Research Based on Stability of Manufacturing Clusters from Perspective of Super-network

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Abstract

Based on the issue how ecological technologies influence manufacturing clusters under market disciplines, a manufacturing cluster network model that regards ecological technologies of supplier manufacturers and vendors as subjects has been established. The network flows of super-networks are flow resources of manufacturing clusters. This paper, through analyzing features of suppliers of ecological technologies manufacturers and vendors, has discussed the steady states of manufacturing cluster super-networks and analyzed the influence of flows of ecological technologies utilization rates of ecological technologies, risks of ecological technologies and other parameters on steady states. Finally, the simulation verification on the model has been conducted with cluster particles, key factors which are influencing the model have been analyzed and countermeasures for improvement have been proposed.

Keyword: *ecological technologies, manufacturing clusters, super-networks*

1. Introduction

Under the circumstance of resource shortage, economic downturn and financing difficulty, the production model of traditional manufacturing cluster that is characterized by high inputs, low production and high pollution is no longer adapted to the need of modern society. Firms within the cluster have poor environmental and social performances. So, the challenge faced by runners and managers of enterprises is how to overcome the dilemma and create a low-input, high-production and low-pollution production and “green” model. Ecological technologies are knowledge-intensive resources and an important engine to promote the transformation and upgrading of manufacturing clusters. The integration of ecological technologies with manufacturing industry has facilitated the transformation and upgrading of manufacturing clusters, promoted the sustainable development of manufacturing clusters and constituted an important support for continuous innovation of manufacturing clusters. The reason lies in that ecological technologies can improve the production efficiency of manufacturing clusters, strengthen inherent elastic outputs of production elements and reduce the reliance on resources. However, in the process of integrating ecological technologies and manufacturing industry, only market-oriented products and services that meet market demands constitute a future of ecological technologies and manufacturing convergence. That is manufacturing industry making use of ecological technologies to reduce emissions of waste water, wasting gas and residues, reducing pollution and producing products and services. Only on this way can market risks resulted from homogenization of functions of manufacturing clusters be avoided and risk-aversion incomes and higher added values of products be attained. It makes regional innovation and innovations to be more efficiently developed and diffused within clusters.

From above analysis, the close loop exists among suppliers of ecological technologies, manufacturers and vendors who are mutually influencing and penetrating. By available studies, however, there are few literatures that have integrated suppliers of ecological technologies, manufacturers and vendors in manufacturing clusters under the framework of super-networks though there are considerable literatures on manufacturing clusters. If suppliers of ecological technologies, a comprehensive objective function can be construct. Manufacturers and vendors in manufacturing clusters has been developed, the optimal solution of the comprehensive objective is attained with ant colony algorithm, and the influence of the flowing of ecological technologies, utilization rates of ecological technologies and risks of ecological technologies on evolution of manufacturing clusters has been studied. Studies on this issue have provided not only a theoretical foundation for studying manufacturing clusters but also an idea for making relevant policies for manufacturing clusters led by the government

2. Construct Model

The suppliers of ecological technologies-manufacturers-vendors super-network model, which is introduced m suppliers of ecological technologies, n manufacturers and k vendors. The network flows in the super-network model refer to flowing materials in manufacturing clusters. It is shown on Figure 1.

1) The suppliers in this system constitute three sub networks respectively in the super-network. They are sub network of suppliers of ecological technologies, sub network of manufacturers and sub network of vendors.

2) Resources in different sub networks of the super network can flow freely.

3) Analyze vendors with market needs.

Figure 1. Technologies-manufacturers-vendors Super Network Model

2.1 Behavioral Analysis of Suppliers i of Ecological Technologies

The Suppliers of ecological technologies are owners and producers of ecological technologies and q_{1i} refers to amount of ecological technologies of first-level suppliers of ecological technologies. Moreover, q_{1ij} refers to amount of ecological technologies provided by first-level suppliers i of ecological technologies to manufactures j ; the price of first-level unit product ecological technologies is p_{1i} ; C_{1ij} refers to transaction cost function between first-level suppliers i of ecological technologies and manufactures j and is recorded as $C_{1ij} = C_{1ij}(q_{1ij})$. Assume C_{1ij} as a continuously differentiable convex function on ecological technologies. q_{1ij} ;

$f_{li} = f_{li}(q_{li})$, $\forall i$ refers to the cost paid by suppliers of ecological technologies for attaining ecological technologies and a continuously differentiable convex function.

Describe comprehensive objective optimization of suppliers i of ecological technologies as:

$$\max Z_{li} = \sum_{j=1}^n \rho_{31} q_{ij} - f_{li}(q_{li}) - \sum_{j=1}^n C_{lij}(q_{lij}) \quad \forall j, q_{ij} \geq 0 \quad (1)$$

Describe comprehensive objective optimization of all suppliers of ecological technologies as:

$$\max \sum_{i=1}^m \sum_{j=1}^n (\rho_{31} q_{ij} - C_{lij}(q_{lij}) - \frac{1}{n} f_{li}(q_{li})) \quad \forall Q^1 \in R_+^{1'} \quad (2)$$

2.2 Behavioral Analysis of Manufacturer j

The parameter ρ_{2j} is referring to price of unit product of manufacturer j . The utilization rate of an ecological technology by manufacturer j is presented to the parameter δ . In order to generate to the parameter j , record the amount of ecological technologies attained from supplier of ecological technologies as q_j , and production cost as $f_{2j}, f_{2j} = f_{2j}(q_{2j}, \delta)$. Assume f_{2j} as a continuously differentiable non-negative function r_{2j} refers to a risk function undertaken for attaining, that is, function related to amount q_{2j} of ecological technologies and the risk factors parameter η . Where, C_{2ij} refers to the transaction cost function between manufacturer j and supplier i of ecological technologies. The function related to amount q_{ij} of ecological technologies, is recorded as $C_{2ij} = C_{2ij}(q_{2ij})$. Furthermore, assume C_{2ij} as a continuously differentiable non-negative convex function.

The objective of manufacturer j is in the following.

$$\mu_{2j} = \sum_{i=1}^m (\rho_{32} q_{2ij} - C_{2ij}(q_{2ij})) - f_{2j}(q_{2j}, \delta) - r_{2j}(\eta, q_{2j}) \quad (3)$$

Describe comprehensive objective optimization of all manufacturers is in the following.

$$\sum_{j=1}^n u_{2j} = \sum_{j=1}^n \sum_{i=1}^m (\rho_{32} q_{2ij} - C_{2ij}(q_{2ij}) - \frac{1}{m} f_{2j}(q_{2j}, \delta) - \frac{1}{m} r_{2j}(\eta, q_{2j})) \quad (4)$$

The objective function of manufacturers j is a continuously differentiable convex function and so is its comprehensive objective function. Solution of the objective function is also solution to the inequality.

2.3 Demand Market k and Equilibrium Condition

The parameter ρ_{3k} is in the markets parameter k . Furthermore, d_{3k} present demand for a product by the demand market k , assume d_{3k} as a continuously d function.

$$d_{3k} = d_{3k}(\rho_{31}, \rho_{32}), \forall k \quad \rho_{31} > 0, \quad \rho_{32} > 0;$$

2.4. Comprehensive Objective of Suppliers of Ecological Technologies, Manufacturers and Vendors

$$\begin{aligned} \max \quad & \sum_{i=1}^m \sum_{j=1}^n (\rho_{31} q_{ij} - C_{1ij}(q_{1ij}) - \frac{1}{n} f_{1j}(q_{1j})) \\ & + \sum_{j=1}^n \sum_{i=1}^m (\rho_{32} q_{ij} - C_{2ij}(q_{2ij}) - \frac{1}{m} f_{2j}(q_{2j}, \delta) - \frac{1}{m} r_{2j}(q_{2j}, \eta)) \\ & + \sum_{k=1}^2 d_k(\rho) \end{aligned} \quad (5)$$

Where, constraint conditions are in the following.

$$\begin{aligned} \sum_{i=1}^m \sum_{j=1}^n q_{kij} &\leq S^i, \forall i \\ \forall q_{kij} &\geq 0 \end{aligned}$$

3. Function Setting

1) Amount of ecological technologies of suppliers of ecological technologies.

$$q_{11} = q_{111} + q_{112};$$

$$q_{12} = q_{121} + q_{122};$$

$$Q_1 = q_{111} + q_{112} + q_{121} + q_{122};$$

2) Processing cost function of suppliers of ecological technologies.

$$f_{11}(q_{11}) = 2q_{11}^2 + 3q_{11} + 4;$$

$$f_{12}(q_{12}) = 2q_{12}^2 + 3q_{12} + 4;$$

3) Cost function of suppliers of ecological technologies.

$$C_{111}(q_{111}) = 0.5q_{111}^2 - 3q_{111} - 2;$$

$$C_{112}(q_{112}) = 0.4q_{112}^2 - 3.3q_{112} - 5;$$

$$C_{121}(q_{121}) = 0.5q_{121}^2 - 3q_{121} - 8;$$

$$C_{122}(q_{122}) = 0.5q_{122}^2 - 3.5q_{122} - 8;$$

4) Ecological technology function attained by manufacturers.

$$q_{21} = q_{211} + q_{212};$$

$$q_{22} = q_{221} + q_{222};$$

$$Q_2 = q_{211} + q_{212} + q_{221} + q_{222};$$

5) Processing cost function of manufacturers

$$f_{21}(q_{21}, \delta) = \delta (-0.2q_{21}^2 - 0.2q_{21} + 3);$$

$$f_{22}(q_{22}, \delta) = \delta (-0.3q_{22}^2 + 2q_{22} - 8);$$

6) Cost function of manufacturers.

$$C_{211}(q_{211}) = 0.5q_{211}^2 - 0.3q_{211};$$

$$C_{212}(q_{212}) = 0.5q_{212}^2 - 2.3q_{212};$$

$$C_{221}(q_{221}) = 0.2q_{221}^2 - 0.1q_{221};$$

$$C_{222}(q_{222}) = 0.5q_{222}^2 + 2.1q_{222};$$

7) Risk function of applying ecological technologies by manufacturers.

$$r_{21}(\eta, q_{21}) = \eta(-0.5q_{21}^2 + 0.3q_{21} - 3);$$

$$r_{22}(\eta, q_{22}) = \eta(-0.5q_{22}^2 + 0.2q_{22} - 2);$$

8) Demand function of market

$$d_{31}(\rho_3) = -0.05\rho_{31}^2 - 0.02\rho_{32}^2 - 2\rho_{31} - 3\rho_{32} + 1300;$$

$$d_{32}(\rho_3) = -0.07\rho_{31}^2 - 0.08\rho_{32}^2 - 2\rho_{31} - 1.5\rho_{32} + 1200;$$

4. Simulation by the Model Particle Algorithm Optimization-oriented

This paper applies particle swarm algorithm. In order to seek for an optimal solution to the model, it presents solutions generated in the swarm with microevolution particles. Every micro particle has its own position vector and speed vector and the fitness function in the swarm is the objective function in the model.

Such algorithm is in accordance with the principle of survival of the fittest and the search is practiced through particles seeking for the optimal solution in the solution space. As an optimal algorithm of swarm intelligence, the algorithm is advantaged by swarm intelligence, solutions to nonlinear functions and quick convergence. Since the originating, the algorithm has attracted wide attention from scholars from home and abroad, arousing a fashion to study the algorithm and penetrating into many fields

4.1 Initialization

$$1) \quad i = 2, j = 2, k = 2 \quad i = 2, j = 2, k = 2;$$

$$2) \quad \text{For all } i \text{ and } j, \text{ set them as following. } q_{ijk} = \frac{S^i}{m};$$

3) Initialize all other variables to 0.

$$4) \quad S^1 = 40; \quad S^2 = 50;$$

5) Set $T = 1$; condition for ending iteration: convergence precision is that $\varepsilon = 10^{-3}$, that is, formulas that meet the following (*) will end after iterating for T times or that a network reaches a stable state when no change happens to the flow in the network; moreover, meet

$$\begin{aligned} & |q_{111}^T - q_{111}^{T-1}| < \varepsilon, |q_{112}^T - q_{112}^{T-1}| < \varepsilon, |q_{121}^T - q_{121}^{T-1}| < \varepsilon, |q_{122}^T - q_{122}^{T-1}| < \varepsilon, |q_{211}^T - q_{211}^{T-1}| < \varepsilon \\ & |q_{221}^T - q_{221}^{T-1}| < \varepsilon, |q_{222}^T - q_{222}^{T-1}| < \varepsilon, |\rho_{31}^T - \rho_{31}^{T-1}| < \varepsilon, |\rho_{32}^T - \rho_{32}^{T-1}| < \varepsilon, \quad (*) \end{aligned}$$

And output the value of $q_{111}^*, q_{112}^*, q_{121}^*, q_{122}^*, q_{211}^*, q_{212}^*, q_{221}^*, q_{222}^*, \rho_{31}^*, \rho_{32}^*$, when the network reaches the stable state.

4.2 Sensitivity analysis of δ, η

The following picture Figure 2 and Figure 3 presents $\eta = 8$ and $\eta = 4$ the optimal value of a three-layer network when the utilization rate of the ecological technology is that $\delta = 0.1:0.1:1$.

Figure 2. $\eta = 8$ The Optimal Value of a Three-layer Network

Figure 3. $\eta = 4$ The Optimal Value of a Three-layer Network

$$\eta = 4, \quad \rho_{31} + \rho_{32} = 200 ;$$

$$\rho_{31} = 84.8842 ; \quad \rho_{32} = 115.3707 ; \quad q_{111} = 9.5218 ; q_{112} = 11.4824 ; q_{121} = 4.1435 ;$$

$$q_{122} = 13.0218 ; q_{211} = 50 ; q_{212} = 50 ; q_{221} = 50 ; q_{222} = 50$$

$$\eta = 8, \quad \rho_{31} + \rho_{32} = 238$$

$$\rho_{31} = 106.0374 ; \quad \rho_{32} = 132.9681 ;$$

$$q_{111} = 10.5393 ; q_{112} = 18.183 ; q_{121} = 11.4932 ;$$

$$q_{122} = 2.2531 ; q_{211} = 50 ; q_{212} = 50 ; q_{221} = 50 ; q_{222} = 50$$

The higher of the utilization rate of ecological technology resources is, the higher the prices of products and services after integrating ecological technologies and manufacturers will be and the more powerful flowing of ecological technologies will be. Thus do so, the competitive advantages will be enhanced the manufacturing clusters be continuously rising to the senior stage. However, the rising of risk factors has little influence on ecological technologies flowing from manufacturers to market, which indicates an improvement of the ability of manufacturing clusters to avoid risks and a higher output with the rising of utilization rate of ecological technologies.

4.3 Analysis of Simulation Results

1) In order to construct the model, we can get through analyzing the factor endowment prices of ecological technologies provided by suppliers of ecological technologies to manufacturers. When C_{1ij} , C_{2ij} is lower, it will be to easy get the prices. Meanwhile, it will promote the circulation of ecological technologies. The reducing of processing costs f_{1i} , f_{2j} of ecological technologies by manufacturers will enable manufacturers to attain higher incomes and promote the circulation of ecological technologies. The generation and circulation of these ecological technologies generate high energy through efficient operation of suppliers of ecological technologies and manufacturers. In turn, the generation and circulation of the high energy attract more ecological technologies to converge. Convergence of more ecological technologies will reduce market transaction costs and improve the utilization rate of ecological technology resources

2) From the constructed model, we can get through analyzing prices ρ_{31} , ρ_{32} products and services produced by manufacturers with ecological technologies. When he the parameter ρ_{31} , ρ_{32} is higher, to attain more profits is easier from the market and more resources to attain in the process of expanding the market. In turn, however, the market will generate more requirements to suppliers of ecological technologies and manufacturers who adjust and adapt themselves according to

disturbances in the market. Such disturbances promote suppliers of ecological technologies and manufacturers to exchange, cooperate, learn and seek for new models that are adaptive to the market. For example, manufacturers make use of ecological technologies to lower costs of production and improve production efficiencies. Moreover, disturbances in the market constitute another incentive to upgrade the whole network. Meanwhile, support from government to manufacturing clusters in the process of network upgrading is equally important. Also, the manufacturers and suppliers should formulate corresponding measures according to changes of external environment.

3) From the simulation diagram of the model, we can see that the higher the utilization rate δ of ecological technologies is the higher output generated by identical resource endowment will be. Moreover, the higher utilization rate will promote intimate interactions among suppliers of ecological technologies, manufacturers and the market, attract more external resources of manufacturing clusters to converge in this area and result in relative capacity and absolute capacity of resource expansion of manufacturing clusters within the threshold. In this circulation of flowing of ecological technologies-integrating of ecological technologies and manufacturing industry-fast flowing of ecological technologies, the intellectual and professional properties of ecological factor endowment are improved constantly and so are productivity effect and added value of manufacturing industry

5. Empirical Analysis

The traditional model of manufacturing clusters of Wenzhou is featured with high input, high productivity and high pollution. Under such model, both quality of products and services are in the bottom part of the value chains. Meanwhile, the practice of making profits from scale merits and increasing efficiency has severely destroyed the ecological environment. After the happening of the financial crisis, some undesirable phenomenon appeared, such as resource constraint, financing difficulty and significant declining of exportation. In order to maintain the vitality of manufacturing clusters, the government has actively guided the integration of manufacturing industry and ecological technologies in manufacturing clusters. Meanwhile, suppliers of ecological technologies have developed ecological manufacturing clusters, attracted institutions for researching, developing and designing high-tech ecological technologies and established supporting intermediary agencies and service organizations through converging around manufacturing industry through ecological technology research, development centers and patents. Furthermore, the government has taken some preferential measures in order to speed up the flowing of ecological technologies between suppliers of ecological technologies and manufacturers, improve utilization rate of ecological technologies by manufacturers, create more outputs with identical investment of factor endowment and produce more products and services with higher added values. In this case, government policies refer to policy support by the government to ecological enterprises related to manufacturing industry. To transformed and upgraded enterprises, government support has led to a reduction of enterprise risks and an improvement of innovation and technical levels. In the evolutionary system, disturbance of these factors has resulted in a high probability of manufacturing clusters converging to a benign model and a tendency of traditional manufacturing clusters choosing to promote transformation of manufacturing clusters with ecological technologies.

However, simple utilization of ecological technologies can not overcome the dilemma faced by manufacturing industry even to a degree of attaining profits with price advantage and at the cost of ecological destruction. In this case, the

government encourages enterprises in manufacturing clusters to be market-oriented and make an active use of ecological technologies. Meanwhile, the government has strongly supported these enterprises and increased the penalty cost of environmental pollution so as to achieve a win-win of ecological benefits and economic benefits, establish a competitive while cooperative relationship among enterprises in the clusters and drive the transformation of other polluting enterprises. However, simple transformation of manufacturing industry while separating from ecological technologies is incapable of realizing a balance between ecological benefits and economic benefits; finally, manufacturers will apply ecological technologies under the driving of government and other enterprises. Therefore, a important way to transform and upgrade manufacturing clusters is upgrading manufacturing clusters under the guidance of ecological technologies.

6. Conclusion and Future Development

In the paper, objective functions of suppliers of ecological technologies, manufacturers and vendors, along with their comprehensive objective, are analyzed; moreover, the influence of ecological technology cost, utilization rate of ecological technologies and risks ecological technologies on the comprehensive objective is discussed. Furthermore, a specific discussion on the case is conducted. Considering above research, this paper has inferred conditions for optimizing outputs of integrating market-oriented ecological technologies and manufacturing industry and concluded the following enlightenment:

1) Apply different measures to enhance the flowing of ecological technologies in different stages of integration of ecological technologies and manufacturing industry. At the early stage of the integration, there is no much penetration between them and support from the government is needed. During this stage, the government can issue some preferential policies to stimulate the integration, establish a platform for communicating between ecological technologies and manufacturing industry and speed up the proliferation of ecological technologies and flowing of ecological technologies, such as government subsidies and tax exemption. As the development of manufacturing clusters becomes more mature and outputs of manufacturing industry increases constantly, greater influence on enterprises will be caused by the more fierce competition among enterprises, costs of ecological technologies, processing of ecological technologies and utilization rates of ecological technologies. At this point, enterprises should enhance their innovation, improve technologies and raise production efficiency.

2) In order to create more benefits and promote the transformation of manufacturing industry, the integration of ecological technologies and manufacturing must be oriented by market. Meanwhile, manufacturing clusters should pay close attention to changes in domestic and foreign markets and adjust themselves according to the changes. When the integration of ecological technologies and manufacturing industry is more mature, the government should reduce its administrative interference to the market and focus on market services while encouraging more enterprises to participate in the reconstruction of ecological technologies, open up new markets and strengthen their competitiveness in the market.

3) Manufacturing clusters should encourage enterprise innovation, establishment of a scientific research platform and knowledge innovation so as to improve the ability of production and innovation. Meanwhile, enhance market competition and construct a more open environment so as to attract ecological technology resources within the threshold of manufacturing clusters, increase the relative capacity and absolute capacity of ecological technology resources and deepen specialized

division of ecological technologies. In the early stage, there are small gains from integration of ecological technologies and manufacturing industry.

So, the paper has proposed to drive the development of manufacturing clusters with ecological technologies under market constraints, established a suppliers of ecological technologies-manufacturers-vendors super network model and discussed the influence of flowing of ecological technologies, utilization rates of ecological technologies and risks of ecological technologies in order to overcome the dilemma faced by China's manufacturing clusters. On the other hand, the research can also focus on the influence of network density, network structure and social relations on the super-network model, which is to be further studied in future.

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