The User Manual for the model of Clustered Locations of Urban Services, Transport, and Economic Resources (CLUSTER)

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1 Introduction to CLUSTER

The Clustered Locations of Urban Services, Transport, and Economic Resources Program (CLUSTER) is an agent-based prototype on modeling retail location choice on supply chains consisting of consumers, retailers, and suppliers. Introduced in Huang and Levinson (2011), this model aims to investigate the effects of transportation cost, consumers' travel behavior, and suppliers' locations on retail location choice. The latest version of the CLUSTER java applet is freely available for non-commercial use at its home page: http://street.umn.edu

2 The model

2.1 Assumptions and definition of cluster

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

Two kinds of markets are tested based on this framework: first, a market of homogenous goods; second, a market of two complementary goods where exists consumers' trip chaining behavior in shopping. The computational models are programmed in java, where each agent is modeled as an object. In the beginning of each round, consumers patronize retailers based on their rules to meet their needs on 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 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; retail distribution patterns in equilibrium are visualized by the *Pajek* Software (**?**).

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

$$\varphi_n = \frac{1}{M}\sum_{i=1}^{M}\frac{\varepsilon_i}{\tau_i} \tag{1}$$

where ε_i is the number of numbers in cluster i; τ_i is the number of locales covered by cluster i; M is total number of clusters.

2.2 Consumers

In a market of homogenous goods (named x) with W_x total number of retailers, a consumer selects a retailer to patronize based on 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 number of retailers of product x) is represented as:

$$A_{pi} = k_1 \cdot d_{pi}^{-\beta} + \epsilon_p \tag{2}$$

Where d_{pi} is the shortest distance between consumer p and retailer i; k_1 and the scaling parameter β are positive constants. The function indicates that longer travel distance would generally diminish consumers' willingness to patronize. 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 from home to visit R_{xi} and R_{yj}. Given W_x number of R_{xi} and W_y number of R_{yj}, there are in total $W_x \cdot W_y$ trip candidates.

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

$$A_{pt} = \sum_{t=1}^{W_x \cdot W_y} k_1 \cdot d_t^{-\beta} + \epsilon_p \tag{3}$$

After calculating all retailers' attractiveness indexes, a consumer probabilistically selects a retailer to patronize. The probability for consumer p to patronize retailer R_{xi}, ρ_{pi}, is calculated based on a simplified version of Huff's model (**?**):

$$\rho_p = \frac{e^{A_{pi}}}{\sum_{i \in W_x} e^{A_{pi}}} \tag{4}$$

In the market of two 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 ρ_{pi} for consumer p has a greater chance 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.

2.3 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:

$$\Pi_{xm} = (\sum_{p=1}^{N} \lambda_x \cdot \rho_{pm}) \cdot [\theta_x - \sum_{k=1}^{K} (\delta_x + u \cdot \sigma_{mk}) d_{mk}] \tag{5}$$

Where λ_x indicates individual customer's demand on product x (with total N customers); ρ_{pm} stands for the probability for consumer p to patronize the retailer in locale m; θ_x means retail unit sales price of product x (a constant in the model); δ_x means 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; d_{mk} is a binary variable, which equals 1 if a retailer in locale m patronizes supplier k. $\sum_{p=1}^{N} \lambda \cdot \rho_{pm}$ represents total expected sales of products in locale m. The part in brackets refers to expected profit per product, equaling sales 200price 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 a retailer patronizes its closest supplier. After evaluating profits of all the C locales on the circle, retailer R_{xi} moves to the locale that provides the highest expected profit Π_{xi}, given others are geographically fixed at that time.

Each retailer can only move once per round; the sequence of moving is randomly decided.

2.4 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 co-locate. It is presumed that suppliers can always produce enough goods to meet market demand.

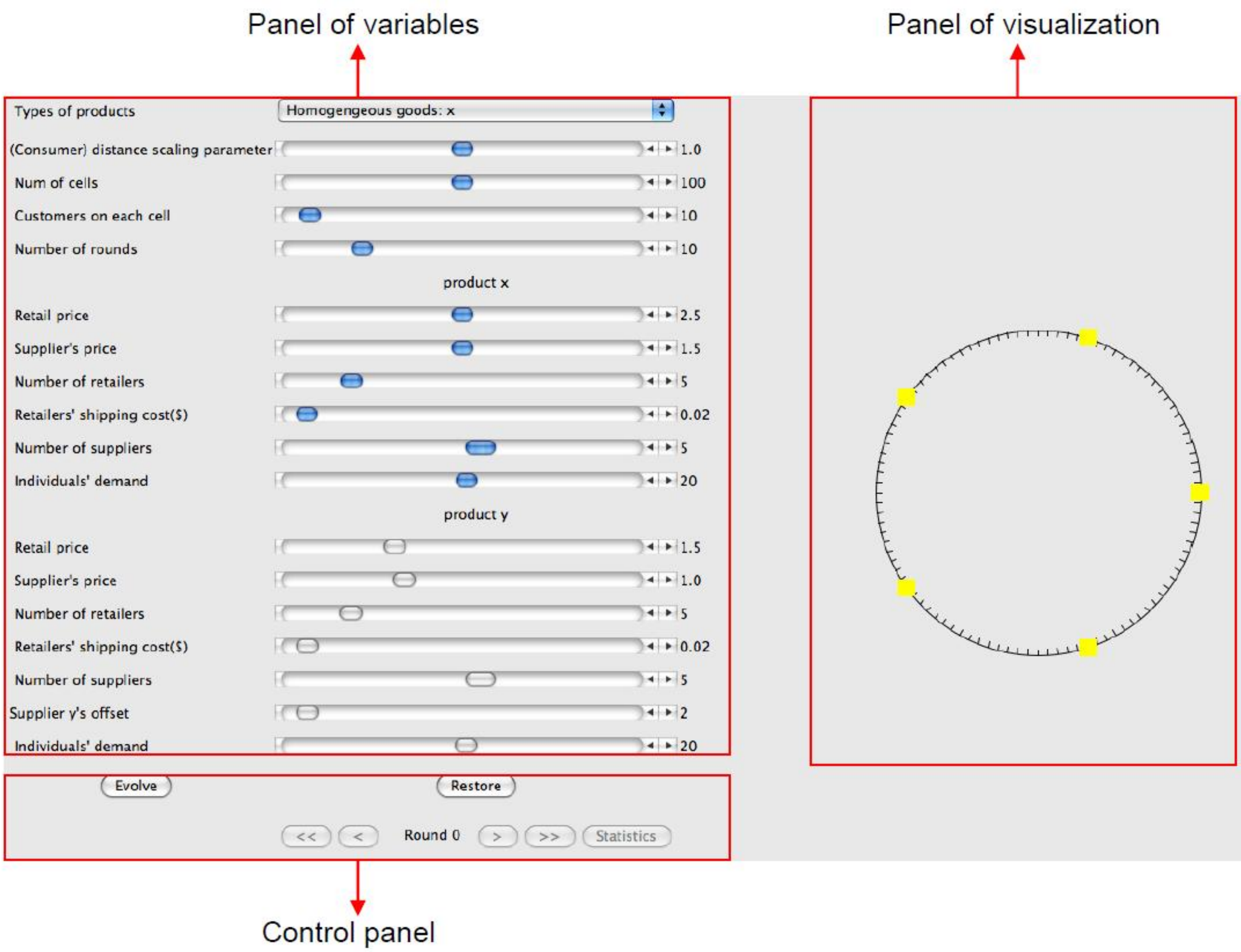

Figure 1: The user interface for the CLUSTER applet

3 The User Interface

The CLUSTER java applet has three panels: the panel of variables, the control panel, and the visualization panel, which are shown in Figure 1. This section introduces the function of each panel.

3.1 Panel of variables

In the first row the user can choose the type(s) of products: "homogeneous goods: x" or "heterogeneous goods: x and y". If the scenario of homogeneous goods is chosen, the variables for product y are disabled, and are enabled otherwise.

The consumer distance scaling parameter (β) ranges from 0 to 2.0. The greater the parameter is, the faster the consumer's utility decreases with distance. The variable of the

Table 1: Values of parameters (Model 1: homogenous goods; Model 2: heterogeneous goods)

Variables	Descriptions	Model 1	Model 2
β	exponent of distance decay	1.0	1.0
k_1	constant	1	1
C	# of locales on the circle	100	100
N	total number # of consumers	10000	10000
K	# of suppliers of x	5	5
L	# of suppliers of y		5
u_x	unit shipping cost per locale distance of product x (\$)	0.02	0.02
u_y	unit shipping cost per locale distance of product y (\$)		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		20

number of cells shows the number of discrete cells on the circle. On each cell there are a number of customers who can be placed by changing the number of customers on each cell (ranging from 1 to 200). The marks of each cell on the visualization panel will be painted darker as the number of customers on each cell increases. The number of rounds (iterations), in the next row, ranges from 1 to 50, with the default value 10.

For retailers of product y, there are several variables: retail unit sale price, supplier's unit sales price, number of retailers, retailers' shipping cost (shipping products from suppliers to retailers), number of suppliers, and individuals' demand on product x. The explanations for the variables and values for the base case are shown in Table 1.

Suppliers' locations are evenly distributed. Given different numbers of suppliers, suppliers' space between each other on the circle varies. In the scenario of heterogeneous products x and y, users can also set suppliers of product y's spatial offset from suppliers of product x; suppliers' locations will immediately be plotted as the number of suppliers and the value of offset are given.

3.2 Control Panel

There are two buttons on the control panel: "Evolve" and "Restore". The Evolve button, once clicked, runs the program. As the program is running, there will be a message box at the end of the panel showing the progress. Retailers' locations at the end of each round will be plotted on the panel of visualization. Once the program ends, users can check the locations of retailers in each round by licking <, <<, >, >>. The Restore button can restore the values of parameters to the base case.

3.3 Visualization panel

The visualization panel visualizes the locations of retailers and suppliers. Suppliers are marked by rectangles; retailers are represented by circles. Objects of yellow color indicate objects of product x. Objects of red color indicate those of product y.

References

A. Huang and D. Levinson. Why retailers cluster: an agent model of location choice on supply chains. *Environment and Planning B*, 38(1):82–94, 2011.