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'Develop or Copy' Decision of New Information Technology

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Abstract

The present paper aims at discussing 'develop or copy' decision problem on new information technology in a formal way by focusing on its unique feature.

Information technology is characterized by its unique feature that it costs almost none to make a copy of it while its research and development requires a huge amount of money and man-hours. It distinguishes the decision on information technology development from that on other technologies: If there is no incentive mechanism for encouraging the innovation the people may well tend to sit back for emerge of new information technology and to copy it rather than to develop it by themselves. If the society seeks to develop new information technology seriously it has to introduce some social mechanism by which strong incentive for research and development of new information technology can be provided.

We first show by using simple mathematical models that if the society introduces no incentive mechanism it is really possible that no one feels interested in development of new information technology. Then, after proposing several conditions, each of which represents desirability of the mechanism to realize innovation of information technology, we formally compare four types of incentive mechanisms in terms of them . We believe that our formal treatment based on intuitive but rigorous inference succeeds in clarifying the discussion.

1 Introduction

The present paper will discuss incentive mechanisms for encouraging innovation of new information technology.

The question of 'develop or copy' decision seems analogous to the classical but still controversial 'make or buy' decision problem. However, we will focus on a unique feature of information technology that it costs almost nothing to make a copy of it while its research and development requires a huge amount of money and man-hours.

It distinguishes the decision on information technology development from that on other technologies: If there is no social device the people may well tend to sit back for emerge of new information technology and to copy it rather than to develop it by themselves. If the society seeks to develop new information technology seriously it has to introduce some social mechanism by which strong incentive for research and development of new information technology can be provided.

The paper discusses and compares four types of incentive mechanisms in terms of their desirability to realize innovation of information technology. The argument is carried out in a formal way based on simple and intuitive but rigorous inference since we believe the attitude is the most appropriate to reveal essence of the mechanisms and to clarify their advantage and disadvantage without ambiguity.

2 Desirability Conditions of Incentive Mechanisms

This section begins with giving a definition of original information technology. Since research and development of original information technology usually requires a huge amount of resources while the cost for copying it is negligible, the people may feel no interests in its research and development. We will explore conditions under which an original information technology sufficiently attracts researchers and developers whenever it is 'socially desirable'.

Let a society S consist of s people, *i.e.*, $S = \{1, 2, \ldots, s\}$ and t be information technology. We assume that every people in the society uniformly estimate 'intellectual excitement' created by t to be $v(t)$ dollars in monetary term. It means that the people are not willing to pay for t more than $v(t)$ if they buy it and they evaluate t as $v(t)$ if it is in their hand. We also suppose that they consider that the technology t is worth $V(t)$ dollars when selling it.

Definition 1 *Information technology t is called original if we have $v(t) < V(t)$.*

The definition has the following implications: If the technology is not original enough and there is another person who develops a similar technology, then the interested people in t may possibly move to the second innovator to purchase the technology. In order to keep the people back the first innovator has to propose $V(t)$ such that $V(t) \leq v(t)$.

Let us denote a set of original information technologies we are concerned with by T. Since the present paper is interested only in the original information technology, we assume

Assumption 1 *For each $t \in T$ there is one and only one potential innovator of t in S.*

The potential innovator is a person in S who has technological ability to innovate t but is not necessarily motivated economically to research and develop t. We will write i_t for the potential innovator. We assume that i_t is completely determined by t.

In order to highlight the unique feature of information technology we put

Assumption 2 *The people in the society are able to copy any $t \in T$ without any cost.*

This assumption implies that the potential innovator is simply a person who has the knowledge of t at the beginning point.

Suppose another n_t people of the society besides the potential innovator i_t are interested in t. Let us denote the group of the interested people except i_t by $N_t \subset S$, where $|N_t| = n_t$.

Even if the technology is original and $V(t) > v(t)$ holds, each person in N_t gets $v(t) - V(t)/n_t$ provided that the people in N_t equally share $V(t)$. To make $v(t) - V(t)/n_t$ positive n_t should be relatively large. We assume this, *i.e.*,

Assumption 3 *For each $t \in T$ we have $v(t) - V(t)/n_t > 0$, that is, $n_t > V(t)/v(t)$.*

Since all the people who are interested in t evaluates it as $v(t)$, the total 'needs' for the technology in the society is evaluated by $(n_t+1)v(t)$. Let $C(t)$ indicate all the 'cost' for the potential innovator to develop the technology. Then,

Definition 2 *We say development of the technology t is needed by the society S if the needs for t by the society exceeds the cost, i.e., if we have*

$$C(t) < (n_t + 1)v(t).$$

We will call $D(t) = (n_t + 1)v(t) - C(t)$ desirability of the technology t.

It should be noticed that the value $D(t)$ is completely determined the technology itself.

Even if t is needed by the society, the potential innovator may not be willing to carry out the research activity if, for example, only one buyer of t appears and his/her utility $v(t)+V(t)-C(t)$ is negative. We will then introduce incentive mechanism as device to activate the potential innovator.

Definition 3 *An incentive mechanism M (for innovation of information technology) is a set of utility functions of all the people in the society, that is, $M = \{u_i^M\}_{i \in S}$, where for each $i \in S$ u_i^M is a utility function from T into the set of all the reals.*

We will denote the society S equipped with M by (S, M).

Definition 4 *Let $t \in T$. (S, M) is called to activate the potential innovator i_t of the technology t if we have*

$$u_{i_t}^M(t) > 0$$

where $M = \{u_i^M\}$.

The definition claims that under (S, M) i_t should try to develop t if $u_{i_t}^M(t) > 0$.

Now we propose four desirability conditions of incentive mechanisms.

Definition 5 *We say (S, M) satisfies the individual incentive condition of the information technology t if (S, M) activates the innovator i_t of t, whenever development of t is needed by the society, or formally, if we have*

$$D(t) > 0 \Rightarrow v_{i_t}^M(t) > 0$$

where i_t is the potential innovator of t.

Under such a mechanism any information technology can provide incentive to the potential innovator as far as it is needed by the society.

Definition 6 *We say (S, M) satisfies the social incentive condition of the information technology t if the social surplus $SS^M(t)$ created by t under (S, M) is positive whenever development of t is needed by the society, or formally, if we have*

$$D(t) > 0 \Rightarrow SS^M(t) > 0$$

where $SS^M(t)$ is defined by

$$SS^M(t) = \Sigma_{i \in S} u_i^M(t).$$

Under such a mechanism any information technology can produce positive social surplus as far as it is needed by the society.

Definition 7 *We say (S, M) satisfies technology and individual incentive compatibility if*

$$(\forall t, t' \in T)(D(t) \geq D(t') \Leftrightarrow u_{i_t}^M(i) \geq u_{i_t}^M(t'))$$

where i_t is the potential innovator of t.

The definition claims that research and development driven by individual interest is actually compatible with the needs of the society and vice versa. In this case the individual interest always leads the society to a desirable direction in the sense of $D(t)$.

Definition 8 *We say the society (S, M) satisfies technology and society incentive compatibility if*

$$(\forall t, t' \in T)(D(t) \geq D(t') \Leftrightarrow SS^M(t) \geq SS^M(t'))$$

The definition means that the desirability of information technology measured by the social surplus is equivalent to that in terms of the net social needs.

3 Incentive Mechanisms for Innovation

Let $t \in T$ be given. First let us consider a social situation with 'free mechanism' where no intervention from the society are realized. Then, a person, say i_t^*, appears in N_t, who first pays $V(t)$ to the potential innovator and then collect $V(t)/(n_t - 1)$ each from other $n_t - 1$ persons in N_t to allow them to make a copy of t. We call i_t^* the copy organizer. In this case the copy organizer i_t^* gets $v(t)$ exactly.

This implies

Definition 9 *We say a mechanism $M_0 = \{u_i^0\}$ is the free mechanism if*

$$u_i^0(t) = \begin{cases} v(t) + V(t) + R(t) - C(t), & \text{if } i = i_t \\ v(t) + V(t) - V(t), & \text{if } i = i_t^* \\ v(t) - V(t)/(n_t - 1), & \text{if } i \in N_t - \{i_t^*\} \\ 0, & \text{otherwise} \end{cases}$$

where $R(v(t))$ represents 'reputation', 'prize' or 'honor' brought by the innovation, which is assumed to be determined by $v(t)$.

Then we have,

Lemma 1 *If*

$$(n_t + 1)v(t) \leq v(t) + V(t) + R(v(t)) \quad \text{or}$$

$$n_t v(t) \leq V(t) + R(v(t))$$

holds then (S, M_0) satisfies the individual incentive condition of t.

The condition of the lemma represents the needs for the technology is not so high compared with the utility of its innovator, that is, the technology t is not desired so strongly by the society. Conversely speaking, Lemma 1 indicates that if the needs of the society is higher than the utility of the innovator the society S does not always satisfy the social development condition of t.

To provide the people with motivation for innovation even in such a situation the society has to introduce some devices or mechanisms. One of ways to do it directly is to regulate the society by imposing law of prohibiting the copy. Then since the people in N_t cannot copy t even though they are interested in it, everyone in N_t pays $V(t)$ for t.

Definition 10 *We say a mechanism $M_1 = \{u_i^1\}$ is the leagal regulation mechanism if*

$$u_i^1(t) = \begin{cases} v(t) + n_t V(t) + R(v(t)) - C(t), & \text{if } i = i_t \\ v(t) - V(t), & \text{if } i \in N_t \\ 0, & \text{otherwise} \end{cases}$$

Proposition 2 *Let M_1 be the legal regulation mechnism. Then,*

1. *(S, M_1) satisfies the individual incentive condition of t*
2. *(S, M_1) satisfies the social incentive condition of t.*

In this case the utility of the people in N_t is $v(t) - V(t) < 0$. Hence similar to the case of the free mechanism there must appear a copy organizer i_t^*. Then the remaining people in N_t can get $v(t) - \frac{V(t)}{n_t - 1}$. Since $v(t) - \frac{V(t)}{n_t - 1} > v(t) - V(t)$ and $v(t) - \frac{V(t)}{n_t - 1}$ is positive if n_t is relatively large, the people may not obey the law.

Another and more feasible way for the society is to encourage the innovation by providing subsidy K and 'emotional praise'. Let the subsidy mechanism I be a subsidy mechanism where K is raised from only the people in N_t. That is,

Definition 11 *We say a mechanism $M_2 = \{u_i^2\}$ is the subsidy mechanism I if*

$$u_i^2(t) = \begin{cases} K + R'(v(t)) + V(t) + v(t) - C(t), & \text{if } i = i_t \\ v(t) + V(t) - V(t) - K/n_t, & \text{if } i = i_t^* \\ v(t) - V(t)/(n_t - 1) - K/n_t, & \text{if } i \in N_t - \{i_t^*\} \\ 0, & \text{otherwise} \end{cases}$$

where i_t^* denotes the copy organizer. K denotes monetary prize while $R'(v(t))$ represents mental or emotional praise.

Proposition 3 *Let M_2 be the subsidy mechanism I such that*

$$K + R'(v(t)) \geq n_t v(t) - V(t).$$

Then,

1. *$K + R'(v(t))$ is positive.*
2. *(S, M_2) satisfies the individual incentive condition of t.*
3. *(S, M_2) satisfies the social incentive condition of t.*

A proof of *3.* of **Proposition 3** shows that as n_t and/or $R'(v(t))$ increases the social surplus goes up as well. It clearly suggests that education on science and technology, which creates interests in new technology in the society, plays a crucial role to increase the social surplus, since it helps increase of n_t.

When $K + R'(v(t)) = n_t v(t) - V(t)$ holds, we call the subsidy mechanism balanced since then the potential innovator gets activated while the load over the people in N_t is minimized.

Proposition 4 *Let M_2 I be the balanced subsidy mechanism I. Suppose that $t \in T$ $R'(v(t)) = 0$. Then,*

1. *(S, M_2) satisfies the technology and individual compatibility.*
2. *(S, M_2) satisfies the technology and social compatibility.*

M_3 is called a subsidy mechanism II if it is exactly the same as the subsidy mechanism I except that the money K is raised as tax from all the members except the innovator in the society S. That is,

Definition 12 *We say a mechanism $M_3 = \{u_i^3\}$ is the subsidy mechanism II if*

$$u_i^3(t) = \begin{cases} K + R'(v(t)) + V(t) + v(t) - C(t), & \text{if } i = i_t \\ v(t) + V(t) - V(t) - K/s, & \text{if } i = i_t^* \\ v(t) - V(t)/(n_t - 1) - K/s, & \text{if } i \in N_t - \{i_t^*\} \\ -K/s, & \text{otherwise} \end{cases}$$

where i_t^* is the copy organizer.

Proposition 5 *Let M_3 be the subsidy mechanism II such that*

$$K + R'(v(t)) \geq n_t v(t) - V(t).$$

Then,

1. *$K + R'(v(t))$ is positive*
2. *(S, M_3) satisfies the individual incentive condition of t*
3. *(S, M_3) satisfies the social incentive condition of t.*

Proposition 6 *Let M_3 be the balanced subsidy mechanism II. Suppose that $R'(v(t)) = 0$. Then,*

1. *(S, M_3) satisfies the technology and individual compatibility.*
2. *(S, M_3) satisfies the technology and social compatibility.*

Corollary 7 *Let M_2 and M_3 be the balanced subsidy mechanism I and II, respectively. Suppose $R'(v(t)) = 0$ for both the mechanisms. Then, we have $SS_3(t) > SS_2(t)$.*

We may think that in this sense the mechanism II is more desirable than the mechanism I.

The final mechanism discussed in this paper to support R & D activities of new information technology is a project team based mechanism, where Assumption 1 is relaxed to allow cooperative R & D activities. That is, we consider a situation where a project team is organized to share the huge cost $C(t)$ of the development and to distribute the income $V(t)$ to each member of the team equally.

Let $L \subset N_t$ form a project team. Set $|L| = k$, where $k < n_t$.

Definition 13 *We say $M_4 = \{u_i^4\}$ is the k-person project team based mechanism if*

$$u_i^4(t) = \begin{cases} V(t)/k + v(t) - C(t)/k, & \text{if } i \in L \\ v(t) + V(t) - V(t), & \text{if } i = i_t^* \\ v(t) - V(t)/(n_t - k), & \text{if } i \in N_t - \{i_t^*\} \cup L \\ 0, & \text{otherwise} \end{cases}$$

where i_t^* is the copy organizer in N_t.

Proposition 8 *Let $M_4 = \{u_i^4\}$ be the k-person project team based mechanism. Then*

1. *(S, M_4) satisfies the individual incentive condition of t if $k > \frac{C(t) - V(t)}{v(t)}$.*
2. *(S, M_4) satisfies the social incentive condition of t.*
3. *(S, M_4) satisfies the technology and individual compatibility.*
4. *(S, M_4) satisfies the technology and social compatibility.*