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Industrial Structure Change and Its Eco-environmental Influence since the Establishment of Municipality in Chongqing, China

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Abstract

The change of regional industrial structure best reflects the transformation of resource utilization in human society, and also results in a visible alteration of its eco-environmental effect. It is a significant content for regional sustainability development and man-land relationship research to explore the eco-environmental effect of regional industrial structure change. The eco-environmental influence produced by nine-industry subclasses' development was analyzed, and at the same time, the historical trace of industrial structure development in Chongqing after municipality establishing was reviewed briefly. Making use of eco-environmental influence modulus of industrial departments (EIMID), we quantitatively evaluated the entire eco-environmental impact of industrial structure change in Chongqing from 1997 to 2008 by integrated eco-environmental influence modulus of industrial structure (IEIMIS). Our research showed that the industrial structure had experienced two significant transformations since the establishment of municipality in 1997 and that IEIMIS presented an approximate U-shaped curve with an ascent trend after an initial decline and fluctuated in a certain range. From 1997 to 2001 the economic development was rather sustainable in Chongqing, but from 2002 to 2008, the social development was at the expensive of eco-environment deterioration and the industrial structure change intensified human activity's pressure on local environment. It was concluded that as the youngest municipality and the city still in industrialization increasing stage in China, Chongqing faced an arduous task of industry upgrading and optimizing. Developing circular economy and eco-industry and implementing cleaner production methods would be the optimum choice for its future development. Sufficient attentions of the supervision mechanism of environmental protection also should be given.

Keywords: Industrial structure change; Eco-environmental influence; Countermeasure; Chongqing

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1. Introduction

The coupling and feedback relationship between eco-environment evolution and human activities, especially economic activities during the industrial development, is always one of the hot topics in the fields of geography, ecology, and environmental sciences. The Industrial Transform (IT) research had attracted extensive attention of the scientists worldwide since it was promoted in the International Human Dimensions Programme on Global Environmental Change (IHDP) (Larry, 1999). As the "resource converter" and the "controller of the quality and quantity of pollutant" (Chen, 1990), industrial structure is the main link where human act on the eco-environment system, and refers to the property relation reflecting the economical and technological contacts among different industries (Su, 2006). Used for measuring the state and level of regional development, industrial structure's composite type and combined strength to a great extent determine the economic benefits, the efficiency of resources utilization, and the threaten to environment (Cui, 1998). Therefore, research on the interaction between industrial structure and environment quality, from the perspective of industrial structure evolution, may bring a breakthrough in developing man and environment coupling system. And because of the types and the amounts of resource consumed and pollutants produced by different industrial structures varying widely in the same technology state, the adjustment of industrial structure is highlighted for special attention in improving the quality of eco-environment when the effect of micro-perspective environmental pollution treatments are getting weaker and weaker (Cui and Li et al., 1997). Furthermore, the research on the extent assessment, mechanism analysis, and countermeasure suggestion towards the influence of industrial structure development on natural environment has become one of the key issues on sustainable development, man-land relationship research (Zhang, 2008).

At the present time, the research on impact of industrial structure on eco-environment with profound significance, to which a lot of attentions has been given, however, is still relatively insufficient and lack of systematic development. In respect of research contents, most of the studies mainly concentrated on the influence of single industry on eco-environment, or on the influence of single industry or human's activities on the microcosmic and specific ecological or environmental factor (Henrik, 2004). Taking the former for example, the studies of eco-environmental effect of the primary industry including agriculture(Grant and Pattey, 2008), forest industry(Brian and Kimberly, 2007), animal husbandry (Hildebrandt and Eltahir, 2006), and fishery (Corea and Jayasinghe et al., 1995; Robert and Les et al., 1995), the secondary industry, such as mining industry (Bowell and Warren et al., 1995; John, 2000), manufacturing industry(Yang and Wang et al., 2008), power industry (Simon and Paul, 1981; Ma and Cheng, 2004), and construction industry (Tong and Cui et al., 2010), and of the tertiary industry, inclusive of tourism (Warnken and Buckley, 1998; Gong and Lu et al., 2009), and transportation industry(Dierkes and Geiger, 1999; Viard and Pihan et al., 2004), et al, have been explored in depth and resulted in a large number of significant findings. In spite of that, it is relatively weak for the research of industrial structure's influence on eco-environment, which is profoundly manifested in the research area and method. That means almost all the few existed researches focused on not the entire area's but the urban area's industrial structure and its eco-environmental effect(Grimm and Grove et al., 2000; Shochat and Stefanov et al., 2004), and moreover, employing qualitative analysis method rather than quantitative evaluation (Arrhenius, 1992; Afroz, 1993).

Thus although, it has been believed that the transformation of regional industrial structure could produce powerful effect on eco-environment, we still can not fully understand the environmental impact, especially in the fragile and rapidly urbanizing area in developing countries, like Chongqing in China, which was one of the worst cities for air pollution in the world. Therefore, this paper took Chongqing City for instance to assess quantitatively the influence of industrial structure change on the eco-environment since the establishment of municipality.

2. Research area

Chongqing City, the research area, locates in the upper reaches of the Yangtze River and at the joint of central China and west China, as shown in Fig. 1. As the nation's fourth municipality, Chongqing is the economic center and the hub of all transportation (water, land, and air) in and out of southwestern China. Ranging from 105º11´E to 110º11´E and from 28º10´N to 32º13´N, it covers an area of 82, 400 km2. The city slopes down from north and south towards the Yangtze valley, crisscrossed by rivers and mountains, and featured by sharp rises and falls with altitude varying from 145 to 2797 m above sea level. Typical karst landscape is common in this area, and stone forests, forests of peaks, limestone caves and valleys can be found in many places. It is dominated by the subtropical

humid monsoon climate with four distinct seasons, with a long frost-free period, mean daily temperature of 18.5℃, and mean annual precipitation of 1200 mm (Chongqing Statistical Bureau, 2009).

As a mountainous city, Chongqing is characterized by the coexistence of large urban area, large rural area, and large reservoir area, so called “the provincial framework, but the municipality’s organization”. It is also the confluence area of the Jialing River and the Yangtze River with the Three Gorges Reservoir Area occupying 85% of its territory. As the national ecological barrier concerning the ecological security of the Yangtze River Basin, the reservoir faces unprecedented menace from both natural conditions and human activities. The eco-environment of the Three Gorges Reservoir Area is too fragile to carry large-scale urban development and population agglomeration. But the part of reservoir in Chongqing is now suffering from overcrowding population and serious environmental problems, evidenced by its population density twice that of the nation’s and four times that in the same type of other hill regions in China in 2008 (He and Liu et al., 2009). Local rivers’ carrying capacity of pollutants has been reduced since the completion of Three Gorges Reservoir (Wang and HU et al., 2009). So the whole city is affected and limited significantly by natural environment. Moreover, with heavy industry as mainstay industry, Chongqing is one of the old industrial bases in China, and has a large demand on energy sources, more than 70% of which is coal (Wang and He et al., 2006). It has long been suffering from heavily coal-smoke pollution with total suspended particulate (TSP)/particulate matter (PM_{10}) and sulfur dioxide (SO_2) as the main pollutants (Ma and Guo et al., 2005).

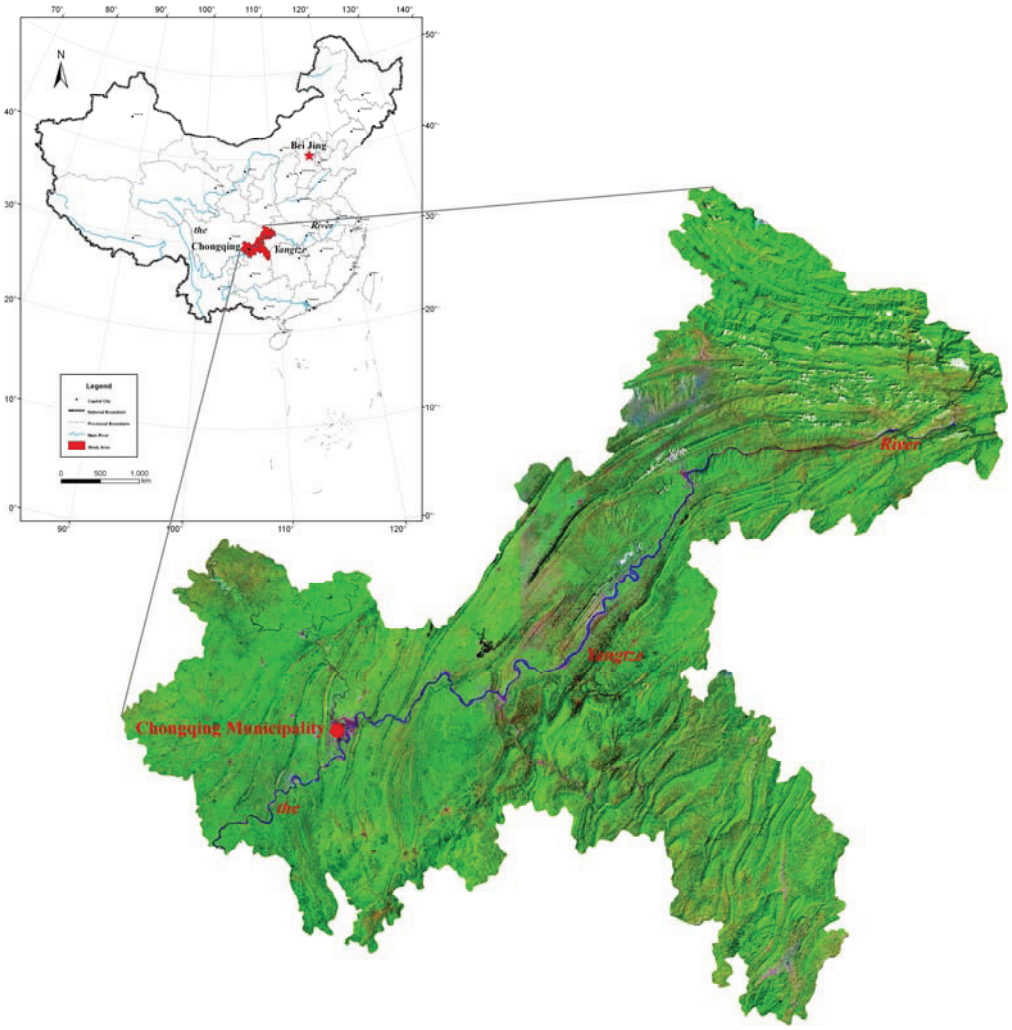


Fig. 1. Location of the research area

As the largest and youngest municipality in China, Chongqing consists of nine urban districts (the so-called city zone) and another 31 counties around them. In 2008, the population was 32.57 million, in which 27.9% were non-agricultural. The nominal Gross Domestic Product (GDP) amounted to 509.66 billion RMB¥ (1US$≈6.9RMB¥) in 2008, an increase of 23.6% from 2007. In that year, the primary industry only provided 11.3% of the total GDP, however, 47.7% and 41% are provided by the secondary industry and the tertiary industry. The average growth rate of GDP reached 11.0% from 1997 to 2008 in the city (Chongqing Statistical Bureau, 2009). Since the establishment of municipality in 1997, Chongqing has pursued a series of strategies for economic development. Additionally, the Chinese government carried out a large-scale development plan for West China in 1998. Since then the pace of development in the study area has been considerably quickened. However, the rapid industrialization and urbanization increased demands for various natural resources, which enhanced the resource and environmental pressure on local area. Due to the implantation of "exploiting resettlement policy" in Three Gorges Reservoir Area, the consequence of uncontrolled industrial development in the reservoir area is particularly serious. Although the local government attached great importance to the environment protection, and people's awareness of environment protection was also aroused, the state of environment in Chongqing seemed not to be optimistic. According to the State Bulletin of China's Environment (Ministry of Environmental Protection of the People's Republic of China, 2009), Chongqing always ranked as one of the cities with poor air quality in China.

3. Research methods

3.1 Data source

In this investigation, the basic socio-economic data of Chongqing were derived from the local government and Chongqing Statistical Yearbook (Chongqing Municipal Bureau of Statistics, 1998–2009). Besides, a few statistical data were collected from China Statistical Yearbook (National Bureau of Statistics of China, 2009). To learn more about the change of eco-environment in the study area, there is some information obtained by experts' consultation and by methods of estimation from recommended literatures. These data were used to analyze the change of the regional industrial structure and its eco-environmental impact.

3.2 Reclassification of industries and the their eco-environmental influence of in Chongqing

Industrial structure refers to the property relation which reflects the economical and technological contacts among different industries (Su, 2006), which means that not only the change of quality portion, but also the change of relationship among industries, are included in the industrial structure change. It is a traditional common method to use the transformation of the proportion of production value or the employee number in different industrial departments to make a quantitative evaluation of the industrial structure change (Zhang, 2008).

For Chongqing City, taking its actual condition of industrial development into account, we further divided its industries into nine subclasses from the Three-industry Classification based on the different way and extern of influences on environment of the diverse industries, and the main eco-environmental influences of these nine subclasses were also made a list of as shown in Table 1.

3.3 Assessment of eco-environmental influence of the industrial structure change in Chongqing

In our study, we evaluated the influence on local eco-environment of the industrial structure in Chongqing based on the eco-environmental influence modulus of industrial departments, which was called EIMID for short. The EIMID was a series of values ranging from 1–5 to express the relative magnitude of the eco-environmental effect of divers industries in Chongqing. In consideration of the research results acquired on the similar parameter by other scholars (Peng and Wang et al., 2005), and the results also being quoted many times and having reasonable application effect (Wu and Li, 2009; Zhang and Bai et al., 2008), we cited the values and applied them into our study to express the relative magnitude of the eco-environmental effect of different industries as shown in Table 2.

First, we established the quantitative correlation between local eco-environmental quality and industrial structure based on the different extent and degree of influences on study area's eco-environment of nine subclasses industries

by EIMID. Then, we could acquire the integrated eco-environmental influence modulus of industrial structure (IEIMIS) of a certain year in Chongqing through the weight summation of the production value proportion of each industrial department in the same year and its associated EIMID.

Table 1. Main Eco-environmental influences of nine-subclass-industry in Chongqing

No.	Industry types	Contents	Main eco-environmental influences
1	Planting industry	Cereal and other crops; vegetables and gardening; fruits, nuts, drinks and spices; traditional Chinese medical materials	Soil erosion and salinization; water, soil, and air pollution by overuse of pesticide and fertilizer(John, 1980); decrease of ecosystem services and loss of biodiversity in special land types, such as marsh land and coastal land, et al(Peng and Wang et al., 2005)
2	Forest industry	Forest cultivation; bamboo felling and transportation; forest-related products	Forest coverage decline leading to the decrease of its regulation ability, the water storage ability of soil(Zhang, 2008), absorbing of greenhouse gas and the ability of water erosion prevention; degradation of surface water alteration and biodiversity(Brian and Kimberly, 2007)
3	Animal husbandry	Livestock raising; hog raising; poultry raising; animal hunting; and others, such as silkworm cocoons, et al	Grassland and vegetation degradation; land desertification; water and air pollution; enhancement of infection spread by livestock excrements and forage(Peng and Wang et al., 2005)
4	Aquaculture	Getting aquatic products in inland water areas, such as breeding and fish, et al	Water pollution; eutrophication (Corea and Jayasinghe et al., 1995); aggravating water resource crisis(Peng and Wang et al., 2005); exhausting of certain species due to over fishing; deterioration of hydrosphere ecosystem
5	Light industry	Industries producing consumer goods or hand tools, such as food manufacturing; cultural educational and sports goods; papermaking and paper products; raw chemical materials and chemical products; instruments, meters, cultural and office machinery, et al	Eutrophication of water quality due to waste water(Zhang, 2008); wide pollution to soil and air by waste gas and solid; noise pollution
6	Heavy industry	Industries providing main means of production for other industrial , such as mining and quarrying, raw materials industry; manufacturing industry and electric power, et al	Intensifying water resource shortage crisis; land surface damage; river and ground water pollution(Bowell and Warren et al., 1995); soil erosion(Peng and Wang et al., 2005); ecosystems destruction; environmental pollution by waste water, air and solid
7	Construction industry	Industries of surveying; designing; constructing; repairing and renovating of buildings	Noise pollution; air pollution, especially by construction dust's TSP(Zhang, 2008); impact on groundwater level and quality by foundation excavation (Peng and Wang et al., 2005); impact on soil inner circulation(Wu and Li, 2009); soil pollution by construction waste; land surface damages resulting from sand mining and quarrying
8	Transportation industry	Industries of engaging in passenger and freight transportation through waterway, railway, highway, or airway	Permanently occupation of farmland and forest land with deprival of biological production; cutting down supplement for ground water(Peng and Wang et al., 2005); air and soil pollution by heavy metal(Viard and Pihan et al., 2004), carbon monoxide and nitrogen oxides from emission of tail gas(Van Bohemen and Janssen Van De Laak, 2003); causing wildlife habitat fragmentation and forming species immigration barriersby traffic lines(Peng and Wang et al., 2005)
9	Other industries	All other industries except the above-mentioned in Chongqing	Having varying interferences and influences on the natural eco-environment of Chongqing

IEIMIS, measuring the entire influence of industrial structure on eco-environment in study area, was always proportionate to the effect degree of industrial structure on local eco-environment, which meant that the higher IEIMIS was, the higher the eco-environmental effect degree of industrial structure. So, we were able to judge the

regional eco-environmental state and its variation trend due to the industrial structure evolvement by the change of IEIMIS during the period of research.

Table 2. Eco-environmental influence modulus of industrial departments (EIMID)

Industry types	Planting industry	Forest industry	Animal husbandry	Aquaculture	Light industry
Modulus	3	2	2	2	4
Industry types	Heavy industry	Construction industry	Transportation industry	Other industries	
Modulus	5	3	4	1	

4. Research results and analysis

4.1 Structural change of industry in Chongqing

Chongqing had undergone an unprecedented change in the local economy since 1997, the year when Chongqing Municipality was established. Its GDP increased from 136, 024 million RMB in 1997 to 509, 666 million RMB in 2008, with an annual growth rate of 11.0%. Three characteristics presented in the evolution of industrial structure could be seen from Fig. 2 during the research period. First, the city experienced two structural transitions in three-industry, with the output value sequence of "secondary> tertiary>primary" in 1997, to that of "tertiary>secondary>primary" in 1998, and to that of "secondary> tertiary>primary" in 2007 and keeping the situation to the end of the study period in 2008. Second, there were significant differences among three-industry structure change in production value. On one hand, the proportion of the output value of the primary sector kept on being the lowest level all through and decreasing continuously, on the other hand, that of the secondary and the tertiary sector held in the higher level and their curves crossed two times with a temperate fluctuation during the period, showing that the secondary and the tertiary sector were the predominant producing sectors in Chongqing. Third, three industries diversified their proportion changes from 1997 to 2008. The primary industry had the greatest proportion change, followed by the secondary industry, and the tertiary industry having the least. Consequently, it could be taken for granted that the industrialization was the main factor promoting the structural change of industry in Chongqing, and the industries associated with urbanization and service sector had relatively weak effect on this transformation.

Besides, the employed population among three industries exhibited the characteristic of maintaining stability in the proportion sequence of "primary>tertiary>secondary" in the research period, which could be apprehended from Fig. 3. The proportion of the primary sector's employed population kept declining, and that of the tertiary and secondary sector went upward, which indicated that the surplus labors continued to transfer from the primary sector to the other two sectors from 1997 to 2008.

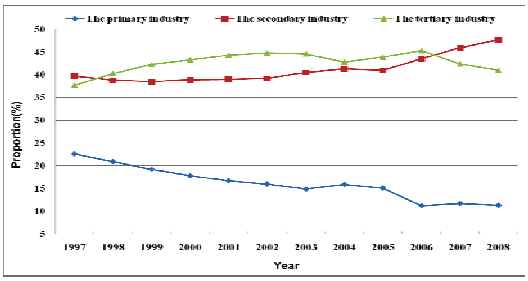


Fig. 2. Structural change of three-industry in production value in Chongqing from 1997–2008

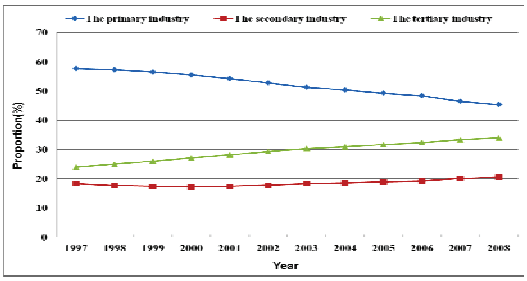
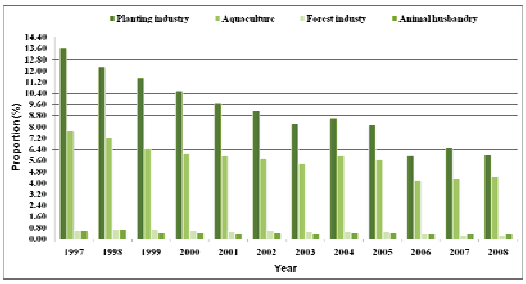
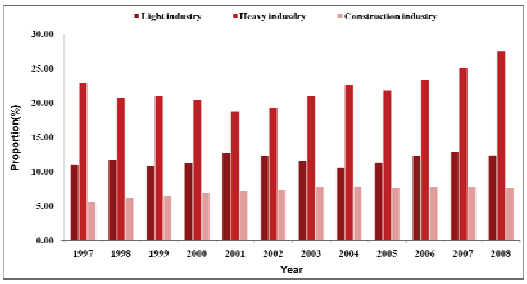


Fig. 3. Structural change of employed population of three-industry in Chongqing from 1997–2008

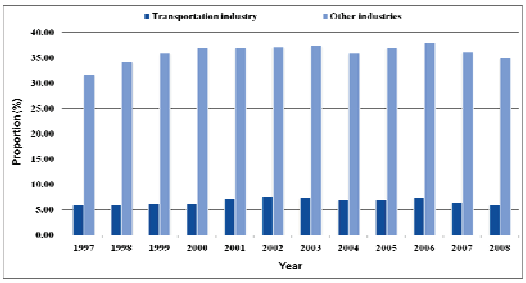
In additional, nine industry subclasses in Chongqing also had notable different changes in production value proportion from 1997 to 2008(Fig. 4). The proportion of planting industry, forest industry, animal husbandry, and aquaculture showed the tendency to descend with slight fluctuation, but that of the light industry and heavy industry rose with undulate form, coupled with the construction industry ascending steadily. During the same period, the proportion of transportation industry fluctuated to a certain degree, and the other industries in the city rose at first and lowered later. Even more important was the fact that the city' pillar industries had been converted from the planting industry, light industry, heavy industry, and other industries into the light industry, heavy industry, and other industries since the municipality was established.



a. Planting industry, animal industry, aquaculture, and forestry industry



b. Light industry, heavy industry, and construction industry



c. Transportation industry and other industries

Fig. 4. Structural change of nine-subclass- industry in production value in Chongqing from 1997–2008 (a, b, c)

4.2 Eco-environmental influence of the structural change of industry in Chongqing

From Fig. 5, we could find that IEIMIS in Chongqing showed an approximate U-shaped curve with an ascent trend after an initial decline and fluctuated in a certain range, suggesting that the influence on natural eco-environment of industrial structure was relatively moderate as a whole during the study period. In the descending stage, the curve of IEIMIS decreased from 2.91 in 1997 to 2.77 in 2001, the reason of which lied in the factor of the implementation of Natural Forest Protection Project, Grain for Green Program, and the negative effect of removal of the enterprises in the reservoir area and the international financial crisis. In view of GDP's continuous growth in those five years, it could be initially confirmed that the development of economy and society was not at the expense of destruction of natural environment, and the industrial structure change was conductive to the reduction of human's effect on local eco-environment. Consequently, the regional economic development was rather sustainable during this time. At the stage of rising from 2002 to 2008, IEIMIS kept on mounting up fast to the peak value of 2.98 in the study period, with an obvious ascending tendency in the years followed. There could be no doubt that the social development in this area during these seven years was at the price of eco-environment deterioration and the

industrial structure change intensified human activities' pressure on the local environment evidenced by the vigorous growth of GDP. That was mainly because under the development plan for West China and the construction of Three Gorge Project, Chongqing City accelerated the development of industrialization after 2001. However, the fact of industrial structure's heavy industry-oriented trait and the extensive economy growth mode enhanced the disturbance degree of human's effect and adversely affected the eco-environmental quality. Hence, it was urgent for Chongqing to upgrade and optimize industrial structure and to put more attention to the supervision of environmental protection in future.

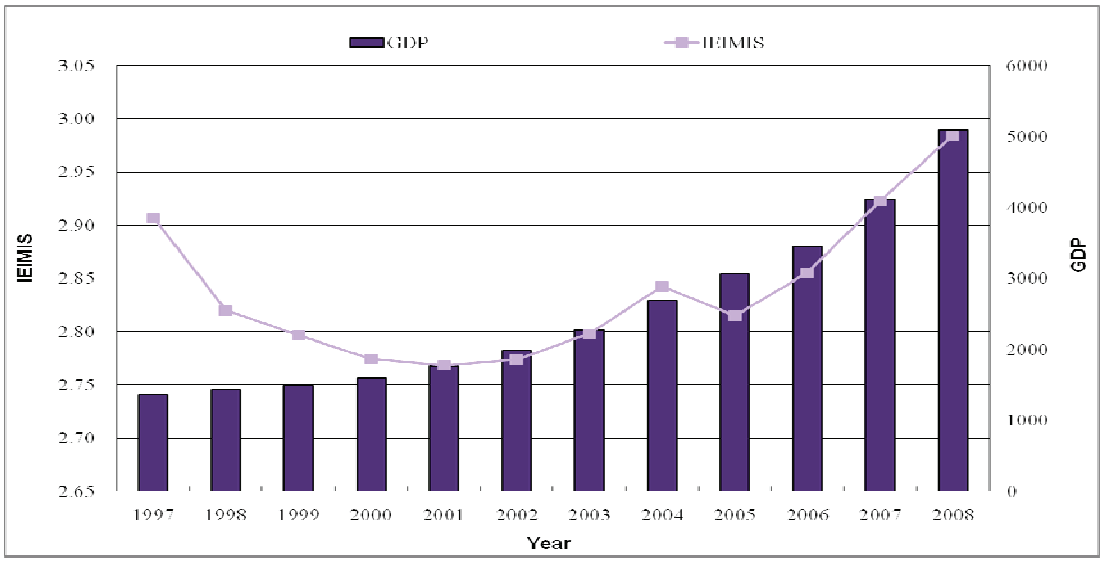


Fig.5. IEIMIS and GDP change in Chongqing from 1997-2008

5. Conclusions

Chongqing City had experienced two times remarkable transition of industrial structure since the establishment of municipality in 1997. Analyses of the historical trace of Three-industry structure development in Chongqing after municipality establishing showed that the industrialization was the main factor promoting the structural change of industry in Chongqing, and the industries associated with urbanization and service sector had relatively weak effect on industrial structure transformation.

Based on EIMID, we conducted to estimate the entire eco-environmental impact of industrial structure change in Chongqing from 1997 to 2008 by IEIMIS. Our assessment result demonstrated that IEIMIS presented an approximate U-shaped curve with an ascent trend after an initial decline and fluctuated in a range from 2.77 to 2.98, suggesting the influence of industrial structure change was relatively moderate as a whole during the study period. From 1997 to 2001, because of the implementation of Natural Forest Protection Project, Grain for Green Program, removal of enterprises in the reservoir area, and the financial crisis, the industrial structure change was beneficial to the reduction of human effect on local eco-environment. And that the regional economic development was rather sustainable during this time. But from 2002, IEIMIS kept on mounting up fast to the peak value of the study period in 2008 with an obvious ascending tendency in the years followed. There could be no doubt that the social development during these seven years was at the price of eco-environment deterioration and the industrial structure change intensified human activities' pressure on local environment evidenced by the vigorous growth of GDP. That was mainly because the industrialization development in the city was accelerated after 2001 under the development plan for West China and the construction of Three Gorge Project. The fact of heavy industry-oriented trait and the extensive economy growth mode enhanced the disturbance degree of human activity on local eco-environment.

As the youngest municipality and the city still in industrialization increasing stage in China, Chongqing faced an arduous task of industry upgrading and optimizing. Developing circular economy and eco-industry, and

implementing cleaner production methods will be the optimum choice for Chongqing City's economic development. Last but not the least is that sufficient attentions of the supervision mechanism of environmental protection should be given.

Acknowledgements

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