Primitive Market Formation: an Agent-based Model

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ABSTRACT

This project studies market formation by the locating and pricing strategies of agents that can produce, exchange, and consuming goods in each of every period. We set up an agent-based model in which there are two types of goods, certain locations that can possibly become markets and a number of agents. Each agent has an ability to produce only one kind of good. In order to increase his utility, he has to exchange for the other good by the amount of good he possess. We find parameters like the ratio of number of agents and locations and the ratio of production and consumption can influence markets structure. We then add a bargaining system into the model, and find the market structure changes under certain condition such as when production rate equals to consumption rate. Also, the relative price by bartering converges to a private but common price.

KEYWORDS: market formation, market structure, bargain,

1 INTRODUCTION

This project studies market formation by the locating and pricing strategies of agents that can produce, exchange, and consuming goods in each of every period. We set up an agent-based model in which there are two types of goods, certain locations that can possibly become markets and a number of agents. Each agent has an ability to produce only one kind of good. In order to increase his utility, he has to exchange for the other good by the amount of good he possess. We find parameters like the ratio of number of agents and locations and the ratio of production and consumption can influence markets structure. We then add a bargaining system into the model, and find the market structure changes under certain condition such as when production rate equals to consumption rate. Also, the relative price by bartering converges to a private but common price.

The agent-based modeling is widely used by social scientists in studying the collective behavior consisting of large number of adaptive agents involved in parallel local interactions nowadays. These local interactions give rise to macroeconomic regularities such as shared market protocols and behavioral norms, which in turn feed back into the determination of local interactions[1]. In the discipline of Economics, bottom-up modeling of market processes Agent based computational economics (short for ACE) is one of the most active areas of ACE research. Various kinds of markets including financial, electrical, labor, retail, e-commerce, and entertainment are all the focuses. Some scholars like Tesfatision [1] (1996) developed a trade network game to study the market structure. There is also one software called **...**builds up a platform for trading network

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[1] See Tesfatsion L., Agent-Based Computational Economics: Growing Economies from the Bottom Up, Artificial Life, 2002(8), p62.

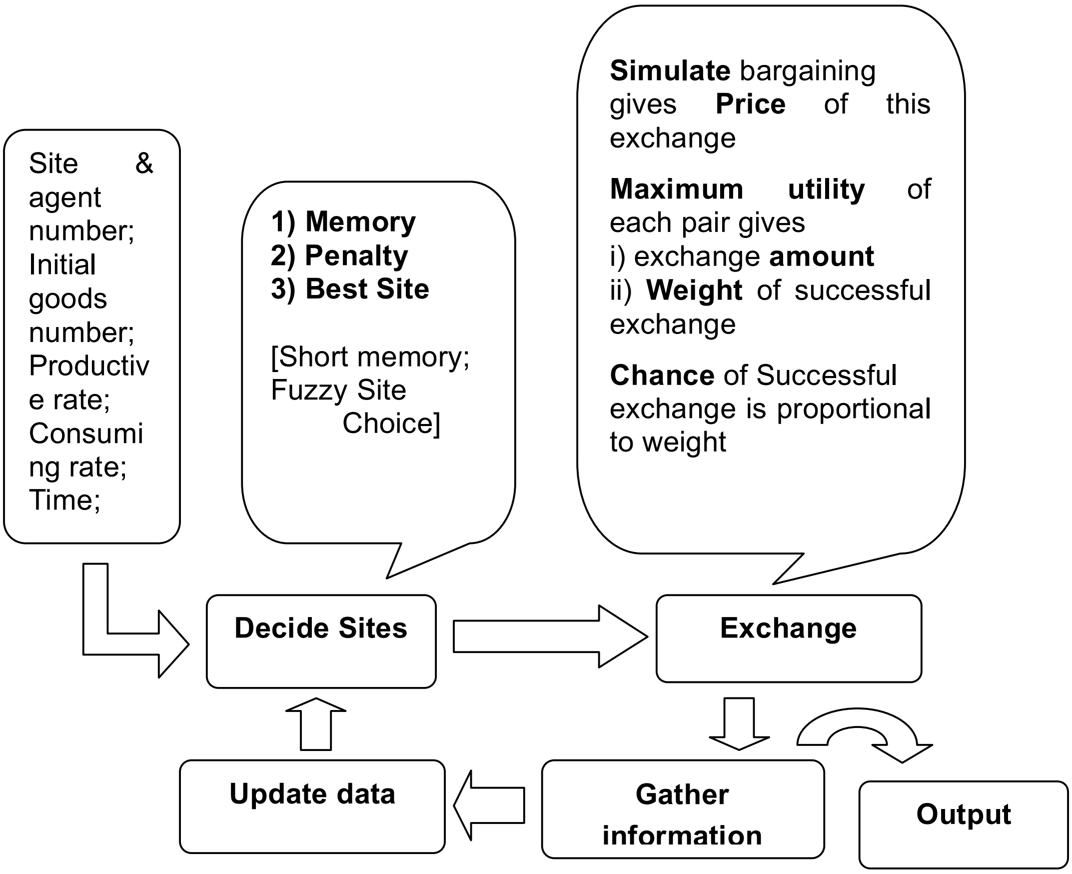
study by controlling the parameters of buyers, sellers and dealers. But these researches mainly focus on the strategies of agents and formation of trading relationships instead of location and pricing formation. Regarding to agent-based model on primitive market economy, there are also many related literatures. Epstein and Axtell (1996) built up a multi-agent model named "Sugarscape" and later, some social scientists use it to simulate the formation of primitive pricing system [2]. Although this model contains path selection, the pricing system is relatively simple: price is merely the geometric average of the marginal substitution of two goods. Gintis [3](2005) drives the price system in the model of decentralized bilateral exchange. In that system, prices quickly converges to a private but public prices by setting up the learning strategies of low scoring agents. However, neither location selection nor bargaining are considered in this model. When updating the strategies, agents should know all the possible payoff of everybody, which is considered to be global information. SUN and HAN [4] study the way agents utilize in formation from trading history on influencing the evolution process and the emergence of geographic market structures. Their result is that when there is just personal information keeping without a collective memory of all the past trading information, no centralized market emerges. Only when trading becomes a public information or well communicated within groups can central market emerges. Again, as the focus of this paper is geographic patterns instead of discussion about market characteristics, pricing, bargaining or transaction cost system are all not included. There are tons of related literatures about bargaining in Economics, but most of them mainly focus on the optimal strategies using backward induction, which is considered to be unrealistic in the real world. Therefore, we set up our own bargain system in this project using a more realistic strategy of human being: they each have a psychological reserved price of a certain good. After asking the price of the other agent, he can adjust his price We demonstrate that market structure and price system has some correlation that cannot be separated. The purpose of this project is to view location and pricing elements as a whole and explore the factors contributing to market structure, relative price and the inter-relationship between these location selection and pricing system in the model.

2 THE STRUCTURE OF PRIMITIVE MARKETS

Suppose there are n goods and N>n agents. Every agent owns the ability to produce a single kind of good. Assume that each agent has a Cobb-Douglas form of utility function[2]; which means in order to lead a better life, the agent must exchange for another good. In our system, we assume there are m (m>>1) places that can possibly become markets[3]. In the initial period, each agent has the same impression about the every possible site, and chooses one site at random. If agents at that site carry different kinds of goods, they start trading with each other. A score of 10 will be added to an agent's impression of that particular site once a trade is successful; otherwise, if the trade is unsuccessful, 3 points will be taken of. After all the possible trades are finished this period, agents will update the price together with site information and consume part of both goods at a certain rate control by the system. The flow chart of this simple market economy is as follows:

[2]

[3] Since we do not introduce path selection in this model, a site has an infinite capacity of agents. Also, we do not consider the consumption and time when an agent moves to a site.



3 SIMULATION ANALYSIS

In order to study the factors contributing to market formation and pricing system and their inter-relationship, we first separate pricing from location selection problem and then add a bargain system in it Three different kinds of model are constructed in our project: the first one is only location selection without pricing system with a utility function "tent map". 后面我没有想好怎么写The parameters in the following simulation are n=2, N=500, m=500, periods=1000.

MODEL I: MARKET EMERGENCE WITHOUT BARGAIN.

Three specific principals are set up in model I:

1) Every agent wants to keep every goods to a certain amount (best amount). He wants to reach his best amount by exchange.

2) When two agents exchange, they exchange the as many as possible.

3) We don't introduce price in the model, so we design that the value of one unit goods i always equals to that of 1 unit goods j.

At every period, agents decide to go to one site. He tends to go to his most successful sites in his memory. A site will gain k score if the agent performs one successful exchange there and will lose m score if the agent performs one unsuccessful exchange there. At each site, we collect all agents who choose to be there and combine them into all possible pair. That is, we match 2 agents if they produce different goods. For each pair, agents estimate goods mutually and get a score finally. The score is then used as weight to measure the chance of success of their exchange. Pairs are ordered by the score from high to low, which decide if they exchange goods proportional to their score. Once 2 agents exchange successfully they will not appear again, thus in each period, no matter successful or not, one agent only perform exchange once. When one period is over, every agent consumes a certain amount of each goods respectively, and he will produce the goods that he produces. What he can offer to exchange for next period is the difference between inventories currently and his best amount.

Now we will focus on the evaluation of goods between 2 agent, say A and B. Suppose A produce goods i, B produce goods j and As' inventory of goods j is x , while his best amount of j is x_0; Bs' inventory of goods i is y while his best amount of i is y_0. A can offer y' of goods i and B can offer x' goods j. From 2), the exchange amount is: $\min\{x', y'\}$.

The difference $D_{A\to B} = (x + x' - x_0)$ means: after exchange, the difference between As' inventory of goods j and his best amount. From 1), if $D_{A\to B} < 0$, the bigger $-D_{A\to B}$ is, the stronger As' willing to exchange with B; if $D_{A\to B} > 0$, the bigger $D_{A\to B}$ is, the weaker As' willing to exchange with B. For simplicity, we define the value function as following:

$$\begin{cases} V_{A\to B} = -k_- \cdot D_{A\to B} & D_{A->B} \le 0 \\ V_{A\to B} = -k_+ \cdot D_{A\to B} + w_0 & 0 < D_{A\to B} \le \dfrac{w_0}{k_+} \\ 0 & other \end{cases}$$

$V_{A\to B}$ is the evaluation of A to Bs' goods. From similar analysis, we have $V_{B\to A}$ to measure the evaluation of B to As' goods. The product:

$$V_{AB} = V_{A\to B} V_{B\to A}$$

gives mutual evaluation of agent A and B.

We discover that the ratio of production rate and consumption rate (short for r) has a strong influence on market formation pattern. When r<1, agents trade with each other at the every starting periods, but the successful trade amount quickly converges to zero and remain constant. When r is larger than 1.04, hierarchical market structure emerges (See Figure 1).

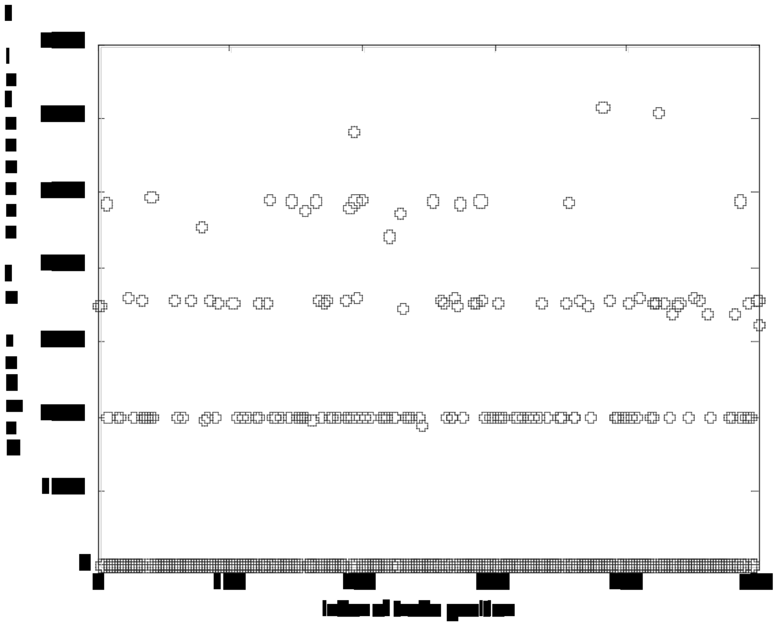


Figure1: markets emerge with hierarchical structure

As can be seen from this graph, the hierarchical market system can be divided into five levels of markets according to the amount of successful trades that been recorded in the figure. The largest 3 markets have approximately 6000 total amounts of trades each, which followed by 17 markets with about 5000 amounts of trades each. There are 47 sites in third level with an amount of 3500 trades respectively. 91markets all have an amount of successful trade amount at about 2000 times and the rest 342 sites has no record of trade during 1000 periods.

When r is between 1.00 and 1.03, two categories of market patterns emerge. Hierarchical structure only shows up about every one out of time simulations. For the rest of nine the times, market structure appears as scattered, random patterns. Relatively less variation

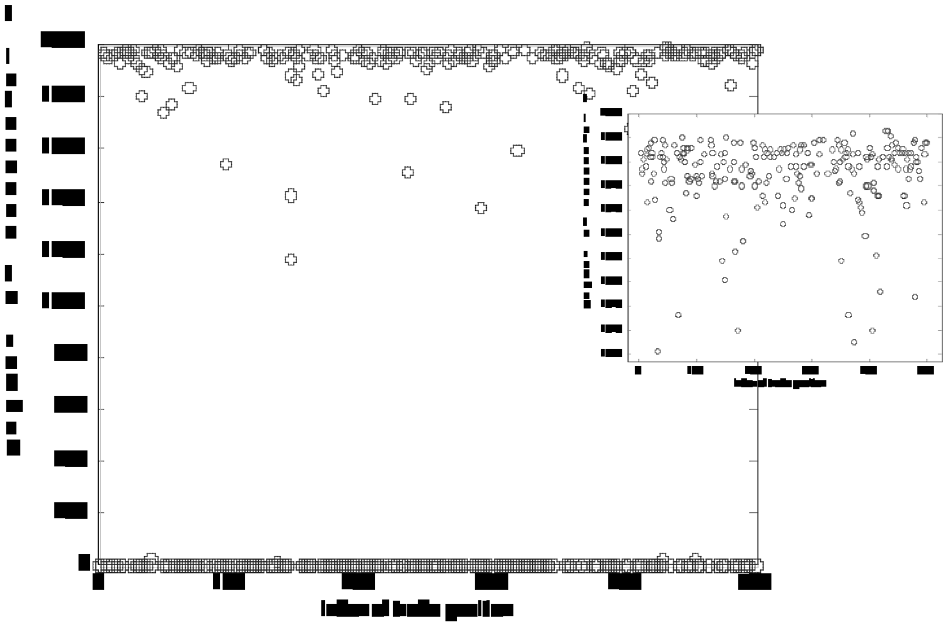


Figure2: markets emerge with no hierarchical structure

(The smaller graph at the right side is the partial enlarged pattern of figure 1 which means the amount of trades at different sites actually varies)

MODEL II: MARKET EMERGENCE WITH LOCAL PRICE SYSTEM.

//☒有关引入局域价格机制的原因；

Bargain Model Based on Local Price System

There are only two kinds of goods, A and B, in the market, and each agent can choose one of the two to produce for its personal consume and trade for the other. The agent will make such a choice according to its ability to produce either kind of production. Here, the ability can be defined as the number of some kind of goods A or B that one agent ($agent_i$) can produce in the unit time, if it decides to only produce this kind. So this ability can be marked as n_{ai} or n_{bi}. If this agent is good at producing x ($x \subset \{a,b\}$), or its n_{xi} is larger, it will choose to only produce good x.

Every agent in this transaction wants to maxim its profit, so as to $agent_i$, the price is expected to be lower, but to $agent_j$, the price is expected to be higher. In order to make the deal, the two agents have to play a game, and make some concession to achieve its final price, which is acceptable to both sides. In the traditional game theory, this game is always supposed to find the optimal solution. That means, either agent is clever enough to have a clear idea on the other's cost, and able to make the profit of both side maximum. Thus, the final price determined according to the traditional game theory, is the optimal, and can make the profit of both side to achieve a higher level.

But in real world, at least in China, people do not make deals in this way. What this bargain model wants is the most realistic solution, but not the optimal solution. So how real people make deals has to be modeled and simulated. In this paper, a new bargain model is developed.

In order to develop this bargain model, three basic hypotheses have been made as follows:

1. If this transaction is possible, neither of the two agent should quit while in bargain;
2. While bargain, the agent has no idea about other's psychological activities or cost;
3. Every agent will only decide its price according to the profit it wants to obtain.

From these hypotheses, some key points can be indicated.

1) The condition decides whether the transaction is possible

Assume there are two agents involved in one transaction. In order to decide whether the transaction is possible, a matrix, Ep , is introduced as follows:

$$Ep = \begin{bmatrix} n_{ai} & n_{bi} \\ n_{bj} & n_{bj} \end{bmatrix} \qquad (1)$$

Here, the elements in row_i the first row represent $agent_i$'s ability to produce different goods. If the largest elements of different row belong to the same volume, the transaction between these two agents will not happen, because that means both agents are good at producing the same goods.

2) How profit decide price

It is acceptable to suppose that $agent_i$ is good at producing A, and $agent_j$ is good at producing B. Thus $agent_i$ should trade its A for $agent_j$'s B. Assume that $agent_i$ have to use p A to change one B. So the parameter p can be described as the price. In order to make the process to detect the price easier, an other matrix, Cp , is given as below:

$$Cp = \begin{bmatrix} 1/n_{ai} & 1/n_{bi} \\ 1/n_{aj} & 1/n_{bj} \end{bmatrix} \qquad (2)$$

Here, every element of this matrix represents the cost of corresponding product produced by some agent.

Suppose the price is p ,and $agent_i$ use p A to exchange one B, and its profit is:

$$B_i = \frac{1}{n_{bi}} - \frac{p}{n_{ai}} \qquad (3)$$

According to equation (3):

$$p = \left(\frac{1}{n_{bi}} - B_i \right) n_{ai} \qquad (4)$$

That is to say: if $agent_i$, who need goods B, want to make profit B_i in this trading, it should make the price p as the result of equation (4).

As to the other agent, $agent_j$, who need A, if it want to obtain profit B_j, it also should decide its price according to the following equation:

$$p = \frac{1}{\left(1/n_{aj} - B_j \right) n_{bj}} \quad (5)$$

In equation (4), and (5), such parameters as $n_{ai}, n_{bi}, n_{aj}, n_{bj}$ are fixed, and the agents can only decide the profits they expect, B_i, B_j. And from these equations, another important thing can be indicated that neither $agent_i$ nor $agent_j$ will involve the parameters belong to other agent in the functions, which decide the price. This means that no one will consider others' information while deciding its price.

3) How the bargain is going on?

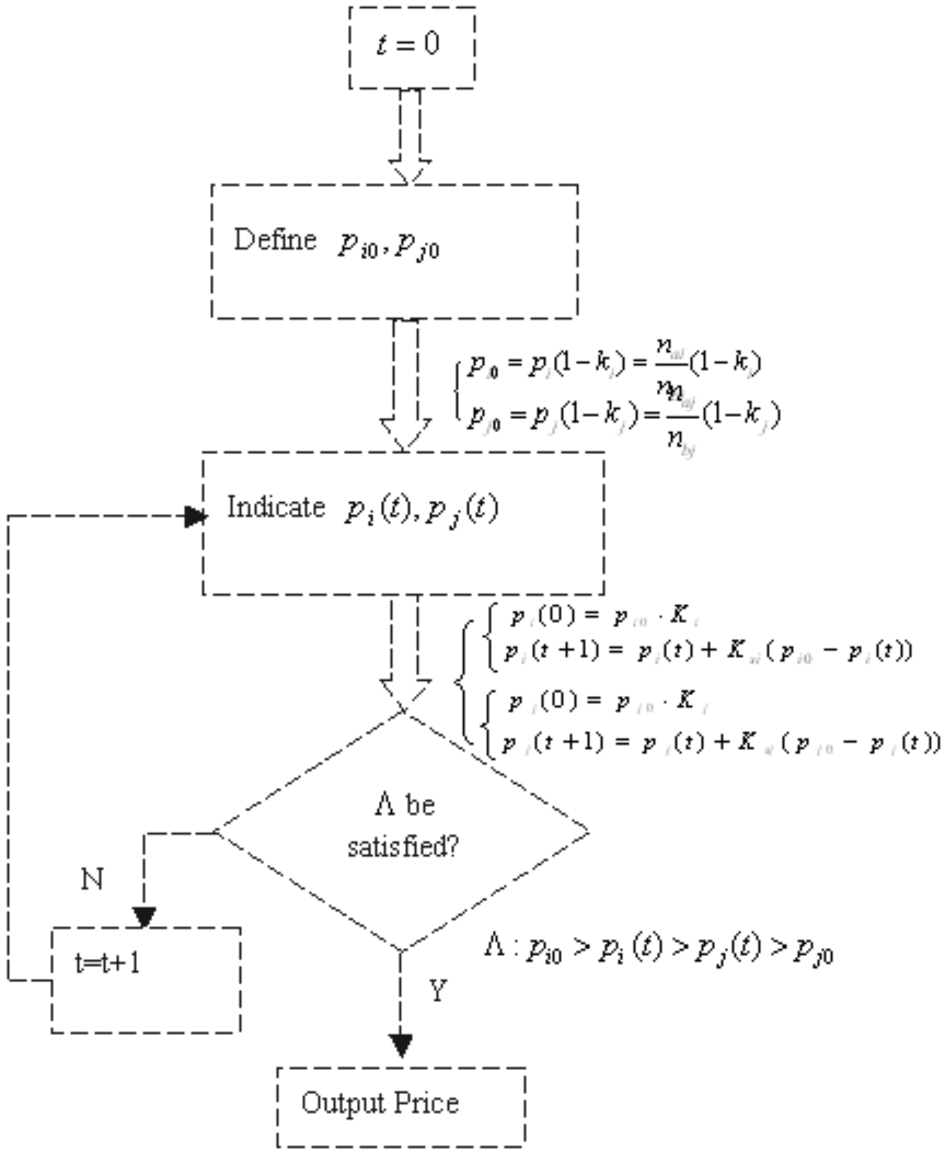
The agents take parts in the transaction only because they want to obtain some profit form the exchange. So every agent has an expected minimal profit rate, B_{i0}. According to the equations above, the agent can indicate some price, p_{i0}, as its bottom line. If great variance exists between two agents' bottom line, they can never achieve the agreement in the trading price, and the transaction has to be canceled.

If the transaction does need to be canceled, the agents involved in the transaction should define an initial profit rate, $B_i(0)$, and indicate its initial price, $p_i(0)$, by equation (4) or (5). And the agent will use the initial price as its first quotation. Usually, the transaction cannot be accomplished with these initial prices, because there is always great difference between the first quotations (but not the bottom line) of the two agents, and as the result, bargain appears.

The process of bargain can be explained by the flowchart in the Fig.1.

MODEL III: MARKET EMERGENCE WITH GLOBAL PRICE SYSTEM.

The third model in this paper is a modified version of the first model by introducing the relationship between supply amounts of different goods. Under the same conditions as Model I, suppose agent ***A*** and agent ***B*** are in the same potential market while ***A*** is a maker of Good 1 and ***B*** is a maker of Good 2. ***A*** has m_1 Good 1 for trade; B has m_2 Good 2 for trade. We set the optimal trade for ***A*** is using $\frac{m_1}{m_2}(1 - random[0, 0.2])$ Good 1 to exchange one Good 2 from others, and the optimal trade of ***B*** is using one Good 2 to exchange $\frac{m_1}{m_2}(1 + random[0, 0.2])$ Good 1 from others, where $random[0, 0.2]$ means a uniformly distributed random number on the interval [0, 0.2]. If ***A*** trade with ***B***, the final exchange ratio between Good 1 and Good 2 (here we name it as global price for short) is on the interval $\left[\frac{m_1}{m_2}(1 - random[0, 0.2]), \frac{m_1}{m_2}(1 + random[0, 0.2])\right]$. Here the introduction of the random numbers denotes the agents want to obtain some profits from the exchange. Then the process of bargain between ***A*** and ***B*** is illustrated in the Fig.2, where $p_{i0} = \frac{m_1}{m_2}(1 - random[0, 0.2])$ and $p_{i0} = \frac{m_1}{m_2}(1 + random[0, 0.2])$.



CONCLUSION AND FUTURE RESEARCH

The purpose of this project is to view location and pricing elements as a whole and explore the factors contributing to market structure, relative price and the inter-relationship between these location selection and pricing system in the model. By setting up an agent-based model in which there are two types of goods, certain locations that can possibly become markets and a number of agents, we investigate the market formation by the locating and pricing strategies of agents that can produce, exchange, and consuming goods in each of every period. We run altogether three different kinds of models (one is a simple location selection without bargain system and the other two are implanted with a bargain system, but one with global price and the other private price). In the first model, the ratio of production rate and consumption rate (r) has a strong influence on market structure; that is, if $r < 1$, the market never emerges, and the exchange tend to converge to zero as time passes by. Only when r is no less than 1.04 then the structure of market begins to emerge. A well-developed market (after 1000 period) shows a hierarchical structure. We get several central markets where major proportion of exchanges takes place. And also we will see some smaller markets where exchanges take place with a lower proportion than central markets. Most of the potential markets fail to become markets, and very few exchanges take place there except for initial several times. When $1 <= r < 1.04$, scattered markets will show up instead of central market. In the latter models with bargain system, r is not as important as in the previous model. The hierarchical structure will always show up. Finally, we explore the influence of agent number and potential markets number on the market formation and structure. The result shows that the hierarchical structure will always emerge when the number of potential markets is not very small.

Much work has left to been done in the future researches. The economic activities in this project are too simple which remain to be developed. Some important factors such as travel costs, path pattern selections are not considered in our system; pricing system and bargain process still needs to be discussed in details. Besides, whether price information spread or learned by the others (i.e. information communication within confined groups) has an influence on market structure is another important field of future research.

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