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Correlation analysis and modeling of economic development based on principal component analysis

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Abstract. To improve effectiveness of research on sustainable development of agricultural economy of poor county in the case of resource and environment restriction, a kind of research method based on Fuzzy Analytic Network Process (FANP) model is proposed. Firstly, indexes for research on sustainable development of agricultural economy of poor county that consist of economic development subsystem, ecological environment subsystem and social development subsystem are constructed, and their elements are analyzed; secondly, classical analytic network process is improved with triangular fuzzy rules, weight of various indexes in sustainable development of agricultural economy of poor county is determined according to fuzzy preference programming method, of which criterion weight, coupling weight and accessory index weight are involved; finally, it is shown that sustainable development problem of agricultural economy of poor county can be researched effectively with the proposed method through empirical analysis and corresponding countermeasure and suggestion are proposed.

Key words. Resource and environment, FANP model, Poor county, Agricultural economy, Sustainable development.

1. Introduction

Seen from the global scope, as a kind of complex resource providing series products and service, resource and environment have decisive role in economic development. However environmental and economic development is often shown as contradictory unity. When economy of many countries and regions is developed rapidly, overdevelopment and over-consumption of resource and environment are caused and serious environmental pollution and resource shortage are caused. Especially, resource and environment problem becomes more prominent after entrance into the 20th century. At present, our country has become the second largest energy con-

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sumption country in the world. Take agricultural economy of poor county as example, and behind continuous and rapid increase of economy, agricultural economy of poor county is being confronted with 4 "unsustainables": firstly, it is hard to sustain land and space; secondly, it is hard to sustain energy and water resource; thirdly, it is hard to sustain heavy population burden; fourthly, it is hard to sustain environmental carrying capacity.

Development of agricultural economy of poor county over the past 20-plus years has been based on resource exchange and comparative advantage. Development resource of which agricultural economy of poor county lacks most is capital, technology and market, and therefore, institutional innovation advantage of the reform and opening-up policy is utilized sufficiently by agricultural economy of poor county to change precious development resource at the expense of cheap land and general labor and ecological environment, and the development lasts for more than 20 years. But agricultural economy of poor county pays enormous resource and environment price for supernormal economic growth. When industrialization is developed rapidly, tight restriction condition from development resource comes in advance, and serious tight resource restriction condition has appeared in some important natural resource fields. Moreover, in addition to tight restriction from hard resource, agricultural economy of poor county is also confronted with tight restriction from soft resource development. Education, talent, technology, system, investment environment, innovation strength, management efficiency and cultural taste factors etc. also restrict further development of economic society in different degrees. Behind continuous and rapid increase of economy for many years, increase vigor of extensive entrepreneurial economy has been released completely, and agricultural economy of poor county does not have enough total resource and environment capacity to support and bear high-consumption production mode. Unsustainability in terms of resource means that agricultural economy of poor county will be confronted with new strategic choice: change resource dependence idea and economic growth mode, take soft resource as main supporting point of future economic increase and develop innovative economy by taking self-dependent innovation as power with advantage of institutional innovation and technology leading. Tight restriction reflects one important feature of agricultural economy development of poor county, which is an objective fact that cannot be avoided to plan agricultural economy development of poor county, and agricultural economy of poor county must be based on the fact, establishing the consciousness of resources crisis, updating resource-based view and placing development under tight restriction condition consciously, and researching great strategic problem concerned with agricultural economy development of poor county and point distribution problem to great project, water resource problem and strategic resource control problem.

The essence of sustainable development of agricultural economy in poor counties is to realize the sustainable development of agricultural economy in poor counties and society with development basis of protecting and rationally utilizing natural resources and maintaining a good ecological environment, which aims at achieving sustained and stable economic development, continuously meet the people's growing material and cultural needs, while not affecting the needs of future generations to

continue the development, establish a correct concept of agricultural economy development in poor counties, improve agricultural economic planning and civil code of conduct in poor counties, control the consumption of natural resources, maintain ecological balance, establish benign operation mechanism of high efficiency and low energy consumption. In the aspect of economy, sustainable development requires full play to the potential of agricultural economy in poor counties to make the agricultural economy in poor counties develop towards a steady, efficient, high-quality and innovative direction with minimum resource utilization. In this paper takes the agricultural economy of poor counties as an example to discuss how to overcome the difficulties and achieve the sustainable development of economy under the dual constraints of resources and environment. This paper takes example of agriculture economy in poor counties and discussed how to tackle difficulties to realize sustainable economic development under the constraints of resources and environment. The paper proposed a research method based on FANP model for the issue of sustainable development of agricultural economy in poor counties under constraints of resources and environment, constructed research indexes of agricultural economic sustainable development in poor counties to determine the weights of the various indexes of agricultural economic sustainable development in poor counties from classical network analysis method by using triangular fuzzy rules, realizing quantitative study on the sustainable development of agriculture economy in poor counties.

2. Index system construction

2.1. Principles of index system construction

The early warning system of the sustainable development of agricultural economy in poor counties is a kind of multi-alarm system, which should be systematic, hierarchical, logical, stable and operable. The systematic principle refers to that the construction of the index system should have the full range of features supporting operation of the whole system, cover multi indexes of agricultural economy, ecology, environment, resources and other aspects of poor counties, and organically combine all factors of agricultural economic development of poor counties.

The principle of hierarchy refers to that the system should be able to comprehensively reflect alert, warning sources and warning signs, reflect the relationship between the indexes and in line with logic rules of economic development. According to the correlation between the indexes, it can be divided into different categories and multiple levels, and refine indexes from top to bottom for study and analysis. The development of agricultural economy in poor counties is a long-term dynamic process, therefore there should be long-term monitoring and early warning of agricultural economy in poor counties, warning index with flexibility while maintaining relative stable should be selected. Construction of early warning system of agricultural economic development in poor counties is to provide decision-making basis for economic management and planning, at the same time to reduce the operation cost of early warning system, the selection of indexes should be simple and clear, data should be in simple form and easier to acquire and collect.

2.2. Sustainable development index system of agricultural economy in poor counties

According to different disciplines, there are different classification methods of index system of sustainable development. A poor county is a complex system, which consists of many interacting and interrelated subsystems. In the design, hierarchical thinking divided sustainable development index of agricultural economy in poor counties into 3 subsystems: economic index, ecological environment index and social index, based on which refinements are made according to early warning index and alarm index, as shown in Table 1.

Table 1. Sustainable development index system of agricultural economy in poor counties

Subsystem	Alarm index
Economic development subsystem	Economic strength
	Infrastructure construction
	Economic structure
	Economic operation quality
	Economic performance
Ecological environment subsystem	Per capita resources
	Forestland resources
	Environmental resources
Social development subsystem	Population
	Education
	Hygiene
	Culture
	Social security
	Social stability

2.3. Elements of the early warning system of sustainable development of agricultural economy in poor counties

Early warning of sustainable development of agricultural economy in poor counties is a complex process of statistical analysis and forecasting, which need to combine early warning theory and index system of sustainable development of agricultural economy in poor counties to reasonably design structure of early warning system. The system consists of alert, warning source, warning signs and warning degrees, etc. Alert is what needed to detect and forecast in early warning. Warning source is the root of the alarm, in the early warning of sustainable development of agricultural economy in poor counties, warning sources usually come from natural factors (such as economic volume is below the threshold) and external factors (such as the national economic policy changes) and internal factors (such as economic investment in poor counties declines).

Warning sign is the precursor of the outbreak of the alert, the analysis of warning sign is a key link in the early warning process. Generally speaking, different alerts correspond to different warning signs. There is direct or indirect relationship between

warning signs and alert. Warning degree is the warning level, description of severity of alert according to the change of the warning signs. The key to determine the warning degree is to determine the police line based on historical analysis, expert survey, international comparison, mathematical methods and other factors.

3. Sustainable development of FANP

3.1. ANP decision

First, build the decision factor sets for analysis on agricultural economy and establish decision model. However, the relationship among each influential factor is rather complicated during decision, so it is necessary to sort out this relationship prior to decision and calculate and allocate ANP decision weight so as to achieve the integrate decision for analysis on agricultural economy. During the decision, APN algorithm can be divided into two layers: one is the control layer where there are decision objectives and decision criterions which are independent of each other; the other is network layer where the elements on this layer are dominated by control layer and the relation among elements constitute the network form. ANP decision process is shown in Fig. 1.

There are three relationship types for element in ANP network: internal relationship, external relationship and feedback relationship. The external relationship reflects the relationship influence existing among element group: for example, element C_1 has an influence on and association with element C_3 in Fig. 1 and there is a external association between C_1 and C_3; the internal relationship reflects the influence and association inside element group and the internal association is formed among elements inside C_2 in Fig. 1; but the feedback reflects the bidirectional association among element group, that is, element C_1 has an influence on element C_2 in Fig. 1 and meanwhile element C_2 also has an influence on element C_1, so the similar feedback association is formed.

After accomplishing the criterion for control layer of network model and building of element, it is necessary to compare the importance of elements dominated by criterion in accordance with criterion and confirm the priority in accordance with decision preference and influential association, in which this quantized order index is the dominance. Here two types of dominance are defined: one is the direct dominance, that is, under the given criterion, directly compare the two elements; the other is the indirect dominance, that is, under the given criterion, utilize the association of two elements to compare with the other element (sub-criterion). The dominance comparison among elements is based on 1-9 scaling method to quantify. The concreteness is shown in Table 2.

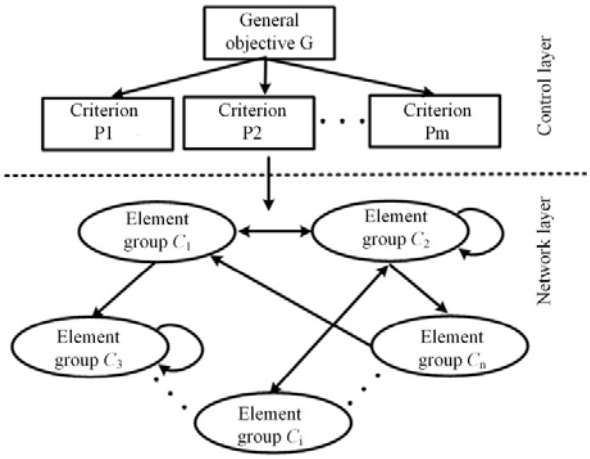

Fig. 1. ANP model

Table 2. Saaty's 1-9 scaling method

Scale value	Implication
1	Two elements have the same importance
3	One element is slightly more important than the other one
5	One element is obviously more important than the other one
7	One element is intensely more important than the other one
9	One element is extremely more important than the other one
2,4,6,8	Adopt compromise value mode

3.2. Fuzzy programming

During decision, it is necessary to adopt quantitative and qualitative modes to compare the element association. Analytical hierarchy process (AHP) or ANP is frequently used in the past literature to carry out decision, but during evaluation, due to the existence of information uncertainty, the precise valuation mode will lead to thinking that the participation is excessive and the decision is not objective enough, hence, the fuzzy mode is adopted here to carry out decision to improve the fairness of decision.

The frequently-used triangular fuzzy number M can be shown as (l, m, u) and meet $l \leq m \leq u$. In the formula, the parameter l, m, u is the probable value of minimum probability, general probability and maximum probability of fuzzy decision degree. The membership function of M is the form as shown in Fig. 2.

$$\mu_M(x) = \begin{cases} (x-l)/(m-l), l \leq x \leq m, \\ (\mu - x)/(\mu - m), m \leq x \leq \mu, \\ 0, otherwise. \end{cases} \tag{1}$$

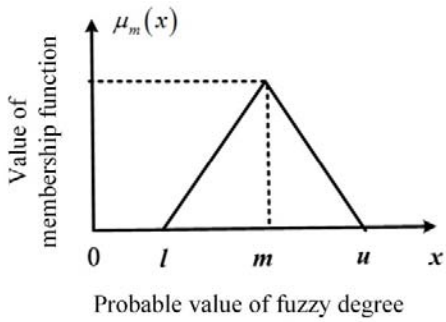

Fig. 2. Triangular fuzzy number

Given $A = (l_{ij}, u_{ij})$ as scope discriminant vector of index n, l_{ij} as lower bound of expert's discriminant value and u_{ij} as upper bound of xpert's discriminant value. The scope discriminant and weight vector can be got with fuzzy programming calculation.

Under the circumstance of uniformity, it meets:

$$l_{ij} \leq \frac{\omega_i}{\omega_j} \leq \mu_{ij} \,. \tag{2}$$

In the formula (2), $i = 1, 2, \cdots, n-1$, $j = 2, 3, \cdots, n$, $j > i$.

Under the circumstance of inconformity, it meets:

$$l_{ij} \tilde{\leq} \frac{\omega_i}{\omega_j} \tilde{\leq} \mu_{ij} \,. \tag{3}$$

Operator $\tilde{\leq}$ is the fuzzy operation identification and the inequation in formula (3) shows that the weight vector shall try to meet the upper and lower bound of expert's discriminant value.

If the weight vector can be adopted to calculate the triangular fuzzy rule, then the form of expert's discriminant opinion expressed is as follows:

$$\mu_{ij}\left(\frac{\omega_i}{\omega_j}\right) = \begin{cases} \dfrac{(\omega_i/\omega_j) - l_{ij}}{m_{ij} - l_{ij}}, \dfrac{\omega_i}{\omega_j} \leq m_{ij} \,, \\ \dfrac{\mu_{ij} - (\omega_i/\omega_j)}{\mu_{ij} - m_{ij}}, \dfrac{\omega_i}{\omega_j} \geq m_{ij} \,. \end{cases} \tag{4}$$

The value scope of membership shown in formula (4) is $(-\infty, m_{ij})$, which meets linear decreasing characteristics within the value scope of (m_{ij}, ∞). If $w_i/w_j < l_{ij}$ or $w_i/w_j > u_{ij}$ is met, $u_{ij} < 0$; if $w_i/w_j = m_{ij}$ is met, the maximum value obtained by u_{ij} is 1. Within the value scope of (l_{ij}, u_{ij}), then there is the following form:

$$Q^{n-1} = \{(w_1, w_2, \cdots w_n) | w_i > 0, \sum_{i=1}^{n} w_i = 1\} \,. \tag{5}$$

The fuzzy membership on the feasible region of value can be defined as

$$u_p(w) = \min_{ij} \{u_{ij}(w) | i = 1, 2, \cdots, n-1;\ j = 2, 3, \cdots, n;\ j > i\}. \tag{6}$$

After the fuzzy programming of weight vector $w \in Q^{n-1}$, if the discriminate matrix is not inconformity, the value of $u_p(w)$ is negative. The assumptions above can confirm the maximum value in formula (6), which is the selection rule of weight vector. It can be proved that $u_p(w)$ is convex set, hence, there is always a maximum value for membership of weight vector $w^* \in Q^{n-1}$:

$$\lambda^* = u_P(w^*) = \max_{w \in Q^{n-1}} \min_{ij} \{u_{ij}(w)\}. \tag{7}$$

The problem solving weight vector above can be converted into the following programming problem:

max λ

$$\lambda \le u_{ij}(w), i = 1, 2, \cdots, n-1;\ j = 2, 3, \cdots, n;\ j > i \tag{8}$$

$$\sum_{k=1}^{n} w_k = 1, w_k > 0, k = 1, 2, \cdots, n.$$

According to formula (4), formula (8) can be converted into nonlinear programming problem and the form is as follows:

$$\max \lambda$$

$$(m_{ij} - l_{ij})\lambda w_j - w_i + l_{ij} w_j \le 0.$$

$$(u_{ij} - m_{ij})\lambda w_j + w_i - u_{ij} w_j \le 0. \tag{9}$$

$$\sum_{k=1}^{n} w_k = 1, w_k > 0.$$

In formula (9), $k = 1, 2, \cdots, n$, $i = 1, 2, \cdots, n-1$, $j = 2, 3, \cdots, n$ and $j > i$. Its optimal plan is (w^*, λ^*), where w^* is the corresponding weight vector of membership with the maximum value; λ^* is the uniformity characteristic index. The bigger the value of λ^* is, it means the higher uniformity of decision is. If $\lambda^* > 0$ is met, $l_{ij} \le \left(w_i^*/w_j^*\right) \le u_{ij}$ is workable and the uniformity of characteristic discriminant matrix is better; if $\lambda^* \le 0$, it means that equivalence shall be carried out between $\left(w_i^*/w_j^*\right)$ and inequation (3) and the uniformity of characteristic discriminant matrix is poor.

Above

Below

4. Experimental analysis

4.1. Model assumption

A total of 30 indexes from 4 aspects for sustainable economic development in some poor county has been selected in the Paper, in which the actually values are all from economic society programming and each actual index of economic development in some poor county from 2008-2014, and dimensionless naturalization treatment has been carried out for them, so based on this, the evaluation model is built and according to the specific situation in model, the following assumptions are made:

Assumption 1: starting from the ninth Five-Year plan, China has recognized the importance of developing ecological economy and has reflected the resolution of developing ecological economy from each policy and system.

Assumption 2: each index in economic program has reflected the process of individual gradual and progressive sustainable development of ecological economy for sustainable development of ecological economy.

Assumption 3: assuming that the sustainable development degree of ecological economy in economic development program respectively is quasi sustainable development, weak sustainable development ability and strong sustainable development ability.

4.2. Build evaluation model

The conclusion is drawn in the Paper by building evaluation model for sustainable economic development in some poor county with FANP model and by evaluating the overall situation of sustainable economic development in some poor county and the 4 aspects of sustainable economic development in some poor county (namely, development level, development efficiency, development potential and development coordination).

For FANP mode algorithm, as the input sample of input layer, the individual connection between the top and bottom is achieved, while there is no connection among 4 layers of network layer, so it does not need to consider the correlation among each input, however, the initial weight value of network makes the status value of 4 network layers close to zero during inputting and accumulating and the random number got by weight is rather small, so the sample input needs to be naturalized and handled.

When the overall evaluation is carried out on the economy in some poor county with FANP model, to make it convenient for evaluating the degree of sustainable development of ecological economy, the sustainable development degree can be divided into 4 types: namely, unsustainable development (expressed with code 00 and value being 0), quasi sustainable development (expressed with code 01 and value being 1), weak sustainable development ability (expressed with code 10 and value being 2'+0=2), strong sustainable development (expressed with code 11 and value being 2'+1=3), which can be judged with two more specific indexes:

If $2.5<F<3.0$, the sustainable development ability of ecological economy is strong;

if 1.5<F<2.5, the sustainable development ability of ecological economy is weak; if 0.5 <F<1.5, the ecological economy is quasi sustainable development; if 0.0<F<0.5, the ecological economy is unsustainable development

Table 3. FANP model for ecological economy

Year	Evaluation result	Actual result evaluated	Determination of evaluation result
2008	(0.0000, 0.0005)	0.0005	Unsustainable development
2009	(0.0000, 0.0001)	0.0001	Unsustainable development
2010	(0.0000, 0.0000)	0.0000	Unsustainable development
2011	(0.9928, 0.0000)	1.9992	Weak sustainable development ability
2012	(1.0000, 0.0325)	2.0321	Weak sustainable development ability
2013	(1.0000, 0.0125)	2.0114	Weak sustainable development ability
2014	(1.0000, 0.2362)	2.2361	Weak sustainable development ability

It can be seen from Table 2 that the ecological economy has experienced the process from unsustainable development to sustainable development and finally to gradual mature in the past 7 years. We still adopt FANP model to further analyze 4 aspects on sustainable development ability of ecological economy, namely, sustainable development level, sustainable development efficiency, sustainable development potential and sustainable development coordination, so as to find out the weak link of sustainable economic development in some poor county. Starting from the view convenient for evaluating sustainable development, we build the output of model result to show the degree of sustainable development, that is, value 0 means that the development ability is the lowest and value 3 means that the development ability is the strongest, based on which the level, efficiency, potential and coordination of sustainable development of ecological economy can be evaluated.

Create FANP network model meeting the requirements above with mathematical software and see Table 4 for operation result.

Table 4. Evaluation result for development ability of ecological economy from 2008-2014

Year	2008	2009	2010	2011	2012	2013	2014
Development level	-0.0471	0.4862	0.6103	1.4264	1.3883	2.4197	2.4134
Development efficiency	0.1338	0.3418	0.3207	0.5223	1.4629	1.9473	1.9495
Development potential	0.9907	1.0516	1.4591	1.5682	1.8183	2.0643	2.3576
Development of coordination	0.7882	1.1152	0.9058	1.4282	1.8670	1.8978	1.8990

5. Conclusions and analysis

(1) Seeing from the evaluation of the whole economy development situation of the poor county between 2008-2014 by FANP evaluation model, the overall economic quantity increased from 0.005 in 2008 to 2.2362 in 2013, with a gradual overall rising process, which indicates the ecological economy has experienced a overall situation

of unsustainable development to sustainable development in the first 6 years of 21st Century. However, seeing from the development process, this is a slow process.

According to hypothesis of this Paper: the social and economic development planning is a gradual process that gradually guide the economy of the poor county to develop as the process goes: unsustainable development–quasi sustainable development-weak capability of sustainable development-strong capability of sustainable development. But from the analysis of the results of the FANP model, although the economy development in the poor county has been on the rise in first 7 years in 21st Century, but it is also slow, and still in the stage of weak capability of sustainable development, for a few years there was even a slight downward trend, for example, it declined from 0.001 in 2008 to 0.005 in 2009, decreased by 80%; it declined from 0.001 in 2009 to 0.000 in 2010, decreased by 10%. Although the decline trend has been effectively controlled and reasonably improved, it also shows that there is a problem of sustainable economic development in the poor county.

(2) Using FANP evaluation model to evaluate 4 aspects of economic sustainable development in the poor country during 2008-2014, seeing from overall development ability, we can find the economic development momentum of the poor county is gratifying, with development level, development efficiency, development potential and development coordination increasing in different degrees. On development level, the economic starting point of the poor county is relatively low, the evaluation result of development level in 2008 was just -0.0471, not reaching expected gauge city level. Except for slight decrease during the period of 2011-2012, the development level has been straightly rising gradually, especially during the period of 2010-2011 and 2012-2013, during which rising amplitudes were respectively as high as 133% and 74%; Seeing from the development efficiency curve, the economic development efficiency levels during the period of 2008-2011 calculated by FANP model, were respectively 0.1338, 0.3418, 0.3207 and 0.05023, indicating weak foundation of development efficiency and slow efficiency development. But during the period of 2011-2014, the economic development efficiency rose by leaps and bounds, which indicates consciousness of ecological economy in the province has been strengthened, industry and agricultural production has increasingly attached importance to scientific and technological content and efficiency, and ecological economic benefits has been promoted to increase under the practice of ecological economy under the perennial planning & programming guidance of the province.

Seeing from economic development potential map, there is great ecological economic development potential, just see from starting point in 2008, it has reached the level of 1 and gradually increased with no downward trend in following years, and in 2014 it reached the level of 2.3576, indicating infinite potential of development of ecological economy in the province; seeing from the coordination of eco economic sustainable development, the guiding role government plays on eco economy and the leading role market plays on eco economy are mainly considered, since 2010, there was a significant growth in the development coordination ability, for example, development coordination ability in 2011 increased 57% than that in 2010, and development coordination ability in 2013 increased 109% than that in 2012, indicating that ecological economy has gradually begun to shift from government

control to market allocation of resources, the role of market allocation of resources has been brought into full play, and the coordinated ability of ecological economic development has been further strengthened.

Generally speaking, the overall level of sustainable development of ecological economy is gradually rising, but we should also see the problems: first, the starting point of development level, efficiency, capability and coordination ability of ecological economy are relatively low, they were respectively -0.047 1, 0.1338, 0.9907 and 0.7889 in 2008, even the development level in 2008 was only -0.0471(in the evaluation of various indicators, we use 0 for the lowest value), although four indexes were gradually increased afterwards, but it is an indisputable fact that starting point is low of economy in the poor county.

Secondly, we see the four indexes were not steadily rising in rising process, sometimes there was a short downward trend, and sometimes with a sharp increase, which is adverse to steady development of ecological economy, a sharp increasing trend is not a good thing for provinces with originally weak ecological economic foundation. On the premise that various factors hindering the development of ecological economy are not cleared and reasonable policies and systems are not established, various factors originally hindering the ecological economic development would become more obvious in high-speed development and become insurmountable obstacles to ecological economic development.

6. Countermeasures and suggestions

(1) In macroeconomic policies of the government, the government should strengthen macro guidance and specific services of human ecological economy, such as the introduction of capital, technology, organization of production, development of the market, and to strengthen ecological and environmental construction and publicity; to speed up ecological system innovation, adjust the industrial structure, improve the ecological and economic benefits, rationally develop superior resources, promote the ecological economic structure tends to coordination and rationalization, control population growth, improve the quality and attach importance to human resources.

(2) In micro operation of the enterprises, to determine dual goals of internal economy and external economy of enterprises, and rely on its ecological and resource advantages to develop ecological products, being market-oriented, technology-driven and eco-centered and taking into account the benefits and manpower to set up the marketing concept of ecological products, and strive to realize the technology ecology and industrial ecology.

(3) Give full play to the ecological economy to combine development of ecological industry and human and social resources such as ethnic customs, historical culture together, and organically combine development of ecological products and ecological tourism, ecological consumption, ecological culture together by developing Eco Tourism Cultural Festival, ecological cultural exchanges, product exhibitions and other activities to construct the ecological economy with local characteristics, and fundamentally promote the sustainable development of the economy in impoverished counties.

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