonal probabilities in the transition matrix increased significantly, indicating greater rigidity in the distribution pattern. The trend of club convergence began growing in a deteriorating direction, meaning that water-scarce regions became increasingly likely to remain scarce while water-abundant regions maintained their advantage.

The speed of convergence accelerated post-2008, with the probability of remaining in the same category increasing by an average of 8.5% across all states. This solidification of water resource disparities suggests that natural endowments, reinforced by socioeconomic factors and water infrastructure development, have created persistent club structures. The findings underscore the need for strengthened inter-regional water resource coordination and targeted allocation policies to address these entrenched disparities.

### References

- [5] References to cloud model and GIS applications in water resources research.
- [6] LIU Bintao, TAO Heping, KONG Bo, et al. Research on water resources security and its temporal-spatial distributions of Yunnan Province, China[J]. Journal of Natural Resources, 2014, 29(3): 454-465.
- [7] LEI Ying, JIANG Dong, YANG Xiaohuan, et al. The water distribution model application based on spatial information technology[J]. Geo-Information Science, 2007, 9(5): 64-69+127.

- [8] BAO Chao, HE Dongmei. Spatiotemporal characteristics of water resources exploitation and policy implications in the Beijing-Tianjin-Hebei urban agglomeration[J]. Progress in Geography, 2017, 36(1): 58-67.
- [9] ZHANG C, LIU Y, QIAO H. An empirical study on the spatial distribution of population, economy and water resources in northeast China[J]. Physics and Chemistry of the Earth, Parts A/B/C, 2015, (79): 93-99.
- [10] DAVIJANI M H, BANIHAJIB M E, ANVAR A, et al. Optimization model for the allocation of water resources based on the maximization of employment in agriculture and industry sectors[J]. Journal of Hydrology, 2016, 533: 430-438.
- [11] HU Z, CHEN Y, YAO L, et al. Optimal allocation of regional water resources: From a perspective of equity-efficiency tradeoff[J]. Resources, Conservation and Recycling, 2016, (109): 102-113.
- [12] ZHANG Mingming. Systems analysis and optimal allocation of water resources in the middle reaches of Heihe River[D]. Xi' an: Northwest University, 2007.
- [13] HOU Jingwei, KONG Yunfeng, SUN Jiulin. Optimal allocation of water resources based on multi-objective fish-ant colony algorithm[J]. Resources Science, 2011, 33(12): 2255-2261.
- [14] PAN Xiongfeng, YANG Yue. Research on regional innovation club convergence and influencing factors in China[J]. Studies in Science of Science, 2014, 32(2): 314-319.
- [15] ZHOU Di. Regional disparities and distribution dynamic of financial scale in China from “Quantity” and “Quality” perspective-based on Gini decomposition and extended distribution dynamics models[J]. Shanghai Economic Review, 2015, (1): 19-29.
- [16] PAN X, LIU Q, PENG X. Spatial club convergence of regional energy efficiency in China[J]. Ecological Indicators, 2015, 51: 25-30.
- [17] SHI Hui. Spatial dependence and distribution of agricultural productivity among provinces in China[J]. Resources Science, 2010, 32(7): 1323-1332.
- [18] LE G J. Space-time analysis of GDP disparities among European regions: A Markov chains approach[J]. International Regional Science Review, 2004, 27(2): 138-163.
- [19] ZHOU Di, CHENG Huiping. Evolution of convergence and spatial patterns of agricultural modernization in China[J]. Journal of South China Agricultural University (Social Science Edition), 2015, (1): 25-35.

*Note: Figure translations are in progress. See original paper for figures.*

*Source: ChinaXiv – Machine translation. Verify with original.*