Regional Sustainable Development Analysis Based on Information Entropy—Sichuan Province as an Example

Xuedong Liang 1, Dongyang Si 2 and Xinli Zhang 2,*

1 School of Economics, Sichuan University, Chengdu 610065, China; liangxuedong@scu.edu.cn
2 The Economy and Enterprise Development Institute, Sichuan University, Chengdu 610065, China; 2016225025033@stu.scu.edu.cn
* Correspondence: zhangxinli@scu.edu.cn; Tel.: +86-139-8087-6069

Academic Editor: Kevin W. Li
Received: 12 September 2017; Accepted: 10 October 2017; Published: 13 October 2017

Abstract: According to the implementation of a scientific development perspective, sustainable development needs to consider regional development, economic and social development, and the harmonious development of society and nature, but regional sustainable development is often difficult to quantify. Through an analysis of the structure and functions of a regional system, this paper establishes an evaluation index system, which includes an economic subsystem, an ecological environmental subsystem and a social subsystem, to study regional sustainable development capacity. A sustainable development capacity measure model for Sichuan Province was established by applying the information entropy calculation principle and the Brusselator principle. Each subsystem and entropy change in a calendar year in Sichuan Province were analyzed to evaluate Sichuan Province’s sustainable development capacity. It was found that the established model could effectively show actual changes in sustainable development levels through the entropy change reaction system, at the same time this model could clearly demonstrate how those forty-six indicators from the three subsystems impact on the regional sustainable development, which could make up for the lack of sustainable development research.

Keywords: regional sustainable development capacity; information entropy; Brusselator model; capability measurement; evaluation index system

1. Introduction

Along with the world’s economic structural adjustment, China’s economic development pressure has been gradually increasing, with regional development being often unbalanced, uncoordinated, and discontinuous. As a large developing country, China has a large population, resource shortages, ecological imbalances, environmental pollution, and serious social and environmental problems such as rising unemployment [1]. Therefore, only by insisting on sustainable development strategies in China to implement economic, social, and environmentally coordinated development strategies can the present problems be fundamentally solved. As the basic requirement for the implementation of a scientific development perspective, sustainable development needs to consider all aspects of economic construction, political construction, cultural construction, social construction and ecological civilization construction, and needs to consider regional development, economic and social development, and the harmonious development of society and nature.

Since 2007, more than half of the world’s population has been living in cities. Due to the acceleration of the urbanization process and the deterioration of the organization and service functions of urban ecosystems, economic activities, ecological environmental capacity, and even social sustainable...
development have sharply reduced [2,3]. In 1992 the Chinese government introduced for the first time a sustainable development strategy into the long-term planning of economic and social development. However, after more than 20 years’ development, there are still many issues in the sustainable development of Chinese regions, while at the same time the regional sustainable development problems have been found to be increasingly complex, such as concentration of the population, traffic jams, housing shortages, resource shortages, biodiversity reductions, “heat island” effects, noise, and air and water pollution. Regional sustainable development emphasizes the coordinated development of the economy, society and the ecology to promote the regional economy, improve residents’ lives, ensure an efficient use of resources and maintain the environment [4,5]. Because of the complex interrelationships and interactions between the society and the environment, regional sustainable development research has become increasingly popular. Significant research has focused on regional sustainable development and its influencing factors by considering sustainable development path selection and capacity improvement problems with a view to change the traditional regional development paths to develop new paths for regional sustainable development.

Berry and Portney examined 50 large U.S. cities using two original databases as the foundation and explored the actual behavior of the cities with respect to sustainability and economic development policies. The results showed that the high number of programs aimed at achieving sustainability were linked to the inclusion of environmental advocacy groups. This relationship did not appear to compromise business advocacy groups and the inclusion of environmental groups in the policymaking was supported by the high rates of economic growth within the cities [6]. Fang et al. examined the sustainable development of an innovative city as the research object and argued that this necessary transition to sustainable development was being constrained by a series of bottlenecks in investment, income, techniques, contributions, and talents [7]. Zhang et al. studied the effects of infrastructure development, land use change, industrial structure and income on sustainable urban development. The results suggested that moderate land use change with steady economic growth was the key to sustainable urban development [8]. Through extensive investigation and research, Tweed and Sutherland focused on the link between sustainable urban development and cultural heritage and found that building a culture within a city could play an important role in sustainable urban development [9].

Significant research has examined regional sustainable development from an application perspective by establishing evaluation systems and evaluation models which analyzed the ecological environment, economic development and social construction, providing a reference for the promotion of regional sustainable development capacity. With the emergence of a series of ecological problems, Zhao et al. introduced a methodology for urban eco-security evaluation and applied a fuzzy comprehensive evaluation (FCE) calculation procedure. Statistical data during the period of 2005–2012 from Mianyang was examined using this methodology, which found that critical security and slight insecurity had a main impact on the urban ecological environment [10]. However, such indices are difficult to measure and quantify without sufficient spatial-temporal analysis. Shen et al. established an integrated model based on hierarchical index system for monitoring and evaluating urban sustainability. This was able to provide a theoretical basis for a comprehensive assessment of urban sustainability from a spatial-temporal perspective [11]. Yin et al. used eco-efficiency as an index to measure urban sustainable development and applied a data envelopment analysis model to describe the eco-efficiency of 30 Chinese provincial capital cities. The results showed that almost half the cities were fairly eco-efficient [12]. Javadian et al., focusing on the environmental dimension of sustainable urban development, conducted an environmental suitability analysis of educational land use in Tehran using AHP and GIS. By using the two models they were better able to determine which locations were environmentally suitable for educational land use, thereby providing a reference for sustainable urban development [13].

From the literature review, it can be seen that significant work has been done in improving regional innovation environments, enhancing innovation capacities, and changing regional development ideas.
However, with increased focus on sustainable development problems, the requirements for regional sustainable development capacity have been continually extended. This is because of the need to consider the “economy-society-nature” relationship within complex sustainable development systems and the many factors that must be considered. To effectively define the data to ensure useful information to assess regional sustainable development ability, it is important to adopt appropriate data mining methods to analyze the index data and the target data. In order to assess the regional sustainable development capacity measurement process, the concept of information entropy and dissipative structure theory are combined to allow for an analysis of the performance of a regional operation system entropy change from the perspective of entropy flow transformation, which uses regional economic development, social development and ecological development as the point of contact. Because the dissipative structure theory developed from complex system theory is well justified and positioned to capture the complex and dynamic nature of the regional sustainable systems, and the regional system organization, functions and mechanisms are well described, thus Information entropy and dissipative structure theory provide an appropriate reference for regional sustainable development capacity evaluation research. Besides, to effectively define the data to ensure useful information to assess regional sustainable development ability, it is important to adopt appropriate data mining methods to analyze the index data and the target data.

The main purpose of the research in this paper is summarized as follows: first, a regional sustainable development capacity evaluation index system is established based on the previous scholars about the index system of regional sustainable development research results. Then, the index system is divided according to certain properties, and the entropy change analyzed. Regional sustainable development capacity is then studied using the information entropy concept and dissipative structure theory.

2. Measurement Index System of Regional Sustainable Development Capacity

How to get the proper and objective measure and evaluation about sustainability is one of the most fundamental issues of sustainability research [14–17]. The index system used in this paper was from a database from a previous regional sustainable development capacity study. The index system included most of the data needed to measure regional sustainable development capacity and the potential impacts. Regional sustainable development capacity analysis needs to comprehensively consider the sustainable development of the economy, the ecological environment and society, so that the real regional sustainable development capacity is reflected.

Economic sustainable development capacity refers to the economic elements of the regional sustainable development capacity study. On the one hand, economic development is the foundation of region social development, on the other hand, the economic growth at the cost of ignoring social development for the long run is unsustainable [18]. To comprehensively reflect the level of the regional economy, the regional economic sustainable development capacity needs to include all existing and potential economic capacity. Ecological environmental sustainable development capacity refers to the environmental elements of regional sustainable development capacity, which requires not only research on the regional environmental protection construction ability, but also on the coordination and development abilities of the regional environment and its resources. Social sustainable development capacity refers to the social factors of regional sustainable development capacity, which mainly focuses on the impact on the citizens’ life of the regional social mechanism and includes the effects of social progress as well as the effects of education and daily entertainment conditions [19].

Due to the multifaceted overlapping contents of the economy-environment-society complicated system’s components [20,21], the regional system is a multi-level, multi-functional and dynamic complex system which encompasses economic structure, social structure and natural structure. Each subsystem in this complex relationship influences the others, resulting in a chain-like structure for the regional sustainable development capacity evaluation system. After a detailed analysis was carried out on the index system, some indexes such as the rapid development of the economy and
social construction ability were found to effectively reflect the regional carrying capacity and the production capacity of the complex regional system. As these indexes can effectively promote regional sustainable development capacity, they can be classified as efficiency indexes. Indexes such as waste emissions and birth rate belong to pressure indexes, which can have a certain negative impact on regional sustainable development. Combining the concepts of information entropy and dissipative structure theory, the regional system comprised of the economic, social and environmental subsystems can be redefined, with positive and negative entropy flows and change as the key points, so as to study the sustainable development condition of each subsystem. In view of this, based on the principles of scientific nature and operability, comprehensiveness and representativeness, we chose China’s Sichuan Province from 2007–2015 as the basis to build the regional sustainable development ability index system, as shown in Table 1.

In this paper, the economic, urban ecological environment and social sustainable development capacity were chosen as first grade indexes from the literature review and the Sichuan Province 2008–2016 statistical yearbook. Then, combined with entropy change, these first-grade indexes were divided into positive efficiency indexes and negative pressure indexes, so a more comprehensive index system was established. The indexes are not completely independent each other. To some extent, urban economic development promotes the city’s social and environmental construction, and the environmental index influences development and promotes the development of the urban economy and society, and a harmonious social atmosphere affects economic development and environmental protection. Urban sustainable development capacity indexes are closely related to each other, and provide decision support for urban sustainable development capacity measurements (as shown in Figure 1). For urban sustainable development capacity analysis, the relationships between the three first grade indexes and their independence need to be considered.

Table 1. Index system used to evaluate sustainable development.

| Target-Grade | First-Grade Index | Second-Grade Index | Third-Grade Index |
|--------------|-------------------|--------------------|-------------------|
| Regional economic sustainable development capacity | Efficiency indexes C1 | Gross Domestic Product C11 | Primary Industry-owned Value Added C12 |
| | | Secondary Industry-owned Value Added C13 | Tertiary Industry-owned Value Added C14 |
| | | Agriculture, Forestry, Animal Husbandry and Fishery-owned Value Added C15 | Industry-owned Value Added C16 |
| | | Construction-owned Value Added C17 | Finance-owned Value Added C18 |
| Regional sustainable development capacity | Pressure indexes C2 | Total Investment in Fixed Assets C21 | Total Investment in Fixed Assets in Agriculture, Forestry, Animal Husbandry and Fishery C22 |
| | | Total Investment in Fixed Assets in Industry C23 | Total Investment in Fixed Assets in Construction C24 |
| | | Total Investment in Fixed Assets in Finance C25 | Total Investment in Fixed Assets in Real Estate C26 |
| Regional environment sustainable development capacity E | Efficiency indexes E1 | Complete investment industrial pollution control E11 | Investment in waste water treatment E12 |
| | | Investment in waste gas treatment E13 | Investment in waste solid treatment E14 |
| | | Total investment in fixed assets of energy industry E15 | Forest Area E16 |
| | | Forest Coverage Rate E17 | Area of Wetlands E18 |
| | | Green Covered are as % of Completed Area E19 |
### Table 1. Cont.

| Target-Grade | First-Grade Index | Second-Grade Index | Third-Grade Index |
|--------------|-------------------|--------------------|-------------------|
|              | Pressure indexes E2 |                    |                   |
|              | Total Emissions of SO2 E21 |                |                   |
|              | Total Waste Water Discharged E22 |            |                   |
|              | Total Emissions of Waste Oxygen Water Needed by Chemistry E23 |          |                   |
|              | Total Emissions of Ammonia and Nitrogen E24 |             |                   |
|              | Total Volume of Natural Gas E25 |             |                   |
|              | Total Volume of Water Supply E26 |           |                   |
|              | Total Volume of Electricity Consumption E27 |         |                   |
|              | Geological Disasters E28 |              |                   |
|              | Education Expenditure S11 |              |                   |
|              | Culture, Sport and Media Expenditure S12 |            |                   |
|              | Social Safety Net and Employment Effort Expenditure S13 |          |                   |
|              | Medical and Health Care Expenditure S14 |           |                   |
|              | Number of Civil Vehicle S15 |            |                   |
|              | Per Capita Area of Roads S16 |           |                   |
|              | Number of Community Service Facilities S17 |         |                   |
|              | Population Birth Rate S21 |              |                   |
|              | Population Death Rate S22 |              |                   |
|              | Population Natural Growth Rate S23 |          |                   |
|              | Unemployed Persons in Urban Area S24 |         |                   |
|              | Unemployment Rate in Urban Area S25 |        |                   |
|              | Per Capita Consumption of Residents S26 |       |                   |

### Figure 1. Index support figure.

#### 3. Measurement Methods for Regional Sustainable Development Capacity

##### 3.1. Measurement Based on the Information Entropy-Brusselator Model

The information entropy concept was first proposed by Shannon in 1948 as an application concept in information theory. As entropy theory developed, the information entropy concept was gradually introduced into many fields to allow for the exploration of the orderly degree of a system. Information
entropy can effectively describe the order degree of an organized system and highlight the disorganized degree in the quantitative performance of a system. The greater the degree of disorganization, the lower the degree of order. On the contrary, the smaller the information entropy, the smaller the degree of disorganization, and the higher the degree of order. Information entropy theory can be used for all statistical process analysis and has the advantage of overcoming the problems of complexity and uncertainty [22]. In this paper, regional sustainable development was regarded as the complex system, and information entropy was introduced to analyze the changes in regional entropy trends to measure the regional sustainable development capacity. Research on sustainable development capacity can be conducted by judging whether the system is a dissipative structure.

From the analysis of the regional system, it was found that along with energy production and exchange, regional internal operations and the external environment have close material and information transformations. At this level, the regional system matches the assumption of a dissipative structure. Therefore, the regional system quantitative method using information entropy is feasible for this paper. The regional system operation needs inner workings (human activities) to achieve material, energy and information production and exchange, so the system is open all the time. According to dissipative structure theory, information entropy flows in regional systems can be divided into efficiency entropy flows and pressure entropy flows according to their properties [23]. Pressure entropy flow (positive entropy) is the root of chaos in a regional system, as it encompasses human activities, increasing birth rates, pollutant emissions and energy consumption, all of which could have a negative influence on the regional system. Negative influences result in an increase in pressure entropy flow (positive entropy), which is closely related to spontaneity and initiatives in the system. Contrary to the positive entropy, the efficiency entropy flow (negative entropy) can effectively decrease the influence of positive entropy and eliminate the regional system’s internal chaos. In an open system, government construction investment, environmental protection and social construction can increase the negative entropy flow, meaning that the regional system constantly exchanges energy and information with the outside environment. Such an exchange pushes the system to develop in an orderly direction and, therefore, increase the sustainable development capacity of the system as shown in Figure 2. The generation of negative entropy is because of the external environment and organization. Therefore, based on the theory of information entropy, whether an operating system has a higher regional sustainable development capacity can be judged from the change in the system’s internal entropy flow.

![Figure 2. The framework for regional system development.](image-url)
In a regional system, the efficiency entropy flow and the pressure entropy flow are independent. Whether the regional system has a dissipative structure requires an independent analysis of the internal system entropy flow, so the current state of the regional system is defined according to the changes in entropy value [24]. Therefore, the Brusselator model was introduced to study the relationship between entropy flows in the system and to identify whether the system had a dissipative structure [25–27].

\[ H^+ \text{ and } H^- \text{ can be set as the positive entropy flow and negative entropy flow, respectively. Then, } h^+ \text{ and } h^- \text{ represent their corresponding quantification factors. } S_y \text{ represents the dissipation structure and } S_n \text{ represents the dissipative structure, which are the possible states of the emergency supply chain system under the impact of positive and negative entropy flows [28–30]. According to the three molecular expressions in the Brusselator model, the management entropy for the emergency supply chain system can be expressed as:} \]

\[ H^+ \xrightarrow{k_1} h^+ \]

\[ H^- + h^+ \xrightarrow{k_2} h^- + S_n \]

\[ h^- + 2h^+ \xrightarrow{k_3} 3h^- \]

\[ h^+ \xrightarrow{k_4} S_y \]

where \( k_1 \text{–} k_3 \) are constants, \( h^+ \) is the positive management entropy flow, and \( h^- \) is the negative management entropy flow. Equations (1) and (3) promote an increase in \( h^+ \), and Equations (2) and (4) reduce \( h^+ \). Equation (2) helps increase the negative management entropy flow \( h^- \), and Equation (4) results in its decrease.

Combined with the Brusselator principle, the equation below was established to study the entropy flow changes in regional sustainable development capacity:

\[ |H^-| - |H^+| \begin{cases} > 0 & \text{positive indexes} \\ = 0 & \text{critical state} \\ < 0 & \text{negative indexes} \end{cases} \]

To learn how the information entropy-Brusselator model works, a working draft was built, as shown in Figure 3.
3.2. Calculating the Regional System’s Regional Information Entropy

The steps for the regional sustainable development capacity measurement, and to judge whether it is a dissipative structure are shown below. Data preprocessing for data standardization was needed before the calculation. Normalized processing was used for the data standardization in this paper. As the pressure entropy index and the efficiency entropy index need independent operations, their positives and negatives were ignored. The processing equation is as follows:

\[ X_i = \frac{x}{\text{maxx}} \]  

(6)

The data after processing allows for the calculation index entropy changes throughout the years to be determined. For example, in the evaluation of the n index in m year, the information entropy of i index can be obtained using the following equation:

\[ h_i = -\frac{1}{\ln m} \sum_{j=1}^{m} x_{ij} \ln \frac{x_{ij}}{x_i} \]  

(7)

where, \( h_i \) is the information entropy of the \( i_{th} \) index, and \( x_{ij} \) is the standardized data for the \( i_{th} \) index in year \( j \): \( x_j = \sum_{i=1}^{m} x_{ij} \)

A quantitative measurement model for regional sustainable development capacity is required for the index information entropy calculation, so that the actual sustainable development capacity level of the regional system can be identified through the information entropy changes. Using the entropy weight method, the equation to calculate the weight of the \( i_{th} \) index is:

\[ W_i = \frac{1 - h_i}{n - \sum_{i=1}^{n} h_i} \]  

(8)

where \( 0 \leq W_i \leq 1, \sum_{i=1}^{n} W_i = 1 \).

Superiority quantitative evaluation score values over the years based on information entropy can be determined by Equation (9):

\[ Q_j = \sum W_i X_i \]  

(9)

where \( W_i \) is index weight for each index and \( X_i \) is the index standardized value of each index.

The results from Equation (9) can be further used to identify the change in each subsystem’s evaluation values. The equation for this is:

\[ \triangle Q_j = |Q_j^+| - |Q_j^-| \]  

(10)

where \( Q_j^+ \) is the pressure evaluation, and \( Q_j^- \) is the efficiency evaluation.

Finally, the total entropy change in Sichuan Province system can be determined. According to the calculation results and dissipative structure theory, the system sustainable development capacity evaluation value for Sichuan Province can be expressed as the sum of the variance of the three subsystem evaluations. This expression is shown in Equation (11):

\[ \triangle Q = \triangle Q_C + \triangle Q_E + \triangle Q_S \]  

(11)

The detailed process for the regional sustainable development measurement is shown in Figure 4.
where \( \omega_j \) is index weight for each index and \( x_j \) is the index standardized value of each index.

The results from Equation (9) can be further used to identify the change in each subsystem's evaluation values. The equation for this is:

\[
\Delta \epsilon_j = \epsilon_j - \epsilon_j + \epsilon_j (10)
\]

where \( \epsilon_j \) is the pressure evaluation, and \( \epsilon_j \) is the efficiency evaluation.

Finally, the total entropy change in Sichuan Province system can be determined. According to the calculation results and dissipative structure theory, the system sustainable development capacity evaluation value for Sichuan Province can be expressed as the sum of the variance of the three subsystem evaluations. This expression is shown in Equation (11):

\[
\Delta = \Delta \epsilon + \Delta \epsilon + \Delta \epsilon (11)
\]

The detailed process for the regional sustainable development measurement is shown in Figure 4.

Figure 4. Technical flow chart.

4. Case Analysis

4.1. Data Sources

The data in the Sichuan Province 2008–2016 statistical yearbooks was analyzed to obtain the regional sustainable development evaluation data, as shown in Table 2.

Table 2. Index data.

| Index | Unit | 2007     | 2008     | 2009     | ... | 2013     | 2014     | 2015     |
|-------|------|----------|----------|----------|-----|----------|----------|----------|
| C1    |      | 10,562.39| 12,601.23| 14,151.28| ... | 26,392.07| 28,536.66| 30,053.10|
| C11   | \( \times 10^8 \) RMB | | | | | | | |
| C12   | \( \times 10^8 \) RMB | 2032 | 2216.15 | 2240.61 | ... | 3368.66 | 3531.05 | 3677.30 |
| C13   | \( \times 10^8 \) RMB | | 5823.39 | 6711.87 | ... | 13,472.05 | 13,962.41 | 13,248.08 |
| C14   | \( \times 10^8 \) RMB | | | 5198.8 | ... | 9551.36 | 11,043.2 | 13,127.72 |
| C15   | \( \times 10^8 \) RMB | | | | ... | 3425.61 | 3594.17 | 3745.32 |
| C16   | \( \times 10^8 \) RMB | | | | ... | 11,540.86 | 11,851.99 | 11,039.08 |
| C17   | \( \times 10^8 \) RMB | | 727.38 | 867.26 | 1033.63 | ... | 2038.17 | 2225.44 | 2321.38 |
| C18   | \( \times 10^8 \) RMB | | | | | | 1755.22 | 1953.51 | 2202.23 |
| C21   | \( \times 10^8 \) RMB | | | | | | | |
| C22   | \( \times 10^8 \) RMB | | | | | | | |
| C23   | \( \times 10^8 \) RMB | | | | | | | |
| C24   | \( \times 10^8 \) RMB | | | | | | | |
| C25   | \( \times 10^8 \) RMB | | | | | | | |
| C26   | \( \times 10^8 \) RMB | | | | | | | |
| Index | Unit | 2007     | 2008     | 2009     | ... | 2013     | 2014     | 2015     |
|-------|------|----------|----------|----------|-----|----------|----------|----------|
| E11   | ×10^4 RMB | 201,033  | 193,808  | 96,191   | ... | 188,392  | 232,452  | 118,258  |
| E12   | ×10^8 RMB | 9.9757   | 7.5227   | 5.2686   | ... | 2.9791   | 5.4168   | 5.5112   |
| E13   | ×10^4 RMB | 83,307   | 86,503   | 31,900   | ... | 148,926  | 164,883  | 46,883   |
| E14   | ×10^4 m^2  | 1464.34  | 1464.34  | 1703.74  | ... | 1703.74  | 1738.16  | 1870.66  |
| E15   | %       | 30.3     | 30.3     | 35.2     | ... | 35.2     | 35.76    | 38.65    |
| E16   | ×10^8 m^2  | 96.17    | 96.17    | 96.17    | ... | 174.78   | 174.78   | 174.78   |
| E17   | %       | 34.2     | 35.3     | 36.4     | ... | 38.4     | 37.51    | 38.7     |
| E18   | ×10^4 t   | 117.87   | 114.8    | 113.53   | ... | 81.67    | 79.64    | 71.65    |
| E19   | %       | 30.3     | 30.3     | 35.2     | ... | 35.2     | 35.76    | 38.65    |
| E20   | ×10^8 t   | 25.2961  | 26.2343  | 26.2709  | ... | 30.7648  | 33.1277  | 34.1607  |
| E21   | ×10^4 t   | 77.1     | 74.9     | 74.8     | ... | 123.2    | 121.63   | 118.64   |
| E22   | ×10^8 t   | 5.97     | 6.19     | 5.95     | ... | 13.7     | 13.47    | 13.14    |
| E23   | ×10^4 m^3  | 62.99    | 59.5     | 51.11    | ... | 59.02    | 61.01    | 62.98    |
| E24   | ×10^8 m^3  | 213.98   | 207.64   | 223.46   | ... | 242.47   | 236.9    | 265.5    |
| E25   | ×10^8 KW/h | 1177.51  | 1210.13  | 1324.61  | ... | 1948.95  | 2014.79  | 1992.40  |
| E26   | unit     | 934      | 2161     | 1997     | ... | 2161     | 2758     | 349      |
| S11   | ×10^8 RMB | 451.44   | 540.65   | 684.66   | ... | 540.65   | 1056.9   | 1252.33  |
| S12   | ×10^8 RMB | 45.7     | 59.37    | 87.35    | ... | 59.37    | 135.64   | 139.41   |
| S13   | ×10^8 RMB | 422.36   | 513.65   | 645.79   | ... | 513.65   | 927.01   | 1111.75  |
| S14   | ×10^8 RMB | 219.1    | 263.34   | 372.96   | ... | 263.34   | 584.1    | 686.4    |
| S15   | ×10^8 unit | 183.62   | 219.05   | 284.69   | ... | 573.03   | 666.92   | 767.13   |
| S16   | sq. m     | 11.5     | 11.84    | 12.14    | ... | 11.84    | 13.32    | 13.63    |
| S17   | unit      | 4872     | 5559     | 5768     | ... | 5552     | 12,790   | 18,762   |
| S18   | %         | 9.21     | 9.54     | 9.15     | ... | 9.9      | 10.22    | 10.30    |
| S19   | %         | 6.29     | 7.15     | 6.43     | ... | 6.9      | 7.02     | 6.94     |
| S20   | %         | 2.92     | 2.39     | 2.72     | ... | 3        | 3.36     | 3.36     |
| S21   | ×10^4 person | 34.53    | 37.86    | 36.28    | ... | 42.87    | 54.36    | 54.64    |
| S22   | %         | 4.2      | 4.6      | 4.3      | ... | 4.1      | 4.2      | 4.1      |
| S23   | RMB       | 5259     | 6072     | 6863     | ... | 12,485   | 13,755   | 14,774.00|

### 4.2. Data Processing

The main purpose of this study was to analyze the sustainable development capacity of Sichuan Province. Information entropy in regional system development is needed. Therefore, the data in Table 2 need to be investigated the changing trends in the positive or negative entropy flow by independent mathematical analyses. Each index has different units that need to be dealt with before data standardization. According to the efficiency of the entropy flow and pressure entropy flows, the indexes each year are normalized and standardized results obtained. MATLAB (The Mathworks, Inc., Natick, MA, USA) was used to further process the data according to entropy weight theory. The index weights and the information entropy for each index are shown in Table 3:
### Table 3. Data standardization and processed results for information entropy.

| Index | 2007 | 2008 | 2009 | ... | 2013 | 2014 | 2015 | Entropy Weight |
|-------|------|------|------|-----|------|------|------|----------------|
|       |      |      |      |     |      |      |      |                |
| C1    |      |      |      |     |      |      |      |                |
| C11   | 0.351| 0.419| 0.471| ... | 0.878| 0.950| 1.000| 0.974          |
| C12   | 0.553| 0.403| 0.609| ... | 0.916| 0.960| 1.000| 0.990          |
| C13   | 0.333| 0.417| 0.481| ... | 0.965| 1.000| 0.949| 0.972          |
| C14   | 0.296| 0.347| 0.396| ... | 0.728| 0.841| 1.000| 0.967          |
| C15   | 0.543| 0.592| 0.598| ... | 0.915| 0.960| 1.000| 0.989          |
| C16   | 0.331| 0.418| 0.479| ... | 0.974| 1.000| 0.931| 0.972          |
| C17   | 0.313| 0.374| 0.445| ... | 0.878| 0.959| 1.000| 0.968          |
| C18   | 0.152| 0.197| 0.255| ... | 0.797| 0.887| 1.000| 0.922          |
| C2    |      |      |      |     |      |      |      |                |
| C21   | 0.217| 0.274| 0.438| ... | 0.810| 0.908| 1.000| 0.956          |
| C22   | 0.176| 0.268| 0.441| ... | 0.666| 0.751| 1.000| 0.950          |
| C23   | 0.280| 0.389| 0.581| ... | 0.951| 0.967| 1.000| 0.971          |
| C24   | 0.361| 0.405| 0.752| ... | 0.519| 0.472| 1.000| 0.978          |
| C25   | 0.037| 0.056| 0.124| ... | 1.000| 0.441| 0.366| 0.851          |
| C26   | 0.203| 0.231| 0.354| ... | 0.801| 0.927| 1.000| 0.943          |
| E1    |      |      |      |     |      |      |      |                |
| E11   | 0.865| 0.834| 0.414| ... | 0.810| 1.000| 0.509| 0.972          |
| E12   | 1.000| 0.754| 0.528| ... | 0.299| 0.543| 0.552| 0.975          |
| E13   | 0.505| 0.525| 0.193| ... | 0.903| 1.000| 0.284| 0.930          |
| E14   | 0.821| 1.000| 0.671| ... | 0.138| 0.166| 0.025| 0.847          |
| E15   | 0.408| 0.423| 0.514| ... | 0.982| 0.892| 1.000| 0.978          |
| E16   | 0.783| 0.783| 0.911| ... | 0.911| 0.929| 1.000| 0.999          |
| E17   | 0.784| 0.784| 0.911| ... | 0.911| 0.925| 1.000| 0.999          |
| E18   | 0.550| 0.550| 0.550| ... | 1.000| 1.000| 1.000| 0.980          |
| E19   | 0.884| 0.912| 0.941| ... | 0.992| 0.969| 1.000| 1.000          |
| E2    |      |      |      |     |      |      |      |                |
| E21   | 1.000| 0.974| 0.963| ... | 0.693| 0.676| 0.608| 0.993          |
| E22   | 0.741| 0.768| 0.769| ... | 0.901| 0.970| 1.000| 0.997          |
| E23   | 0.592| 0.575| 0.574| ... | 0.946| 0.934| 0.911| 0.987          |
| E24   | 0.415| 0.431| 0.414| ... | 0.953| 0.937| 0.914| 0.967          |
| E25   | 1.000| 0.945| 0.811| ... | 0.937| 0.969| 1.000| 0.999          |
| E26   | 0.806| 0.782| 0.842| ... | 0.913| 0.892| 1.000| 0.999          |
| E27   | 0.584| 0.601| 0.657| ... | 0.967| 1.000| 0.989| 0.991          |
| E28   | 0.297| 0.686| 0.634| ... | 0.686| 0.876| 0.111| 0.941          |
| S1    |      |      |      |     |      |      |      |                |
| S11   | 0.360| 0.432| 0.547| ... | 0.432| 0.844| 1.000| 0.969          |
| S12   | 0.321| 0.417| 0.613| ... | 0.417| 0.953| 0.979| 0.959          |
| S13   | 0.380| 0.462| 0.581| ... | 0.462| 0.834| 1.000| 0.975          |
| S14   | 0.319| 0.384| 0.543| ... | 0.384| 0.851| 1.000| 0.964          |
| S15   | 0.239| 0.286| 0.371| ... | 0.747| 0.869| 1.000| 0.957          |
| S16   | 0.844| 0.869| 0.891| ... | 0.869| 0.977| 1.000| 0.999          |
| S17   | 0.260| 0.296| 0.307| ... | 0.296| 0.682| 1.000| 0.912          |
| S2    |      |      |      |     |      |      |      |                |
| S21   | 0.894| 0.926| 0.888| ... | 0.961| 0.992| 1.000| 0.999          |
| S22   | 0.880| 1.000| 0.899| ... | 0.965| 0.982| 0.971| 1.000          |
| S23   | 0.869| 0.711| 0.810| ... | 0.893| 0.952| 1.000| 0.997          |
| S24   | 0.632| 0.693| 0.664| ... | 0.765| 0.995| 1.000| 0.993          |
| S25   | 0.913| 1.000| 0.935| ... | 0.891| 0.913| 0.891| 1.000          |
| S26   | 0.356| 0.411| 0.465| ... | 0.845| 0.931| 1.000| 0.974          |

The standardized data can be dealt with using Equations (7)–(11) to determine the efficiency entropy flow, the pressure entropy flow changes in each subsystem and the quantitative evaluation value over several years. The results are shown in Tables 4 and 5.
### Table 4. System entropy flow change.

| Item                  | Year | 2007   | 2008   | 2009   | ... | 2013 | 2014 | 2015 |
|-----------------------|------|--------|--------|--------|-----|------|------|------|
| Economic subsystem    |      |        |        |        |     |      |      |      |
| Efficiency entropy flow $h_C$ |     | 0.971  | 0.979  | 0.987  | ... | 0.998| 0.999| 1.000|
| Pressure entropy flow $h_C$ |     | 0.941  | 0.937  | 0.942  | ... | 0.988| 0.975| 0.976|
| Entropy change $\Delta h_C$ |     | 0.030  | 0.042  | 0.045  | ... | 0.010 |0.024 |0.024 |
| Ecological environment subsystem | |        |        |        |     |      |      |      |
| Efficiency entropy flow $h_E$ |     | 0.984  | 0.985  | 0.963  | ... | 0.954 |0.968 |0.923 |
| Pressure entropy flow $h_E$ |     | 0.969  | 0.986  | 0.987  | ... | 0.996 |0.997 |0.956 |
| Entropy change $\Delta h_E$ |     | 0.015  | −0.001 | −0.024 | ... | −0.042 |−0.029 |−0.033 |
| Social subsystem      |      |        |        |        |     |      |      |      |
| Efficiency entropy flow $h_S$ |     | 0.949  | 0.963  | 0.975  | ... | 0.966 |0.997 |1.000 |
| Pressure entropy flow $h_S$ |     | 0.977  | 0.978  | 0.986  | ... | 0.999 |1.000 |1.000 |
| Entropy change $\Delta h_S$ |     | −0.028 | −0.015 | −0.011 | ... | −0.033 |−0.003 |−0.000 |
| Total entropy flow change $\Delta h$ | | 0.017  | 0.026  | 0.010  | ... | −0.065 |−0.008 |−0.009 |

### Table 5. Quantitative evaluation of the system.

| Item                  | Year | 2007   | 2008   | 2009   | ... | 2013 | 2014 | 2015 |
|-----------------------|------|--------|--------|--------|-----|------|------|------|
| Economic subsystem    |      |        |        |        |     |      |      |      |
| Efficiency evaluation value $Q_C$ |     | 0.003  | 0.004  | 0.005  | ... | 0.009 |0.010 |0.011 |
| Pressure evaluation value $Q_C$ |     | 0.001  | 0.001  | 0.002  | ... | 0.006 |0.004 |0.004 |
| variation value $\Delta Q_C$ |     | 0.002  | 0.003  | 0.003  | ... | 0.003 |0.006 |0.007 |
| Ecological environment subsystem | |        |        |        |     |      |      |      |
| Efficiency evaluation value $Q_E$ |     | 0.004  | 0.005  | 0.003  | ... | 0.002 |0.002 |0.001 |
| Pressure evaluation value $Q_E$ |     | 0.000  | 0.001  | 0.001  | ... | 0.001 |0.001 |0.001 |
| variation value $\Delta Q_E$ |     | 0.004  | 0.004  | 0.002  | ... | 0.001 |0.001 |0.000 |
| Social subsystem      |      |        |        |        |     |      |      |      |
| Efficiency evaluation value $Q_S$ |     | 0.000  | 0.001  | 0.001  | ... | 0.001 |0.001 |0.001 |
| Pressure evaluation value $Q_S$ |     | 0.000  | 0.000  | 0.000  | ... | 0.000 |0.000 |0.000 |
| variation value $\Delta Q_S$ |     | 0.000  | 0.001  | 0.001  | ... | 0.001 |0.001 |0.001 |
| Total evaluation value change $\Delta Q$ | | 0.006  | 0.008  | 0.006  | ... | 0.005 |0.008 |0.008 |

### 4.3. Results and Discussion

To better observe each subsystem’s entropy flow over the years, the data from Tables 4 and 5 was used to generate an entropy flow variation graph and a system value variation graph, as shown in Figures 5–12.

It can be seen that in Figure 5 the efficiency entropy change is relatively stable over the years, suggesting that the economic subsystem support for the sustainable development capacity of the regional system in Sichuan Province is rising steadily. The pressure entropy flow has a sharp increase in 2010, and then is gradually increasing from 2011 to 2013, suggesting the sustainable development capacity is reducing. It declines in 2014, and keeps steady until 2015, suggesting that the economic sustainable development capacity of the subsystem is on the rise. Combined with Figure 5, it is easy to see that the efficiency entropy flow is always greater than the pressure entropy flow in the economic subsystem. From the perspective of the value analysis (Figure 6), although the pressure evaluation value reaches the highest value in 2013, but the efficiency value does not catch up, and the efficiency value is always growing faster than the pressure value and the sustainable development of the economic subsystem capacity keeps increasing.
In Figure 7, the ecological environmental subsystem efficiency entropy flow is always lower, and has almost the same growth trend as the pressure entropy flow, except for 2007, which shows that the matters concerning pollutant emissions, energy consumption and nature environmental protection are increasingly serious. The efficiency entropy flow is higher than the pressure entropy flow in 2007, which proves that ecological environment problems have not been paid due attention. Meanwhile, as shown in Figure 8, the efficiency evaluation values is declining sharply in 2009, and the efficiency evaluation values are seriously below the pressure evaluation values after 2009. Combined with the entropy change and the evaluation value in the ecological environmental subsystem in Figure 11, the entropy change is negative, indicating that although measures are being taken in a timely manner, the effect is not so good. The sustainable development capacity in the ecological environmental subsystem is weak and needs effective measures to promote the sustainable development capacity.
Figure 8. Evaluation value change in the ecological subsystem.

Figure 9 shows that the social efficiency entropy flow has a smooth growth between 2007 and 2009, and a sharp decrease in 2010, then, it remains steady from 2010 to 2013, while at the same time, the pressure entropy flow is rising steadily and higher than the efficiency entropy flow. However, the value of the efficiency entropy and the pressure entropy is the same from 2014 to 2015. This suggests that the social subsystem maintains an internal balanced development. In the light of the development trend, the social subsystem will support for the sustainable development capacity of the regional system in Sichuan Province.

Combined with Figure 10, the pressure evaluation flow is lower than the efficiency evaluation flow over the past years, so Sichuan in general needs to invest more in social development, people’s livelihood security and development mode transformation to improve social equality and promote the sustainable development capacity of the social subsystem.

Figure 9. Entropy flow change in the social subsystem.

In Figure 11, the ecological environment subsystem entropy is negative, except in 2007, and the social subsystem entropy is also always negative, indicating there are no effective measures in Sichuan Province to promote ecological environment and social sustainable development. Although Sichuan Province’s economy has experienced rapid development, the investment ratio in social development
and people’s livelihood security declines, which results in slower ecological environment and social development than economic development.

It can be observed in Figure 12 that the sustainable development capacity decreases over the years. Before 2008, the sustainable development capacity of Sichuan Province showed a rising trend, which shows it had a certain sustainable development ability. However, after 2008, the regional sustainable development capacity flow has a big decline until to 2013. After 2013, the sustainable development capacity shows an increase, the effect is very obvious. After the analysis of the three subsystems’ entropy value changes and evaluation values, it can be found that the changes in Sichuan’s sustainable development capacity and ecological environmental subsystem are very similar (Figure 12).

![Figure 11. Entropy flow change in the regional sustainable development capacity.](image1)

![Figure 12. Evaluation value change in the regional sustainable development capacity.](image2)

Although the rapid development of the economy plays an important role in enhancing regional sustainable development, it cannot offset the impact of the ecological environmental subsystem or the social subsystem for the sustainable development capacity in Sichuan Province. The sustainable development of the ecological environmental subsystem and the social subsystem is also very important.

The above analysis of the three subsystems shows that Sichuan Province needs reasonable planning to promote the virtues of economic, environmental and social development. In view of the change of the entropy flow and the overall system in the three systems, the following proposals are given:

1. Economic strength is the power of regional sustainable development. Sichuan Province needs to have scientific planning to arrange the regional economic structure, promote the regional carrying capacity, and develop basic and potential industries.

2. Better ecological condition is a prerequisite for regional sustainable development. Cities should put more effort into green development, resource recycling, energy conservation, and emissions reductions. For example, by developing new energy industries, having a comprehensive
utilization of resources and ecological resources, and maintaining a circular economy to promote the sustainable development of the regional ecological environment.

3. Regional harmony is the foundation of regional sustainable development. In the process of regional sustainable development, social security construction is basic. Increasing spending on social construction, strengthening social security and regional infrastructure, and smoothing regional development are very important in creating a good social order and living environment for area residents.

4. For a city’s sustainable development, the equal distribution of resources is also very important, so Sichuan Province should take some measures to allocate the resources more equally. Such as making more poor people who came from the ethnic areas to afford the cost of the doctor and have more children who came from the poor areas can receive good education. The increasing of social equality is helpful to improve the ability of the sustainable development of the social system, so as to improve the Sichuan Province sustainable development capacity.

5. In terms of the sustainable development of the whole system, there needs to be a comprehensive evaluation of the existing sustainable development level in Sichuan Province. Then corresponding laws and policies system should be developed which highlight the coordinated development of the economy, society and the ecological environment. In this way, economic development advantages could be made full use of to promote environmental protection and social construction. Finally, the sustainable utilization of resources, economic development, ecological environment development and social construction could make up a virtuous circle.

5. Conclusions

Using the 2008 to 2016 Sichuan Province statistical yearbook, this paper established an index system for regional sustainable development capacity to comprehensively analyze the economic subsystem, environmental subsystem and social subsystem in Sichuan Province. Combined with the use of the information entropy principle, an analysis of the entropy flow change was conducted to derive a comprehensive evaluation value of the regional sustainable development capacity. From this research, the following conclusions were made:

1. Based on information entropy theory, traditional qualitative analysis can be converted to vector calculations to avoid the influence of subjective preferences. Through the establishment of an information entropy-Brusselator judgment model, the economic, ecological environment and the social subsystem entropy value changes can be analyzed so as to identify the sustainable development capacity of each subsystem and the whole province.

2. The information entropy model established in this paper can be used to find the advantages and disadvantages in system operations and can therefore assist in finding a more reasonable internal improvement focus for the system to provide a decision basis for effective improvements.

3. Through the analysis of each subsystem entropy flow change in Sichuan Province, it was found that as the economy develops, the complexity of the economic subsystem, environmental subsystem and the social subsystem increase. Although the sustainable development ability in Sichuan Province is rising, its ecological environmental protection and social construction still need to be strengthened.

On the whole, the highlights of this paper can be summed up in three points. First of all, in order to conduct a comprehensive and objective analysis for the regional sustainable development capacity, the paper introduced forty-six indicators and established a relatively complete index system. Afterwards, the model which is built by information entropy and Brusselator can effectively reduce the confusion of the whole system on problems solving, and get a clear research results about the three subsystems internal change and the overall change of the regional system. Finally, this paper can be applied to the relevant study about the index system establishing of sustainable development or the evaluation of regional sustainable development capacity.
The established index system comprehensively considers various factors, but there are still certain limitations. The index system does not contain all the regional sustainable development capacity influencing factors. In addition, this paper focused on a static independent analysis of the data indexes, without studying the internal logic relationships between the indexes and a dynamic evaluation of the indexes. Therefore, further improvements to the evaluation index system are planned as a focus at a later time to further study the internal logical relationships and to dynamically evaluate the index.

Acknowledgments: This research is funded by the National Nature Science Foundation of China (71601134), 2017 Social science “thirteen five” plan annual projects in Sichuan Province (SC17TJ010), the basic research and business expenses research project of Central Universities in Sichuan University (skqy201652).

Author Contributions: The study was designed by Dongyang Si in collaboration with all co-authors. Data was collected by Dongyang Si. The first and final drafts were written by Dongyang Si. The defects of draft were critiqued by Xuedong Liang. The results were analyzed by Dongyang Si and Xinli Zhang. The research and key elements of models were reviewed by Xuedong Liang. The writing work of corresponding parts and the major revisions of this paper were completed by Dongyang Si.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Qin, T. Challenges for sustainable development and its legal response in China: A perspective for social transformation. Sustainability 2014, 6, 5075–5106. [CrossRef]

2. Madlener, R.; Sunak, Y. Impacts of urbanization on urban structures and energy demand: What can we learn for urban energy planning and urbanization management? Sustain. Cities Soc. 2011, 1, 45–53. [CrossRef]

3. Xie, X.F.; Pu, L.J. Assessment of urban ecosystem health based on matter element analysis: A case study of 13 cities in Jiangsu Province, China. Int. J. Environ. Res. Public Health 2017, 14. [CrossRef] [PubMed]

4. Wu, J.; Wu, G.; Zhou, Q.; Li, M. Spatial variation of regional sustainable development and its relationship to the allocation of science and technology resources. Sustainability 2014, 6, 6400–6417. [CrossRef]

5. Li, F.; Liu, X.S.; Hu, D.; Wang, R.S.; Yang, W.R.; Li, D.; Zhao, D. Measurement indexes and an evaluation approach for assessing urban sustainable development: A case study for China’s Jining City. Landsc. Urban Plan. 2009, 90, 134–142. [CrossRef]

6. Berry, J.M.; Portney, K.E. Sustainability and interest group participation in city politics. Sustainability 2013, 5, 2077–2097. [CrossRef]

7. Fang, C.L.; Ma, H.T.; Wang, Z.B.; Li, G.D. The sustainable development of innovative cities in China: Comprehensive assessment and future configuration. J. Geogr. Sci. 2014, 24, 1095–1114. [CrossRef]

8. Zhang, H.Y.; Uwasu, M.; Hara, K.; Yabar, H. Sustainable urban development and land use change—A case study of the Yangtze River Delta in China. Sustainability 2011, 3, 1074–1089. [CrossRef]

9. Tweed, C.; Sutherland, M. Built cultural heritage and sustainable urban development. Landsc. Urban Plan. 2007, 83, 62–69. [CrossRef]

10. Zhao, C.R.; Zhou, B.; Su, X. Evaluation of urban eco-security—A case study of Mianyang city, China. Sustainability 2014, 6, 2281–2299. [CrossRef]

11. Shen, L.; Kyllo, J.M.; Guo, X.L. An integrated model based on a hierarchical indices system for monitoring and evaluating urban sustainability. Sustainability 2013, 5, 524–559. [CrossRef]

12. Yin, K.; Wang, R.; An, Q.; Yao, L.; Liang, J. Using eco-efficiency as an indicator for sustainable urban development: A case study of Chinese provincial capital cities. Ecol Indic. 2014, 36, 665–671. [CrossRef]

13. Javadian, M.; Shamskooshki, H.; Momeni, M. Application of Sustainable Urban Development in Environmental Suitability Analysis of Educational Land Use by Using AHP and GIS in Tehran. In Proceedings of the 2011 International Conference on Green Buildings and Sustainable Cities, Bologna, Italy, 15 September 2011.

14. Zhang, M.; Tan, F.; Lu, Z. Resource-based cities (RBC): A road to sustainability. Int. J. Sustain. Dev. World Ecol. 2014, 21, 465–470. [CrossRef]

15. Silvestre, W.J.; Antunes, P.; Amaro, A.; Filho, W.L. Assessment of corporate sustainability: Study of hybrid relations using Hybrid Bottom Line model. Int. J. Sustain. Dev. World Ecol. 2015, 22, 1–11.

16. Shaker, R.R.; Zubalsky, S.L. Examining patterns of sustainability across Europe: A multivariate and spatial assessment of 25 composite indices. Int. J. Sustain. Dev. World Ecol. 2014, 22, 1–13. [CrossRef]
17. Tan, F.; Lu, Z. Assessing regional sustainable development through an integration of nonlinear principal component analysis and Gram Schmidt orthogonalization. *Ecol. Indic.* **2016**, *63*, 71–81. [CrossRef]

18. Yang, F.; Pan, S.; Yao, X. Regional Convergence and Sustainable Development in China. *Sustainability* **2016**, *8*. [CrossRef]

19. Dempsey, N.; Bramley, G.; Power, S.; Brown, C. The social dimension of sustainable development: Defining urban social sustainability. *Sustain. Dev.* **2011**, *19*, 289–300. [CrossRef]

20. Salvati, L.; Carlucci, M. A composite index of sustainable development at the local scale: Italy as a case study. *Ecol. Indic.* **2014**, *43*, 162–171. [CrossRef]

21. Böhringer, C.; Jochem, P.E.P. Measuring the immeasurable—A survey of sustainability indices. *Ecol. Econ.* **2007**, *63*, 1–8. [CrossRef]

22. Zhang, Y.; Yang, Z.F.; Li, W. Analyses of urban ecosystem based on information entropy. *Ecol. Model.* **2006**, *197*, 1–12. [CrossRef]

23. Tian, S. Research on Negative Entropy of High-Tech Virtual Enterprise Based on Dissipative Structure. In Proceedings of the 2009 IEEE 16th International Conference on Industrial Engineering and Engineering Management (IE and EM 2009), Beijing, China, 21 October 2009.

24. Prigogine, I.; Allen, P.M. The Challenge of Complexity, See, Self-Organization and Dissipative Structures. In *Complexity and Management*; Schieve, W.C., Allen, P.M., Eds.; University of Texas Press: Austin, TX, USA, 2011.

25. Rees, W.E. Economic development and environmental protection: An ecological economics perspective. *Environ. Monit. Assess.* **2003**, *86*, 29–45. [CrossRef] [PubMed]

26. Liu, Y.B.; Song, X.F. The coupled mode and discrimination of urbanization and ecological environment. *Sci. Geogr. Sinica* **2005**, *25*, 408–414.

27. Yang, Q.L.; Zhang, Y. Research on Evaluation of Sustainable Development Based on Management Entropy for Scenic Areas. In Proceedings of the 2012 International Conference on Environment Materials and Environment Management, EMEM 2012, Wuhan, China, 4 August 2012.

28. Bao, B.Y.; Kong, X.L. The Analysis about the Dissipative Structure on Innovation Management. In Proceedings of the International Conference on E-Business and E-Government (ICEE 2010), Guangzhou, China, 7 May 2010.

29. Xiang, P.C.; Zou, L. Application of the dissipative structure theory in construction project management. *Int. J. Advan. Comput. Technol.* **2011**, *3*, 364–374.

30. Chen, F.; Zhang, X.H. Research on evolution of Chinese telecom industry system based on dissipative structure theory. *J. Comput.* **2011**, *6*, 725–731. [CrossRef]

© 2017 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).