Analyzing the Spatial Correlation Between Regional Economic Level and Water-Use Efficiency in Jiangsu Province

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Abstract. A spatial regression model between regional economy and water-use efficiency was built by using per capita GDP and water consumption of every ten thousand yuan of all the cities in Jiangsu province during 2009 to 2011. Based on spatial correlation analysis between economy and water-use efficiency in Jiangsu province through Moran's index, local Lisa figure and Moran scatter chart, the regional economy development and water-use efficiency in Jiangsu province are obviously spatial-clustered, decreasing progressively from southern, central to northern cities. When considering the relationship between per capita GDP and water use of per every ten thousand yuan, HH zone does not exist, LH zone includes Xuzhou, Huaian, Lianyungang, Suqian, Yancheng and Yangzhou cities, LL zone is Taizhou, and HL zone includes Nanjing, Wuxi, Changzhou, Suzhou and Zhenjiang cities. It could be concluded that spatial differences of regional economic developing level is the most significant factor to water-use efficiency.

Keywords: Regional economy · Water-use efficiency · Spatial correlation

1 Introduction

In order to achieve the sustainability of water resources and social economic development, the Chinese Government released the strictest water resources institution in which addresses the total volume control of water use, water use efficiency and water quality. Improving water-use efficiency means to conserve water resources, reduce waste, promote structural adjustment of water use, change the ways of water use and production. However water use efficiency is different in terms of different regions, and related with regional economic development. Regional is an open and complex system, and inter-regional interaction and mutual influence can lead to a high correlation between regions in many characters (Cui and Wei 1999). How to quantify the relationship between water use efficiency and economic development in different regions concerns the improvement of water use efficiency.

In the context of spatial difference of regional economy discussions have taken place in the literature on how to reveal the spatial difference of regional economy through

F. Bian and Y. Xie (Eds.): GRMSE 2015, CCIS 569, pp. 525–533, 2016.
DOI: 10.1007/978-3-662-49155-3_55

spatial econometric models (Barro and Sala 1991; Chen and Fleisher 1996; Giuseppe 2006; Sergio et al. 1999; Wei and Fan 2000; Long 2001; Shen and Zhai 2003; Ou and Gu 2004). Wang and Wu (2005) investigated that regional economic growth was not only dependent on its internal factors, but also increasingly the surrounding areas in an open regional economy. Li (2006) estimated the spatial difference of water use efficiency of China. The results showed a higher level of economic development were accompanied by a high rate of urbanization, the increasing proportion of non-agricultural industries and a reducing proportion of agricultural water consumption. So it can reduce the water consumption per ten thousand yuan GDP and improve outcome per water use unit. The above studies emphasize either the regional spatial difference of economy or one of water use efficiency, and less address both of them. This paper explores the regional spatial relationship difference of both economy and water use efficiency using the exploratory spatial data analysis in the 13 cities of Jiangsu province.

Exploratory spatial data analysis is a spatial data analysis method with identification function. The spatial autocorrelation coefficient is usually used to measure and test the space distribution of the adjacent objects and their attributes. It includes the positive spatial correlation with similar values and trend and the negative spatial correlation with the opposite values and trends. This paper uses the exploratory spatial data analysis method, combines, and builds the spatial correlation model of single factor and double factors with the data of regional economic development level and water-use efficiency to improve the efficiency of regional water by analyzing the spatial difference of regional economic. The specific analysis of Moran index, local Lisa I figure and Moran scatter diagram is used to explore the space relation of regional economy of Jiangsu province and water-use efficiency with Geoda spatial analysis software.

2 Study Area and Data Sources

Since 1992 Jiangsu province has kept a stable growth year by year. In 2011 year, the GDP was 54058.2 billion yuan, and per capita GDP was 68347 yuan with an increase of 6057 yuan than one of 2000 year.

Jiangsu province has 13 cities, and water use among the cities is obviously different. The acreages of the southern, northern and central sub-regions of Jiangsu province account for 28 %, 20 % and 52 %, however the water uses of the three sub-regions water consumption of southern Jiangsu region account for 41.8 %, 34.8 % and 23.4 %. Jiangsu province is rich in water resources, but scarce per capita water resources. Water shortage use efficiency and worse water environment has become constraints in promoting the economic development of Jiangsu (Gu 2013). Since 1949, Jiangsu province has implemented a balanced development and unbalanced development, regional common development, southern Jiangsu development, coastal development five development strategies in the regional economic development. However because of the difference of nature, society, economy, history, and other factors, economic differences of among the cities and among sub-regions are obvious (Zhu et al. 2004). With the development of regional economy, the demand of water resources increases gradually.

It is a necessary way to improve the utilization rate of water use to ease the water shortage (Sun et al. 2004).

The per capita GDP and water use per ten thousand yuan output value of 13 cities in Jiangsu province are used from year 2009 to 2011 in the following model. The GDP per capita data come from the statistical yearbook of Jiangsu province, and water use data of ten thousand Yuan output value is from the official reports on water resources in Jiangsu province. Combined with the administrative map of Jiangsu province, per capita GDP was taken as a variable indicator to measure regional economic differences, and ten thousand yuan output value of water consumption as measures of regional water use efficiency.

3 Methods

3.1 Global Spatial Autocorrelation

Global spatial autocorrelation indicates the characteristics of the spatial distribution of global location and attribute variables, and is used to test the spatial correlation or spatial heterogeneity across the adjacent regions in the whole research area. Moran's I is the commonly used indicator, and the formula is shown as following.

$$I = \frac{N \sum_{i=1}^{N} \sum_{j=1}^{N} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{N} \sum_{j=1}^{N} w_{ij} \sum_{i=1}^{N} (x_i - \bar{x})^2} \tag{1}$$

where, N is the number of the space units; x_i and x_j indicate the attributes of regional i and j; $\bar{x}$ is the sample mean, $\bar{x} = \frac{1}{N} \sum_{i=1}^{N} x_i$; S2 is the sample variance, $\mathrm{S2} = \frac{1}{N} \sum_{i} (x_i - \bar{x})^2$; w_{ij} is the binary spatial weight (using adjacent standard, when adjacent regional i and $j = 1$, when regional i and j non-adjacent $= 0$).

$$w_{ij} = \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1N} \\ w_{21} & w_{22} & \cdots & w_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ w_{N1} & w_{N2} & \cdots & w_{NN} \end{bmatrix} \tag{2}$$

Moran index generally ranges from -1 to 1. A Moran value greater than zero indicates the positive correlation, the Moran value of samples closer to 1 indicates that they have similar attributes and put them together. So the overall spatial difference is small. A value less than zero indicates the negative correlation, the Moran value of samples closer to -1 indicates that they are put together with different attributes, and they have the huge spatial difference. When Moran index I equals zero, it shows that the samples

are independent each other, and randomly distributive in space. So there is no spatial autocorrelation among them.

3.2 Local Spatial Autocorrelation

Ansalin proposed a local Moran index (LMI), also known as LISA (Local indicator of Spatial Association). LISA is used to measure the effects of aggregation or discrete to each geographical unit as the center of a small area, and identify the spatial concentration (hot or cold spots) and outliers (Anselin 1995). Moran scatter chart and Lisa are used to explore the spatial distribution by the visualization of spatial relationship. For example, LMI of zone i can be expressed as follows.

$$I_i = \frac{(x_i - \bar{x})}{S^2} \sum_{j \neq i} w_{ij}(x_j - \bar{x}) \tag{3}$$

where I_i is the LMI.

4 Results

4.1 Spatial Data Analysis of Regional Economy in Jiangsu Province

The univariate Moran's index autocorrelation test of per capita GDP of 13 cities in Jiangsu province was made by software Geoda. Figure 1 showed that the Moran values of economic were 0.5811, 0.5979 and 0.6029 from year 2009 to 2011. Moran value is positive and greater than 0.5 under the Significant levels 0.01. So the 13 cities economic development demonstrated a strong positive correlation in space, Moran value was increasing year by year, and their mutual penetration degree and spillover effect were becoming more and more obvious.

The indicators of four quadrants in Fig. 1 were: high - high (HH), low - high (LH) and low - low (LL), high - low (HL). The indicators of the 13 cities focused mainly on the HH and the LL quadrants. Two cities located in the LH quadrant, and no city were in the fourth quadrant. So it showed that – HH and LL coexisted. Suzhou, Wuxi, Changzhou, Zhenjiang, Nanjing cities located in the – HH. Suzhou, Wuxi and Changzhou cities are an economic developed part of the Yangtze River Delta. Although the per capita GDP of Zhenjiang is slightly lower than other four cities located in HH quadrant, it is adjacent to Nanjing and Changzhou, and located in Shanghai-Nanjing industrial belt with transportation, ports, freight and other advantages, and the economy has made a rapid development in recent years. As Jiangsu's political, economic and cultural center, the economic development of Nanjing has been in a leading position in a long time. Taizhou and Nantong cities were in LH quadrant. They are located in the north of the Yangtze river without obvious advantages, and economic development has been slow. Yangzhou, Yancheng, Huaian, Xuzhou, Lianyungang and Suqian cities were in LL quadrant. Yangzhou is close to the economy strongly developed southern regions:

Suzhou and Wuxi and some other rich cities. The economy of its' northern cities were poor, so they also showed a low value.

Figure 2 shows that there is an obvious geographic difference of 13 cities' economy in Jiangsu province. It includes the developed south, the middle central and the less developed north in Jiangsu province. The gray zone in Fig. 2 indicates no significant, the red zone (HH) shows economy development levels are high, the blue zone (LL) indicates low levels of economic development, and light blue zone represents the low level of economic development and high level development. The aggregation of south and north of Jiangsu province is significantly in spatial, and the central Jiangsu is non-significant. It reveals that the regional economic development in Jiangsu province is uneven in spatial distribution and presents a big north-south differences. The cities like Suzhou and Nanjing in south are the priority development cities, focusing on investment and construction. So it plays an important role in the process of rapid economic development, and the north only get more development in recent years because they are put into a part of a national strategy (Yang and Zhu 2013).

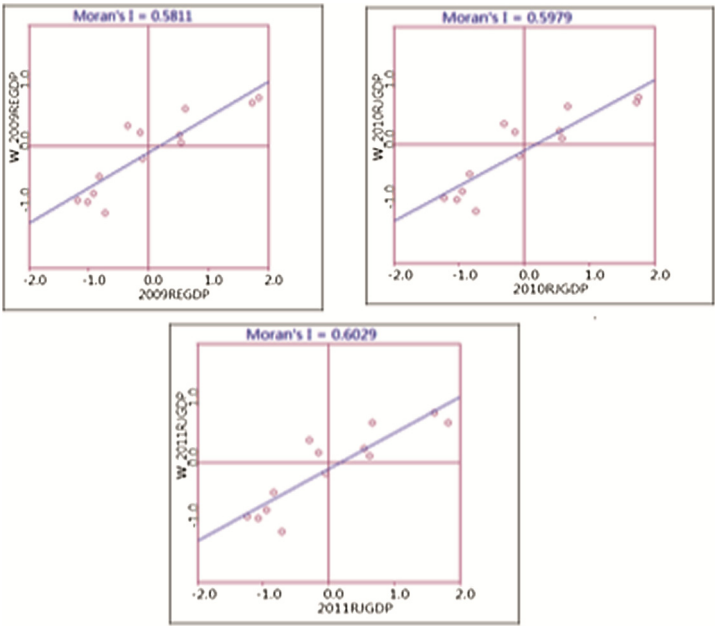

Fig. 1. The Moran scatter chart of economic level of 13 cities in Jiangsu province

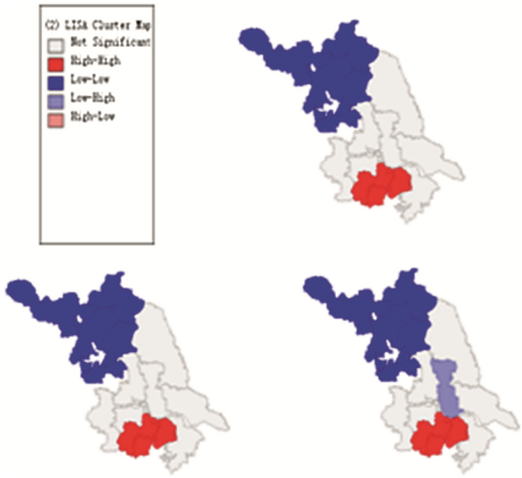

Fig. 2. The Lisa cluster of economic level of 13 cities in Jiangsu province (Color figure online)

4.2 Spatial Data Analysis of Water-Use Efficiency in Jiangsu Province

Figure 3 shows that Moran values of water use efficiency of the 13 cities in Jiangsu province from 2009 to 2011 were 0.4572, 0.4608 and 0.4188 under the significant level 0.01. Water use efficiency of the 13 cities was the spatial correlation, the neighbor cities had many obvious similarities, and the inter-annual fluctuations between them were small. Huaian, Lianyungang, Yancheng and Yangzhou cities were in the HH quadrant, indicating that water use of per ten thousand yuan were high, and their neighbor zones were also high. Nantong and Xuzhou cities were in the LH quadrant, water use of per ten thousand yuan were relatively low and their neighbor zones were much higher, which implied that their water use efficiency was relatively higher than their adjacent cities. Suzhou, Wuxi, Changzhou, Zhenjiang and Nanjing cities were in LL, which indicated that water use of per ten thousand yuan of these cities and neighbor zone were low. Taizhou cities was in the HL quadrant, and its' water use of per ten thousand yuan and neighbor zones were low.

Figure 4 showed that the red HH zones were the several cities in northern Jiangsu, indicating the water use efficiency is low in Northern region. The LL blue zones were a few cities located in southern Jiangsu, and sometimes also showed no significant. These results displayed that the high water use efficiency is not common, and there is enough space for water use. Xuzhou city located in northern Jiangsu was in LH zone, surrounded by red zone, and its water use efficiency was higher in contrast with other cities. Taizhou city located in the central of Jiangsu province was in the HL zone. Its water use efficiency was low and neighbor was high. The above analysis shows that the order of water use efficiency level is decreasing progressively from southern, central to northern of Jiangsu province.

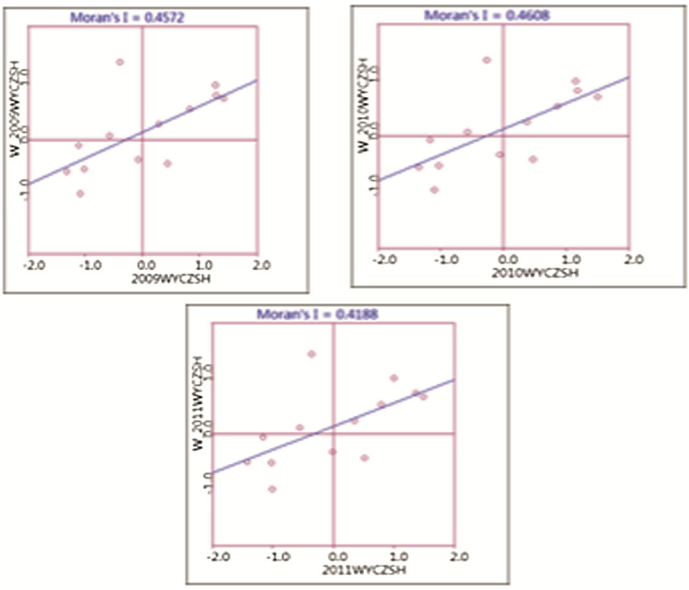

Fig. 3. The Moran scatter chart of water use efficiency of 13 cities in Jiangsu province

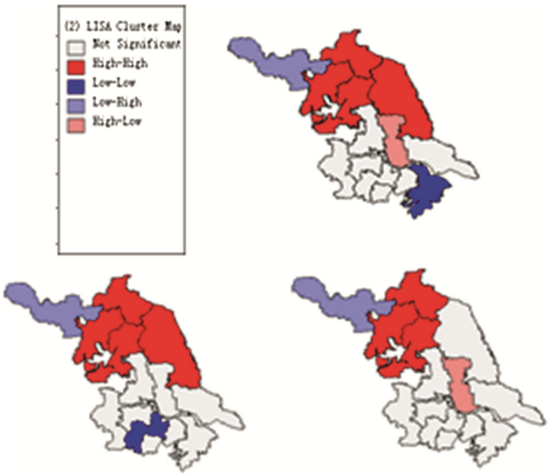

Fig. 4. The Lisa cluster of water use efficiency of 13 cities in Jiangsu province (Color figure online)

4.3 Two-Factor Association Analysis of Regional Economy and Water-Use Efficiency in Jiangsu Province

Figure 5 showed the spatial relationship between regional economy development level and water use efficiency of the 13 cities in Jiangsu province. The model data were from

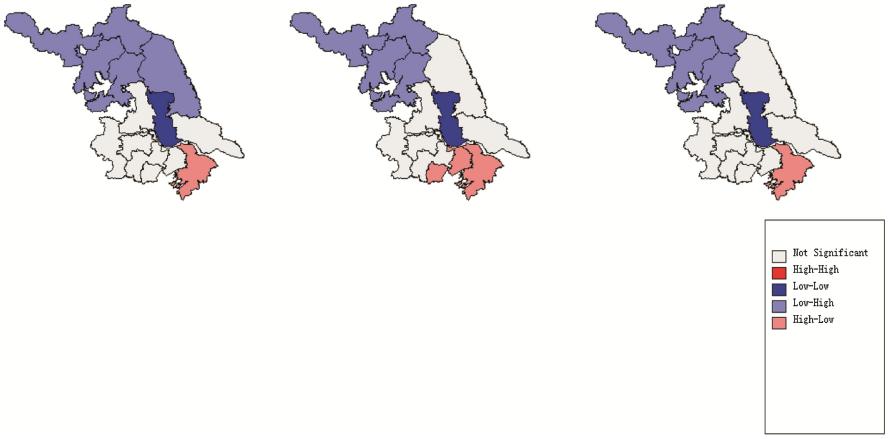

Fig. 5. The double factor Lisa cluster of economic level and water use efficiency of the 13 cities in Jiangsu province (Color figure online)

per capita GDP and water use of per ten thousand yuan in 2009 to 2011. The HH red zone did not exist. It reveals that the high level of economic development and the high water use of per ten thousand yuan (low water use efficiency) zones did not exist. This supports the claim of the positive correlation between water use efficiency and economic development level.

The LL zone was the city where the economic development and water use of per ten thousand yuan were low (high water use efficiency), and the corresponding area was Taizhou city located in the central of Jiangsu province. The economic development of the city lags far behind the southern cities and its water use efficiency is higher than northern cities. The LH light blue zone indicates a low level of economic development and high water use of per ten thousand yuan (low water use efficiency). There are five northern cities in LH zone. HL light red zones indicate high levels of economic development and low water use of per ten thousand yuan (high water use efficiency), mainly gathered and concentrated in economically developed southern cities. These results imply that the economic level is almost consistent with the geographic distribution of water use efficiency in Jiangsu Province, and there are a long time gap between the north and south cities. So a high economy level supports the improvement of water use efficiency.

5 Conclusions

Both economy level and water use efficiency display the significant spatial clustering in Jiangsu province from 2009 to 2011. There is a clear difference among the southern, central and northern cities, and the spatial correlation of the 13 cities is obvious. The water use efficiency of the southern cities is high because of high economic level, and the one of middle and northern cities is low because of the backward economy. The flow of production factors and human resource makes the gap of different cities bigger

and bigger. So the economic level has been the most significant factor affecting the water use efficiency in a long time.

Acknowledgements. Support for this research was provided by a grant from the National Natural Science Foundation of China (No. 51109055, 51279223, 51479119, 51579064), Public-services Foundation of Ministry Water Resources of China (No. 201301003, 201201022), The National Soft Science Research Program (2014GXS4B047), and Social Science Foundation from the Jiangsu Province (No. 11GLA001).

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