Agent-based Model of Coevolutionary Processes of Firms Technologies and Consumers Preferences

– Simulation of Lock-in Behavior –

Shingo TAKAHASHI, Kotaro OHORI

Waseda University,Japan
shingo@waseda.jp, oohori@fuji.waseda.jp

Abstract

In this paper we propose a model of coevolutionary processes of firms technologies and consumers preferences, and discuss some economical properties emerged from their interactions in the whole market. The model can represent essential interactions of firms and consumers based on their individual diversity, then would be expected to be a tool for analyzing coevolutionary processes of firms' technologies and consumers' preferences.

Using the proposed framework we also construct a simulation model to simulate macro behavior of lock-in in a market. From the simulation we verify some economical propositions, which should validate a part of the model. Then we apply the model to some real market situation such as memory card market in which de facto standard competitions are going.

Contact:
Prof. Shingo Takahashi
Dept. of Industrial Management and Systems Engineering
Waseda University
Shinjuku, Tokyo, 169-8555, Japan
Email: shingo@waseda.jp

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1. Introduction

This paper presents an agent-based model as a framework for analyzing the coevolutionary processes of technologies firms possess and preferences consumers use to select products. The model clarifies heterogeneities included in firm agents and consumer agents.

The model represents interactions between firms and consumers through a product space. To keep the model simple, other strategies such as sales, logistics or planning are not included in the model explicitly.

The researches of interactions of firms and consumers have been done mainly in economics. There have been found some influential propositions concerning network effect or lock-in problems (Ida 2003,Rohlfs 2001).

In agent-based approach, some researches can be seen such as lock-in model with replicator dynamics(Deguchi 2003) , technology transition(Struben 2004), innovation(Cartier 2004) or consumer behavior(Takahashi 2004).

We consider interactions between firms, between consumers, and between firms and consumers, in essential way that each agent learns and evolves its decision rule.

This paper aims at verifying some well-known conventional propositions in economics within our model. This would provide validity with the model. In particular, we focus on the simulation of lock-in behavior, and apply our model to memory card market.

2. CAMCaT:Coevolutionary Model

We introduce an agent-based model (CAMCaT: Coevolutionary Agent-based Model for Consumers and Technologies) to analyze coevolutionary processes of technological innovation in firms and consumers preferences in choices of goods. The main framework of the model consists of consumer population, firm population and product space (Fig.2.1).

2.1 Model of Firms

Each firm, based on its technology, inputs products into the product space. Each firm primarily performs such activities as getting information on consumers' behavior of choosing goods, recognizing other firms' behaviors as an environment, and developing its technologies.

1) Chromosome of Firm

The chromosome of a firm consists of three parameters that describe management strategy, technological strategy and possessed technologies. The management strategy and technological strategy represent the firm's vision concerning its core competence and technology, while the possessed technologies representing patents or equipments required for further developments.

2) Input of Products

Each firm has its own rule of inputting products, which is defined based on the management strategy and possessed technologies. The input rule specifies how often firms input products into the product space. The attributes of a product are specified depending on the possessed technologies. In our model only the variety of products to be input is specified. The amount of them is constant. The main concern of CAMCaT is to consider the evolutionary process of consumers and firms expressed as chromosomes, though in case of focusing on some marketing research, how much products should be produced and input might be a main problem.

3) Evaluation of Firm

Each firm evaluates the possibility that its possessed technologies survive in competitive markets. The evaluation is calculated from the aspects how the possessed technologies fit the firm's strategy and how the input products are accepted in the market.

4) Acquisition of Technology (licensing, M&A)

Based on its evaluation of a firm, each firm gets other firms' technologies. Highly evaluated Firms inherit their technologies to the next generation in GA. Low evaluated Firms tend to get other highly evaluated technologies. This process is performed with the selection operator in GA. Note that selected are not firms themselves, but technologies.

5) Acquisition of Technology (cross license, R&D)

There are cases where a firm develops technologies by itself or gets cross licenses with other firms. These processes are performed with the crossover or mutation operators in GA. In our simulation the management strategy itself does not evolve.

6) New Entry

In each generation, the population size of firms is renewed by entering new firm agents into the firm.

2.2 Model of Consumers

Each consumer recognizes the product space as a market environment, then selects and buys a product. Technological development including innovation affects the behavior of consumers' selections so that consumers evolve their own selection rules.

1) Chromosome of Consumer

The chromosome of each consumer is defined by characteristics, cutoff values and evaluation weights. The characteristics parameter is originally introduced in our model, the parameter which basically represents the tendency of purchase by each consumer. The model can express very independent consumers who purchase products without being affected from others' behavior or very sensitive consumers to fashion. This formulation provides us with analyzing the so-called band-wagon effect.

2) Evaluation and Purchase of Products

Each consumer evaluates products by the evaluation rule of products and purchases one having the maximum utility bigger than the cutoff values.

3) Evaluation of Selection Rule

After selecting products, each consumer evaluates his own chromosome. Based on the evaluation result, the cutoff values are revised.

4) Band-wagon Effect

The parameters other than the characteristics are revised after consumers evaluate their chromosome. The partial selection of the genetic operators is used to revise the parameters of the chromosome. This can be considered as the band-wagon effect that shows influences from other consumers.

5) Information Exchange and Gathering

Each consumer revises his chromosome after the evaluation of the result of his behavior. The revision of the chromosome represents the core of learning process of the consumer, the learning process which is based on the way of information exchange with other consumers or gathering information from advertising media. The process is performed with crossover and mutation operators in GA.

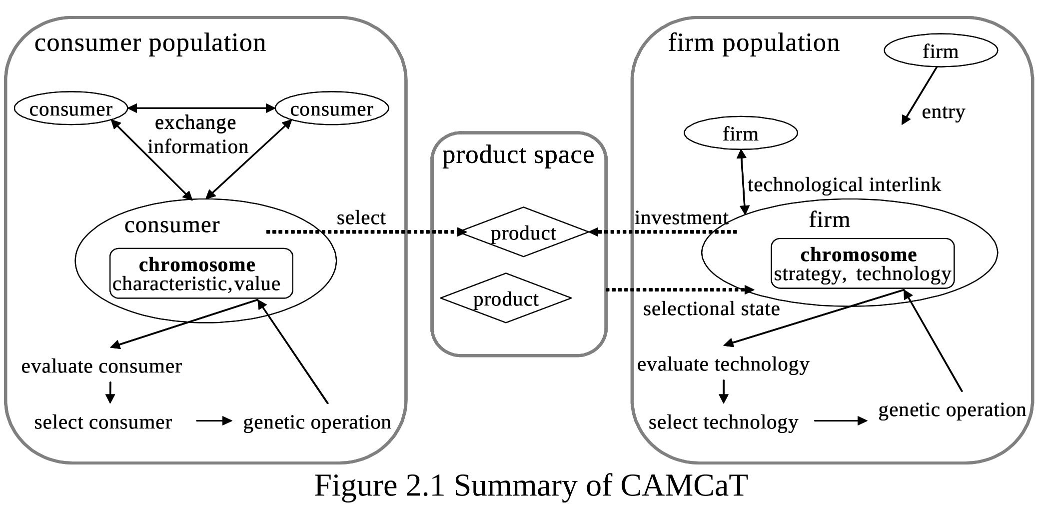

Figure 2.1 Summary of CAMCaT

3. Simulation of Lock-in Behavior

Using the framework of CAMCaT, we present a specific simulation of lock-in behavior in a market. CAMCaT has a very wide applicability for investigating various market situations. This paper aims at simply tracing the lock-in behavior.

3.1 The Parameters in Product Space

The product space is a set of products with some attributes. Here we specify 6 attributes defined by $A = (a_{ik})$, $(1 \le a_{ik} \le 200)$ where, $i = 1,2,\ldots l$, $k = 1,2,\cdots,6$, i identifies an individual product, the maximum number is l . k is the attribute number of a product.

3.2 The Parameters in Firm Population

The initial size of the firm population is 5. A generation cycle in simulation is set by the steps 2) through 6) described below. We performed 3000 generations in a simulation.

1) Generating Initial Population

The chromosome of a firm consists of the leadership degree L , firm's vision C and possessed technology T , defined by Chromosome of firm $i = (L, C, T)$,where

$$L = (l_i)\ (0.05 \le l_i \le 0.15)\ , C = (c_{ik})\ (\sum_k c_{ik} = 1)\ , T = (t_{ik})\ (1 \le t_{ik} \le 200\ ), i = 1,2,\cdots,m\ , k = 1,2,\cdots,6$$

i expresses a firm, the initial value of m is 5. m increases by revising the population size in step 6. k expresses a technology attribute.

The leadership degree affects the frequency of inputting products etc. The firm's vision represents a technological strategy seeing which technology attributes.

2) Inputting Products

Each firm i inputs a product, according to the degree of leadership parameter, with the possibility function $pthrow_i$ defined by

$$pthrow_i(ts) = \frac{1}{e^{1/l_i} * l_i^{\,t} * ts!}\ ,\ ts = t \bmod 25$$

ts is given by generation number t modulo 25 .

The attribute A of input product j is set by calculating from the possessed technology T of the firm.

3) Evaluating a Firm

Each firm i is evaluated using the fitness function defined below.

$$f_i = w_a * share + w_b * (1 - risk) + w_c * selfvalue$$

where $$share = \frac{\text{the number of consumers purchasing product } i}{\text{total number of consumers}}\ ,\quad risk = \frac{\sum_k |\, t_{ik} - a_{jk}\,|}{l_i}\ ,$$

$$selfvalue = \sum_k c_{ik} * t_{ik}\ .$$

$share$ shows the share of the product firm i inputs. $risk$ represents the difference between the most purchased product j and firm's technology. $selfvalue$ shows the fitness of technology with firm's vision. The weight parameters are set to $w_a = 0.18, w_b = 0.17, w_c = 0.65$. Each parameter is normalized to [0,1], then the maximum value of fitness is 1.

4) Selecting Technology

Chromosomes of firms are selected after the evaluation. We use Baker's linear ranking method.

5) Crossover and Mutation

We use random mask crossover with crossover rate 0.1. The mutation rate is basically 0.03, modified higher in generation of no product entry. The mutated value is decided by a normal distribution with possessed technology as mean.

6) Revising Population Size

The population size is revised in each generation according to some entry parameters such as leader or follower firms' entry rates and new technology.

3.3 The Parameters in Consumer Population

The population size of consumer is 100. A generation is composed of 2) through 6) below. A simulation repeats 3000 generations.

1) Generating Initial Population

The chromosome of a consumer consists of the degree to others D, cutoff value C, purchasing weight for product attributes W, and the common attribute value A defined by chromosome of consumer i = (D, C, W, A) where $D = (d_i)$ ($0 \le d_i \le 1$), $C = (c_{ik})$ ($0 \le c_k \le 200$), $W = (w_{ik})$ ($\sum_k w_{ik} = 1$), $A = (a_{ijk})$ ($1 \le a_{ijk} \le 200$), $i = 1,2,\cdots,n$ $k = 1,2,\cdots 6$ $j = 1,2,\cdots l$. i is a consumer index, n is the total number of consumers, j is a product index which varies by inputting products, and k is an attribute index.

2) Evaluating Products

Each consumer rejects products below the cutoff values, and selects a product with the maximum utility. The utility function of consumer i for product j is defined by $u_{ij} = \{\sum_k b_k * a_{ijk} * d_i + \sum_k w_k * a_{ijk} * (1 - d_i)\} * c_j$, ($c_j = \{0,1\}$) where b_k represents the attribute of the most purchased product.

3) Evaluating Selection Rule

After selecting product, each consumer evaluates his own selection rule using the fitness function.

$$f_i = w_a * (1 - PS) + w_b * sumcut + w_c * 1 / maxcut$$

PS is the value of non-cutoff products, *sumcut* is the sum of cutoff values, and *maxcut* is the maximum. The weights are set to $w_a = 0.56, w_b = 0.38, w_c = 0.06$. Each parameter is normalized to [0,1].

4) Selecting Consumers

According to the evaluation of consumers, chromosomes of consumers are selected with the roulette method.

5) Crossover and Mutation

Crossover rate is 0.6, and mutation 0.15.

4. Experimental Results

Based on the results seen from the experimentations with CAMCaT, we verify some economical propositions: 1) Ever evolving consumers have cognitive limits of product technologies, 2) Lock-in needs critical mass, 3) Early entry is better for getting de facto standard, and 4) Lock-in wave changes standard. The forth is newly found in our experimentation. Finally we see a memory card market simulation result.

1) Ever evolving consumers have cognitive limits of product technologies

We compare two cases: small and development capabilities by changing attributes in mutation (Fig.4.1)

High technology is difficult to get high fitness value. Consumers can hardly recognize high technology products.

2) Lock-in needs critical mass

This paper defines lock-in as the state in which a standard keeps 100% market share against other standards entries. As a simulation result (Fig.4.2), the lock-in of a standard comes after some critical mass of share is reached. This suggests that before getting the critical mass, acquisition of technology is more effective than product marketing.

3) Early entry is better for getting de facto standard

Short intervals of new entries do not allow early entry product to be a de facto standard. However, if the interval of new entries is long enough, an early entry product tends to be a de facto standard.

4) Lock-in wave changes standard

Once lock-in is built up, how or when does it switch to another? This seems very tough question. Higher technology is not necessarily a successor. In our experimentation, de facto standard 6 switches to a new de facto standard 18 after the share has waved because of other firms non-expected entries (ex. standard no.17)(Fig.4.3). We can see similar wave in consumer population as well. We call this situation “lock-in wave.”

5. Conclusions

This paper presents a framework, called CAMCaT, for analyzing coevolutionary processes in which interactions between firms’ technology and consumers’ demands.

Our model consists of firm population, consumer population, and product space. The agents in each population learn and evolve their own behavior mutually depending on the other population. There are essential interactions between the two populations by exchanging action results.

This paper performed some experimentation especially on lock-in behavior. We verified some economical propositions and applied it to memory card market. This gives a part of validity of the model.

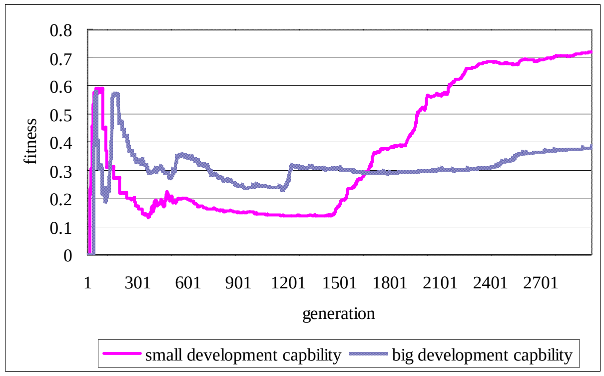

Figure 4.1 Technology Development and Consumers fitness

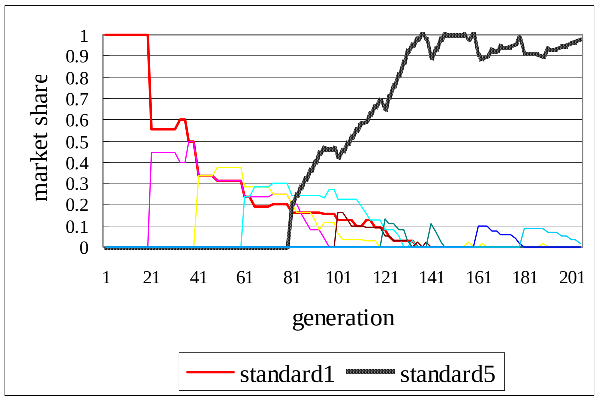

Figure 4.2 Critical Mass for Lock-in

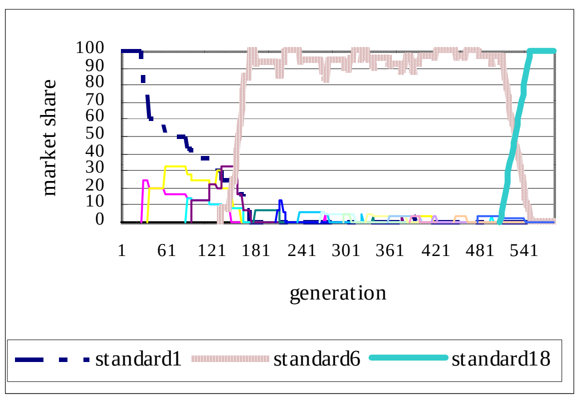

Figure 4.3 Lock-in Wave

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