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Environmental Impact Assessment of Industrial Structure Change in a Rural Region of China

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Abstract As the embodiment of human activities, the change of regional industrial structure is an essential driving factor of global environmental change. Consequently, the research on the change of regional industrial structure and associated effects on the environment is one of the key issues of researches on sustainable development, human–environment relationship, and regional response to global environment change. However, compared to the flourish of researches on environmental impact assessment of industrial departments, few studies have been conducted to assess the environmental impact of regional industrial structure. In this study, based on a synthetic analysis of environmental disturbances of different industrial departments, the environmental impact coefficient of industrial department associated with the index of environmental impact of industrial structure was constructed, so as to make a quantitative assessment of environmental impact of the change of regional industrial structure. And the results of the case study in Lijiang City, a rural region of China, have showed that there are two obvious changes of industrial structure in the study area from 1992 to 2003, associated with a continuous decreasing of the index of environmental impact of industrial structure, which indicated a positive environmental effects of the change of regional industrial structure.

Keywords Change of industrial structure · Environmental impact assessment · Environmental impact coefficient of industrial department · Lijiang City, Yunnan Province, China

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1 Introduction

The influence and feedback between man and the nature are always the key topics in the fields of geography, ecology, and environmental sciences. As almost all social economic activities can be classified into the category of industrial economic activities, industrial structure has become an important bridge between human activities and natural environment in the modern society (Cui 1995; Cui and Yang 1998). Therefore, as one of the key issues of researches on sustainable development, human–environment relationship, and regional response to global environmental change, the research on the extent assessment, mechanism analysis, and countermeasure suggestion of environmental impact of regional industrial development and associated industrial structure change, has become an important basis of the regulation of regional industrial structure.

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Although the very topic has already come to attention, the research on environmental impact of industrial development is still devoid of the in-depth and systemic study. As for the research content, few studies have been conducted to assess the environmental impact of regional industrial structure, and most researches have been focused on the environmental effects of the development of a single industrial department, such as agriculture (Goodland 1995; Huang et al. 2004; van der Werf 1996), forest industry (Seppala et al. 1998), animal husbandry (Liu 2000; McGechan and Topp 2004), aquaculture (Piedrahita 2003), tourism (Cui and Yang 1997; Mbaiwa 2003), mining industry (Rigina 2002; Rybicka 1996), chemical industry (Pravdic 1995), construction industry (Li 2001) and transportation industry (Zhou 2000). Furthermore, even in the few researches on environmental impact of regional industrial structure, all are carried out through the qualitative analysis (see Li et al. 2002; Zhang and Wu 1999; Zhou 1999), or the correlation analysis between industrial structure change and environmental quality indicators (see Cui 1995; Cui and Yang 1998).

Although it has been convinced that the change of industrial structure has great effect upon the nature, we still cannot fully understand the environmental impact. With a case study in Lijiang City, Yunnan Province, China, the research reported in this paper aims to make a quantitative assessment of the environmental impact of the change of regional industrial structure.

2 Materials and Methods

2.1 The study area

Lijiang City, the case study area, is situated in the northwest of Yunnan Province, China, which has been internationally identified as a globally significant region for its rich biodiversity, rare ecosystems and high concentration of endemic biodiversity (Xu and Wilkes 2004). Lijiang City is located between the longitude 99°23′ and 101°31′E and between the latitude 25°59′ and 27°56′N, with Yangtze (Jinsha) River flowing through (Fig. 1). The total land area is 20,600 km^2 with 92.3% mountainous area.

As Lijiang City locates in the transition zone extending from the low altitude of Yunnan–Guizhou Plateau to the high altitude of Qinghai–Tibet Plateau, it covers two physiognomy units, that is, Hengduanshan Canyon and Dianxi Plateau, which make there are high mountains in the center and gorges all around with rugged terrain, lean soil, and heavy water and

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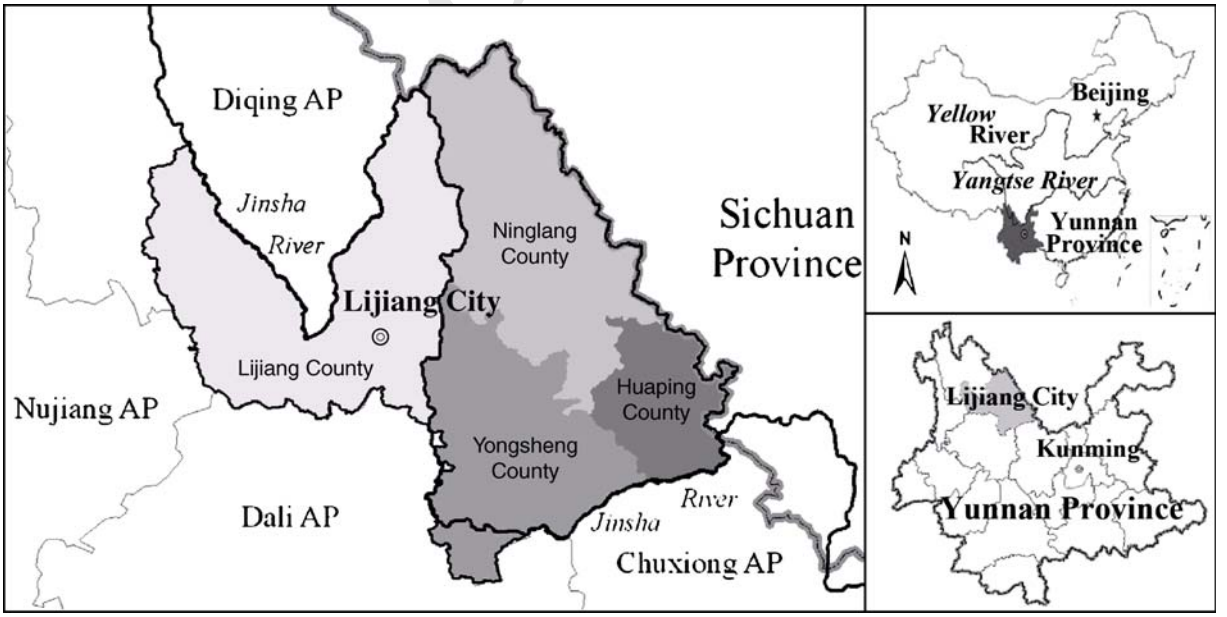

Fig. 1 The location of Lijiang City of Yunnan Province, China. *AP* means Autonomous Prefecture

soil erosion. The study area has a low latitude and plateau monsoonal climate with clearly demarcated four seasons as dry in winter and spring and wet in summer and autumn. The average annual temperature is 12–20°C, and the mean annual rainfall is about 1,000 mm.

Due to the location of backland in China, mountainous terrain, and undeveloped traffic, Lijiang City had always been in the historical phase of traditional agriculture before 1990s, with an unsubstantial basis of social–economic development. Since tourism was confirmed to be the pillar industry of Lijiang City in 1994, there have been rapid economic development and industrial structure change associated with obvious environmental problems, such as the increase of mountain landslide and snowline altitude in Yulong Mountains (Li 2004). Till 2003, GDP per person in the study area has added up to 3,712 RMB, and the three industrial structures are 26.2:29.9:43.9. The total population is 1.119 million, with 87.1% agricultural population and 57.7% minority population, which major in Naxi, Yi, and Lisu ethnic group, etc. There are five counties, that is Gucheng, Yulong, Yongsheng, Huaping and Ninglang, which include 69 towns and 4,462 administrative villages totally. As the counties of Gucheng and Yulong were come from former Lijiang County in December, 2002, we take Gucheng County and Yulong County as a whole with their former name of Lijiang County, so as to ensure the continuity of historical data in the research.

2.2 Classification of industrial structure

Industrial structure refers to the composition, interrelationship and quantitative proportion of all the industrial departments within a given region. Accordingly, the change of industrial structure not only refers to the change of the structural proportion resulted from the difference among the development of industrial departments, but also includes the change of interrelationships among industrial departments. Generally speaking, the change of industrial structure can often be quantified by the alteration of the proportion of value-added or employment number of different industrial department.

Taking industrial development actuality of the study area into account, we subdivided regional industrial structure into the following nine groups based on the classification of three industrial structure, according to the difference between environmental impacts of industrial departments in the way and extent: (1) Planting industry, refers to industrial departments raising crops, including the production of grains, economic crops, forage, green manure and horticultural plants such as vegetables and flowers; (2) Forest industry, includes the production of forest planting, forest-related products gathering, and bamboo cutting; (3) Animal husbandry, refers to industrial departments breeding and raising livestock; (4) Aquaculture, refers to industrial departments devoted to the cultivating or catching of aquatic animals and plants; (5) Light industry, refers to industrial departments manufacturing consumer goods or hand tools; (6) Heavy industry, refers to industrial departments producing main means of production for other industrial departments, including mining industry, raw materials industry and manufacturing industry; (7) Construction industry, refers to industrial departments involving surveying, designing, constructing, repairing and renovating of buildings; (8) Transportation industry, refers to industrial departments engaging in passenger and freight traffic through railway, highway, waterway or airway; and (9) Other industry, including all other industries except those mentioned above.

2.3 Environmental impact of the development of different industrial departments

In the process of industrial development, all industrial departments exploit resources from the nature while releasing man-made products and wastes, which cause various environmental disturbances.

The growth of planting industry often leads to the reclamation of unsuitable land resulting in land degradations such as soil erosion and salinization, and is associated with the decrease of land use types with significant importance to ecosystem services, such as marshland and coastal land. The circulations of surface water or groundwater are greatly altered by agricultural irrigation engineering. Meanwhile, pesticide, fertilizer and irrigating domestic sewage always lead to water pollution and soil contamination, which further threaten the survival of wildlife in agricultural landscapes and result in biodiversity loss ultimately. And air pollution is often brought by planting activities. For example, CO_2 emission due to the decrease of soil organic carbon in cultivate land, CH_4

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emission from rice paddy, N_2O emission associated with the process of soil nitration and de-nitration, and decomposed materials of pesticide leftover, all contributes to the air pollution.

Deforestation leads to the direct decrease of forest, which results in the decrease of absorbing of greenhouse gas and the alteration of surface water. Due to simple structure and limited food chain in artificial forest ecosystems, the functions of material flow, energy flow and product flow are degraded.

Overgrazing often causes soil desertification and meadow degradation. In details, excrements and fodders of livestock pollute the water, by means of decreasing oxygen content and throwing off effluvium. Animal husbandry causes air pollution in the same way. Respiration of livestock, decomposing of forage and excrement all contribute to the air pollution. And forage particulate and pollen are component of fine particulate ashes which pollute the air badly. By trampling on the soil, livestock make the soil tight and impermeable. Hence, it is considered as a detriment to meadow vegetation and a reason of soil bareness. Excrements pollute the soil as well. Besides, environmental contaminations remained within the animal body can easily cause infection and spread abroad to wildlife.

The rapid development of freshwater aquaculture often aggravates water resource crisis through increasing groundwater level and deteriorating water pollution. Surplus baits of aquaculture may lead to eutrophication of adjacent natural water body. And over catching of marine fishes may lead to exhausting of certain species.

Manufacturing industrial departments take up large area of space. As a result, farmland and forest land are encroached. The discharge of waste water, gas and solid, especially those from heavy industrial departments, leads to wide pollution to natural environmental elements, including soil, water and air. Water consumption for manufacturing industry is so large that it enlarges the rareness of water resource. Constructional engineering does a lot of damage to soil structure along with the removal of topsoil, and vegetation coverage is turned into concrete floor. Gene mutation resulted from inbreathing of industrial toxin, often leads to the death of wildlife nearby, and associated biodiversity loss and ecosystem collapse.

In the development of construction industry, the exploitation of certain materials, such as detritus and sand, maybe cause the change of terrain. Constructional digging, dynamiting and depositing may lead to water pollution and soil pollution, with a great contribute to air pollution through drifting dust. The level and quality of groundwater are also highly affected by constructional digging. Deforestation and vegetation destruction in the process of construction usually bring soil erosion and habitat damage of wildlife. Constructional noise also goes against the subsistence of animals around the building site.

Traffic facilities often take up large area of farmland and forest land with permanent deprival of biological production. As the concrete surface of road is incapable of holding water, supplement for ground water is cut down. And traffic lines often lead to the shifting of rivers. Emission of tail gas, such as carbon monoxide and nitrogen oxides, pollute the air badly. The road dusts also contribute to air pollution. Grains of inorganic compound in tail gas go into the soil and surface water directly and cause the pollution. Furthermore, traffic lines often result in the fragmentation of wildlife habitat and become significant barriers of species immigration. And traffic noise also goes against the subsistence of animals nearby.

2.4 Environmental impact assessment of the change of regional industrial structure

In this study, we assess the environmental impact of regional industrial structure based on the index of environmental impact of industrial structure. Firstly, in order to establish the quantitative correlation between industrial structure and regional ecological quality, according to the difference in the extent and depth of environmental impact of industrial departments, we can measure the relative intensity of the environmental impact of different industrial departments with a value ranging from 1 to 5 as shown in Table 1, which is defined as the environmental impact coefficient of industrial departments. Secondly, the index of environmental impact of industrial structure (IEIIS) is constructed through the weighted summation of the production value proportion of each industrial department and associated environmental impact coefficient, so as to make a quantitative assessment of integrated environmental impact or disturbance of regional industrial structure. Generally speaking, the higher IEIIS is, the higher the human disturbance of industrial structure on the nature, and

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Table 1 Environmental impact coefficient of different industrial department

Industrial department	Planting industry	Forest industry	Animal husbandry	Aqua-culture	Light industry	Heavy industry	Construction industry	Transportation industry	Other industry
Coefficient	3	2	2	2	4	5	3	4	1

the higher the environmental impact of industrial structure. Lastly, according to the change of IEIIS in the study period, we can make a quantitative assessment of the environmental effects of the change of regional industrial structure.

Here, it is important to point out that the environmental impact of industrial structure we discussed is quite different from that of regional industrial economy. The former is a structural impact, while the latter is a gross impact. And the former is far more important to the regulation of regional industrial structure and to the planning of regional sustainable development. It is just because that in a given study area, the production value of all industrial departments usually increase. Therefore, no matter how industrial structure and associated IEIIS change, there is always a steady increase in the environmental impact of regional industrial economy.

3 Results and Discussion

3.1 Change of regional industrial structure

3.1.1 Change of industrial structure in the whole city

Generally speaking, the regional economic and social development of Lijiang City has increased dramatically in the past decade. GDP has changed from 935.08 million RMB in 1992 to 4,140.50 million RMB in 2003 with an average annual growth rate of 31.16%, which is much higher than that of the whole nation of China. From Fig. 2, we can see that there are significant changes of regional three industrial structure in the view of production value of industrial departments from 1992 to 1995, 1998, 2001 and 2003. Firstly, in the study period, there are mainly two industrial structure transformations in Lijiang City, which showed the optimization of regional industrial structure. In 1992, the proportion of production value of the primary industry was the highest, with that of the secondary industry lowest. In 1998, the tertiary industry took the first place and then the primary industry and secondary industry in turn. And in 2003, the order changed again with the tertiary industry, secondary industry and primary industry in turn. Secondly, in the process of industrial structure change, the proportion of the primary industry kept decreasing continuously, while that of the secondary industry and tertiary industry fluctuated due to the difference of their growth rate in the study period. Lastly, the change of the proportion of the primary industry was the highest, with the tertiary and secondary industry in turn. It showed that the driving forces of industrial structure change were highly correlated with urbanization and tourism development, and that industrialization processed slowly in the study area.

Through the change of three industrial structure in the view of employed population of industrial departments in the study period as shown in Fig. 3, we can find that the proportion of employed population in the

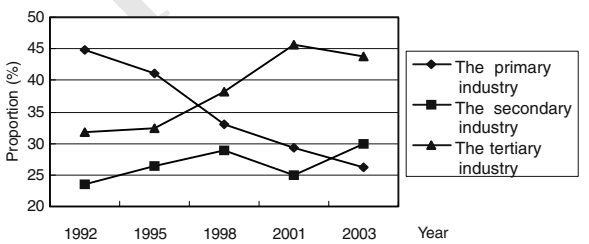

Fig. 2 The changes of three industrial structure of Lijiang City in production value

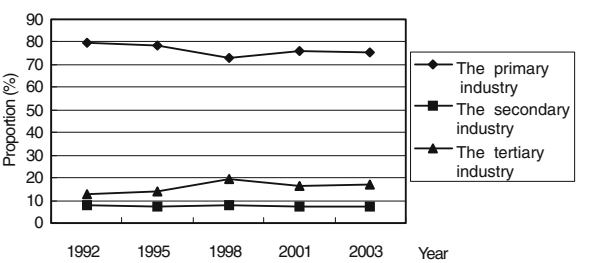

Fig. 3 The changes of three industrial structure of Lijiang City in employed population

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primary industry went beyond 70% with a little fluctuation, the proportion in the secondary industry was always the lowest under 10%, and the proportion in the tertiary industry was also low with a higher fluctuation. It showed that the secondary industry and tertiary industry contributed little to the shift of surplus labor forces of rural area in Lijiang City.

Furthermore, through the change of detailed industrial structure in the view of production value of industrial departments as shown in Table 2, we can also find that: (1) in the study period, behaviors are various among different industries. There are a great decrease of the proportion of planting industry, light industry and heavy industry, a great increase with fluctuation of construction industry and transportation industry, a little fluctuation of forest industry, animal husbandry and aquaculture, and a continuously great increase of other industry; and (2) the key industrial departments have changed from the planting industry, heavy industry, light industry and other industry in 1992, to the other industry, construction industry and planting industry in 2003.

3.1.2 Change of industrial structure in counties

As shown in Fig. 4, the changes of industrial structure are quite different among counties, which can be concluded as follows. Firstly, in 1992, the primary industry took up the largest proportion in all the four counties. But as Lijiang County and Huaping County are more developed than Yongsheng County and Ninglang County, the proportions of the primary industry, secondary industry and tertiary industry in the former two counties were nearly even, while those in the latter two counties showed a striking contrast with a high proportion of the primary industry and low proportion of the secondary industry. Secondly, in the study period, the proportion of the primary industry in all the counties kept decreasing while the secondary industry and tertiary industry increased

Table 2 The change of detailed industrial structure of Lijiang City in production value (%)

Counties		Planting industry	Forest industry	Animal husbandry	Aqua-culture	Light industry	Heavy industry	Construction industry	Transportation industry	Other industry
Lijiang City	1992	26.93	4.82	9.20	0.73	14.01	21.00	9.73	2.72	10.86
	1995	24.78	3.06	11.62	1.65	7.56	12.02	6.83	5.63	26.86
	1998	18.30	2.59	9.88	1.56	6.54	11.33	11.01	6.14	32.66
	2001	16.25	2.21	8.72	1.73	4.86	9.39	10.80	8.25	37.78
	2003	12.40	1.89	8.59	1.55	3.99	9.55	16.40	7.73	37.88
Lijiang County	1992	22.07	2.71	7.05	0.21	22.89	22.24	8.99	1.77	12.08
	1995	23.79	1.17	10.95	0.35	8.86	8.27	10.00	5.69	30.93
	1998	15.05	1.18	8.56	0.25	8.37	7.21	15.60	5.94	37.84
	2001	14.14	0.97	6.66	0.94	5.28	6.18	13.11	7.29	45.44
	2003	9.45	0.83	7.11	0.68	4.59	5.54	21.08	6.51	44.22
Yongsheng County	1992	36.43	2.91	8.91	1.97	14.92	8.67	12.05	2.63	11.50
	1995	30.74	3.80	12.46	4.41	10.43	6.51	2.84	4.52	24.29
	1998	24.63	2.47	10.25	4.49	9.51	6.02	5.54	6.26	30.82
	2001	19.32	2.82	9.08	3.67	8.25	4.94	6.53	10.37	35.01
	2003	17.46	2.48	8.83	3.65	7.19	6.74	7.31	10.08	36.26
Huaping County	1992	21.46	2.26	8.95	0.23	5.84	43.95	8.02	5.62	3.68
	1995	15.62	2.23	9.61	0.73	2.08	33.03	7.11	9.88	19.71
	1998	13.56	2.39	9.54	1.12	1.47	29.88	8.13	9.47	24.45
	2001	12.47	2.42	9.40	1.36	1.01	26.13	8.33	11.74	27.15
	2003	9.17	2.24	8.59	1.25	1.21	26.15	10.44	12.86	28.09
Ninglang County	1992	26.60	16.34	14.69	0.17	4.14	11.19	9.23	1.05	16.58
	1995	28.06	9.22	15.15	0.66	2.32	6.87	5.51	1.19	31.02
	1998	23.57	8.84	14.76	0.48	2.94	8.61	10.20	1.47	29.12
	2001	23.68	5.58	15.36	0.91	2.91	4.98	15.41	1.61	29.55
	2003	18.55	4.70	14.62	0.84	3.20	10.62	13.37	1.71	32.38

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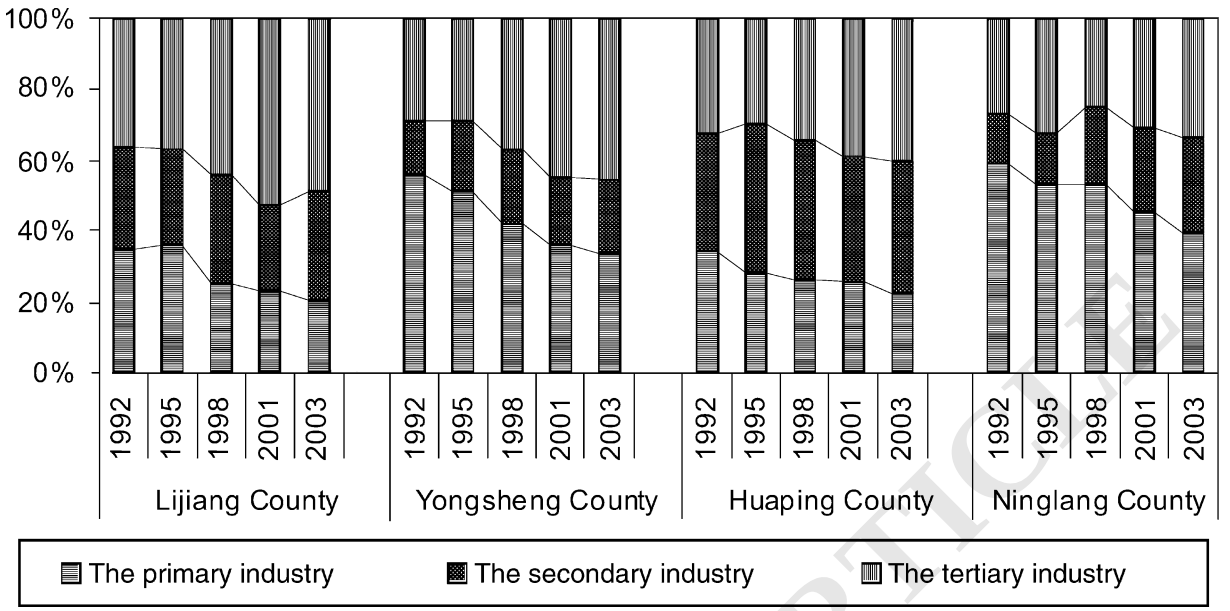

Fig. 4 The changes of three industrial structure in each country of Lijiang city

with various rates. In details, the decrease of the proportion of the primary industry in Lijiang County, Yongsheng County and Huaping County all resulted from the increase of the tertiary industry, while in Ninglang County it was mainly due to the increase of the secondary industry. Lastly, in 2003, the difference of industrial structure among counties was highly enlarged, and each county had developed a special industrial structure. For example, in Lijiang County, the tertiary industry was developed well, and the industrial structure was the tertiary industry, secondary industry and primary industry in turn. In Huaping County, the industrial structure was the same as that of Lijiang County, with a much more proportion of the secondary industry. The tertiary industry took up the largest share in industrial structure of Yongsheng County, while the proportion of the primary industry exceeded that of the secondary industry and ranked second. In the industrial structure of Ninglang County, the primary industry played the leading role, followed by the tertiary industry and secondary industry.

Furthermore, through the change of detailed industrial structure in the view of production value of industrial departments in each county as shown in Table 2, it can also be concluded that: (1) In Lijiang County, the proportion of planting industry, light industry and heavy industry decreased dramatically while that of other industry, construction industry and transportation industry increased. And the main industrial departments had changed from planting industry, light industry and heavy industry in 1992, to other industry and construction industry in 2003; (2) In Yongsheng County, planting industry and light industry kept decreasing while other industry and transportation industry increased greatly. Planting industry, light industry, construction industry and other industry were the main industrial departments in 1992. And in 2003 they were replaced by other industry, planting industry and transportation industry; (3) In Huaping County, heavy industry and planting industry decreased dramatically while other industry, transportation industry and construction industry increased. Heavy industry and planting industry took up the largest share in 1992 while replaced by other industry, heavy industry, transportation industry and construction industry in 2003; and (4) In Ninglang County, forest industry and planting industry kept decreasing while other industry and construction industry increased. The main industrial departments in 1992 were planting industry, other industry, forest industry, animal husbandry and heavy industry. And they were replaced by other industry, planting industry, animal husbandry, construction industry and heavy industry in 2003.

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3.2 Environmental impact of the change of regional industrial structure

Through Fig. 5, the change of IEIIS in the study area from 1992 to 2003, can be concluded as follows: (1) In Lijiang City, IEIIS was always at a moderate level and kept decreasing at the rate of annual 2.23%, which indicated that the change of regional industrial structure had a positive effect on the nature, and that there was a relative decrease of the pressure on regional environmental protection; (2) IEIIS in Lijiang County kept decreasing, while that in the other three counties dropped and then bounded back with the same turning point in 2001, which indicated that the environmental impact of regional industrial structure in all the counties might rebound after the decreasing before 2001, and attentions still needed to be paid on the environmental impact of industrial structure; (3) In the study period, IEIIS of Lijiang County decreased the most by 32.81%, followed by that of Huaping County and Yongsheng County. IEIIS of Ninglang County decreased the lowest by 12.55%. To a certain extent, the decreasing amount in all the four counties could be set as a standard in assessing the performance of industrial structure regulation aimed at environmental protection; (4) In the study period, IEIIS of Huaping County was always the highest in all the counties. It might result from the large proportion of heavy industry in the industrial structure; and (5) IEIIS of Ninglang County fluctuated in a narrow range in the study period, which was mainly because the change of regional industrial structure mainly exhibited as the decrease of the proportion of planting industry and forest industry, and the increase of that of other industry and transportation industry, while the environmental impact coefficients of these industrial departments were all low.

Considering the changes of IEIIS and gross domestic product (GDP) in the study area simultaneously as shown in Fig. 5, we can also find that, along with the decrease of IEIIS, GDP kept increasing with a gross augment of 342.8% from 1992 to 2003, which indicated that the rapid economic and social development was not at the cost of deterioration of natural environment, and the regulation of industrial structure contributed to the restriction of human disturbance on natural environment in Lijiang City. Therefore, in the perspective of reducing human disturbance and protecting natural environment, the economic development of Lijiang City was sustainable in the past 11 years. However, along with the increase of GDP, there was the increase of IEIIS of Yongsheng County from 2001 to 2003, Huaping County from 2001 to 2003, and Ninglang County from 1995 to 1998 and from 2001 to 2003, which showed the un-sustainability of regional development in these study periods.

As to the advancement of the positive environmental impact of regional industrial structure change, the key issues still related to the promotion of industrial departments with lower environmental impact coefficient, and the restriction of industrial departments with higher environmental impact coefficient. In other word, the aim of industrial structure transformation is to realize the transformation from economic benefits driving to synthetic driving of social, economic, ecological and environmental benefits. In that case, social economic development will go with the improvement of regional environmental quality. Besides, it can also reduce the environmental disturbance of the development of industrial depart-

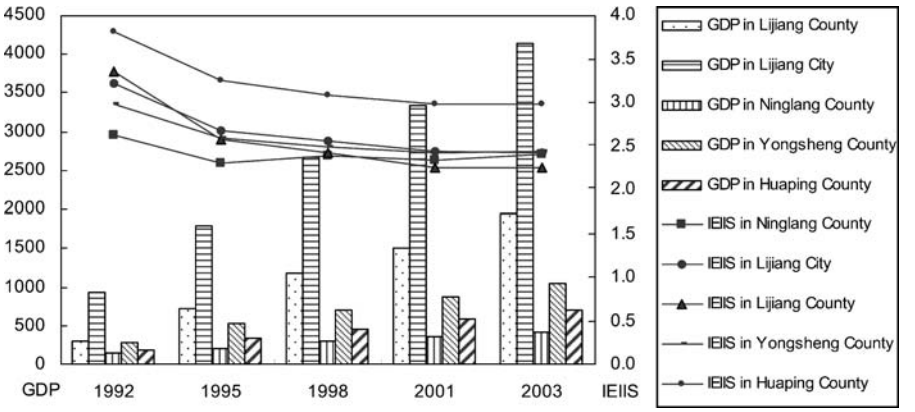

Fig. 5 The changes of GDP and IEIIS in the study area

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ments through the clean production and innocuous waste treatment. Furthermore, according to forward and backward connection among different industrial departments, different kinds of industrial departments should be spatially allocated and rationalized. Industry chain and product chain should also be developed so as to realize the reuse of industrial wastes, and to ultimately reduce the whole environmental impact of industrial economy.

3.3 Methodology

The most methodological deficiency of the study reported in this paper, is the quantification of the environmental impact coefficients of industrial departments according to qualitative analysis of the environmental impact of industrial departments, while these coefficients cannot precisely reflect the difference among the environmental impacts of industrial departments. How to quantify theses environmental impacts will be the focus of further researches. What's more, in order to assess the environmental impact accurately, a more detailed classification of industrial structure is needed.

The transformation of regional industrial structure not only depends on the human demand for the products, but also results from resource gift. It doesn't mean that we should advocate industrial departments with low environmental impact coefficient as much as possible. Consequently, industrial structure regulation can't be simply based on the environmental impact coefficient of industrial departments, and the feasibility assessment of industrial departments should be taken into account, so as to make a rational development of industrial departments according to natural resources.

There are three levels in the researches on environmental effects of the change of regional industrial structure. Firstly, it is the environmental impact assessment of the change of regional industrial structure in the view of such single element as climate, soil, water, wildlife et al.; secondly, it is the construction of assessment index system so as to make a quantitative assessment of environmental impact of industrial structure change as a whole; lastly, it is the environmental impact assessment of spatial pattern change of the same industrial structure. Obviously, the study reported here belongs to the research at the second level. Further researches should be focused on the environmental impact assessment of spatial pattern change of the same industrial structure.

4 Conclusions

Based on the construction of the index of environmental impact of industrial structure, taking Lijiang City in Yunnan Province, China as the study area, we made a quantitative assessment of the environmental effect of the change of regional industrial structure. The results were concluded as follows: Firstly, there was dramatic change of industrial structure in Lijiang City with twice industrial structure transformation in the past 11 years, which may be due to the slow industrialization and rapid urbanization and tourism development. Secondly, the change of regional industrial structure was various among the four counties of Lijiang City. Lijiang County and Huaping County had realized the optimization of industrial structure with rapid economic and social development, while the optimization of industrial structure was further needed in Yongsheng County and Ninglang County with relatively undeveloped economy and high proportion of the primary industry. Thirdly, the environmental impact of industrial structure in Lijiang City was moderate and kept decreasing in the study period, which indicated that the change of regional industrial structure had positive effect on the nature. Lastly, in the four counties of Lijiang City, except for the continuous decrease in Lijiang County, the environmental impact of industrial structure all dropped and then bounded back in the other three counties, which showed that industrial structure regulation aiming at environmental protection still needed to be focused.

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