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Why retailers cluster: an agent model of location choice on supply chains

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Abstract. This paper investigates the emergence of retail clusters on supply chains comprised of suppliers, retailers, and consumers. An agent-based model is employed to study retail location choice in a market of homogeneous goods and a market of complementary goods. On a circle comprised of discrete locales, retailers play a noncooperative game by choosing locales to maximize profits which are impacted by their distance to consumers and to suppliers. Our findings disclose that in a market of homogeneous products symmetric distributions of retail clusters arise out of competition between individual retailers; average cluster density and cluster size change dynamically as retailers enter the market. In a market of two complementary goods, multiple equilibria of retail distributions are found to be common; a single cluster of retailers has the highest probability to emerge. Overall, our results show that retail clusters emerge from the balance between retailers' proximity to their customers, their competitors, their complements, and their suppliers.

1 Introduction

Rules governing the agglomeration and dispersion of economic behavior depend on numerous factors that may impact firms' motivations and strategies. Empirical studies have found that hierarchical distributions of economic activities and resources exist in almost every city, region, and nation [such as the US carpet production industry concentrated in Dalton, Georgia (Krugman, 1991a) and the Italian textile industry in Prato (Porter, 1990)]. From a systems perspective, urban areas are not only concentrations of places and people, but also "systems of organized complexity" where a large number of quantities vary simultaneously and "[are interrelated] into an organic whole" (Jacobs, 1961, page 432).

Adopting a similar view, we attempt to understand what can promote the concentration of human activities. This understanding suggests two insights we need to consider in modeling this phenomenon: first, numerous supply chains are interwoven in the urban milieu; second, structural and behavioral patterns of cities result from all kinds of economic agents' interactions. Our interest in the microfoundation of the clustering of retail businesses leads us to study retailers' relationships with suppliers and consumers, and their impacts on large-scale clustering patterns.

The rest of this paper is organized as follows. In section 2 we review literature on the mechanism of business clustering and the agent-based approach in modeling urban systems. In section 3 we describe our agent-based framework of a three-layer supply chain network. Section 4 displays and analyzes the simulation results. The implications of the findings are discussed in section 5. Lastly, section 6 concludes the paper.

2 Literature review

Business clustering patterns have been a topic of extensive study. Traditional economic geography theories explained spatial distributions mainly through differences in underlying characteristics: say, geography, labor, and products (Christaller, 1933; Lösch, 1940; Marshall, 1890; Ottaviano and Ouga, 1998; Weber, 1909). For instance, central place theory posits a hierarchy of communities in terms of a variety of stores, where goods of higher order tend to stay farther away from each other than goods of lower order in that they serve a larger threshold population; moreover, higher order places offer all the goods offered at lower order ones, but not vice versa (Christaller, 1933). The findings are very intriguing; Christaller's theory, nevertheless, cannot explain how such patterns gradually emerge.

When researchers began to search for the 'invisible hand' that contributes to agglomeration, they resorted to the microexplanations with different hypotheses about the causes, such as pure competition (Hotelling, 1929), different orders (by importance) of food (Eaton and Lipsey, 1982; Quinzii and Thisse, 1990), transport cost (Fujita and Ogawa, 1982), economies of scope (Fujita et al, 1988), and economies of scale and imperfect competition (Krugman, 1991b). Krugman (1991b; 1996) further argued that firm location choice is balanced by centripetal and centrifugal forces. The centripetal forces include market-size effects, thick labor markets, and pure external economies; the centrifugal forces include high land rents, immobile factors, and pure external diseconomies. In addition, some other research found that the interactions between upstream and downstream firms can result in agglomeration, wherein multiple equilibria may exist (Krugman and Venables, 1995; 1996). While these models implied the functioning of supply chains, they did not explicate the balancing forces stemming from the interactions of different business agents.

Since the 1960s, with the development of computing technology, many computerized prototype models have been built to assist planning and policy development in metropolitan areas; most models were mathematically or behaviorally based. Examples include the highly disaggregated EMPIRIC model (Hill et al, 1966), the Detroit prototype of the National Bureau of Economic Research Urban Simulation Model (Ingram et al, 1972), the TRANUS model (de la Barra et al, 1984), the ITLUP model (Putman, 1991), the MEPLAN model (Hunt and Simmonds, 1993), the California Urban Futures models (Landis, 1994; Landis and Zhang, 1998) [see Wegener (2004) for a historical review]. Yet such models did not adequately tackle the increasing complexities of the interactions between a variety of components in urban systems. To meet this challenge, some new planning support systems have been developed. A case in point is the UrbanSim program which incorporated the interactions between land use, transportation, environment, and urban policies by modeling the behavior of urban agents at different levels (Waddell, 2002; Waddell et al, 2003).

In recent years agent-based models have gained popularity in revealing the complexity of spatial interactions, dynamics, and self-organization (Parker et al, 2003; Portugali, 1999). Urban systems have been modeled as complex systems where complex systematic properties can emerge out of simple interactive rules among different agents. Some models have examined the evolution of environmentally based land-cover systems (Brown et al, 2005; Evans and Kelley, 2004; Webster, 2003; Wu and Webster, 1998; 2000) and of human settlement patterns (Sanders et al, 1997). Additionally, there are some models focusing on residential development modeled in a grid-cell environment (Berger, 2001; Berger and Ringler, 2002; Manson, 2000; Parker and Filatova, 2008). Other microscopic modeling approaches include fractal growing (Batty, 1991; Batty and Xie, 1999) and space syntax (Batty and Rana, 2004; Peponis et al, 1998). Whereas the models provided different insights on the self-organization of urban clusters, they have not seriously addressed transport costs. Dealing with transport cost in a more rigorous and mature way, while likely adding to the complexity of the model, is necessary to gain a better understanding of the effects of networks on spatial locations.

By explicitly tackling business interactions on supply chains, we employ the agent-based approach to explain the emergence of retail clusters from a microscopic perspective.

The agents, connecting on supply chains, are consumers, retailers, and suppliers. This research appropriates and applies the notions of centripetal and centrifugal forces in economics (Krugman, 1991a; 1996), indicating that urban space can self-organize into order and pattern even based on simple and decentralized decisions of individual firms and consumers.

3 The model

3.1 Assumptions and definition of cluster

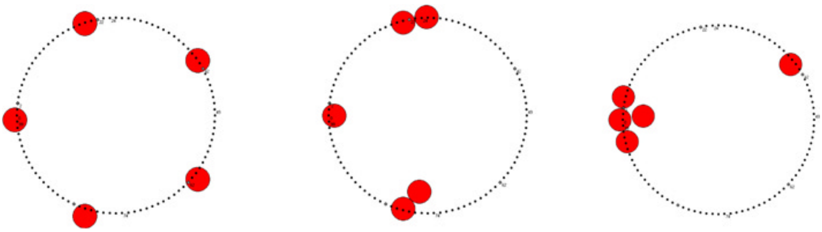
In a simplified three-layer supply chain, products flow from suppliers, via retailers, to consumers; cash proceeds in the opposite direction. All agents are presumed to have perfect information; they locate on a circular area of discrete locations. The idea of a circle, probably first adopted by Hotelling (1929), has the following advantages: (1) one dimension (which simplifies the model and highlights the embedded economic mechanism); (2) providing an enclosed area (which is similar to a de facto geographical region and limits the number of location choices for retailers).

Two kinds of markets are tested on the basis of this framework: first, a market of homogeneous goods; second, a market of two complementary goods which entails consumers' trip-chaining behavior in shopping. The computational models are programmed in Java, where each agent is modeled as an object. At the beginning of each round, consumers patronize retailers on the basis of their rules to meet their needs for the product; after consumers finish shopping, retailers calculate their profits (revenue – cost) and assess the profitability of other locales. At the end of each round, given that others are fixed, each retailer moves to the locale that can provide the highest profit. The locales and profits of retailers are updated for each round.

Before elaborating the agents' rules, it is important to define a cluster for this research. A cluster is defined as an agglomeration of retailers which are geographically adjacent or colocated. The density of a cluster is calculated as the number of retailers in a cluster divided by the number of locales in the cluster. The average cluster density of n retailers, φ_n, is formulated as:

$$\varphi_n = \frac{1}{M} \sum_{i=1}^{M} \frac{\alpha_i}{\tau_i}, \qquad (1)$$

where α_i is the number of retailers in cluster i; τ_i is the number of locales covered by cluster i; and M represents the total number of clusters. Some examples of calculating cluster density can be found in figure 1.



(a) (b) (c)

Figure 1. [In color online, see http://dx.doi.org/10.1068/b36018] Exemplary retail distribution patterns on a circle of discrete locales. (a) Has five clusters, each of which has only one retailer; therefore average cluster density equals 1. (b) Has three clusters, one cluster has two adjacent retailers; one cluster has only one retailer; the final one has two colocating retailers. The average cluster density equals $(2 + 1 + 1)/3 = 1.33$. (c) Has two clusters; one cluster has only one retailer, while the other has four retailers covering three locales. The average cluster density equals $(1 + 4/3)/2 = 1.17$.

3.2 Consumers

In a market of homogeneous goods (named x), with W_x the total number of retailers, a consumer selects a retailer to patronize on the basis of its attractiveness, which depends on the observable shortest distance between the consumer and the retailer and other unobservable factors. For example, for consumer p the attractiveness index, A_{pi}, of retailer R_{xi} (the ith retailer of product x) is represented as:

$$A_{pi} = k_1 d_{pi}^{-\beta} + \epsilon_p , \qquad (2)$$

where d_{pi} is the shortest distance between consumer p and retailer i; and k_1 and the scaling parameter β are positive constants. The function indicates that longer travel distances would generally diminish consumers' willingness to shop. White noise, ϵ_p, shows a certain degree of randomness.

In a market of two complementary goods sold by two kinds of retailers, let R_{xi} indicate retailer i of product x, and R_{yj} indicate retailer j of product y. A trip is defined as a round trip for a consumer to travel from home to visit R_{xi} and R_{yj} so as to buy both goods. Given W_x, the number of retailers R_{xi}, and W_y, the number of retailers R_{yj}, there are a total of $W_x W_y$ trip candidates.

The utility for consumer p to patronize retailer R_{xi} and R_{yj} (indicated by pair t) equals:

$$A_{pt} = \sum_{t=1}^{W_x W_y} k_1 d_t^{-\beta} + \epsilon_p . \qquad (3)$$

After calculating all retailers' attractiveness indexes, a consumer probabilistically selects a retailer to patronize. In a market of homogeneous goods the probability for consumer p to patronize retailer R_{xi} (indicated by ρ_{pi}), is calculated on the basis of a simplified version of Huff's (1964) model:

$$\rho_{pi} = \frac{\exp A_{pi}}{\sum_{i \in W_x} \exp A_{pi}} . \qquad (4)$$

In the market for two complementary goods, the probability for consumer p to visit R_{yj} can be similarly calculated.

The roulette wheel selection method is adopted for a consumer to select a retailer in each round. This approach indicates that retailer i with higher σ_{pi} for consumer p has a greater probability to be selected by this consumer. A consumer's probabilities of patronizing all retailers comprise a wheel of selection, which is updated for every round. A spin of the wheel selects a retailer; once a retailer is selected, a consumer buys all needed products from this retailer. The sequence for consumers to patronize retailers is randomly decided for each round.

3.3 Retailers

Retailers connect suppliers and consumers on supply chains. In each round a retailer evaluates expected profits of all locales and moves to the locale of the highest profit. For example, retailer R_{xi}'s expected profit in locale m, Π_{xm}, is calculated as:

$$\Pi_{xm} = \left(\sum_{p=1}^{N} \lambda_x \rho_{pm} \right) \left[\theta_x - \sum_{k=1}^{K} (\delta_x + u\,\sigma_{mk}) \gamma_{mk} \right] , \qquad (5)$$

where λ_x indicates a customer's demand for product x (with a total of N customers); ρ_{pm} stands for the probability of consumer p patronizing the retailer in locale m; θ_x is the retail unit sales price of product x (a constant in the model); δ_x is the supplier unit sales price of x (a constant); u is the transport cost per unit distance per product;

σ_{mk} indicates the shortest distance between supplier k of product x and locale m; γ_{mk} is a binary variable, which equals 1 if a retailer in locale m patronizes supplier k.

$$\sum_{p=1}^{N} \lambda_x \rho_{pm}$$

represents total expected sales of products in locale m. The part in square brackets refers to expected profit per product, equaling sales price minus cost. A retailer's cost includes the purchasing cost of products from a supplier and the shipping cost, which is proportional to shipping distance and quantity of products. Here we assume that a retailer patronizes its closest supplier. After evaluating profits of all C locales on the circle, retailer R_{xi} moves to the locale that provides the highest expected profit Π_{xi}, given that others are geographically fixed at that time. It is presumed that each retailer can move only once per round; the sequence of moving is randomly decided.

3.4 Suppliers

We assume that all suppliers keep the same unit sales price. Moreover, they are evenly distributed on the circle and are fixed in all rounds. Further, in the market of two complementary goods, suppliers of the two products colocate. Suppliers can always produce enough goods to meet market demand.

4 Results and analysis

4.1 The market of homogeneous goods

The basic setting is a circle of 100 discrete locales, where 5000 consumers and 5 suppliers are evenly distributed. Different scenarios are tested with different retail numbers ranging from 2 to 100. The parameter values of this model (model 1) are shown in table 1. We examine retail geographical distribution patterns when stable patterns emerge (ie no retailers change their locales).

Figure 2 shows the numbers of clusters and cluster densities given different numbers of retailers. As can be seen, as the number of retailers increases from 2 to 10, the number of clusters rises to 5 (the same number as suppliers). In particular, when 10 retailers partake in the game, retailers double up at supplier locales; the average cluster density therefore becomes 2. As more retailers enter the market, the number of clusters remains flat; retailers in the clusters stay adjacent to each other while centering around suppliers. The average cluster density declines to 1, while the distribution pattern

Table 1. Values of parameters (model 1: homogeneous goods; model 2: complementary goods).

Variables	Description	Model 1	Model 2
β	distance scaling parameter	1.0	1.0
k_1	constant	1	1
C	number of locales on the circle	100	100
N	number of consumers	5000	5000
K	number of suppliers of x	5	10
L	number of suppliers of y		10
u	unit shipping cost per locale distance ($)	0.02	0.02
θ_x	retail unit sales price of x ($)	2.5	2.5
θ_y	retail unit sales price of y ($)		1.5
δ_x	supplier unit sales price ($)	1.5	1.5
δ_y	supplier unit sales price ($)		1.0
λ_x	individual consumer demand on x	20	20
λ_y	individual consumer demand on y		10

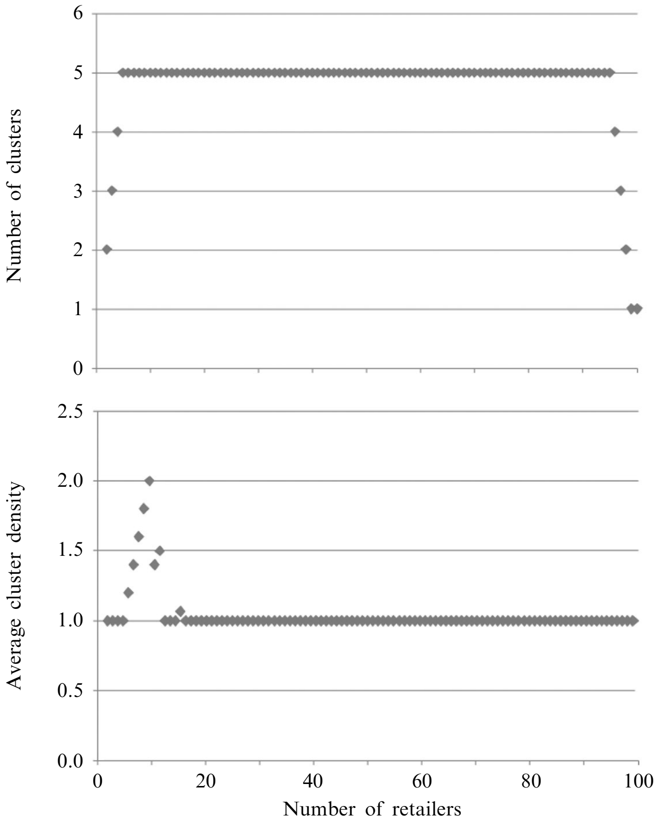


Figure 2. Number of clusters and average cluster density: (a) number of clusters emerging as the number of retailers increases from 2 to 100; (b) average cluster density as the number of retailers increases from 2 to 100.

remains almost symmetric. As the number of retailers approximates 100, which equals the total number of locales on the circle, all clusters connect with each other and each cell is occupied by 1 retailer. Some examples of retail distribution patterns are illustrated in figure 3.

The above analysis indicates that, when the number of retailers is no more than 10, the centripetal force (proximity to suppliers) induces them to double up in suppliers' locales, while the centrifugal force (proximity to customers) keeps the distribution pattern symmetric. As the number of retailers continues to grow, retailers tend to disperse themselves on the circle; the existence of centripetal force, however, keeps them near suppliers. Different numbers of retailers in the competition beget different distribution patterns.

To further explore the effects of the centripetal and centrifugal forces on retail distribution patterns, sensitivity tests are performed on β and u. When examining different values of β or u, we set other parameters to be the same as in table 1.

First, we test the value of β from 0.00 to 2.00 (with step size 0.25) and for each case run the number of retailers from 2 to 30. Figure 4 presents cluster densities for different values of β. We observe that, when β is larger than 0.50, retail distribution patterns are similar to the base case ($\beta = 1.00$) described above. When β equals 0.00 or 0.25, the retail pattern differs considerably from other cases. When β equals 0.00 retailers are evenly distributed and locate only in supplier locales for all scenarios of different numbers of retailers. This is because, as β equals 0.00 consumers are indifferent to

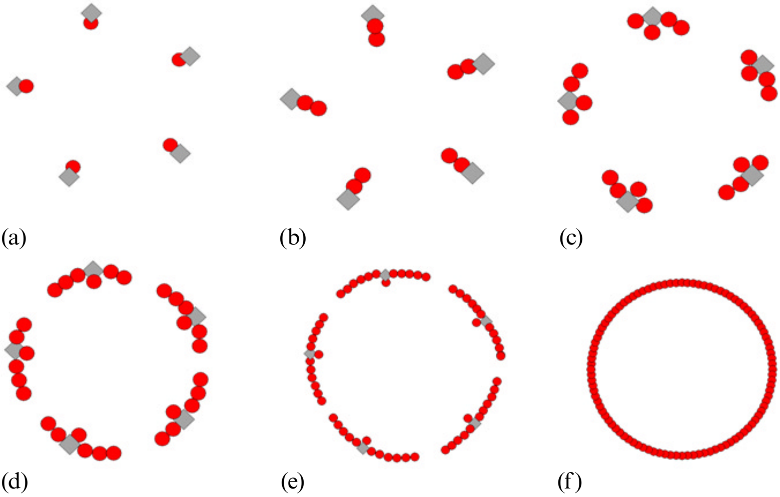


Figure 3. [In color online.] Examples of retail distribution patterns for different numbers of retailers in a market of homogeneous goods [plotted in Pajek (Batagelj and Mrvar, 2009)]. (Circles stand for retailers, and triangles represent suppliers. Objects sitting on top of each other mean that they share the same locale; adjacent objects indicate that they are geographically adjacent.) (a) Displays the distribution pattern of 5 retailers. (b) Shows the pattern of 10 retailers. (c) – (f) Respectively, exhibit retail spatial patterns for 20, 30, 60, and 100 retailers.

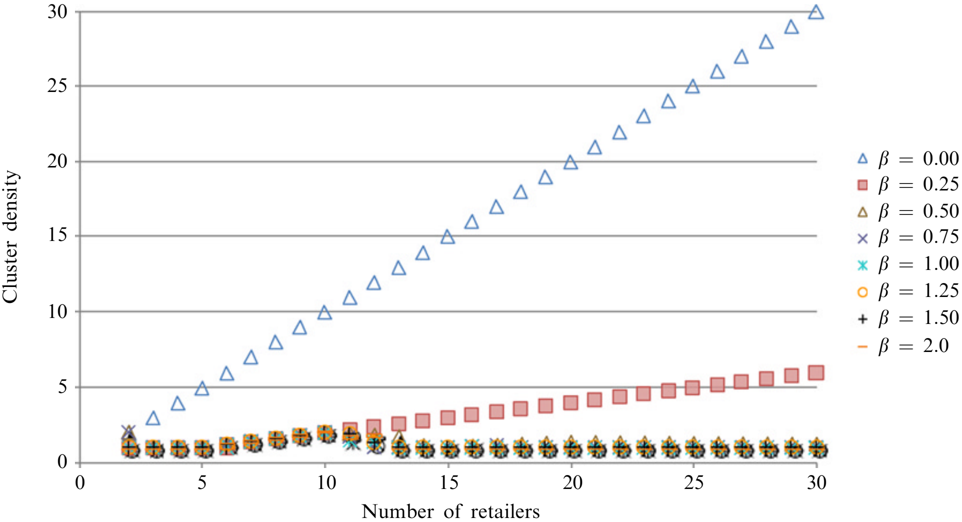


Figure 4. [In color online.] Average cluster densities for the scenarios with retailers ranging from 2 to 30: results of sensitivity tests on β (scaling parameter).

travel and retailers therefore stay in supplier locales to minimize cost. It is interesting to see that all retailers mass in only one supplier's locale; cluster density therefore equals the number of retailers. This is an artifact of the simulation model that retailers choose the first most profitable pattern and do not consider alternative locales of exactly equal profits. They might just as easily cluster uniformly or nonuniformly in any supplier's locale.

We further change the value of u from 0.00 to 0.16, with step size 0.02. Figure 5 shows cluster densities for different values of u. When u is larger than 0.08, retailers tend to double up on suppliers, as their number booms from 2 to 10. However, as the

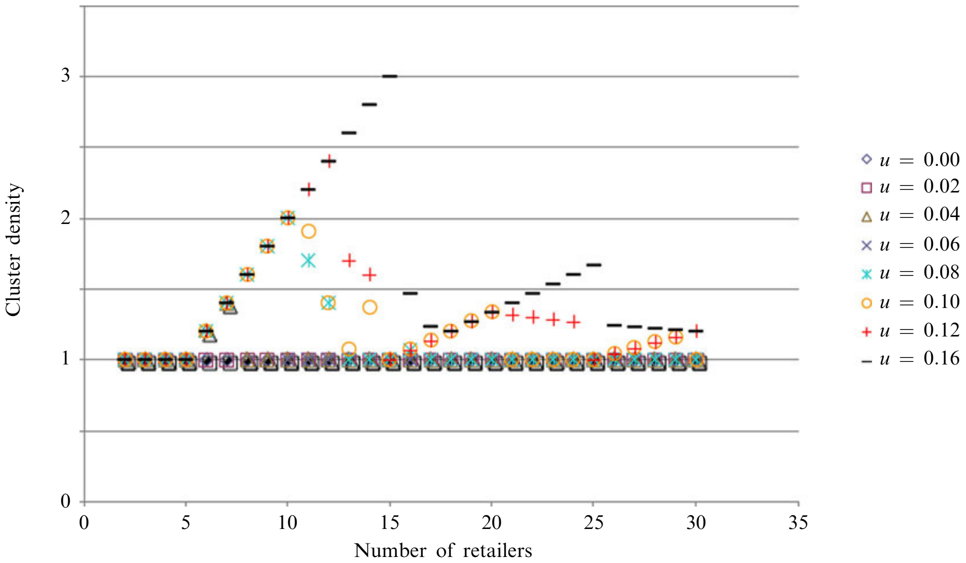


Figure 5. [In color online.] Average cluster densities for the scenarios with retailers ranging from 2 to 30: results of sensitivity tests on u (unit shipping cost).

number of retailers rises to 15, only the case of u equaling 0.16 shows continuing accumulation of retailers in suppliers' locales, different from the result of our base case (where u equals 0.02). In particular, in the case of 15 retailers, every 3 retailers stay in a supplier's locale. When u equals 0.16, although the cluster density curve gradually falls as the number of retailers continues to increase, a rising trend of cluster density can still be noticed when the number of retailers ascends from 20 to 25.

4.2 The market of complementary goods

In the market of two complementary goods, we first examine the scenario of 10 suppliers of product x and 10 suppliers of y, every 2 of which colocate and are evenly distributed on the circle. Table 1 shows the parameter values used in this experiment (model 2). We first set 20 retailers (10 retailers of product x, 10 retailers of product y). Since multiple equilibria are possible, 200 different retail initial location patterns (seeds) are examined.

Given different initial conditions, our results disclose multiple stable patterns, which can be grouped into three categories by the number of clusters (although each individual retailer's final locale may vary in different outcomes). The most common pattern is only one cluster (with probability 0.725), where all retailers accumulate in a supplier's locale; the patterns of two clusters and three clusters emerge with probabilities of 0.24 and 0.036. All the retail distribution patterns share two features: (1) retailers stay only in supplier locales; (2) the same number of retailers of x and retailers of y colocate, indicating that they constitute pairs. It is interesting to notice that the evenly distributed pattern of retailers—every one retailer of x and every one retailer of y double in a supplier's locale—does not appear in this experiment. To further explore this possibility, we intentionally set the initial distribution pattern to be very similar to the evenly distributed one, which ultimately results in the evenly distributed pattern of retailers.

To understand the impact of the number of retailers on retail distribution patterns, we further vary the total number of retailers from 4 to 40 while keeping the same number of retailers of x and the number of retailers of y; other parameters are set to

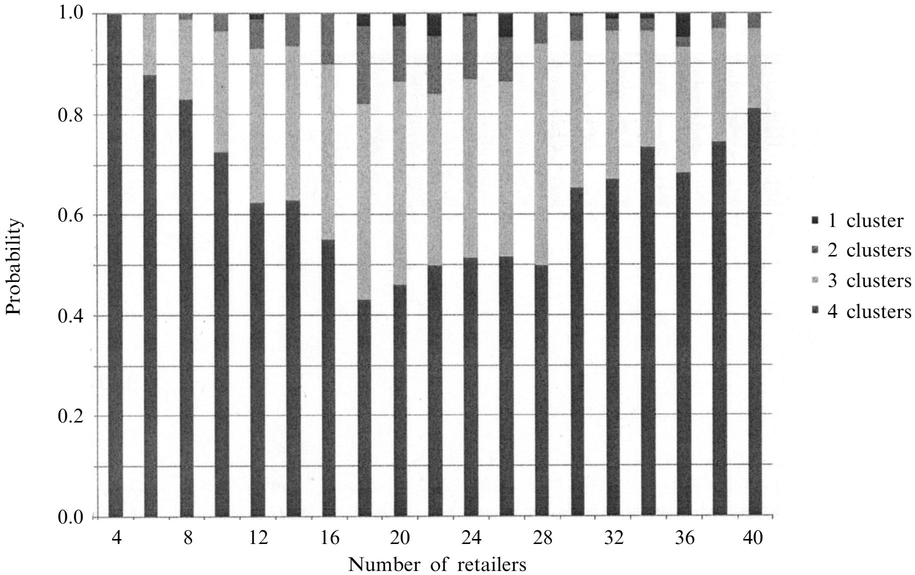


Figure 6. Probability distribution of the numbers of clusters with the number of retailers ranging from 4 to 40 (where the number of retailers of x equals the number of retailers of y), with total 20 suppliers (10 suppliers of x and 10 suppliers of y). The case of one cluster has the highest probability to appear of all the cases; the greater the gap between the number of retailers and the number of suppliers, the more likely that retailers tend to cluster. Additionally, retailers of x and retailers of y only stay in suppliers' locales and constitute pairs.

be the same as the base case. After testing 200 initial distribution patterns for retailers, except for the case of 4 retailers, our simulation results reveal multiple retail patterns for all cases. Figure 6 shows the probabilities for different retail clusters. It is interesting to notice that the pattern of only one cluster has the highest probability to appear for all cases. Moreover, by observing the trend of the histograms of one cluster for different numbers of retailers, we can notice that the greater the gap between the number of retailers and the number of suppliers (which is 10 for each category of products), the more likely that retailers congregate in one cluster. The largest number of resultant clusters is four; the probability of its happening nonetheless never exceeds 0.05.

But what if we have different numbers of retailers of complementary goods? We vary the number of retailers of product y from 2 to 16 while fixing the number of retailers of x to be 10; 200 seeds are also tested for each scenario. The probability distribution for clusters of different sizes is shown in figure 7. Overall, we find that the greater the gap between the number of retailers of product x and the number of retailers of y, the more likely it is that fewer clusters will emerge. Like our previous results, the case of one cluster has the highest probability to emerge and retailers only locate in suppliers' locales. Moreover, when there is more than one cluster in the distribution pattern, the ratio of the number of retailers of x to retailers of y in each cluster is very close. To illustrate, figure 8 shows some retail distribution patterns for 10 retailers of x and 15 retailers of y. Such interesting phenomena indicate that retailers can self-organize themselves into clusters of similar structures.

5 Discussion

Our agent model in the market of homogeneous goods and the market of complementary goods produces the emergence of retail clusters. In a market of homogeneous goods, clusters tend to be symmetric. When retailers are few, they accumulate in suppliers'

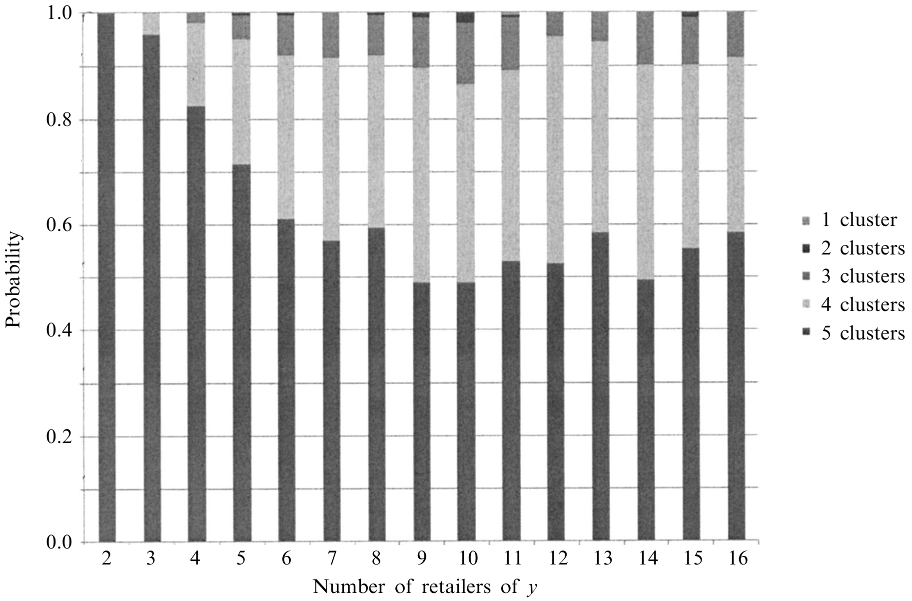


Figure 7. Probability distribution of the number of clusters with 10 retailers of product x and the number of retailers of y ranging from 2 to 16 (shown in the horizontal axis). The case of only one cluster has the highest probability to emerge. The greater the gap between the number of retailers of product x and the number of retailers of product y, the more likely that the case of fewer clusters will emerge.

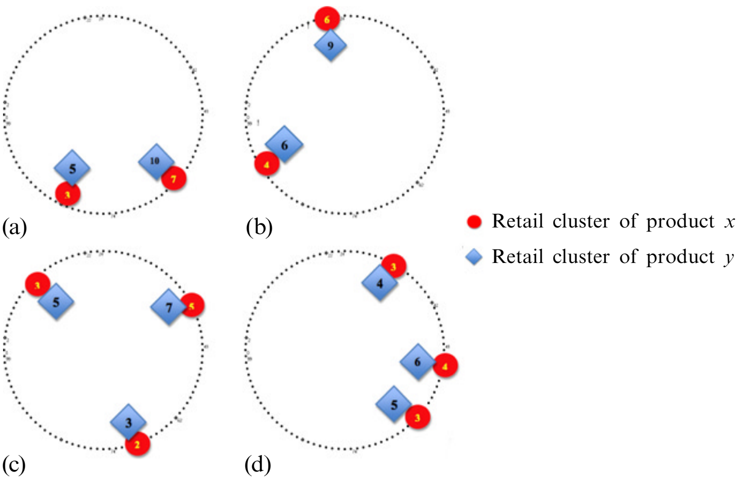


Figure 8. [In color online.] Some retail distribution patterns (with more than one cluster) in equilibrium for 10 retailers of x and 15 retailers of y [plotted in Pajek (Batagelj and Mrvar, 2009)]. A circle stands for a retail cluster of x; a diamond represents a retail cluster of y. Two shapes laid together show that they colocate. The number in each shape indicates the number of retailers. All retailers are found to stay in supplier locales. In (a) the ratio of the number of retailers of x to the number of retailers of y for the two clusters respectively equals 3:5 and 7:10. The ratio of the number of retailers of product to x the number of retailers of product y tends to be close for the emergent clusters. Similar phenomena can be found for other results.

locales; as the number of retailers increases, they spread out around suppliers and incrementally occupy the whole circle. Moreover, a larger scaling parameter (absolute) value for consumers tends to make retailers more dispersed, and higher unit shipping cost makes retailers more concentrated around suppliers. Such results exhibit the balance between proximity to the market and proximity to suppliers which impacts the retail distribution pattern.

In the market of two complementary goods, multiple equilibria of retail distribution patterns are found to be common; nevertheless, the case of only one cluster—where all retailers accumulate in a supplier locale—is most likely to emerge. Moreover, the greater the gap between the number of retailers of x and the number of retailers of y, the more likely it is that dense clusters will emerge. A further exploitation suggests that in the market of homogeneous goods the case of one cluster cannot be stable in that some retailers in the big cluster can easily move to an open space on the circle to occupy a larger market. In the model of complementary goods, however, since consumers consider total travel distance for buying both goods, retail location choice depends not only on their distance to suppliers and consumers, but also on their distance to retailers of complementary goods. Furthermore, for the patterns with more than one cluster, our results imply that emergent clusters, however different in size, tend to have a similar composition in terms of the ratio of retailers of complementary goods.

In central place theory Christaller (1933) claimed that in the areas with evenly distributed population and resources, settlements have equidistant spacing between centers of the same order; high-order services are farther away from low-order services. Yet this research demonstrates that, even in a market of two equally important products, hierarchical distribution patterns can also autonomously emerge. This comports with the notion of retail districts found in many cities, such as the Kappabashi district of Tokyo specializing in kitchen equipment (and plastic sushi) along with similar examples of clustered competitors (Levinson and Krizek, 2008). In our model of complementary goods, although the evenly distributed retail pattern can occur under certain circumstances, to achieve this each cluster requires a very specific timing, which has a high requirements for initial seeds and the sequence of location choice. Therefore it is much less likely to emerge naturally than the hierarchical patterns. Overall, our results find autonomous emergence of retail clusters; the hierarchical distribution patterns (in particular, the pattern of only one cluster) appear with a high probability.

6 Conclusion

This paper builds an agent-based model to examine retail location choice on a supply-chain network of consumers, retailers, and suppliers. In a market of homogeneous goods we find symmetric retail distribution patterns, and average cluster density changes dynamically as retailers join the market. These patterns are affected by shipping cost and consumers' willingness to travel. Our findings demonstrate that the development of a market does not always lead to condensed retail agglomerations. Moreover, the balance between transportation cost and market size considerably impacts the size and density of clusters.

In a market of two complementary goods, assuming suppliers of the two products colocate and evenly distribute themselves, we find self-organizing retail clusters with features different from the results of the first model. First, multiple equilibria of retail distributions are common. Second, colocating of retailers of complementary goods appears with a high probability. Moreover, the likelihood of clustering increases with the gap between the number of retailers of complementary goods and the gap between the number of retailers and the number of suppliers. Third, when more than one cluster occurs, however different in size, the ratio of the number of retailers of one product to the number of retailers of the other product tends to be close for the emergent clusters. Our results illustrate that competition among retailers on supply chains (especially when considering trip chaining for complementary goods on the part of the customer) is sufficient to produce clustering; other mechanisms (such as the desire of customers to comparison shop) are not required, but may also be additional source of clustering behavior. We have not identified whether there is a necessary assumption to produce clustering.

Future research should address the efficiency of such self-organized retail patterns in terms of social welfare, as opposed to a more evenly distributed one (such as posited in central place theory). Empirical studies should also test the hypotheses presented in this research.

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