Evaluation of Fragility of the Economic System in Poyang Lake Ecological Economic Zone

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Abstract   From two aspects，namely the sensitivity of regional economic system to internal and external interference，and its resilience，we establish the evaluation indicator system of fragility of the economic system in Poyang Lake Ecological Economic Zone，and evaluate the internal differences in fragility of the regional economic system，using set pair analysis method. The results show that there is a great difference in fragility of the economic system between different administrative units；the difference in resilience is the major factor responsible for difference in fragility of the economic system in various cities and counties within the region；according to the difference in fragility characteristics，we conduct classification as follows：Nanchang City is a low-sensitivity and high-resilience type；Jiujiang City is a high-sensitivity and high-resilience type；Jiujiang County, Xingzi County，Yongxiu County，Hukou County，Duchang County，Ruichang County，De'an Xian，Wuning County，Pengze County，Leping City，Dongxiang County，Fengcheng City and Gao'an City are a high-sensitivity and low-resilience type；other cities and counties are a low-sensitivity and low-resilience type.

Key words   Fragility evaluation，The economic system，Poyang Lake Ecological Economic Zone，Set pair analysis

The research of fragility，as important research content，has been put on the research agenda by a lot of international scientific programs and institutions，becoming a hot issue that the scientific field of global environmental change and sustainability pay close attention to[1]. The fragility study has translated from fragility of the initial simple natural system to fragility of human system，and the research framework is constantly improved[2-3]，gradually developing into an emerging discipline[1,4]. But in different areas，there are great differences in the definition of the concept of fragility：one view holds that fragility，similar to risk，means exposure to adverse effects or the possibility of suffering from damage；some scholars define fragility focusing on results from the system confronting disturbances；there are also some other concepts of fragility highlighting the manifestations and causes of fragility. Gallopin G. C. conducts analysis on the basis of cause of system fragility，believing that fragility is composed of sensitivity of system to the external disturbance and ability of system to respond to the external disturbance，which is the property of the system[1,5]. Li He and other scholars define the fragility of economic system as the sensitivity of economic system to disturbance inside and outside region，and a kind of state of being inclined to evolve toward a direction unfavorable for sustainable regional development，for want of resilience[6]. The sensitivity of system to disturbance is related to its internal conditions and characteristics of suffering from disturbance，while the resilience is determined by the internal conditions of system.

The construction of Poyang Lake Ecological Economic Zone is a major strategic move based on Jiangxi's unique resources advantages and environmental advantages. At present，the studies concerning fragility of this region mainly include fragility of ecological environment[7-10]，and the fragility of farmers to cope with floods[11]；the studies on fragility of the economic system are relatively weak. The internal characteristics of the economic system are the main cause of fragility. Taking Poyang Lake Ecological Economic Zone as the study area，we establish evaluation indicator system from the sensitivity of economic system to the inside and outside interference and resilience of the system，and use set pair analysis method to study fragility of the economic system in the region，in order to provide a scientific basis for relevant departments to formulate regional economic development policies，and in the mean time，provide a new case and research perspective for the researches of fragility of the economic system.

1   Indicator selection，data source and research method

1.1   Overview of the study area   Poyang Lake Ecological Economic Zone is located in northern Jiangxi Province，including 6 cities（Nanchang City，Jingdezhen City，Yingtan City，Fuzhou City，Xinyu City，and Jiujiang City），and 25 county-level cities（Nanchang County，Xinjian County，Anyi County，Jinxian County，De'an County，Xingzi County，Yongxiu County，Hukou County，Duchang County，Wuning County，Ruichang City，Jiujiang County，Pengze County，Poyang County，Wannian County，Yugan County，Fengcheng City，Zhangshu City，Gao'an County，Dongxiang County，Leping City，Fuliang County，Guixi City，Yujiang County，and Xingan County）. It is an important ecological function conservation zone in

China, responsible for flood regulation, water storage, climate regulation, degradation of pollution and other ecological functions. Continuance and stability of water amount and water quality in Poyang Lake, is directly related to water use safety around the Poyang Lake, and even the middle and lower reaches of the Yangtze River. In recent years, with quickened pace of regional economic development, the regional GDP in 2009 was 445.382 billion yuan, accounting for 58.18% of the provincial GDP. More than half of the province's economic output is concentrated in the region. However, it is in a critical period of mounting pressure on the resources and energy, the deterioration of the ecological quality, along with the region's rapid economic development. Resources and environment is the support system for the economic system, and the regional economic system is vulnerable to the interference of the resources and environmental problems caused by low technology level, having typical characteristics of fragility.

1.2 Establishment of indicator system and data source

The basic purpose of the construction of Poyang Lake Ecologi-cal Economic Zone is to coordinate the spatio-temporal relationships between ecology and economy in the process of economic development. Under the pressure and impact of economic globalization, the quality of resources and environmental should deserve special attention. Low efficiency of resource use will trigger a series of serious resource and environmental issues. As to the fragility assessment of system, if we take all disturbance factors into consideration, there will be too many factors to be analyzed, failing to stress the essentials. In terms of regional resources use problem, we establish sensitivity indicators; in terms of economic scale, industrial structure, economic openness, economic environment and other aspects, we establish resilience indicators. In accordance with scientific, operable, hierarchical, and dynamic principles, we refer to the research results of the previous scholars[3,12-15], to establish evaluation indicator system, and determine the indicator weight using the entropy method[16] (Table 1). All indicator data are from *Jiangxi Statistical Yearbook* in 2010.

Table 1 The evaluation indicator system of fragility of the economic system in Poyang Lake Ecological Economic Zone

Target	Criterion	Function	Indicator	Weight
Fragility of the economic system	Sensitivity	The level of resources utilization	The overall industrial labour productivity (10^4 yuan/person)	0.097 1
			Power consumption per unit of output value (kW·h)	0.083 6
			Fertilizer use efficiency(%)	0.083 1
	Resilience	Economic scale	Per capita GDP(yuan)	0.073 0
			GDP per area (10^4 yuan /km^2)	0.036 3
			Financial self-sufficiency rate(%)	0.062 3
			Investment density of fixed assets (10^4 yuan/km^2)	0.035 0
			Total output value of industry above the designated size (10^4 yuan)	0.043 1
		Industrial structure	Industrialization coefficient of the primary industry(%)	0.063 9
			The proportion of value added in the tertiary industry to GDP (%)	0.077 2
			Social retail goods (10^4 yuan)	0.034 1
		Openness	The proportion of actual foreign capital used to GDP (%)	0.086 4
		Economic environment	Highway mileage(km)	0.035 8
			Phone use rate(%)	0.069 9
			Internet users(person)	0.033 0
			Business transactions of postal and telecommunication services (10^4 yuan)	0.043 6
			Proportion of the number of full-time teachers to the total population(%)	0.042 6

1.3 Research method For the regional economic system, as an open system, there are many certainties and uncertainties. There is no scientific definition accepted with unanimity, but scholars mostly believe that fragility is a relative concept, the intrinsic property of system relative to specific disturbance[1]. Given the complexity and uncertainty of the fragility of the regional economic system, we assess the fragility of the economic system in Poyang Lake Ecological Economic Zone, using set pair analysis method. We synthesize the evaluation indicators of different administrative units in Poyang Lake Ecological Economic Zone in 2009, into the relative closeness to the optimal evaluation set, to reflect the relative size of the fragility of the economic system.

The set pair analysis method is an uncertainty analysis method advanced by the Chinese scholar Zhao Keqin[17]. Due to objective recognition, systematic depiction and specific analysis of uncertainties, the research results are more close to reality[18-19]. The core idea of the set pair analysis is to regard certainty and uncertainty as a system, and view two sets with a link as a set of pairs; in the context of a specific issue, to establish sameness, difference and antagonism connection degree expression of the two sets, in accordance with a certain

particular characteristic of set of pairs, and accordingly conduct the analysis[3].

Let multi-attribute evaluation problem $Q = \{D, E, H\}$, where the administrative region set $E = \{e_k\}$ ($k = 1, 2, \cdots, m$); e_k is the administrative region k; the evaluation indicator set $D = \{d_s\}$ ($s = 1, 2, \cdots n$); d_s is the evaluation indicator s; the decision-making matrix based on Q (set pair analysis problem) $H = (h_{sk})_{n \times m}$; h_{sk} is the value of indicator s in the administrative region k. In the same scale, by comparison, we determine the optimal evaluation indicators, constituting the optimal evaluation set $U = \{u_1, u_2, \cdots, u_n\}$; we determine the worst evaluation indicators, constituting the worst evaluation set $V = \{v_1, v_2, \cdots, v_n\}$. where u_s and v_s are the optimal value and the worst value of the indicators, respectively. When h_{sk} has positive impact on the evaluation results, $a_{sk} = h_{sk}/(u_s + v_s)$, $c_{sk} = h_{sk}^{-1}/(u_s^{-1} + v_s^{-1})$; when h_{sk} has negative impact on the evaluation results, $a_{sk} = h_{sk}^{-1}/(u_s^{-1} + v_s^{-1})$, $c_{sk} = h_{sk}/(u_s + v_s)$, where a_s and c_{sk} are the closeness of h_{sk} to u_s and v_s.

On the basis of the weight w_s of various indicators, we calculate the average same degree of membership a_k and the average opposing degree of membership c_k.

$$a_k = \sum w_s a_{sk}, \quad c_k = \sum w_s c_{sk}$$

where a_k and c_k are the positive and negative degree of h_k close to U. So under the relatively definite conditions, we can define the relative closeness of indicator set of e_k and the optimal evaluation set U: $r_k = a_k/(a_k + c_k)$, where r_k reflects the mutual correlation between indicator set of e_k and the optimal evaluation set U; the higher the value, the greater the correlation with the optimal evaluation set, the more ideal the indicator set of administrative area e_k.

For the specific issue concerning fragility of the economic system in Poyang Lake Ecological Economic Zone, we combine 31 administrative units in the study area together, to conduct analysis, in accordance with the fragility characteristic of the economic system. By standardization processing, we transform all indicators into the indicators having positive impact on the evaluation results, and combine the maxima of indicators into the optimal evaluation set. We synthesize the regional evaluation indicators of different administrative units into relative closeness (r_k) to the optimal evaluation set, to reflect the relative size of the fragility of the economic system. The greater the value of r_k, the higher the fragility degree of the economic system; the smaller the value of r_k, the lower the fragility degree of the economic system.

2   Fragility assessment of the economic system

According to the data from *Jiangxi Statistical Yearbook* in 2010, we display the distribution status of fragility in the regional economic system by Arcgis 9.3 software, after calculating the relative closeness of cities in Poyang Lake Ecological Economic Zone reflecting the size of fragility, using set pair analysis method, as shown in Fig. 1.

From Fig. 1, we can find that there is a prominent difference in fragility of the economic system between different administrative units within Poyang Lake Ecological Economic
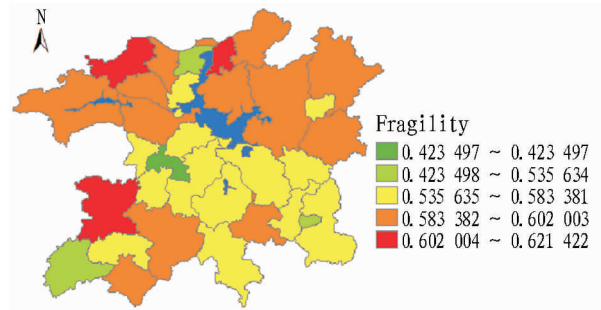

Fig. 1   Spatial distribution of fragility of the economic system in Poyang Lake Ecological Economic Zone

Zone. The fragility of the economic system in Ruichang County, Hukou County, and Gao'an City is the greatest; the fragility of the economic system in Nanchang City is the smallest. Impacted greatly by water body of Poyang Lake, the fragility of the northern region is greater than that of the southern region on the whole. The sensitivity and resilience of the economic system to disturbance are two factors affecting the size of fragility, but the influence degree is different. We conduct correlation analysis of fragility index and sensitivity index, fragility index and resilience index, we get the correlation coefficients of 0.48 and −0.94, respectively. It can be clearly seen that the difference in resilience is the major factor responsible for difference in fragility of the economic system in various cities and counties in Poyang Lake Ecological Economic Zone.

To further investigate the differences and similarities in fragility characteristics of different counties and cities, we draw the scatter plot of regional sensitivity index and resilience index, and divide the fragility of economic system into 4 types (Fig. 2).
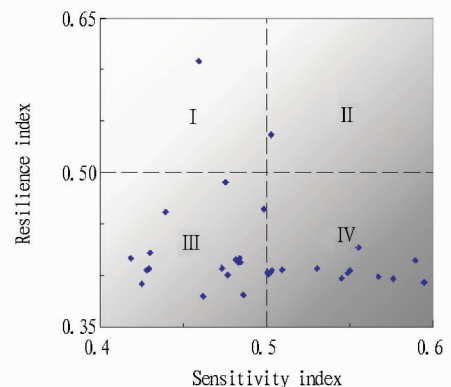

Fig. 2   Scatter plot of the fragility characteristics of the economic system

Type I: low-sensitivity and high-resilience type

It includes Nanchang City. In 2009, GDP in Nanchang City was 124.6 billion yuan, accounting for 28% of GDP in whole region, 11.7 times the average of GDP in 30 other administrative units. Investment density of fixed assets in Nanchang City was 170 million yuan/km², 13 times the average in whole region. In terms of industrial structure, in 2009, the output value of tertiary industry in Nanchang City accounted for 45% of GDP. The total retail sales of social consumer goods were 51.68 billion yuan, accounting for 35.7% of retail sales of so-

cial consumer goods in whole region. In terms of economic scale, industrial structure, and economic environment, Nanchang get score conspicuously higher than other counties and cities, only lagging behind Xinyu City, De'an County, Xingzi County, Duchang County and Pengze County in terms of the economic openness. In face of the inside and outside disturbance, the economic system in Nanchang City shows strong resilience. In terms of the level of overall utilization efficiency of resources, it is also at a relatively high level. Therefore, the degree of fragility of it, is relatively lowest.

Type Ⅱ: high-sensitivity and high-resilience type

It includes Jiujiang City (Xunyang District, Lushan District). Jiujiang City, located in the confluence the Beijing – Kowloon Railway and the Yangtze River, and the connecting band of the Yangtze River Delta and the Pearl River Delta, is transport hub in the Beijing – Kowloon line and an important port for the Yangtze River economic development belt. Xunyang District has opportunities to receive the economic radiation and potential for great development; Lushan District is at a relative disadvantage in terms of the mobility of factors of regional resources. In recent years, Xunyang District, on the basis of project introduction, the transformation of old building, and the market construction, vigorously develops modern urban industry, driving the rapid and steady development of the economy. In 2009, per capita GDP in Jiujiang City reached 61 000 yuan, but per capita GDP in Poyang Lake Ecological Economic Zone was only 19 000 yuan. However, power consumption per unit of output value in Jiujiang City is higher than the regional average, and the resource utilization efficiency is lower than the regional average.

Type Ⅲ: high-sensitivity and low-resilience type

It includes Jiujiang County, Xingzi County, Yongxiu County, Hukou County, Duchang County, Ruichang County, De'an County, Wuning County, Pengze County, Leping City, Dongxiang County, Fengcheng City, and Gao'an City. The water body of Poyang Lake has the most direct impact on 9 counties, which are traditional agricultural production areas. The level of secondary industry, tertiary industry, and urbanization is relatively low in these areas; restricted by the natural, economic, technical and other conditions, the resource use efficiency in these counties is very low; in addition to weak economic concentration and radiation capacity of the central cities, the economic development in the 9 counties has obvious trend of marginalization, showing low resilience of the economic system. The resource utilization efficiency in Leping City, Dongxiang County, Fengcheng City, and Gao'an City is at a relatively low level in Poyang Lake Ecological Economic Zone, and especially the sensitivity score of Gao'an City is just below that of De'an County, Hukou County and Ruichang County in the whole region; in terms of composition of resilience, the score of economic scale, economic industrial structure, economic openness economic environment in Leping City, Dongxiang County, Fengcheng City, and Gao'an City is below the average level, lacking momentum for urban development, showing weak resilience to disturbance.

Type Ⅳ: Low-sensitivity and low-resilience type

They are the remaining cities and counties in Poyang Lake Ecological Economic Zone, including Fuzhou City, Xinyu City, all counties in Yingtan, all counties in Nanchang, all counties in Shangrao, some counties in Jingdezhen and Xingan County. The sensitivity score of these areas is lower than the regional average, and the resource utilization efficiency is at a relatively high level, but the resilience of the economic system to interference of the external environment, lags behind that of Nanchang City and Jiujiang City.

3 Conclusions

The study of indicator system and evaluation methods of fragility in the economic system, is an important means for profound understanding of the economic development status and constraints in Poyang Lake Ecological Economic Zone, which is of great theoretical and practical significance to the construction of Poyang Lake Ecological Economic Zone. In view of mounting pressure confronted by resources and environment in Poyang Lake Ecological Economic Zone, based on analysis of resource utilization, we establish the evaluation model to make initial exploration and evaluation of fragility in the regional economic system, so that we can not only grasp the spatial difference characteristics in macroscopic view, but also analyze the fragility characteristics of different counties and cities in microscopic view.

The results show that there is a great difference in fragility of the economic system between different administrative units (fragility of the northern region is greater than that of the southern region on the whole); the difference in resilience is the major factor responsible for difference in fragility of the economic system in various cities and counties within the region; according to the difference in fragility characteristics, the classification is conducted (Nanchang City is a low-sensitivity and high-resilience type; Jiujiang City is a high-sensitivity and high-resilience type; Jiujiang County, Xingzi County, Yongxiu County, Hukou County, Duchang County, Ruichang County, De'an Xian, Wuning County, Pengze County, Leping City, Dongxiang County, Fengcheng City and Gao'an City are a high-sensitivity and low-resilience type; other cities and counties are a low-sensitivity and low-resilience type).

The fragility of economic system in Poyang Lake Ecological Economic Zone is dynamic, affected by multiple disturbances. Under the influence of multiple disturbances, how the fragility of economic system is changing within the region, is a problem needing to be further dealt with.

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of Classical Learning, and martial arts lawn; open up the ferry travel line from Caoshi Ancient Town to Baimaozhou bar, and the boat travel line from Caoshi Ancient Town to the Yongle River[6], the carriage or riding tours line from Caoshi Ancient Town to Jiangdong Reservoir; raise the level of marketing planning, and strengthen the annual "Ganchunshe", "Lingshan sacrificial rites", "dragon boat race in May" and other traditional festivals; establish large business markets, car parks, hotels and other modern facilities, outside the ancient town, in harmony with the ancient town style, reflecting the idea of "environmental protection".

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