Market Design Analysis for Standardization Problems

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Abstract: The purpose of this paper is to analyze market design for standardization in a standards war. We use an agent-based market model with a technological competition among standards and conduct a simulation on lots of scenarios concerning standardization problems. In recent years a technological progress and a globalization have been intensifying competitions between standards in many markets. In the competitions firms tend to pursuit short-term profits acquisition and winners can get more profits than losers. Moreover a firm strains on its own standard in the competitions. As the result, many stakeholders suffer various types of inconvenience from the competitions based on a market mechanism. Therefore some problems about the standardization are noticed in many markets. However it is difficult for market designers to decide a timing or method for standardization. We would like to support them by using a useful technique in an agent-based social simulation (ABSS), which is called "scenario analysis." This paper simulates various scenarios by combining some situations and design policies. The analysis can show tendencies of market outcomes and the mechanisms of the behaviors under various situation scenarios.

Keyword: Market design; Standardization; Scenario analysis; Evolutionary learning

1. Introduction

In recent years more rapid technological innovations and globalization have been intensifying competitions among standards. In the competitions for a de facto standard, while winners can get a high benefit, losers should pay sunk costs and consumers increase in a switching cost (Inoki, 1998). To remove the costs, a de jure standard or a voluntary standard need to be established. It is difficult, however, to determine how and when the new standard should be established. In this paper we define the problems as "standardization problems." Then this paper would like to focus on the problems under a standards war from the viewpoint of the coevolution of consumers' preferences and firms' technologies.

Various case study approaches and computational simulation approaches analyzed market competitions among standards. Individual case analyses were conducted in some markets, which are a smart card market (Wonglimpiyarat, 2005) and a DVD market and a US cable modem market (Cohen-Meidan, 2007). Rolfs (2001) analyzed the difference between success and failure of firms in various product markets in the 1980s and the 1990s from a point of view of bandwagon by using the concepts of a start-up problem, a network effect and a positive feedback. The case study approaches consider only a particular market situation. On the other hand, computational simulations can treat multiple situations and observe various market dynamics. Ida (2003) built a coevolutionary model of consumers' preferences and product qualities and analyzed about start-up problem mentioned by Rolfs(2001) Deguchi (2003) formalized a lock-in model that two different types of populations interact with each other in various markets the key of which is technological innovation. Though these studies go far toward seeing macro dynamics in a market, most of the models considered only population level learning. So they are not able to describe various emergent phenomena observed in real markets.

An agent-based social simulation (ABSS) begins to cover market problems (Delre et al, 2006, Zhang and Zhang, 2007). ABSS enables us to describe complex micro or individual level interactions in a market and to observe emergent phenomena that can have some interpretations in the market. However there are no conventional models including micro interactions in a firm population or a consumer population for considering the standardization problems which are our target of concern. Also a similar research to the target is the landscape theory for alliance analysis by Axelrod (1995). The research provided a model of firm agents that want to win competitions for a de facto standard. However the model did not represent essential individual level learning in a market.

Our agent-based model can provide emergent market behaviors which arise from the micro interactions among firm and consumer agents and consider market design in terms of coevolution of consumers' preferences and firms' technologies. We emphasize that simulation results in the analysis using ABSS are not enough to support management decision making, because they show different behaviors by every run. So this paper uses a novel analysis method, called "scenario analysis", in ABSS. The method is helpful to provide possible market dynamics and useful policies for market design.

2. Agent-based market model for a standards war

This section introduces an agent-based market model to express various market situations under a competition among standards. We use a framework, called CAMCaT (Coevolutionary Agent-based Model for Consumers and Technologies) which was introduced by Takahashi and Ohori (2005), to build the model. The framework can describe the bounded rationality and heterogeneity of economic entities, and has the following features: 1) economic entities as consumers and firms are regarded as autonomous agents; 2) interactions among consumer agents or firm agents have essential mechanisms interpretable in real markets; 3) consumers' preferences and firms' technologies co-affect their evolutionary behavior.

Our model has the similar features with the framework and so has evolutionary learning processes in a consumer and firm population to represent micro interactions. This can express the coevolution of consumers' preferences and firms' technologies in a product market or a service market with a standards war.

2.1 Firm population

The firm population are 30. A firm belongs to either standard community S_y , where $y \in \{1,2,\ldots, SN\}$, SN is the standard number. The internal model of firm $a \in \{1,2,\ldots,30\}$ consists of standard s_a it adopts, technological concepts c_{ak} and possessed technologies t_{ak} defined by $IM_a = (s_a, c_{ak}, t_{ak})$ where $s_a \in \{1,2,\ldots, SN\}$, $\sum_k c_{ak} = 1$, $t_{ak} \in \{1,2,\ldots, 50\}$, $k \in \{1,2,\ldots, AN\}$ is an attribution index.

The standard s_a means a technological formality and the possessed technologies t_{ak} represent technologies developed under the formality. As Rolfs (2001) pointed out, a specific standard adopted by a family of some different firms forms a technological formality, and the firms in a technological formality "interlink" mutually and develop their technologies under the formality.

2.1.1 Development and launch of a product

A firm a launches a new product p, which consists of a standard $s_p \in \{1,2,\ldots, SN\}$ and attributes $x_{pk} \in \{1,2,\ldots, 50\}$, to a product space depending on its standard s_a and possessed technologies t_{ak}. There is a one-to-one correspondence between the attributes x_{pk} and the possessed technologies t_{ak}, thereby product evaluation by consumers, as we shall see in Section 2.2.1, is equivalent to technology evaluation by them. Since each firm launches only a kind of product to the product space, the product space has 30 products.

2.1.2 Self-evaluation

After the choice of products by consumers, firm a evaluates its technologies and network by using the fitness function ff_a defined by (1).

$$ff_a = wf_a * share_a + wf_b * selfvalue_a + wf_c * network_{S_a} \qquad (1)$$

$$where \quad selfvale = \sum_k c_{ak} * t_{ak} \ , \ wf_a + wf_b + wf_c = 1$$

$share_a$ expresses the share of the products launched by firm a. $selfvalue_a$ represents how close its own technological concepts to technologies. This value shows the direction for improving technologies. $network_{S_a}$ is the number of firms that adopt the same standard with firm a and represents the prevalence level of network effect.

2.1.3 Alliance (Selection in GAs)

A firm interlinks in each time period other firms of the standard community to which it belongs in the firm population. The firm population selects a firm a which has the lowest fitness value (ff_a). The selected firm calculates the utility for a standard community S_y in the firm population by using utility function u_{ay} defined by (2) and switches to the standard that has the highest utility so as to adopt new technologies.

$$u_{aSy} = wf_d * \sum_{b \in S_y} share_b + wf_e * network_{Sy} + wf_f * othervalue_{aSy} \qquad (2)$$

$$where \ \ othervalue_{aS_y} = \sum_{b \in S_y} \sum_k c_{ak} * t \ , \ wf_d + wf_e + wf_f = 1$$

b is the index of the firm that belongs to standard community S_y. $share_b$ expresses the total share of the firms in the community S_y, $network_{sy}$ shows the number of firms in the community S_y and $othervalue_{aSy}$ represents how close its own technological concepts to the possessed technologies of other firms in the community S_y.

2.1.4 Cross-license and co-development (Crossover in GAs)

Firms cross-license and co-develop their possessed technologies for continuous improvement of the technologies. We model the process by using selective crossover operation in GAs. This is a new operation which can represent mutual technological offerings in a standard community (Ohori and Takahashi, 2007). By using the selective crossover, the values of the gene loci with mask 0 are transferred from firm a of higher fitness to firm b of lower fitness with crossover rate $pFCross$. This means cross-license or co-development. The technological concepts in an internal model also change in this process by using the same operation. So the operation determines the direction of technological development as a standard community.

2.1.5 Research and development (mutation in GAs)

Finally each firm promotes research and development (R&D) by using a mutation operation in GAs. The genetic variance σ_f in mutation operation expresses the development power of firms. The genetic rate $pFMut$ in the mutation operation represents how often technological innovation is developed in a market. The research and development rate $pR\&D_{ak}$ of firm a for a technology attribute index k is defined by (3) based on $pFMut$ and technological concepts c_{ak} .

$$pR\&D_{ak} = pFMut * c_{ak} * 10 \qquad (3)$$

A high rate of $pR\&D_{ak}$ of a technology attribute k means that the attribute is frequently developed and will be progressed.

2.2 Consumer population

A consumer population has 500 consumer agents. The internal model of consumer $i \in \{1,2,\ldots,500\}$ consists of dependence and sensibility d_i which means indirect influence such as market trend, a standard s_i of the product which he/she selected, cutoff values c_{ik} and purchasing weights for product attributions w_{ik}, defined by $IM_i = (d_i, s_i, c_{ik}, w_{ik})$ where $0 \le d_i \le 1$, $s_i \in \{1,2,\ldots,SN\}$, $c_{ik} \in \{1,2,\ldots,50\}$, $\sum_k w_{ik} = 1$, $k \in \{1,2,\ldots,AN\}$ is an attribution index.

Cutoff value c_{ik} is used in uncompensated selection rule (Blackwell *et al*, 2001). If any of cutoff value c_{ik} of consumer i for attribute k is higher than a product attribute x_{ak}, the consumer removes the product from his/her evoked set.

2.2.1 Selection of a product

Each consumer evaluates products by an evaluation rule of a product and selects one having the maximum utility bigger than the cutoff values in a product space. The evaluation rule is defined by the utility function u_{ij} of consumer i for product j (4).

$$u_{ij} = (\sum_k b_k * a_{ijk} * d_i + \sum_k w_{ik} * a_{ijk} * (1 - d_i)) * c_j \quad (4)$$

$$where \;\; b_k = \frac{x_{tk}}{\sum_k x_{tk}} \;,\; c_j = \begin{cases} 0 & if\ consumer\ i\ cutoffs\ product\ j \\ 1 & otherwise \end{cases}$$

The parameter b_k is derived from the attributes of the trend product t that has the maximum number of purchases. The parameter a_{ijk} represents the evaluation value of attribute index k of product j by consumer i, the value which is determined depending on the normal distribution with the mean value "product attribute x_{jk} of product j" and the standard deviation "$\sqrt{2}$." The distribution of the value can be interpreted as the gap of perceptions of product attributes among consumers. The first sum $\sum_k b_k * a_{ijk} * d_i$ represents the utility based on a market trend or belief in a market. On the other hand, the second sum $\sum_k w_{ik} * a_{ijk} * (1 - d_i)$ shows the utility depending on differences between individuals. If consumer i cuts off the product, and removes the product from his/her evoked set, c_j is set to zero, otherwise c_j 1.

2.2.2 Self-evaluation

After choice of a product, consumer i evaluates his/her decision and internal model by using the fitness function fc_i (5).

$$fc_i = wc_a*(1 - ncut) + wc_b*sumcut + wc_c*(1/maxcut) + wc_d*network \qquad (5)$$

$$where \quad wc_a + wc_b + wc_c + wc_d = 1$$

ncut is the number of non cutoff products, *sumcut* is the sum of cutoff values, *maxcut* is the maximum cutoff value and *network* is the number of consumers who selected the same standard with consumer *i*. The fitness function represents that a consumer who has a higher evaluation value can reduce recognition effort of products and wrong recognition, and can gain advantage by network effect.

2.2.3 Bandwagon effect (Selection in GAs)

According to the self-evaluation of consumers, some internal models of consumers are selected with the linear ranking selection (Grefenstette and Baker, 1989) based on their fitness value. This selection operation implies the bandwagon effect in a consumer population and selects consumers who have higher fitness value. Since the consumer population are 500 in this paper, we should consider to keep the diversity in the population in an effective way. The ranking selection algorithm used in this paper is more effective to create the diversity in the consumer population. The diversity of internal models in the consumer population depends intrinsically on the value of η^+. For example, if η^+ are given as 1.55, 1.60, 1.80, and 2.00, then the selection rates in the consumer population are calculated respectively as

4.6%, 8.8%, 19%, and 25%. So the higher η^{+}, the lower diversity in the consumer population. This operation successfully expresses the bandwagon effect.

2.2.4 Information exchange and information gathering (crossover and mutation in GAs)

After the selection of internal models in the consumer population, internal models are revised according to the uniform crossover and mutation operations. In our model, the parameters of cutoff values c_{ik} and purchasing weights for product attributes w_{ik} are actually revised. The crossover and mutation rates are *pCCross* and *pCMut*, respectively. The processes of crossover and mutation imply the information exchange between consumers and the information gathering by a consumer. The diversity in the population is increased through the processes.

3. Simulation analysis

This section firstly discusses the calibration of our model parameters and the validation of the model (3.1), and secondly analyzes market design in standardization problems by using scenario analysis (3.2).

3.1 Calibration and validation

It is not straightforward to set the parameters of an agent-based model and to validate it using empirical data. The approaches in conventional researches (Bianchi, 2007, Fagiolo *et al*, 2007) relevant to calibration and validation try to conduct calibration and model validation by confirmation of consistency with "Stylized Fact," empirical data and conventional models. Our model is classified with a middle range model (Gilbert, 2007) which can generate a particular social behavior "qualitatively," and provide common findings and dynamics in various markets rather than a specific market. However the middle range model does not intend to reproduce specific market phenomena exactly and to fit its simulation results to empirical data of a real market. Also, there have been no computational models representing exactly the details of our target problems. So we calibrate and validate our model by verifying the consistency with a stylized fact on the target problems. To analyze various situations of a standards war, we first build a model for basic market features especially on the stylized fact of a start-up problem mentioned by Rolfs (2001).

The stylized fact of a start-up problem can be stated as follows: Consumers do not demand products unless the sufficient improvement of the products quality in the future is guaranteed, while firms do not want to provide them unless the sufficient demand in the future is expected.

The standard number *SN* and the number of product attributes *AN* are set to *SN* = 1 and *AN*=1, respectively. As shown in Table 1, we prepare three patterns A, B and C of a parameter set to calibrate the parameters concerning evolutionary learning processes. The sets of parameters are selected to indicate outstanding features of market phenomena. The parameters setting in pattern C successfully resolves the start-up problem. The parameters in pattern A indicate that consumers tend to require high-spec products, because the consumers positively increase the cutoff levels for the product attributes in the market (wc_b = 0.70, *pCmut* = 0.05 and σ_c = 2.00) and for firms it is difficult to develop their technologies (*pFmut* = 0.01). The pattern B represents that the development power of the firm population is very high(wf_b = 0.70, σf=2.00) and consumers tend to evaluate carefully products (wc_c = 0.50).

Table 1. Patterns of GAs Parameters for calibration

GAs parameters	Notations	Patterns		
		A	B	C
Weights of fitness function	wf_a	0.60	0.20	0.55
	wf_b	0.30	0.70	0.35
	wf_c	0.10	0.10	0.10
Rate of crossover	*pFCross*	0.10	0.30	0.30
Rate of mutation	*pFMut*	0.01	0.01	0.03
Variance of mutation	σf	1.00	2.00	1.00
Weights of fitness function	wc_a	0.10	0.20	0.40
	wc_b	0.70	0.20	0.45
	wc_c	0.10	0.50	0.05
	wc_d	0.10	0.10	0.10
Rate of crossover	*pCCross*	0.30	0.60	0.60
Rate of mutation	*pCMut*	0.05	0.01	0.05
Variance of mutation	σc	2.00	1.00	1.00

We conducted 50 trials in simulation for each pattern and compare the transitions of the average fitness values of all patterns in the consumer population (Figure1). In pattern C the average fitness value increases substantially as the consumers' preferences are learned synchronously with the evolution of firms' technologies. In the pattern A the progress rate of the average fitness value is lower than that of pattern C. Pattern B cannot uplift the average fitness value along the way. So we see that the parameters setting of pattern C resolves the stylized fact on the start-up problem. In Section 3 we set the parameters setting of pattern C to the model parameters relevant to evolutionary computation. We should notice that a ranking selection parameter η^+ which is one of the evolutionary computation parameters is not included in Table 1 because it is a scenario variable described in Section 3.2. As will be shown in our simulation results, the stylized fact on the start-up problem can be resolved in any value of the parameter η^+ (see Section 3.2.1) .

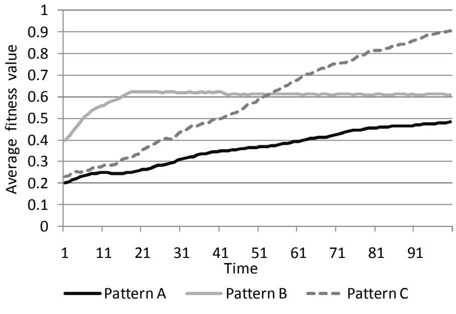


Figure 1. Transition of average fitness values in all patterns of parameters settings

3.2 Scenario analysis for the coordination period of standards in a voluntary standard setting

This section conducts scenario analysis using various scenario variables. We define “scenario” as a set of various situations and policies. The analysis can provide some possibilities of market outcomes generated by all scenarios from macro viewpoint and support a policy making in a market which is difficult to quantitatively predict the impact of the policy (Section 3.2.1). In addition to the analysis from macro point of view, we need to analyze market dynamics in detail from micro point of view by observations of agents’ internal models, which the analysis is called “path analysis”(Section 3.2.2).

In this paper we consider the situation that firms adopting different incompatible standards coordinate a compatible standard before releasing their products in a market. Farrell and Saloner (1988) called this standardization method as “voluntary standard setting.” Yamada(2004) mentioned that the advantage of the setting method is to cut sank costs and switching costs of technologies in a firm population because a standardization committee, which is called a forum or a consortium, determines the compatible standard through a consensus process with other committees before market competitions are intensified. However the committee facing the conflict with incompatible standards does not always create the compatible standard that is useful for consumers with the setting method, because consumers are hardly to take a hand in the process of a voluntary standard setting and then their preferences do not reflect to the product attributes developed by the technologies of the compatible standard. We would like to consider how the standardization committee decides a compatible standard in the voluntary standard setting method.

In our simulation, firms adopting different standards try to coordinate the standards existing in a market for given time periods before they launch products, and to determine a compatible standard. In our model the standards of firms are coordinated through only evolutionary learning processes such as selection, crossover and mutation, which characterize the technologies and technological concepts of the standard. Just after a learning process, firms release products of the standard they adopted at the given time periods.

We specify situation variables and values of the variables for scenario analysis (Table 2). The combination of values of the situation variables determines the 16 market situation under a standards war. Ranking selection parameter η^+ represents the diffusion speed of product information in a consumer population. A large value of η^+ means that mass communication media frequently provide various types of information concerning products or services in the consumer population or word-of-mouth (WOM) strongly influences on online-communication. The number of attributes *AN* represents the number of product specs which are considered by consumers in evaluating products. This number *AN* critically affects the evaluation process of products by consumers. In the case of the large number of *AN* in a market, consumers come down to evaluate many product attributes for the decision of whether or not to cutoff of a product. The number of standards *SN* shows how many standard communities are in the initial condition of a simulation.

Table 2. Patterns of GAs Parameters for calibration

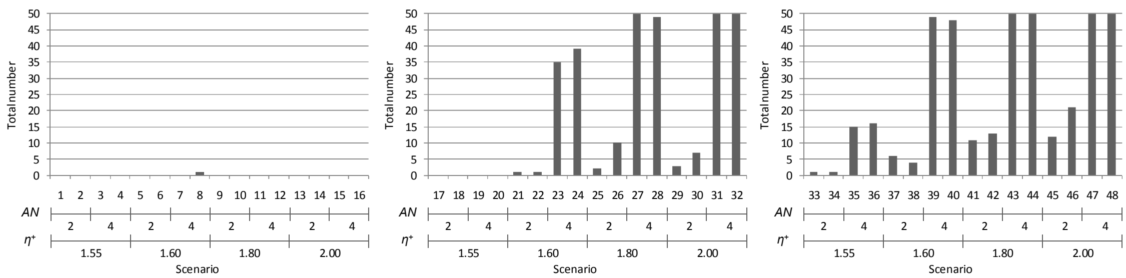
Situation variables	Notations	Values			
		1	2	3	4
Ranking Selection η^+	η^+	1.55	1.60	1.80	2.00
The number of attributes	*AN*	2	4	-	-
The number of standards	*SN*	2	4	-	-

We classify the policy scenario into 3 types according to how long a firm coordinates the standard to other firms' standards: (1) 0 time period; (2) 30 time periods; (3) 50 time periods. The 0 time period implies that the firms do not coordinate their standards, and the competition for a de facto standard consequently rises. We conduct on simulations about 48 scenarios using the 16 situation scenarios and the 3 policy scenarios.

3.2.1 An analysis of tendencies of market outcomes using all scenarios

In the voluntary standard case, we can observe that no firm could gain a market share. In other words, firms generated a useless standard in the market as the result of the coordination among some incompatible standards. The useless standard was not preferred by consumers despite almost firms adopted the standard. The main reason could be that consumers could be unaffected by the evolution of technologies in the standardization process. To verify this case, we simulated 50 trials for each scenario, and counted the number of outbreaks of a useless standard (Figure2). In the simulations, the outbreak of a useless standard represents that more than 90 % of consumers do not select any products in the product space at the end of a trial.

Figure2 (a) shows no outbreak of a useless standard in all scenarios except one (No. 8 scenario) since the start-up problem is resolved. Compared Figure 2(b) with (c), we can confirm the following findings as the tendencies of market changes: Tendency1) the long-term coordination of firms' standards tends to generate a useless standard for consumers in a market; Tendency2) a larger η^+ generates much more outbreaks of a useless standard; Tendency3) there are much more outbreaks of a useless standard in the scenarios of AN=4 than in the ones of AN = 2

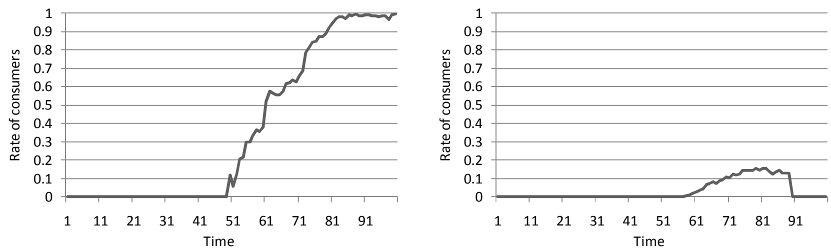


(a) 0 time period (b) 30 time period (c)50 time period

Figure 2. Total numbers of outbreaks of the useless standard

3.2.2 An analysis of market behaviors from observations of internal models

Next we look into agents' internal models in detail to investigate how the outbreaks of a useless standard are presented. Figure 3 depicts the rates of consumers who selected a product with or without the outbreak of a useless standard in scenario 36 (Policy (3), η^+ =1.55, AN =4, SN = 4). We notice that these two types of behaviors can be found in other scenarios.



(a) No outbreak of a useless standard (b) Outbreak of a useless standard

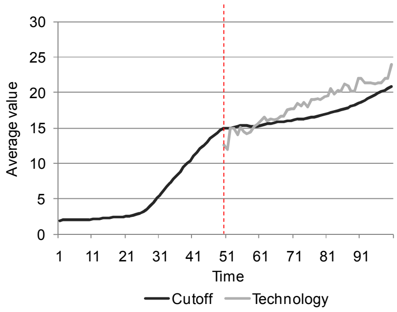
Figure 3. Rate of consumers who can successfully choose a product.

A consumer can select a product, if the products all of whose attributes are larger than the consumer's cutoff values exists in the market. In Figure 3(a) most of consumers selected a product of the voluntary standard coordinated by firms in the market at 80th period. From 50th to 60th period at which firms start to release products of the compatible standard, about 20% of consumers select a product without cutting off all products in the product space. As the result, the rate of consumers who select a product exceeds a critical mass for diffusion of the compatible standard. Then the adopters of the compatible standard increase little by little. On the other hand, Figure 3(b) shows that the rate of consumers who selected a product of the compatible standard increases to about 10% and then drops down to 0%. In the end of the simulation the compatible standard becomes useless.

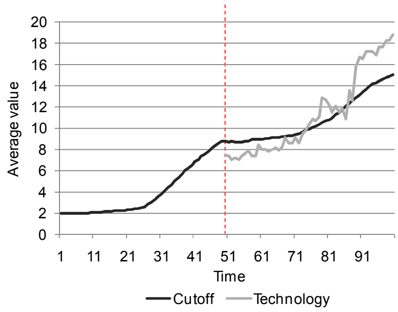
Figure4 shows the transitions of average cutoff values in the consumer population and the average technology values of firms that gained market shares for each attribute number in the case of Fig.3(a). The figures show that lots of consumers cut off products in the product space at 50th period, partly since average cutoff values exceeded average technology values for the product attribute 1, 2 and 3. This case shows that the consumers could not select products immediately after firms released the products because of the difference between cutoff values and technology values, which difference arose from a long coordination time. As the result, Tendency 1) can be confirmed. However we should notice that even if the long coordination time such as in scenario 36, not a few consumers could select products because of a huge variety of preferences indicated as η^+ =1.55. Then the preferences of the consumers who selected the products diffused to other consumers by bandwagon effect. So the consumer population could evolve their preferences along the evolution of technologies as depicted in the Figure6. As the result, most of consumers could select the products of the compatible standard.

In the case of the outbreak of a useless standard as shown in Figure3 (b), consumers failed to learn their preferences along technological innovation, mainly because the cutoff values were much higher than the technology values. In particular, if the value of η^+ is higher such as η^+=1.80 and 2.00, the variety of preferences tends to become much lower. This means that a large variety of preferences in a market converges to one preference before firms release products. This mechanism supports Tendency 2) .

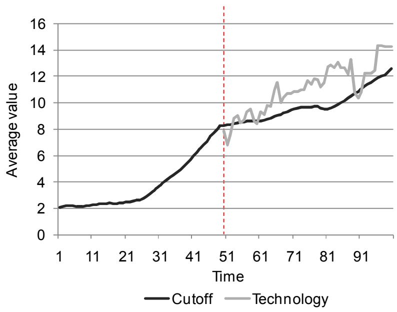
In the scenarios that the number of attributes *AN* is 4, it is difficult to fill in the gap between cutoff values and technology values in all attributes. On the other hand, the probability of causing the gap is lower in the case of the number of attributes is 2. From this mechanism, Tendency 3) can be confirmed.



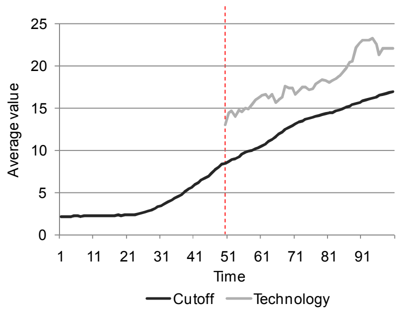
(a)Attribute 1



(b)Attribute 2



(c)Attribute3



(d)Attribute 4

Figure 4. Cutoff values and technology values

4. Conclusion and future works

This paper focused on standardization problems under a standards war by using the scenario analysis. We analyzed the coordination time in voluntary standard settings and revealed the tendencies of market behaviors and the mechanisms of the behaviors under various situation scenarios. So we conclude that the scenario analysis can reveal the tendencies of market behaviors and show the mechanisms of the market behaviors under various situations and policies. The scenario analysis could be a powerful agent-based social simulation technique for market design. The future direction of this study will be one that evolves our model to consider more complex market situations. For an example, we have possibilities to consider various types of standards such as an international standard, an area standard and a national standard. To simulate the situation that there exist the various types of standards, we need to build several different agent populations into our model.

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