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Article

Computational Experiment Approach to Controlled Evolution of Procurement Pattern in Cluster Supply Chain

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Abstract: Companies have been aware of the benefits of developing Cluster Supply Chains (CSCs), and they are spending a great deal of time and money attempting to develop the new business pattern. Yet, the traditional techniques for identifying CSCs have strong theoretical antecedents, but seem to have little traction in the field. We believe this is because the standard techniques fail to capture evolution over time, nor provide useful intervention measures to reach goals. To address these problems, we introduce an agent-based modeling approach to evaluate CSCs. Taking collaborative procurement as research object, our approach is composed of three parts: model construction, model instantiation, and computational experiment. We use the approach to explore the service charging policy problem in collaborative procurement. Three kinds of service charging polices are compared in the same experiment environment. Finally, "Fixed Cost" is identified as the optimal policy under the stable market environment. The case study can help us to understand the workflow of applying the approach, and provide valuable decision support applications to industry.

Keywords: Cluster Supply Chains (CSCs); procurement pattern; controlled evolution; agent-based modeling; computational experiment

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1. Introduction

With the development of the global labor division, industrial cluster is becoming an increasingly common economic model, which has a series of advantages in global competition, such as regional adjacency, industrial relevance, flexibility plus specialization, trust-based cooperation, and so on. In an industrial cluster, a group of complementary business entities can fully obtain sufficient resources and business opportunities by the means of collaboration [1]. The collaboration between enterprises exists not only within the same supply chain (vertical collaboration), but also across different supply chains (horizontal collaboration). As shown in Figure 1, the horizontal collaboration is highly developed (e.g., collaborative procurement [2], collaborative manufacture [3,4], collaborative after-sale [2], collaborative logistics [2,5], *etc.*), and the vertical collaboration has a relatively complete supply chain system (SC1, SC2). As a result, a multi-level, multi-dimension, and multi-function supply chain network can be formed.

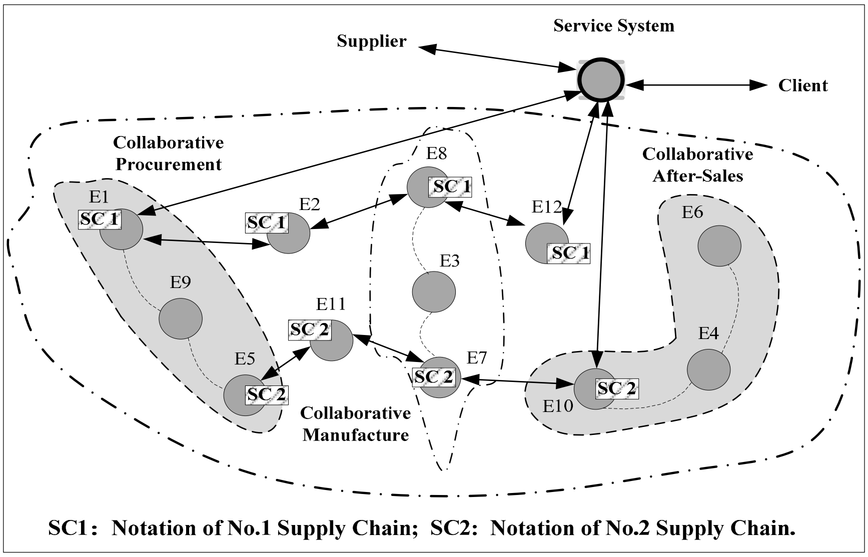


Figure 1. The operating diagram of "Cluster Supply Chain".

The new enterprise collaboration mode is known as "Cluster Supply Chains" (CSCs), which integrates the advantages of supply chain and industrial cluster [2]. Based on the CSC-based collaboration, cluster enterprises can benefit from economies of scale (individual is weak, but organization is strong) and ensure their flexibility (real-time information exchange, quick and flexible operation ability) in the meantime. In the end, the whole industrial cluster can evolve into an inherent, virtuous economic ecosystem, and achieve the purpose of "leverage" in the global competition.

However, CSCs is a truly complex dynamic system. The implementation of these collaboration modes is not that easy. (1) Each enterprise in the cluster should have autonomous decision-making, which has its specific interest. So, some certain interventions need to be adopted to avoid the conflict between individual targets and collective targets [6]. (2) The operation and evolution of CSCs is affected by both external factors (e.g., market conditions, industrial policy, *etc.*) and internal factors (e.g., organizational forms, collaboration strategy, coordination mechanism, *etc.*). Under different conditions, different evolution results may occur. Therefore, how to analyze the possible evolution results caused by the combination of various factors and how to develop effective intervention strategies to achieve the expected evolution goals, have become the key research issues in this field.

At present, although the government, research institutions and enterprises have paid a lot of effort, the practical construction and operation of CSCs doesn't show the desired effect [7–9]. There is still a huge gap between theory development and practical applications [10]. The related theories are not very mature and perfect, which cannot provide effective means to conduct quantitative analysis and research on CSCs. As a result, it is difficult to design a suitable intervention strategy to guarantee the desired evolution results. By means of introducing the concept of "computational experiment" [11], this paper proposes a set of research methods to implement in-depth study on CSCs evolution. Furthermore, collaborative procurement is taken as the research object to show how to apply the method.

This whole paper is organized as follows: Section 2 introduces the related work of this paper; Section 3 proposes a set of agent based models for collaborative procurement; Section 4 gives the instantiation of experiment system for collaborative procurement; Section 5 mainly conducts the computational experiment on collaborative procurement under different service charging policies; Section 6 summarizes the research work and identifies the future research direction.

2. Research Background

2.1. Current Work in the Field of CSCs

The concept of "cluster supply chain" was put forward formally in Li's PhD thesis [2,3], which gives a wide range of discussion on the issues of CSCs, such as coupling, characterization, functional effects, system structure, path changes, integration construction, competition-cooperation game, operation, planning, performance evaluation, and so on. Then, other researchers from different disciplines began to study this new business mode to facilitate its formation and sustainable development, which can be summarized as the following three perspectives:

2.1.1. Economies

This view regards industrial cluster as a specific enterprise organization, in which enterprises are connected with each other by economic cooperation agreement. The coordination among enterprises follows the basic market principles: (1) enterprise will maximize its own profits as much as possible; and (2) it needs to find a balance between its own interest and the collective interest in the meantime [12,13]. Some useful tools have been proposed to evaluate the operation performance of CSCs, such as "balanced evaluation process" [14] and "supply chain committee approach" [15]. However, how to compare the cost performance of different collaboration strategy in a quantitative way is still an unresolved problem.

2.1.2. Management

The view regards industrial cluster as a complex production system, which emphasizes two key characteristics: "organizational interaction" and "collaborative management" [16–18]. The fist key feature pays attention to the exchange of information, resources and personnel among enterprises, which can provide the correct decision support so as to avoid the conflict with other enterprises. The second feature is about how to improve the efficiency in the CSC-based collaboration modes, which needs to achieve a balance between individual autonomy and collective target. All kinds of collaborative modes in CSCs are summarized and classified in [19,20]. However, how to analyze the dynamic evolution process of collaborative modes in CSCs is still a real practical and theoretical challenge.

2.1.3. Sociology

The view regards industrial cluster as a very complex social structure (including enterprises, research institutions, service providers, and so on), which focuses on the diffusion of information and knowledge within the enterprises network. Sociological analysis reveals that industrial cluster can be viewed as a "knowledge system", *i.e.*, the specific knowledge creation and diffusion among a group of individual enterprises. In a cluster, the mutual learning mechanism between individual enterprises can contribute to labor specialization and division, and employee turnover between them [21]. The competition and cooperation mechanism among enterprises can promote the healthy development of regional economy effectively [22]. The SCP (Structure- Conduct-Performance) method was adopted to analyze the relationship between CSCs and regional competitive advantage [23]. However, it is still difficult to assess the importance of cluster for enterprise collaboration and build a virtuous economic system.

2.2. The Collaborative Procurement in CSCs

The evolution of CSCs is realized by the formation and development of various collaboration modes. Only after clarifying the details of each collaboration mode, can the controlled evolution of the whole CSCs be achieved. In CSCs, many manufacturers have numerous and similar demands for common parts, strategic materials and bulk purchasing. As a result, collaborative procurement becomes one of the most important collaboration modes, which can greatly reduce the procurement cost of manufacturers by means of the scale economy. Therefore, collaborative procurement is selected as the research object in the paper. According to the literature [2], there are three types of procurement mode for manufacturers in CSCs: independent procurement, alliance procurement and service procurement. In Table 1, the advantages and disadvantages of different modes are given in detail.

Table 1. Several typical procurement modes in CSCs.

The Type of Demand	Advantages	Disadvantages
Independent procurement (IP)	Manufacturers find the appropriate supplier in its inquiry radius, and get the raw material from suppliers directly.	Because its procurement scale and inquiry radius are small, the procurement price is high.
Alliance procurement (AP)	Because manufacturers do business with suppliers through their alliance leader, their overall procurement scale and inquiry radius can be improved a lot.	Although the procurement price is relatively low, the cost of collaboration is relatively high.
Service procurement (SP)	Manufacturers do business with suppliers through service providers, their overall procurement scale and inquiry radius can achieve the maximum value.	The procurement price depends on the service charging policy taken by service provider.

Manufacturers need to adjust their procurement mode continuously according to market conditions and competitive environment in order to maximize their profits. As shown in Figure 2, the evolution of collaborative procurement in CSCs can appear two trends. (1) The procurement pattern of manufacturers is developed from independent procurement to service procurement. As a result, manufacturers can obtain the lower procurement price, and service providers also earn certain profit.

Finally, a state of profit balance ("win-win") among different roles can be achieved and service procurement pattern becomes the major pattern. (2) The procurement pattern of manufacturers is degraded from service procurement to independent procurement. As a result, manufacturers need to pay more additional procurement cost and service provider cannot maintain its profit. Finally, the state of profit balance cannot be achieved among different roles of agents.

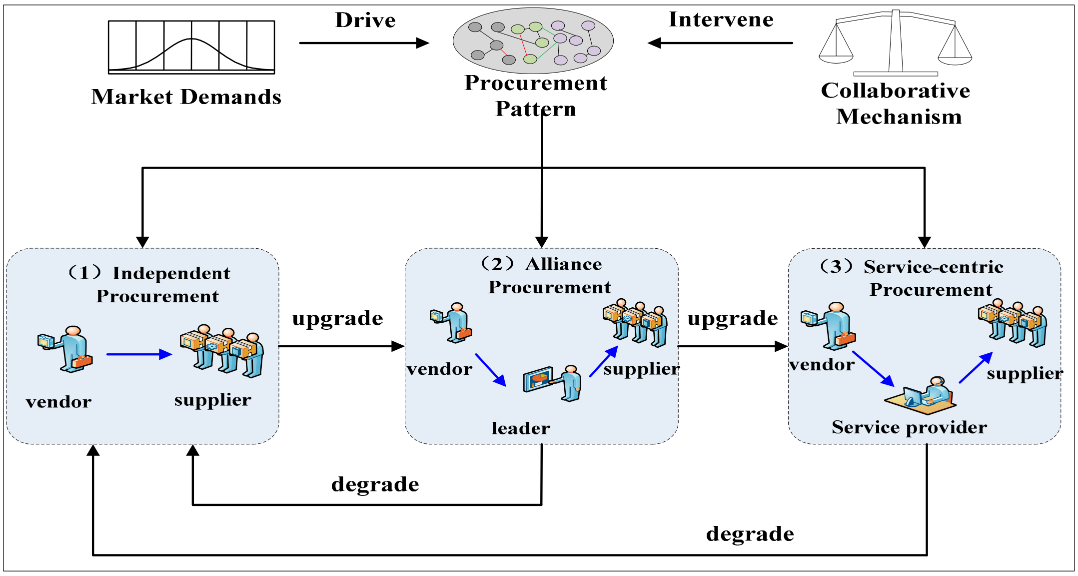


Figure 2. The transformation between different collaborative procurement modes.

The interaction among manufacturers is the driving mechanism of the procurement mode adjustment, which can promote the formation of collaborative procurement alliance and the transformation between different procurement modes. In order to achieve the desired evolution effect, it is very important to provide the effective tools to analyze the possible impact of various factors (e.g., initial setting and intervention strategy) on the evolution of procurement mode.

2.3. Research Method in the Paper

The evolution of collaborative procurement pattern in CSCs is a complex process, which needs to consider the autonomy of individual enterprise, the interaction between various factors, and the emergence of the whole system. However, current research in the field mainly focuses on several issues, such as impact factors [24], strategy optimization [25], mechanism design [26], and so on. As a result, it is difficult for existing studies to provide effective means to reveal the in-depth evolution mechanism. In order to change this situation, it is necessary to put forward a new research approach to realize the systematic research on the evolution of collaborative procurement patterns in CSCs.

According to Wooldridge's definition [27], agent is a natural metaphor for the members in CSCs (e.g., factories, workshops, *etc.*), including autonomy, sociality, reactivity and pro-activity, *etc.* Furthermore, multi-agent system provides a proper way (distributed rather than concentrated, spontaneous rather than planned, concurrent rather than sequential) to describe CSCs. Furthermore, the ACP method (Agent Modeling + Computational Experiments + Parallel Execution) provides a feasible research approach for studying the evolution mechanism of CSCs [10,11].

Compared with the existing studies, computational experiment has a series of advantages, such as precise controllability, flexible design, repeatable operation, and so on. For some special applications (with high risk, high cost, *etc.*), it is difficult or impossible to conduct the related research directly in the real environment. As a result, computational experiment becomes an appropriate choice or even the only choice, such as transportation system [28], war simulation system [29], socio-economic system [30], ecological environment system [31], physiological/pathological system [32], political ecosystem [33], and so on.

Aiming at the proposed research question in Section 2.2, the "computational experiment" based research method is proposed in the paper, which is composed of the following three parts:

(1) How to construct the model of collaborative procurement: Establish individual agent model as the basic building block of experiment system, including suppliers, manufacturers, and service providers; design interaction model to depict three kinds of procurement patterns. The details are given in Section 3.
(2) How to instantiate the model of collaborative procurement: Based on the above models, the behavior rules of various agents in collaborative procurement need to be further defined. Thus, their status can be updated in each time cycle to drive the operation of experiment system. The details are given in Section 4.
(3) How to use computational experiment to analyze collaborative procurement: By changing the combination pattern of external and internal different factors on the final evolution results. The application condition of different intervention policies can be analyzed on experiment results. The details are given in Section 5.

3. Model Construction of Collaborative Procurement

In collaborative procurement, there are three types of enterprise (manufacturer, supplier and service provider). Their interests may be different (e.g., manufacturer and supplier), and even be contradictive (e.g., the profit of service provider comes from the payment of manufacturers). The competition and game between different enterprises promote the creation, evolution and development of the whole industrial cluster. Therefore, the construction of model system needs to focus on two issues: (1) how to build individual agent as the basic building block of the whole system; and (2) how to build the interaction between different agents to drive the system evolution.

3.1. The Entity Model of Enterprise Agent

For enterprise agents, they make decisions and conduct reactions on the basis of their own awareness, preference, processing approach, and the limited information. As the basic building block of experimental system, the architecture of enterprise agent can be divided into four parts: Perception, Decision, Reaction and Adaptation. As shown in Figure 3, the information flow within the agent connect these various parts as a whole: at some time points, the decision-making mechanism will produce corresponding plans based on the perception of information and experience; then, the agent adjusts its behavior policies according to the plan and invoke some appropriate behavior functions to response to the external events; finally, the state properties of the agent will be affected and changed by the changes of external environment, which can affect the decision making mechanism further. Equation (1) gives the expressions of enterprise agent model, which is described by a group of attributes related to time variable. The detailed explanation is given in the following:

$$Agent = < R, S_t, E_t, V_t, Y_t, N > \tag{1}$$

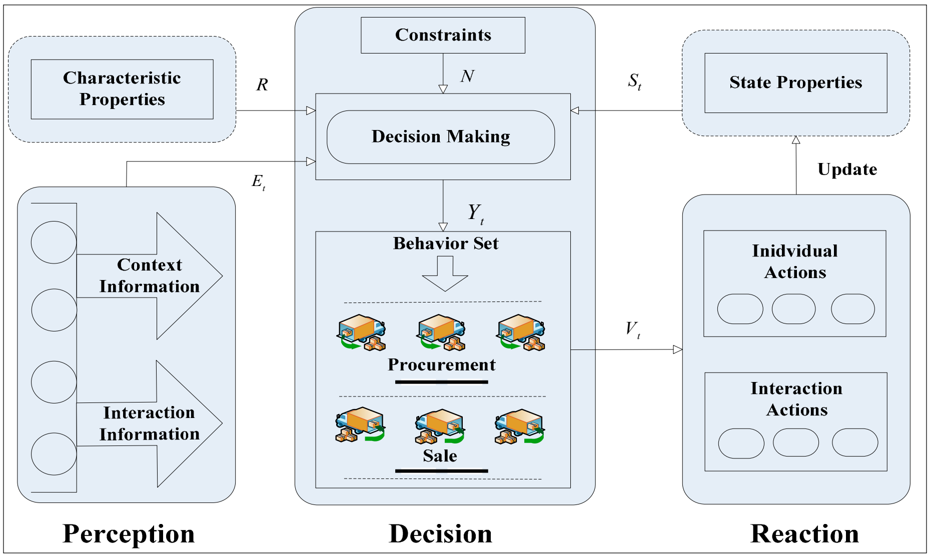


Figure 3. The diagram of enterprise agent.

Characteristic Properties R: the characteristic properties of enterprise agent will remain unchanged during the operating process, which can influence the decisions and behavior of the agent. Taking manufacturer agent as an example, its main characteristic properties are shown in Table 2, and other types of agent are similar to it.

Table 2. The characteristic properties of manufacturer agent.

Name	Explanation
Cost sensitivity: $Cost_R$	For manufacturer agent, $Cost_R$ determines its cost threshold of changing supplier. If $Cost_R$ is high, the frequency of changing supplier is low; if $Cost_R$ is low, the frequency is high.
Risk Preference: $Risk_R$	For manufacturer agent, $Risk_R$ can affect the variation range of adjusting order quantity. If $Risk_R$ is high, the adjustment range is large; if $Risk_R$ is low, the adjustment range is small.
Credit Metrics: $Credit_R$	For manufacturer agent, $Credit_R$ determines the probability of withdrawing from the alliance. If $Credit_R$ is high, the default risk is low; if $Credit_R$ is low, the default risk will be high.

Perceived Events E_t: the perceived external events can stimulate the changes of enterprise agent, including its behavior and state. Taking manufacturer agent as an example, its main perceived events are shown in Table 3, and other types of agent are similar with it.

Table 3. The perceived events of manufacturer agent.

Name	Explanation
Perceived order number: $OrderOut_S(t)$	$OrderOut_S(t)$ is determined by actual market demands. If the product quantity is greater than the actual demand, manufacturer will return backlog products to its supplier, *i.e.*, the buy-back phenomenon.
Perceived supply price: $PriceSupply_S(t)$	$PriceSupply_S(t)$ is obtained by interacting with different entities: (i) interaction with its neighboring manufacturers in its interaction radius; (ii) interaction with procurement alliance leader; (iii) interaction with service provider; and (iv) interaction randomly with supplier in its inquiry radius.

State Properties S_t: The state properties of enterprise agent will change constantly during the operating process, which can reflect its current state. Taking manufacturer agent as an example, its main state properties are shown in Table 4, and other types of agent are similar with it.

Table 4. The state properties of manufacturer agent.

Property name	Explanation
Enterprise Scale: $Sclae_S(t)$	$Sclae_S(t)$ determines the order quantity that it can deal with, which is divided into three types: large, medium and small.
Enterprise Role: $Role_S(t)$	$Role_S(t)$ indicates the possible roles of manufacturer agent, including leader, follower, and service provider. In the operating process of manufacturer, it can switch among these roles.
Procurement pattern: $Pattern_S(t)$	There are three types: independent procurement, alliance procurement and service procurement. The final procurement price can be affected by the selected procurement pattern a lot.
Enterprise profit: $Profit_S(t)$	$Profit_S(t)$ is determined by the difference value between its income and its cost.

The Behavior Set V_t: According to the reactions to the perceived context information, enterprise agent will implement some behaviors to achieve its own interest. The adopted behavior is determined by its state properties, the perceived context and decision mechanism. Enterprise agent can calculate its behavior in the next time step based on the behavior rules, which are shown in Equation (2):

$$\forall v_t \in V_t, \varepsilon(\alpha, v_t, E_t, Y_t) \Rightarrow < S_{t+1}, N, \Lambda > \tag{2}$$

In the equation, $\varepsilon(\alpha, v_t, E_t, Y_t)$ indicates the result assessment after Agent α completing the action v_t under the environment E_t and decision Y_t; $\Rightarrow$ indicates the final result can be achieved after Agent achieves its condition; $< S_{t+1}, N, \Lambda >$ indicates the state of the agent at the next moment S_{t+1} can meet the constraints N and the task standard Λ. The detailed behavior rules of each kind of agent are given in Section 4.

Decision-Making Mechanism Y_t: After perceiving the external events, agent needs to make the appropriate decision in order to ensure its own interests, such as the adjustment of sale price, the replacement of supplier, and so on. In addition, in the process of operation, one agent will constantly interact with other agents to learn new knowledge and update its rule base. Equation (3) indicates the current decision-making mechanism Y_t is decided by the interaction $\oplus$ between the previous decision-making mechanism Y_{t-1} and the previous context E_{t-1}. Equation (4) indicates the function mapping between Y_t and v_t. The detailed decision-making mechanism of each agent is given in Section 4.

$$Y_t = Y_{t-1} \oplus E_{t-1} \tag{3}$$

$$v_t = f(Y_t)\,|_{\varepsilon(\alpha, v_t, E_t, Y_t) \Rightarrow <S_{t+1}, N, \Lambda>} \tag{4}$$

Constraints *N*: the operation of enterprise agent is always restricted by all kinds of constraints, including its own capability and external environment. For example, if a supplier agent has signed the contact with some collaborative alliance, it will be limited by the production capacity and unable to provide raw material to other manufacturers.

3.2. The Interaction Model of Enterprise Agent

Enterprise agents need to adjust their operating strategies according to the evolution of market conditions and competitive environment in order to maximize their profits. For manufacturers, one of the most important things is to find the most suitable suppliers in each time cycle to maintain their competitive advantages. In order to obtain the suppliers' information, manufacturers can get some valuable advice from its neighbors or inquire the price from suppliers directly. Here, the representation of Construct [34–38] is used to describe the interaction process among enterprise agents.

Perception:

$Agent(x).Role_S = manufacturer;\ Agent(y).Role_S = manufacturer;$ // *x* and *y* are manufacturers;

$Availability\ y(t) = true;\ if\ Distance(x,y) < Ri^a$ // Ri^a is the interaction radius of manufacturer *x*;

Decision:

$$ProbInteract\ xy\ (t) = \frac{Ri^a - Distance(x,y)}{Ri^a}$$

// the interaction probability is determined by the distance between *x* and *y*;

$$ProbChange\ xy\ (t) = \frac{Manufacturer(x).PriceIn_S(t) - Manufacturer(y).PriceIn_S(t)}{ProfitShreld * Cost_R}$$

if $Manufacturer(x).PriceIn_S(t) - Manufacturer(y).PriceIn_S(t) > 0$

// the probability of changing supplier is determined by the price difference between *x* and *y*;

Action:

$Communicate\ xyk\ (t) = f(ProbInteract\ xy(t), Known\ yk)$

// manufacturer *x* get the procurement price *k* of manufacturer *y* through their interaction;

Adaptation:

$Known\ x\,(t+1) = Facts\ x(t) + Belief\ \ x(t) + Communicate\ \ xyk(t)$

// Facts *x(t)* indicates the current procurement price of manufacturer *x*;

// Belief *x(t)* indicates the principle of changing supplier of manufacturer *x*, *i.e.*, "the lower price, the better";

$Change\ x\,(t+1) = f(ProbChange\ xy(t), Known\ x(t+1))$

// manufacturer *x* replaces its supplier with the supplier of *y* through comparison;

According to the literature [2], there are three types of procurement patterns for manufacturers in CSCs: independent procurement, alliance procurement and service procurement. The interaction among manufacturers can drive the formation of different procurement patterns and decide its selection among different procurement patterns. The details of each pattern are shown as follows:

3.2.1. Independent Procurement Pattern

At the stage, all the manufacturers trade directly with suppliers. Figure 4 shows the operation mechanism of independent procurement pattern: $R1^a$ represents the interaction radius between manufacturer and manufacturer, and $R1^b$ represents the inquiry radius between manufacturer and supplier. With the diffusion of the supplier information among manufacturers, more and more manufacturers will focus on a small number of suppliers with lower prices gradually. When adopting the independent procurement pattern, the typical operating features are shown in Table 5.

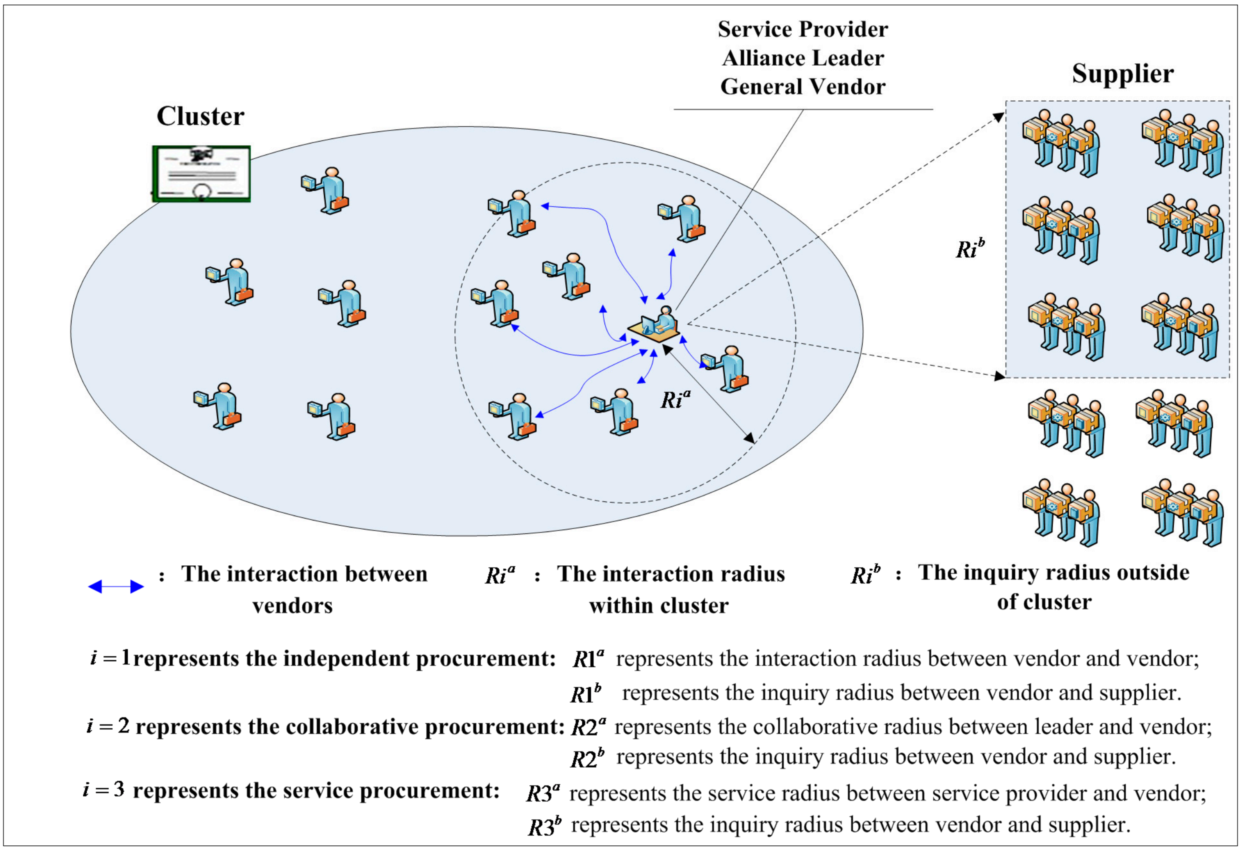


Figure 4. The operation diagram of collaborative procurement.

3.2.2. Alliance Procurement Pattern

With the selection for suppliers concentrated on a small amount of suppliers gradually, manufacturers can get more discounts from suppliers through collaborative procurement (*i.e.*, merge the orders of various manufacturers). Figure 4 shows the operation mechanism of alliance procurement pattern: $R2^a$ represents the collaborative radius between leader and manufacturer, and $R2^b$ represents the inquiry radius between leader and supplier. When adopting the alliance procurement pattern, the typical operating features are shown in Table 6.

Table 5. The features of independent procurement pattern.

Name	Explanation
Interaction Objects	There is some interaction between manufacturers within cluster, but no collaborative relationship.
Inquiry Price Radius	Due to the limited resources and capabilities, manufacturers can only interact with suppliers within the scope of its inquiry radius ($R1^b$). As a result, manufacturer has to select its supplier based on the limited information, which is not necessarily the optimal one.
Interaction Radius	During the operating process, manufacturer can exchange price information with its neighbors within a certain scope (interaction radius $R1^a$), which can help it to find the supplier with the lower price.

Table 6. The features of alliance procurement pattern.

Name	Explanation
Interaction Objects	The role of manufacturers begins to be divided into two categories: leader and follower. The leader can initiate a collaborative alliance between manufacturers to obtain the lower procurement price.
Inquiry Price Radius	Generally, the leader should be a large-scale manufacturer, which can act as the agency of the whole alliance to do business with suppliers. Its ability to obtain information is stronger than ordinary manufacturers (*i.e.*, inquiry radius $R2^b \geq R1^b$), which can be more likely to find the optimal supplier.
Collaboration Radius	The collaboration is implemented within a certain range (*i.e.*, the collaboration radius of leader $R2^a$), which is based on the stable and high degree of trust between manufacturers. However, the leader is not specialized in the operation of collaborative alliance, which may lead to the smaller collaboration scale and the difficulties of expansion.

3.2.3. Service-Centric Procurement Pattern

With the increase of procurement scale, manufacturer leaders who work as agency will have no ability to maintain the extra service. Based on the background, the specialized service providers can be separated from them to achieve the function of collaborative procurement. Figure 4 shows the operation mechanism of service procurement pattern: $R3^a$ represents the service radius of service provider, and $R3^b$ represents the inquiry radius between service provider and supplier. Service providers need to maintain a certain profit to survive, while manufacturers tend to select the lowest-cost procurement pattern. Therefore, it is crucial for service provider to choose the proper service charging policy. The “win-win” situation can be formed only by maintaining a balance between their interests. When adopting the service procurement pattern, the typical operating features are shown in Table 7.

Table 7. The features of service-centric procurement pattern.

Name	Explanation
Interaction Objects	The alliance leader begins to transform into the specialized service provider. The service provider can be responsible for completing the procurement task for manufacturers, which can obtain the lower procurement price.
Inquiry Price Radius	Service provider can select suppliers more systematically and comprehensively. Its ability of obtaining information is stronger than alliance leader (*i.e.*, inquiry radius $R3^b \geq R2^b$), which can be more likely to find the optimal supplier.
Service Radius	As the core of service procurement, service provider can provide procurement service in a broader range (service radius > collaborative radius, *i.e.*, $R3^a \geq R2^a$). At the same time, the coordination cost among manufacturers can be reduced a lot through providing specialized procurement service.

4. Model Instantiation of Collaborative Procurement

In collaborative procurement, enterprise agents can be divided into three categories: manufacturers, suppliers and service providers. Their ultimate goal is to get the maximized profit, which can be achieved by reducing procurement cost and improving sales price. In order to drive the operation of experiment system, their models need to be initiated to clarify how to calculate the behaviors of various agents and update their status in each time cycle. The specific details are shown as follows:

4.1. Operating Mechanism of Manufacturer Agent

The operating process of manufacturer agent is shown as Figure 5: (1) at the time t, manufacturer agent firstly calculate the ordering quantity based on its experience and market forecasting; (2) then, according to its own selection criteria (including product quality, price, credit, *etc.*), manufacturer agent identifies its proper supplier (supplier, alliance leader or service provider) and completes the procurement task; and (3) finally, manufacturer agent determines the sales price, calculates the new profit value, and updates its own state properties, which may lead to the role transformation. The state properties, behavior set, and decision set of manufacturer agent are shown in Tables 8–10, respectively.

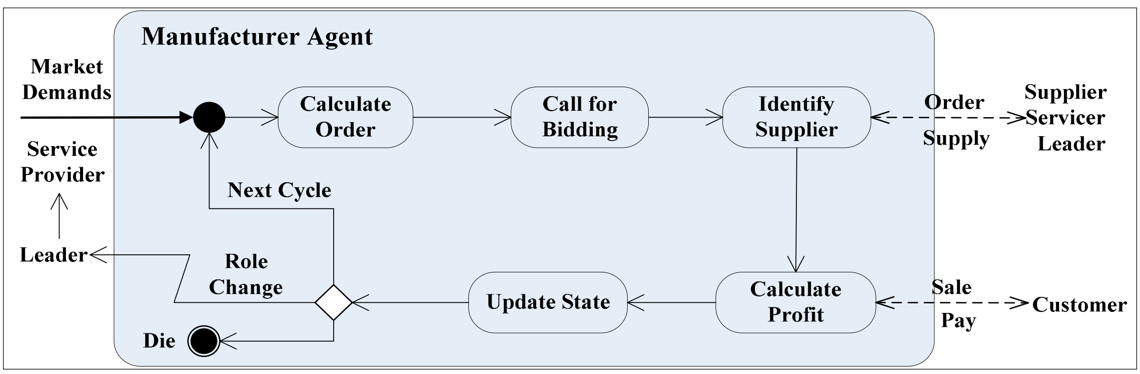


Figure 5. The operating diagram of manufacturer agent.

Table 8. The state properties of manufacturer agent.

Attribute	Calculation
Profit calculation	$S_{profit}(t)=\begin{cases}(r(t)-\rho*w(t))*q_i(t)-cocost_i(t), & X>\sum_{i=1}^{n}q_i(t)\\(r(t)-\rho*w(t))*q_i(t)-(\rho*w(t)-b(t))*\frac{q_i(t)}{\sum_{i=1}^{n}q_i(t)}*(\sum_{i=1}^{n}q_i(t)-X)-cocost_i(t), & X\le\sum_{i=1}^{n}q_i(t)\end{cases}$ X indicates the market demands; $r(t)$ indicates the sale price at the time t; $w(t)$ indicates the raw material procurement price at the time t; ρ indicates the discount rate of procurement; $q_i(t)$ indicates the procurement quantity; $\sum_{i=1}^{n}q_i(t)$ indicates the total procurement quantity of *n* manufacturers; $cocost_i(t)$ indicates the procurement cost, which is the fee charged by alliance leader or service provider; $b(t)$ indicates the price of buy-back. When $\sum_{i=1}^{n}q_i(t)>X$, manufacturer needs to return the remaining products to supplier, *i.e.*, buy-back.
Scale calculation	$Scale_S(t+1)=Scale_S(t)+Scale_S(t)*Grow_S(t)*(1-\frac{Scale_S(t)}{mSize})$ $Scale_s(t)$ is the scale of manufacturer at the time t; $Grow_S(t)$ is the growth rate of manufacturer; $mSize$ is the possibly maximum scale of manufacturer. When the scale and profit of manufacturer is lower than some threshold value, it will go bankrupt.

Table 9. The behavior set of manufacturer agent.

Behavior	Explanation
Supplier adjust	In every cycle, manufacturer needs to adjust its supplier during each time cycle in order to remain its own competitive advantages. If the quality of the new supplier is better than its current supplier, it will change its supplier according to the calculated probability; if not, keep the current situation.
Order quantity adjust	The current order quantity of manufacturer needs to be adjusted according to its perceived market order in the previous time cycle. The adjustment range is determined by enterprise scale and its risk preference coefficient $Risk_R$.
Sale price adjust	The sale price of manufacturer needs to be adjusted according to its sale quantity during the previous time cycle.
Role adjust	The current role of manufacturer agent needs to be adjusted according to its previous scale. There are three conditions in the role transformation: ordinary manufacturer → leader, leader → service provider, leader → ordinary manufacturer.
Enterprise type adjust	The current scale of manufacturer needs to be adjusted according to its profit in the previous time cycle.

Table 10. The decision set of manufacturer agent.

Decision	Explanation
How to change the selection of supplier?	$QoS = \alpha * Property_1 + \beta * Property_2 + ... + \gamma * Property_n$ The above equation gives the standard of selecting supplier, where *QoS* indicates the quality evaluation indicator of supplier; weighting factors need to satisfy 0 ≤ α,β,δ, ε ≤ 1 and α + β + δ + ε = 1; $Property_i$ indicates the *i-th* quality property of supplier, such as product price, product quality, delivery performance, enterprise reputation and so on. Based on the practical need, QoS indicator can be increased or decreased.
How to change the purchase quantity?	$OrderIn_E(t+1) = OrderIn_E(t) + Increment * Risk_R$ The above equation gives the calculation rule, where $OrderIn_E(t+1)$ indicates the ordering quantity of manufacturer at the time t + 1; $Increment$ indicates the baseline value of adjusting ordering quantity; $Risk_R$ indicates the risk preference coefficient of this manufacturer.
How to change the sales price?	During every cycle, manufacturer needs to adjust its sales price according to its own profit in the previous time cycle. If its profit falls, manufacturer will reduce the price for promotion; if its profit increases, manufacturer will increase the price for more interest; if its profit remains stable, manufacturer will keep the price unchanged.
How to change the type of enterprise?	The change of enterprise scale is determined by its profit state. If $Profit_S(t) > 0$, its scale will become bigger; if $Profit_S(t) \le 0$, its scale will become smaller. When its scale reaches a certain threshold value, small firm can transform into medium firm; when its scale reaches another threshold value, medium firm can transform into big firm.
How to change the role of enterprise into leader?	$If(\ Role_S(t) = Vendor\ \ \&\&\ \ Scale_S(t) == large\_scale\ \ \&\&\ \ Profit_S(t) \ge \mathrm{P1})$ $Role_S(t) = Vendor.follower \ \Rightarrow\ Role_S(t+1) = Vendor.leader;$ The above equation gives the conditions of changing into leader. When ordinary manufacturer becomes a large-scale enterprise and its profit surpass the threshold value P1, its role will develop from *follower* to *leader* (initiator).
How to change the role of enterprise from Leader to service provider?	$If(Role_S(t) = leader\ \ \&\&\ \ Scale_S(t) \ge aver\_scale * 5\ \ \&\&\ \ Profit_S(t) \ge \mathrm{P2})$ $Role_S(t) = leader \ \Rightarrow\ Role_S(t+1) = service\_provider;$ The above equation gives the conditions of changing into service provider. When the scale of *leader* is more than five times of the average scale $aver\_scale$ and its profit is more than P2, the role of *leader* will change into $service\_provider$
How to change the role of enterprise from Leader to Manufacturer?	$If(\ Role_S(t) = leader\ \ \&\&\ \ Profit_S(t)\ \le P2)$ $Role_S(t) = leader \ \Rightarrow\ Role_S(t+1) = follower;$ The above equation gives the conditions of changing into ordinary manufacturer. When the profit of *leader* is lower than a certain threshold value P2, the role of manufacturer will degrade to *follower* .

4.2. Operating Mechanism of Supplier Agent

The operating process of supplier agent is shown in Figure 6: (1) supplier agent firstly determines the sales price according to the received procurement order and participates in the bid; (2) if it gets the order, it will complete the order and update its profit and scale; and (3) finally, those suppliers whose profits continue to be negative may be eliminated, and other suppliers will enter into next cycle. The state properties, behavior set, and decision set of supplier agent are shown in Tables 11–13, respectively.

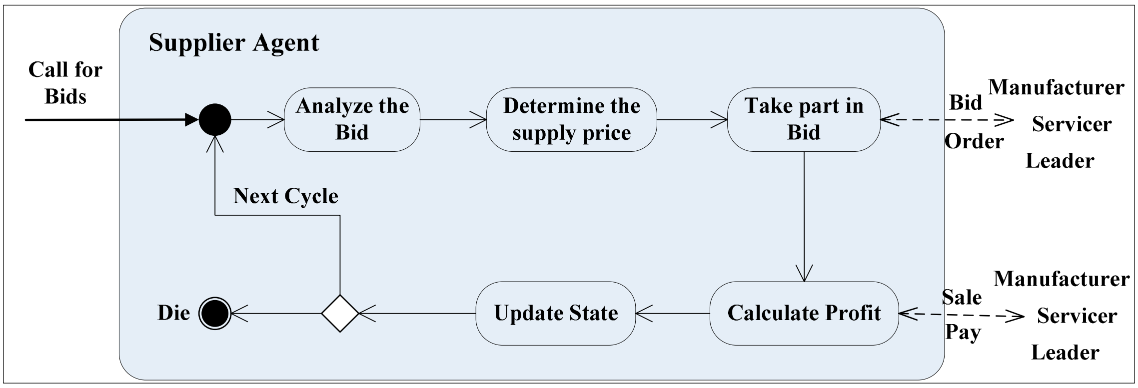


Figure 6. The operating diagram of supplier agent.

Table 11. The state properties of supplier agent.

Attribute	Calculation
Profit calculation	$Profit_S(t)=\begin{cases}(\rho * w(t)-c(t)) * \sum_{i=1}^{n} q_i(t), & X>\sum_{i=1}^{n} q_i(t)\\ (\rho * w(t)-c(t)) * \sum_{i=1}^{n} q_i(t)-(b(t)-v(t)) * (\sum_{i=1}^{n} q_i(t)-X), & X\leq\sum_{i=1}^{n} q_i(t)\end{cases}$
	X indicates the market demands; $w(t)$ indicates the sale price of the supplier at the time t; $c(t)$ indicates the sale cost of the supplier at the time t; $b(t)$ indicates the buy-back price of the supplier; $v(t)$ indicates the residual value of single product; $q_i(t)$ indicates the procurement quantity of the *i-th* manufacturer; $\sum_{i=1}^{n} q_i(t)$ indicates the total procurement quantity of *n* manufacturers; ρ indicates the discount rate provided by the supplier, which changes with the procurement quantity. When $\sum_{i=1}^{n} q_i(t) > X$, manufacturers will return the remaining products to supplier, *i.e.*, buy-back.
Scale calculation	$Scale_S(t+1)=Scale_S(t)+Scale_S(t) * S_{grow}(t) * (1-\frac{Scale_S(t)}{mSize})$
	$S_{scale}(t)$ is the scale of the supplier at the time t; $S_{grow}(t)$ is the growth rate of the supplier; $mSize$ is the possible maximum scale of the supplier. When its scale and profit is lower than the threshold value, the supplier will go bankrupt.

Table 12. The behavior set of supplier agent.

Behavior	Explanation
Sale price adjust	The sale price of supplier agent is adjusted according to its sale quantity during the previous time cycle.
Enterprise type adjust	The scale of supplier agent is adjusted according to its profit during the previous time cycle.

Table 13. The decision set of supplier agent.

Decision	Explanation
How to change sales price?	$PriceOut_s(t) = StandPrice * \beta$ The above equation gives the rule of adjusting sale price, where $StandPrice$ indicates its baseline sales price; β indicates the discount rate, which changes with the procurement quantity. Generally, larger procurement quantity has the bigger discount rate.
How to change enterprise type?	For suppliers, the rule of changing scale is same as that of manufacturer.

4.3. Operating Mechanism of Service Provider Agent

The operating diagram of service provider agent is shown as Figure 7: (1) service provider agent firstly receives and merges the procurement orders from different manufacturers and selects the proper supplier; (2) after manufacturers complete this procurement, service provider agent charges fees and update its profit; and (3) finally, service provider agents whose profits continue to be negative may be eliminated, and other agents will enter into the next cycle. The state properties, behavior set, and decision set of service provider agent are shown in Tables 14–16, respectively.

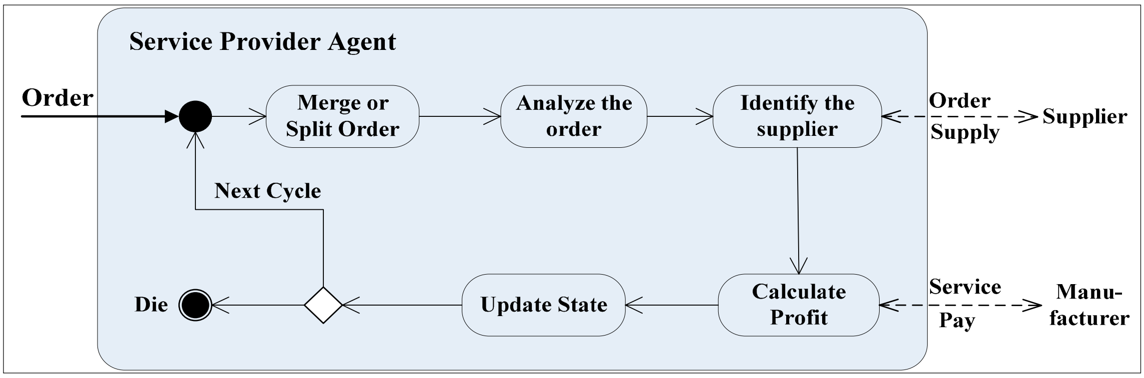


Figure 7. The operating diagram of service provider agent.

Table 14. The state properties of service provider agent.

Attribute	Calculation
Profit calculation	The profit of service provider is determined by its service charging policy. The most commonly used service charging policies include: Transaction ratio, Earnings ratio, Fixed cost, Annual membership fee, and Membership fee plus earnings ratio. The specific calculation formula has been given in Section 3.1.

Table 15. The behavior set of service provider agent.

Behavior	Explanation
Supplier selection	Service provider needs to adjust its supplier through the price comparison in order to ensure its competitiveness. The supplier information is from the interaction with suppliers, which is limited by its inquiry radius.
Service price adjust	The service-charging price of service provider agent is adjusted according to the number of its members and its profit during the previous time cycle.

Table 16. The decision set of service provider agent.

Decision	Explanation
How to select supplier?	For service providers, the rule of selecting supplier is same as that of manufacturer. The difference is that its inquiry radius is bigger.
How to adjust service price?	In the operation process, service provider may adjust its service price according to its own status during the previous *n* time cycles, including the profit trends and the member number. Generally, the service price should remain stable to facilitate the establishment of the long-term cooperation relations between service provider and manufacturers.

5. Computational Experiment of Collaborative Procurement

As shown in Figure 8, the framework of computational experiment is composed of four parts: the initiation of experiment environment, the construction of experiment system, the operation of computational experiment, and the analysis of experiment results. Based on the agent models mentioned above, the whole evolution process of collaborative procurement can be simulated on the Repast Simphony platform.

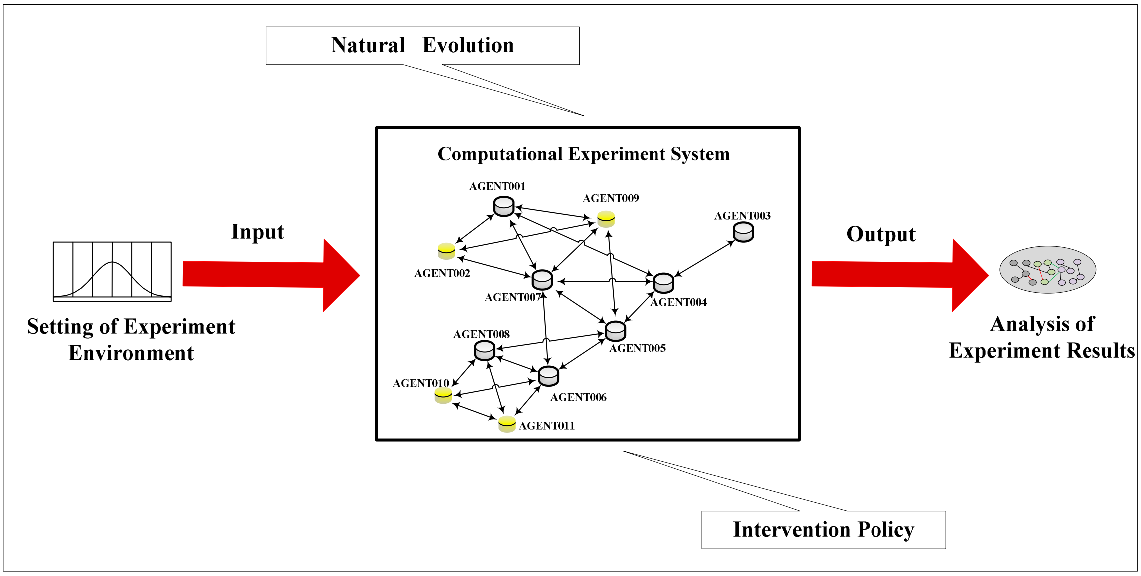


Figure 8. The framework of computational experiment method.

Without external intervention, experiment system will be in a state of natural evolution, which can be used to analyze the impact of initial environment on system evolution; otherwise, experiment system will be in a state of controlled evolution, which can be used to analyze the impact of external intervention on system evolution. This section clarifies the application process of computational experiment method by means of a case study, which takes service-charging policy as the intervention measure in the evolution of procurement pattern.

5.1. Initiation of Experiment System

The display interface of experiment operation is divided into two parts: the upper side indicates the activities of suppliers and the bottom side indicates the activities of manufacturers; gray lines represent the transactions between suppliers and manufacturers; green lines represent the transactions between service provider (or alliance leader) and suppliers; yellow lines represent the transactions between alliance leader and manufacturers; red lines represent the transactions between service provider and manufacturers. The parameters setting of the experiment is shown in Table 17.

Table 17. The parameters setting of computational experiment.

Variable	Values	Total Values
The number of manufacturer	60, located at the bottom side	1
The number of suppliers	60, located at the upper side	1
The scale of enterprise agent	Large (yellow), Medium (dark blue), Small (light blue)	3
Default agent scale	Medium size	1
Enterprise distribution	Random	1
Supplier's own cost	Fixed	1
Supplier's sales price	Bounded random	1
Manufacturer's procurement cost	20% off, when quantity ≥ baseline × 2; 40% off, when quantity ≥ baseline × 5.	2
Manufacturer's sales price	Bounded random	1
Supplier selection criteria	Price	1
Links between enterprises	Manufacturer, supplier; service provider, manufacturer; service provider, supplier; leader, supplier; leader, manufacturer.	5
Stable market demand	$Y \sim N(\mu, \sigma^2) = N(12000, 200^2)$	2
Interaction radius Ri^a	Bounded random in three ranges {r1, r2, r3}, and r1 < r2 < r3.	3
Inquiry radius Ri^b	Bounded random in three ranges {q1, q2, q3}, and q1 < q2 < q3.	3

In the experiment, the market demands are supposed to be stable, which is objective and uncontrollable. In order to realize the controlled evolution, it is very important to identify the applicable condition of various intervention policies, such as the organizational form among enterprises (such as hierarchical or flat form), collaborative strategies (such as the profit distribution policy in the collaboration), coordination mechanism (such as the constraint mechanism for collaboration failure), and so on.

In the case study, service charging policy adopted by service provider is taken as the invention measure in the evolution of procurement pattern. Table 18 gives the possible service charging policies and their parameter setting. Then, in the operation of experiment, service provider will adopt different service charging polices to compete with the other two procurement patterns. By means of comparative analysis, we can clarify the optimal service charging policy in the stable market environment, which can provide decision support to industry.

In order to identify the optimal policy, two main performance indicators are adopted in the experiment analysis: (1) the average profit of manufacturers in different procurement patterns; and (2) the number of manufacturers participating in different procurement patterns. The first indicator is used to judge whether the policy can keep the profit balance between service provider and manufacturers so as to realize the sustainable development of service provider. The second indicator is used to judge whether the policy can make service procurement prevail in the three procurement patterns, and attract manufacturers as many as possible.

Table 18. The possible service charging policy in the service-centric collaborative procurement.

Name	Model	Characteristics
Transaction ratio	$Profit_S(t) = \alpha * sw(t) * q(t)$ Where α indicates the transaction ratio; $sw(t)$ indicates the unit product price when manufacturers participate service procurement; $q(t)$ indicates the ordering quantity of the manufacturer at time t.	High transparency in service cost, which can help manufacturers to make a decision. However, if manufacturers can only obtain low profit from service procurement, the policy may hurt its interests.
Earnings ratio	$Profit_S(t) = \varphi * (w(t) - sw(t)) * q(t)$ Where φ indicates earnings ratio; $sw(t)$ indicates the unit product price when this manufacturers participate service procurement; $w(t)$ indicates the unit product price before manufacturers participate the service procurement; $q(t)$ indicates the ordering quantity of this manufacturer at time t.	This policy makes some improvements on Transaction Radio, which can protect the interest of some low-profit manufacturers. But, it is difficult to identify the earning of manufacturers in the subsequent collaborative period.
Fixed Cost	$Profit_S(t) = fix\_cost$ Where fix_cost is the price charged by the service provider when manufacturers take part in service procurement for one time.	High transparency for both manufacturer and service provider, which can ensure the basic income of service provider. But, the potential income of service provider may be restricted.
Parameter setting	In order to ensure the comparability of different policies, their own possible maximum earnings under their respective parameter setting should be the same. For example, suppose the baseline value of market demand is set as 12,000, the unit product price is X, and the number of manufacturers is set as 60, the comparable parameters of the three policies can be set as the following: • when the earnings ratio α is set to 0.25 and the maximum discount of service provider is 40%, its maximum possible earnings value is 12000 × X × (1 − 0.6) × 0.25 = 1200 × X; • when the transaction ratio φ is set to 0.1, its maximum possible earnings is 12000 × X × 0.1 = 1200 × X; • when the fixed cost fix_cost is set to 20 × X, its maximum possible earnings is 20 × X × 60 = 1200 × X.	

5.2. Operation of Computational Experiment

When the market demand is stable, manufacturer's order size changes little in general, and the return rate is low. Under this situation, the cost of independent procurement is relatively stable. After 100 repeated experiments, it can be found that the evolution process of collaborative procurement under three different service policies can be divided into four basic stages: Independent Procurement (IP, the average time range is about 0–60 time step), Optimal Procurement (OP, the average time range is about 60–110 time step), Alliance Procurement (AP, the average time range is about 110–410 time step), and Service Procurement (SP, the average time range is after about 410 time step).

The whole evolution process is shown in Figure 9. In the first stage, the system is in a relatively balanced state. The initial scale of manufacturers and suppliers are both medium (blue), and manufacturer randomly selects supplier. In the second stage, the scale differentiation among enterprises begins to occur, and some of them have grown into large enterprises (yellow). Through interaction between manufacturers, their procurement focuses on a small amount of suppliers gradually. In the third stage, some large-scale manufacturers begin to launch alliance procurement. In the fourth stage, the initiator of alliance procurement evolves into the specific service provider, and three kinds of procurement pattern coexist at this period.

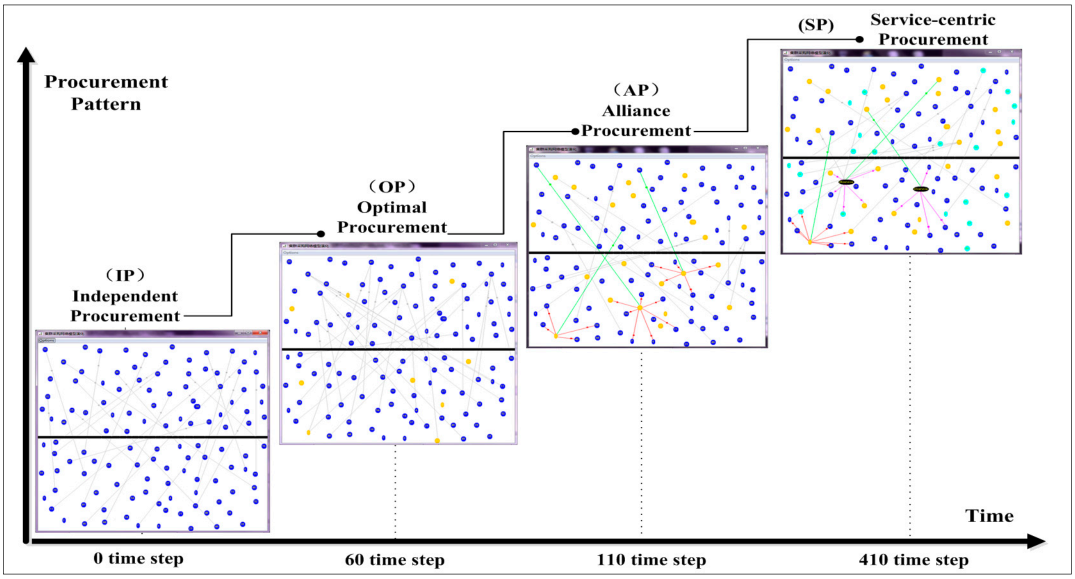


Figure 9. The evolution process of Collaborative Procurement under the stable market environment.

In order to analyze the evolution details of collaborative procurement, Figure 10 shows the performance comparison among three kinds of service charging policies. The detailed comparative analysis result is given in Table 19.

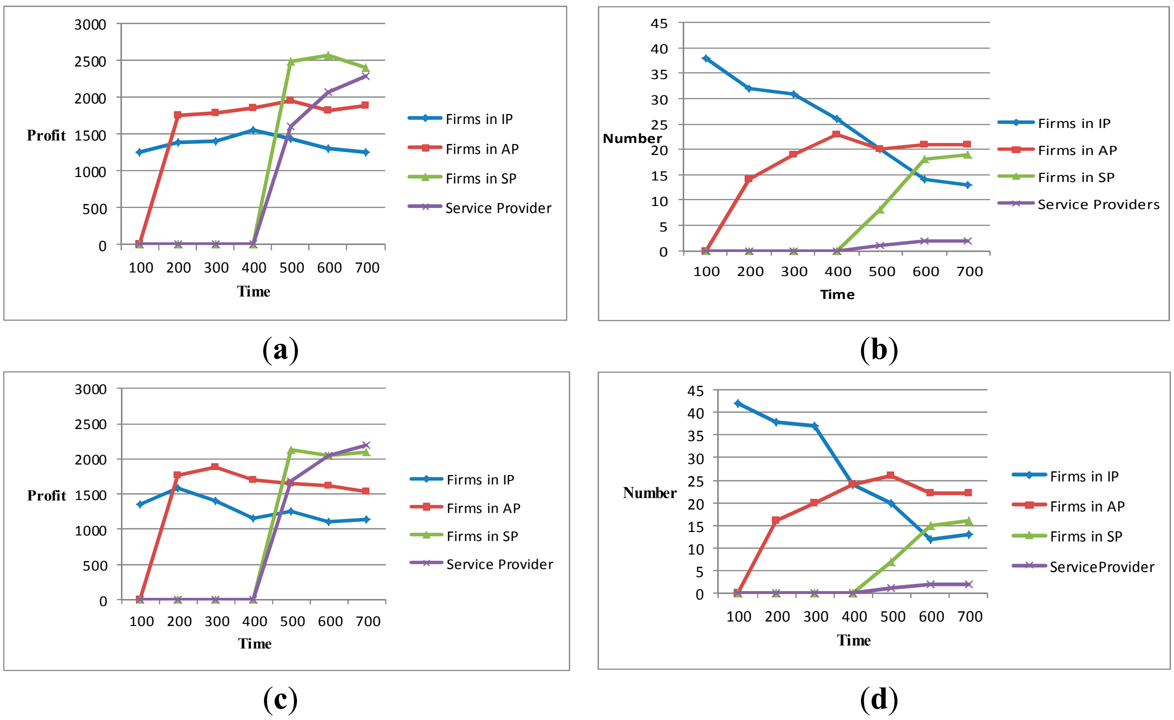
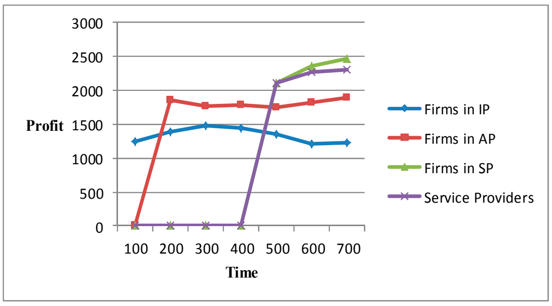
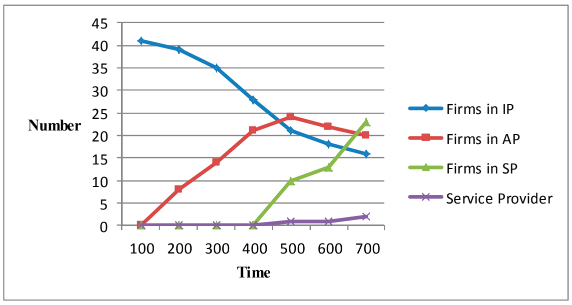


Figure 10. *Cont.*



(e)



(f)

Figure 10. The comparison of three service charging policies under the stable market environment. (**a**,**b**) The comparison of profit and participants number under Earnings ratio policy. (**c**,**d**) The comparison of profit and participants number under Transaction ratio policy. (**e**,**f**) The comparison of profit and participants number under Fixed Cost policy.

Table 19. The comparative analysis of the first computational experiment.

Policy Type	The Average Profit of Manufacturers in Service Procurement	The Number of Manufacturers in Service Procurement
Earnings Ratio policy	The profit of manufacturers in service procurement is higher than the value in the other two patterns. What's more, it is close to the profit of service provider. The profit balance can be achieved in the service procurement. (Figure 10a)	Although the number of manufacturers in service procurement increases stably, it has not become the top one among these three procurement patterns. (Figure 10b)
Transaction Ratio policy	The profit of manufacturers in service procurement is higher than the value in the other two patterns. However, it is lower than the value under the other policies. (Figure 10c)	The number of manufacturers in service procurement increases lowly. What's more, it has a certain gap with the top one among these three procurement patterns. (Figure 10d)
Fixed Cost policy	With the growth of collaborative scale, the profit of both manufacturers and service providers increases steadily. The profit balance can be achieved in the service procurement. (Figure 10e)	The number of manufacturers in service procurement increases rapidly and has already been in a dominant position. (Figure 10f)

5.3. Analysis of Experiment Results

In the CSC-based collaborative procurement, there are three types of enterprise (manufacturer, supplier and service provider). Their interests may be different (e.g., manufacturer and supplier), and even be contradictive (e.g., the profit of service provider comes from the payment of manufacturers). Based on the above experimental results, different evolution results of procurement pattern in CSC may be derived from adopting different service charge policies by service provider.

The features of three service charging policies can be summarized: Earnings Ratio policy pays more attention to the interests of manufacturers; Transaction Ratio policy pays more attention to the interests of service provider; Fixed Cost policy is a balanced charging policy. In terms of manufacturers, the charge of Fixed Cost policy is fixed and transparent, which has the more advantages than the other two policies in price competitiveness. In terms of service provider, the profit of Fixed Cost policy has been growing with the increasing number of manufacturers, which can have more advantages than the other two policies in the profit of service providers. Therefore, the Fixed Cost is a suitable choice under the stable market demand environment.

However, the study is just a tentative exploration for the identification of the optimal service charging policy by means of computational experiment. The given example is simplified to a large extent in order to clarify the workflow of the proposed method. The real service charging policy problem is much more complex, which needs to consider a lot of factors, such as the classification of customer requirements, the fluctuation of market environment, the dynamic game between various service providers, and so on. The real phenomenological experiments will be emphasized in two fields: one is manufacturing cluster, and the other is e-commerce.

In terms of manufacturing cluster, the role of service provider is becoming more and more important with the widely application of CSC. In our practical case study, Global Industrial Supply Co., Ltd, Beijing, China (Hereinafter called GIS) is selected as research object, which is a state-owned enterprise. GIS provides professional industrial services (including pooling procurement, Cutting and Machining logistic distribution, Vendor Managed Inventory, and international trade) for all kinds of manufacturers in North China, such as printing machines (e.g., Beiren Printing Machinery Co., Ltd, Beijing, China), CNC machine tools (e.g., Beijing No1 Machine plant, Beijing No2 Machine plant, Beijing, China), construction machinery (e.g., Beijing BEIZHONG Steam Turbine Generator Co., Ltd, Jing Cheng Heavy Industry Co., Ltd, Beijing, China), environmental protection(e.g., Jingcheng Environment Protection Co., Ltd, Beijing, China), power generation equipment(e.g., BMEI Co., Ltd, Beijing, China, Beijing BEIKAI Electronic Co., Ltd, Beijing, China, Beijing Electric Wire and Cable General Factory, Beijing, China, Beijing Electric Motor Co., Ltd, Beijing, China, *etc*.).

Cluster members can often profit from the operation of GIS. For example, the existing procurement costs can be reduced by about 10 percent to 20 percent by means of the integration and optimization provided by GIS. But, GIS is an independent third party organization with a commercial interest. Consequently, all the savings from CSC do not go to manufacturers. The challenge was to identify a suitable service charge policy to achieve the sustainable development of the whole business ecosystem, which can ensure the reasonable profit of service providers without significantly reducing the benefits gained by manufacturers. In our future research, the proposed method will be used to find a reasonable profit model between manufacturers and industrial service provider in the field of MRO (Maintenance, Repair and Operations) procurement.

Furthermore, the proposed method can be used to solve the service charging policy problem in E-commerce. Currently, many companies such as Amazon, eBay, Alibaba [39] and JD [40] provide platforms with e-commerce infrastructure service for small businesses and individual entrepreneurs, allowing them to open online retail stores. This kind of services has significantly accelerated the growth of e-commerce, as it builds a bridge between traditional retailers and online shopping. With the competition between these platform service providers steadily growing up, it becomes necessary to study and improve the profit model of their own platforms. However, this is a very complex dynamic game problem between multi players. In our future research, the proposed method will be used to compare the difference between two e-platform hosts, which uses different service charging policy, respectively.

6. Conclusions

Companies have been aware of the benefits of developing "Cluster Supply Chain" (CSC), and they are spending a great deal of time and money attempting to develop the new enterprise collaboration mode. Yet, the traditional techniques for identifying CSCs have strong theoretical antecedents, but seem to have little traction in the field. We believe this is because the standard techniques fail to capture evolution over time, nor provide useful intervention measures to reach goals. To address these problems, we introduce an agent-based modeling approach to evaluate CSCs. Taking collaborative procurement as research the object, our approach is composed of three parts:

(1) Model construction of collaborative procurement: Establish individual agent model as the basic building block of experiment system; and design interaction model to depict the driving mechanism of collaborative pattern evolution.
(2) Model instantiation of collaborative procurement: The models are initiated to clarify the behavior rules of various agents. Based on the operation of each agent, the status of experiment system can be updated continuously in each time cycle.
(3) Computational experiment of collaborative procurement: By changing the combination of external and internal factors, a variety of experiment environments can be built to identify the impact of different factors on the final evolution results.

We use the approach to explore the service charging policy problem in collaborative procurement, instantiating them in an agent-based computation model. We evaluate the procurement problem under different service charge strategies. Finally, "Fixed Cost" is identified as the optimal policy under the stable market environment. The experiment can help us to understand the workflow of applying the method, and provide valuable decision support applications to industry.

Our research work will be in two separate papers: (a) model description and concept; and (b) phenomenological experiments. Because of limited space, the paper only focuses on the study of computational experiment method. The follow-up research will be based on the real data of Global Industrial Supply Co., Ltd. (GIS), which focuses primarily on three kinds of phenomenological experiments:

(1) How to use computational experiment to find out the optimal operating parameters for a specific service charging strategy? The research issue needs to emphasize the comprehensive evaluation standard and the practical authentication of experiment results in order to ensure its soundness.
(2) How to use computational experiment to identify the impact of the initial factors on the evolution of CSCs? The initial factors of industrial clusters include industrial range, commercial culture and development history, *etc.* The initial factors of enterprise entity include its self-interest degree, rational degree, *etc*.
(3) How to use computational experiment to find the effective intervention measures to realize the sustainable development of CSCs? The research issue needs to achieve a profit balance between core enterprises, upstream and downstream enterprises, supporting SMEs (small and medium enterprises), and service enterprises.

Author Contributions

Xiao Xue designed and performed the research and wrote the paper; Shufang Wang and Baoyun Lu performed research and analyzed the data. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

References

1. Himmelman, A.T. *Communities Working Collaboratively for a Change*; The Himmelman Consulting Group: Minneapolis, MN, USA, 1992.
2. Huang, B.; Xue, X. An Application Analysis of Cluster Supply Chain—A Case Study of JCH. *Kybern. J.* **2012**, *41*, 254–280.
3. Li, J. Study on Cluster Supply Chain and its Management. Ph.D. Thesis, Huazhong Agriculture University, Wuhan, China, May 2006.
4. Li, J.; Liu, C.; Chang, Y.; Li, B. Integrated analysis of the organizational succession in cluster supply chain and the development of logistical park—The case study of IT industry in Suzhou. *China Soft Sci.* **2006**, *16*, 108–116.
5. Li, J.; Liu, C.; Cai, G. Study on the cluster supply chain and its reverse logistics—The case study of IT industry in Donggua. *Sci. Res. Manag.* **2005**, *26*, 86–92.
6. Villa, A.; Antonelli, D.; Cassarino, I. Issues in the management of collaborative demand and supply networks. In *AAVV. Strengthening Competitiveness through Production Networks*; European Communities: Belgium, Germany, 2005; pp. 47–57.
7. Biswas, S.; Roy, S.; Seshagiri, S. Collaboration in Indian SME Clusters: A Case Study. In Proceedings of the 3rd International Conference on Communities and Technologies, East Lansing, MI, USA, 28–30 June 2007.
8. Xue, X.; Zhu, P.; Huang, B. Research on agent oriented design approach for service system of Cluster Supply Chain. *J. Chin. Comput. Syst.* **2011**, *32*, 1170–1777.
9. Xue, X.; Wei, Z.; Zeng, Z. Cluster Supply Chain-based enterprise collaboration alliances and their supporting service systems. *J. Chin. Comput. Syst.* **2013**, *34*, 107–114.
10. Ioppolo, G.; Saija, G.; Salomone, R. Developing a Territory Balanced Scorecard approach to manage projects for local development: Two case studies. *Land Use Policy* **2012**, *29*, 629–640.
11. Wang, F.; Zeng, D.; Carley, K.M.; Mao, W. Social computing: From social informatics to social intelligence. *IEEE Intell. Syst.* **2007**, *22*, 79–83.
12. Silijak, D.D. *Large-Scale Dynamic Systems: Stability and Structure*; Dover: Mineola, NY, USA, 2007.
13. Li, J.; Liu, C.; Li, B. Modeling of the across-chain inventory coordination in cluster supply chains. *Syst. Eng. Electron.* **2007**, *29*, 1479–1483.
14. Bullinger, H.J.; Kuhner, M.; van Hoof, A. Analyzing supply chain performance using balanced measurement system. *Int. J. Product Res.* **2002**, *40*, 3533–3543.

15. Francis, J. Supply Chain Management & Business Financial Performance. 2009. Available online: http://www.supply-chain.org (accessed on 12 May 2013).
16. Brenner, T. *Local Industrial Cluster: Existence, Emergence and Evolution*; Routledge: London, UK, 2004.
17. Ioppolo, G.; Saija, G.; Salomone, R. From coastal management to environmental management: The sustainable eco-tourism program for the mid-western coast of Sardinia (Italy). *Land Use Policy* **2013**, *31*, 460–471.
18. Zhong, N. *Research on the Risk Management and Control Strategies for the Supply Chain Based on Industrial Clusters*; Wuhan University Press: Wuhan, China, 2009.
19. Xue, X.; Huang, B.; Xiao, T. The study of inter-organizational collaboration by cluster supply chain. In Proceedings of the 2009 International Conference on Automation and Logistics (ICAL), Shenyang, China, 5–7 August 2009.
20. Xue, X.; Wei, Z.; Liu, Z. The impact of service system on the implementation of cluster supply chain. *Serv. Oriented Comput. Appl.* **2012**, *6*, 215–230.
21. Antoldi, F. Between local tradition and global competition: Introduction to phenomenon of Italian industrial districts. In *Small Enterprises and Industrial Districts*; Antoldi, F., Ed.; Il Mulino: Bologna, Italy, 2006.
22. Wu, Q.; Zhan, F. The embodiment and improvement of the structure competitiveness of cluster supply chain. *Econ. Probl. Explor.* **2007**, *6*, 91–94.
23. Yang, J.; You, J.; Cai, Y. Analysis of the system structure and the regional competitive advantage of cluster supply chain based on the SCP framework. *Product. Res.* **2008**, *2*, 61–63.
24. Yang, L.; Xue, X.; Lu, B. Research on affecting factors for collaborative procurement of cluster supply chain based on computational experiments. *Appl. Res. Comput.* **2015**, *32*, 1–6.
25. Li, G.; Ma, S.; Wang, Z.; Chou, W. Supply coordination and optimization model of assembly supply chain based on different delivery policies. *J. Mech. Eng.* **2011**, *47*, 45–52.
26. Liu, C.; Xiao, W.; Li, J.; Ma, S.; Sun, L.; Cao, X. Across-chain purchasing decision model and algorithm for cluster supply chain under limited over-stock contract. *Comput. Integr. Manuf. Syst.* **2013**, *19*, 1115–1126.
27. Wooldridge, M.; Jennings, N.R. Intelligent agents: Theory and practice. *Knowl. Eng. Rev.* **1995**, *10*, 115–152.
28. Huang, H. Dynamic modeling of urban transportation networks and analysis of its travel behaviors. *Chin. J. Manag.* **2005**, *2*, 18–22.
29. Hu, X.; Siguang, Y.; Luo, P. Study on War Complex System and War Gaming & Simulation. *J. Syst. Simul.* **2005**, *17*, 2769–2774.
30. Tesfatsion, L. *Agent-Based Computational Economics*; ISU Economics Working Paper, No.1; Iowa State University: Ames, IA, USA, 2003.
31. Acevedo Miguel, F.; Baird, C.J.; Michael, M.; Donald, L.; Jenny, P.; Judith, R.; Luz, D.; Magdiel, A.; Jacinto, D.; Giorgio, T.; *et al*. Models of natural and human dynamics in forest landscapes: Giorgio-Site and cross-cultural synthesis. *Geoforum* **2008**, *39*, 846–866.
32. Huang, C.; Sun, C.; Hsieh, J.; Lin, H. Simulation SARS: Small world epidemiological modeling and public health policy assessments. *J. Artif. Soc. Soc. Simul.* **2004**, *7*, Article 4.

33. Cioffi-Revilla, C.; Mark, R. Mason rebeland: An agent-based model of politics, environment, and insurgency. *Int. Stud. Rev.* **2010**, *12*, 31–46.
34. Ren, Y.; Carley, K.M.; Argote, L. The contingent effects of transactive memory: When is it more beneficial to know what others know. *Manag. Sci.* **2006**, *52*, 671–682.
35. Carley, K.M. Group stability: A socio-cognitive approach. In *Advances in Group Processes: Theory and Research*; Lawler, E., Markovsky, B., Ridgeway, C., Walker, H., Eds.; JAI Press: Greenwhich, CT, UK, 1990.
36. Schreiber, C.; Singh, S.; Carley, K.M. *Construct—A Multi-Agent Network Model for the Co-Evolution of Agents and Socio-Cultural Environments*; CASOS Technical Report, CMU-ISRI-04-109; Carnegie Mellon University, School of Computer Science, Institute for Software Research: Pittsburgh, PA, USA, 2004.
37. Hirshman, B.R.; Charles, J., St.; Carley, K.M. Leaving us in Tiers: Can Homophily be used to generate tiering effects. *Comput. Math. Organ. Theory* **2011**, *17*, 318–343.
38. Schreiber, C.; Carley, K.M. Validating agent interaction in Construct against empirical communication networks using the calibrated grounding technique. *IEEE Trans. Syst. Man Cybern. Syst.* **2013**, *43*, 208–214.
39. Alibaba Group Co. Available online: http://www.taobao.com and www. tmall.com (accessed on 12 December 2014).
40. Beijing Jingdong Century Trading Co. Available online: http://www.jd.com (accessed on 12 December 2014).