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Technical Innovation in the Japanese Paint Industry*

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I. Introduction

Are there any patterns in industrial innovations? If any, what factors determine the patterns? And how? Answering these questions would be useful for managing technologies in a company both effectively and efficiently.

The purpose of this paper is to inquire into the influence of some factors on technological change through a case study. In particular, the paper focuses on the influences of technology and the product market. In Section II, the viewpoints for grasping the features of technical innovation1 will be introduced. In Section III, the prototype as the criterion of technological change will be propounded. In Section IV, the preceding studies of technological change in the chemical industry, which is different from the empirical basis of the prototype model, will be surveyed. This is because we are interested in the influences of the different technological properties and market properties on innovation. Then in Section V, a case study of the paint industry in Japan will be presented. Paint is described as one of the special chemicals, which are distinguished from commodities such as polyethylene. Finally, we will derive some hypotheses on the relationship between technological change, technological properties and the market properties of the industry from the comparison between the prototype and our case study.

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1. Technical innovation is defined as the introduction and spread of new and improved products and processes in the economy. Freeman (1982), p. 4.
II. The Views on Innovation

In this section, three viewpoints for grasping technical innovation are provided. Those are technological trajectories, the source of innovation and the motive of innovation. Each is explained shortly as follows.

(1) Technological Trajectories

Technical innovation is a complex phenomenon influenced by many factors. Therefore we need a concept that represents clearly the complex nature of technical innovation. Technological trajectory, which is defined as the track of technological change determined by the interaction of each logic of technology, market and organizations, is suitable for this. There are many kinds of technological trajectories. Some of them are universal and others are specific to an industry or a company. Nelson and Winter (1977) mentioned mechanization and latent scale economies as the general trajectories. Dosi (1982) distinguished technological trajectories in a certain technological paradigm from the change of the technological paradigm itself. In this paper, however, we do not actually use the words "technological paradigm". Instead, we will describe such a change as the generation of new trajectories or the extinction of former trajectories. This is because we cannot tell clearly whether new trajectories and old ones are connected or not. In addition, we will regard the change of the type of technical innovation as a kind of technological trajectory. Thus the shift from product innovations to process ones or the shift from radical innovations to incremental ones will be discussed in this respect, despite some difference on the level between the change of the innovation type and the change of a special technology.

(2) The Source of Innovation

There are two different points of interest concerning the source of innovation. The first question is whether the source is located inside or outside the industry. Von Hippel (1988), for example, highlights the role

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2. Nelson and Winter (1977) used "natural trajectory" as a similar concept, but we use the words "technological trajectory" because it seems easier to understand. Innovation avenue which was used in Sahal (1985) also seems to be the same as technological trajectory.
of users. It is the expected profit (the economic rent) that determines the source of innovation in his view. Abernathy (1978), on the other hand, suggests that the uncertainty of the product market and technology regulates the locus of innovation. According to him, intrafirm R&D organizations become the source of innovation when uncertainty about the market and technology is reduced, while users are the source of innovation in the early stage of the industrial life cycle when there is a lot of uncertainty. Regarding the origin of process innovation, Abernathy describes it shifting from the purchasing of general-purpose equipment, through making or remodeling by user companies for their own use, to dependence on specialized equipment suppliers.

The second question is whether the source of innovation is located in big companies, which have large market shares, or small companies, which are rich in entrepreneurship. Big companies may have more managerial resources for R&D or the development of markets, but less flexibility for change. To borrow Freeman's words, this is the problem of the early Schumpeter (Model 1), which stressed the crucial role of entrepreneurs, versus the late Schumpeter (Model 2), which recognized the internalization of scientific and inventive activity within the company.

(3) The Motive for Innovation

There is a traditional question whether market-pull or technology-push is the motive for innovation. This problem has attracted the interest of many researchers since Schmookler (1966) pointed out the critical role of the market in innovation. In recent work, most researchers have reached the conclusion that both forces are relevant, even though there is some difference in weight in some cases. However, it is a more important issue how both forces act on innovation. In this paper, we will also consider the matter of the motive for innovation.

III. The Abernathy-Utterback Model: The Prototype

We need a standard model to measure the feature of technical innovation. Abernathy and Utterback (1978) provide a useful model of innovation. Their model embraces many dimensions necessary to grasp

innovation, namely, product markets, competition, products, production processes, equipment, materials, plant size, and organizations. In addition, their model takes each factor's relationship into consideration. We, therefore, use their model as a prototype, even though it has some problems in respect of generality. Let us look at the model concisely from the viewpoints that are referred to in Section II.

(1) Technology Trajectories

Their model considers that the uncertainty about the market and technology decreases as the industry proceeds along its life cycle. The basis of their model is mechanistic thinking on technology, which emphasizes the connection between structure and function and stresses the exclusion of any slack or disturbance. On these assumptions, the model presents the following technological trajectories.

(a) Standardization and convergence of products.
(b) Mechanization and automation of production processes.
(c) The movement of production processes toward continuity.
(d) Specialization of equipment.
(e) Growth of the production scale.
(f) Shift from product innovations to process innovations.
(g) Shift from radical innovations to incremental innovations.

(2) The Source of Innovation

According to their model, the source of innovation shifts from users to intra-firm R&D in the case of product innovations, while in the case of process innovations it shifts from the purchasing of general-purpose equipment, through its making by users, to dependence on specialized suppliers. Furthermore, as the focus shifts from products to processes, and as the process restricts product change more and more, the role of the supplier becomes significant. On the problem of company size, their model suggests that small entrepreneurial organizations are the source of innovation in the early stage of the industrial life cycle but later the role of big corporations becomes more important.

4. About this point, see Porter (1983) and Hara (1994).
(3) The Motive for Innovation

Their model does not clearly state whether the market or technology is the motive for innovation. Rather it proposes that the characteristic of the market should change as the maturity of industry proceeds. That is to say, the competition in the market moves from the product's function to the product's price. The characteristic of technology that is critical may change as well. The priority shifts from product technologies to component technologies or process technologies.

The Abernathy-Utterback model comes mainly from the experience of the American automobile industry to the middle of the 1970's. It may fit machine or assembly industries. However, there may be a gap between the model and the pattern of technological change in the chemical industry. We will be able to clarify the influence of the technological properties and the product market properties on innovation by comparing the technological change in the chemical industry with the Abernathy-Utterback model.

IV. Technical Innovation in the Chemical Industry

Chemical Industries are the industries that produce products with chemical reactions. Reactors and pipes are the major items of equipment for the process. At least, since the beginning of this century, they have been the industries that are based on the understanding and operation of materials at the molecular level. In this section, let us look roughly at the innovation in the chemical industry with the help of some studies.

(1) Technological Trajectories

There are two notions about technological trajectories in the chemical industry. Some studies regard the chemical industry as an industry that makes homogeneous products. From this viewpoint, the industry should proceed quickly to the specific (last) stage of the
Abernathy-Utterback model, because the standardization of products should be done at the very beginning. Therefore, it should be process innovation that is critical. A continuous process should be realized early in the history of the industry.

Other studies point out the different technological trajectory of the chemical industry. Quintella (1993) and Achilladelis, et al. (1990) suggest that both product innovations and process innovations should be widespread in the chemical industries that produce heterogeneous products, that is, specialties\(^7\). In other words, there should be some chemical industries that do not go along with the Abernathy-Utterback model, according to this view.

Anyway, in the case of the production of commodities such as ethylene or acrylonitrile, there is less dispute than in the case of the specialties\(^8\). It is important, therefore, to study the cases of the specialties more, in order to solve the problem of the technological trajectories in the chemical industry.

(2) The Source of Innovation

Most of the studies are of the same view about the problem of the source of innovation in the chemical industry. They say that the main source of the product innovations in the chemical industry is the R&D of large chemical companies, and that the main sources of the process innovations are large chemical companies and suppliers of equipment\(^9\).

(3) The Motive for Innovation

Both the market and the technology seem to be related to the innovation in the chemical industry, according to most of the studies. The problem is not whether the market-pull or technology-push is the motive, but how both of them are related to innovation. For the solving this problem, a historical case analysis will be useful.

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7. Quintella (1993) categorizes chemical products into four groups, namely, commodities, pseudo-commodities, fine chemicals, and specialties. But it is commodities and specialties that show the most remarkable contrast.

8. The following products are included in specialties: pesticides, pharmaceuticals, dyestuffs, paints, pigments, inks, fats, detergents, cosmetics, perfumes, adhesives, food additives, and so on.

9. For example, see Chapter 2 of Freeman (1982).
V. Technical Innovations in Japanese Paint Companies: a Case Study

V. 1. Why the Paint Industry?

There are some reasons why the paint industry was selected. Firstly, paint is said to be one of the specialties. Technological change in the industries that produce the specialties, as mentioned in Section VI, is a critical matter. Secondly, the paint industry is rich in innovations. Thirdly, there are two world-class paint companies in Japan. Fourthly, these companies specialize in the paint business almost entirely. Finally, direct access to these companies was permitted, and substantial much information was gained.

V. 2. Technical Innovations in Nippon Paint and Kansai Paint

(1) The Profiles of the Companies

We will examine the cases of two leading paint companies in Japan: Nippon Paint Co., Ltd. and Kansai Paint Co., Ltd. The profiles of these companies are summarized in Table 1.
Table 1: The Profiles of Nippon Paint Co. and Kansai Paint Co.

<table>
<thead>
<tr>
<th></th>
<th>Nippon Paint Co.</th>
<th>Kansai Paint Co.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation*</td>
<td>1898</td>
<td>1918</td>
</tr>
<tr>
<td>Sales*</td>
<td>¥149,182 million</td>
<td>¥155,534 million</td>
</tr>
<tr>
<td>Employees*</td>
<td>2,925</td>
<td>3,091</td>
</tr>
<tr>
<td>Product*</td>
<td>Synthetic resin paint (81%), Thinner (5%), etc.</td>
<td>Synthetic resin paint (82%), Thinner (6%), etc.</td>
</tr>
<tr>
<td>Domestic share**</td>
<td>18.2% (No.2)</td>
<td>19.4% (No.1)</td>
</tr>
<tr>
<td>World share***</td>
<td>2.5% (No.9)</td>
<td>2.5% (No.8)</td>
</tr>
</tbody>
</table>

Source:

Nippon Paint is one of the oldest paint companies in Japan, while Kansai Paint was a latecomer to the Japanese paint industry. But at present, as Table 1 indicates, the two companies are very similar in size. Furthermore, they sell their products to the same segments of the market. Both of them deal in a wide range of products, and both depend particularly on heavy users such as automobile manufacturers. Regarding the feature of technological change that is our concern, there are also strong similarities between the two. Since the 1920's when the paint industry became one of the modern chemical industries, both companies have been modifying their product lines and production processes along similar trajectories. By investigating these changes historically, we will be able to understand the technical innovation in the Japanese paint industry. Now, let us look into the product changes, the process changes, and the relationship between them in the two companies.

(2) Product Innovations

Nitro-cellulose lacquers and synthetic resin-based paints were the most important product innovations for the two companies before the oil crises in the 1970's. Both of them were innovations of raw materials, and before the development of nitro-cellulose lacquers, there
were only oil-based paints that were made from natural materials. In 1926, Kansai Paint succeeded in the production and commercialization of the first nitro-cellulose lacquer in Japan. Nitro-cellulose lacquers spread rapidly, because their fast-drying property was convenient for the users. Owing to the success of nitro-cellulose lacquers, Kansai Paint joined the top group of Japanese paint companies, though it was a latecomer to the industry.

Synthetic resin-based paints were also developed in the late 1920's, but their use did not spread until after World War II. After W.W.II, as it became easy to get raw materials, and as the mass markets of construction and consumer durables manufacturing appeared, synthetic resin-based paints spread explosively. The reason for their rapid diffusion was their properties of fast drying and high durability. In addition, the number of product development by the intra-company R&D organizations increased after synthetic resin-based paints became popular. This was mainly because many kinds of synthetic resin, which have different properties, were developed. Furthermore many additives which add special properties to paints were developed, and they amplified the variety of the paints. The paint industry has been rich in its variety of raw materials and of products since that time.

Until the first oil crisis in 1973, both the market and the yield of paint had grown steady, but after that they became unstable. Saving energy became the critical issue for Japanese society of the day. Additionally, the concern about the natural environment increased more and more among the people. Reflecting those social conditions, new trajectories emerged, that is, air-drying type paints and water-thinned paints were developed intensely. Air-drying type paints can save energy because they do not need baking. Water-thinned paints are good for the environment because they do not use organic solvents that pollute the air. Other tendencies also emerged. The development of paints that had some special functions, for example, antibacterial paints, was one of these. The other, and more important, tendencies were the development of new paint and coating systems, namely, electrodepositing coating, powder coating and the pre-coating of paints.

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13. Nippon Paint commercialized its first nitro-cellulose lacquer in 1927. Nitro-cellulose lacquers (and also synthetic resin-based paints) had been developed and commercialized before that in the United States, but Kansai Paint and Nippon Paint, which already possessed R&D organizations, were able to produce them at a relatively early stage.
metallic sheets. Those new coating systems are both efficient and environment-oriented.

Recently, further trajectories have emerged among the paint companies. One of them is marking-film, in other words, sticker-style paint. The other trajectory is the paint companies' entry into industries such as electronic parts or bioreactors, by applying their knowledge of high polymer chemistry, rheology, and so on.

(3) Process Innovations

The production process for liquid paints consists of several subprocesses: raw materials supply, pre-blending, dispersion, adjustment, and canning. In particular, dispersion is a core process in the production of paints. In the dispersion process before 1900, the paint materials were dispersed manually. Then mechanization of the process progressed gradually. First, the roller mill substituted for manual operation, and then, the combination mill allowed the integration of the machines. After World War II, the ball mill became widely used. The ball mill changed the method of dispersion in order to achieve increased efficiency, and was suitable for mass production, thereby becoming popular. The sand mill, which was installed in both companies in 1963, was even more efficient and made continuous operation possible. Now the sand mill is the mainstay of dispersing machines.

Concerning the other sub-processes, automation developed in material handling after 1970. Even color adjusting, which was said to be the most difficult process to be automated, has been partly automated by computer. Information technology has also played an important role in the recent integration of production and logistics. Very recently both companies have founded pipeless plants in which the number of pipes has been reduced by moving tanks flexibly like a flexible manufacturing system (FMS).

In this way, the mechanization and automation of the process have been progressing gradually. The timespan of process innovations is, however, much longer than that of product innovations. Furthermore, even now human power is needed in some operations for economic or technological reasons. For example, injecting a little amount of additives is less costly when done by hand than by machinery. On the other hand, subtle color adjusting needs the sense of a skilled person. A continuous process is also difficult to realize in these paint
companies because of a great variety of products. The process is, therefore, a batch process basically, and automation has been progressing under these conditions. A growth in batch size was seen in the period of high economic growth, but since the oil crises, it has stopped.

Both companies have the experience of the vertical integration of raw materials’ production. Most of the initial reasons were to secure raw materials, but the present reason for the vertical integration of synthetic resin manufacturing, which the companies still continue, is to hold the source of product improvement and product differentiation.

(4) The Relationship between products and processes

We may say that the relationship between products and processes in the paint industry has been looser than that of the machine and assembly industries. Various products can be produced by the same equipment. In other words, minor innovations can be achieved by using the existing equipment. Radical innovations, such as powder coatings, however, need a change of the process.

V. 3. The Feature of Innovation in the Paint Industry

Now let us examine the feature of the technical innovation in the paint industry from the cases of the two Japanese companies, from the viewpoint of comparing it with the Abernathy-Utterback model.

(1) Technological Trajectories

The products have not been standardized or converged. New types of products, for example, water-thinned paint, the paint for electrodepositing coating or powder type paint, have appeared occasionally. New or additional technological trajectories have frequently emerged throughout the history of the industry, especially since the paint industry joined the modern chemical industries which use the technology of synthetic molecules.

A shift from product innovations to process innovations, therefore, has not occurred in the paint industry. And neither has a shift from radical innovations to incremental innovations. Even now, product innovations are still widespread, and radical innovations may occur. The number of innovations is not declining.
We indeed observed mechanization and automation of production processes in the case study. But there appeared to be a limitation on mechanization for economic or technological reasons. The movement toward a continuous process was not accomplished, and the process is still a batch type process basically. The development of specialized equipment was not accomplished. Various products are still made with the same equipment without a change of the structure. A growth in the tank size was observed at one time, but it has stopped in the last two decades. We observed a backward vertical integration of synthetic resin manufacturing. The purpose of this was the differentiation and improvement of the products rather than cost reduction.

In short, technological trajectories in the paint industry do not look like what is described in the Abernathy-Utterback model. Rather, it supports the proposition of Quintella (1993), that the pattern of innovation in the chemical industries which produce specialties, is different from those in the chemical industries which produce commodities.

(2) The Source of Innovation

In the cases of the two companies, most of the sources of product innovations were the intra-company R&D organizations. However, in process innovations, the role of the equipment suppliers was important. In addition, the weak binding force of the process made the role of intra-company R&D more significant. The intra-company R&D also played an important role in new business development. Regarding the problem of how much size is needed in order to innovate, it seems necessary to be large enough to afford an appropriate R&D effort.

(3) The Motive for Innovation

On the motive of innovation, the case study supports the view of many existing studies that both the market and technology influence innovations. Synthetic resin-based paints, for example, stemmed from the development of high polymer chemistry. But their success as products owed much to their properties of fast drying, high durability, and low prices, which were fit for mass production system.

Another example is environment-oriented paint needed now, for which different technologies have been used. Explicitly, several types of paints such as water-thinned paints or powder paints were developed.
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intensively in order to reduce the organic solvents that pollute the air. From this, it is clearer that both suitable market conditions and appropriate technological conditions are necessary for innovations.

VI. Discussion

How is the feature of technical innovation in the paint industry related to the properties of technology and those of the product market? In this section, we will consider these relationships.

Let us begin with the influence of the properties of chemical technology on innovation. The possibility of changing a product's property through changing the production conditions means that there is a weak relationship between the products and the process. This may facilitate product innovations, and prevent the equipment from extreme specialization. This may also facilitate automation and continuous production, because the production conditions are easy to quantify. Raw materials are very important in the chemical industry, because a change of raw materials creates a new product, and a raw material innovation combines immediately with a product innovation. This makes the vertical integration of raw materials significant, as well as for the purpose of quality assurance. The versatility of the chemical technology results in the potential for new business development. Latent scale economies are provided in chemical technology, because the surface area of a tank is \(2 \pi rh\), while the volume of it is \(\pi r^2h\). It makes production very efficient if the process is made continuous and automatic, because most materials are fluid.

There may be some influence of the properties of paint manufacturing technology on innovation. The simple process technology of paint manufacturing may limit the opportunity for, and the attraction of, process innovations. Thus paint makers have been making more efforts to develop the products than the processes. They have been dependent on suppliers for process innovations. The simple process may also make the competition furious. This may have made the big companies like Nippon Paint or Kansai Paint move to the more high-class and heavy-users' market segment.

All considerations above are, however, only possibilities. The other important factor, namely, the properties of the product market, affects the realization of these possibilities. The product market for paints in
Japan is very fragmented and varied. In order to supply this market, a variety of both raw materials and products is needed, and this reduces the lot sizes. This condition limits the movement toward a continuous process, the growth in tank size, and the progress of automation. However, this promotes product innovations.

In addition, the property of the market segment adds variety to the feature of technological change. In the large companies which face the high-grade product market, the processes are more modernized and intra-company R&D for product innovations is also more intensive. They also integrate the resin manufacturing in order to differentiate and improve their products.

Finally, let us think about why the pattern of technical innovation in the paint industry is not consistent with the Abernathy-Utterback model. As mentioned above, the technological properties of the paint industry seem to increase the possibility of technical innovations. The Abernathy-Utterback model is based on mechanistic thinking on technology, but it does not seem to be applicable to all industries. At least in the chemical industry, including the paint industry, there are some differences in the relationship between the equipment structure and its function. Moreover, the Abernathy-Utterback model considers that the uncertainty about the market and technology decreases with time, but again this does not seem to be the case in all industries. In the case of the paint industry, the uncertainty was not reduced because of technological opportunities and because of the change and the variety of the user's needs. In short, the Abernathy-Utterback model is not coincident with the pattern of the paint industry because the premises of the model are not universal but specific to some industries.

VII. Conclusion

Now, we can extract the following hypotheses from our investigation.

Hypothesis 1: Industries based on chemical technology have more opportunities for innovation than those based on mechanical technology.

14. More than 23,000 items are said to be registered at Nippon Paint for different uses.
As the basis of Hypothesis 1, the following factors exist:
(a) The possibility of product innovation by changing the production conditions.
(b) The possibility of product innovation by changing the raw materials.
(c) The possibility of product innovation by technological derivation.
(d) The possibility of process innovation by changing the composition of sub-processes, in particular, by the introduction of a continuous process.
(e) Larger latent scale economies.

Hypothesis 2: Specialties-type product markets (high variety and small lot sizes) facilitate product innovation and restrict process innovation, while commodities-type product markets (low variety and large lot sizes) have the opposite effect.

Hypothesis 3: The property of the market segment for each company gives variety to the feature of technological change.

In this paper, we actually found that there are different patterns of technical innovation in different industries. This is probably due to the technological properties and the market properties of the industry. Therefore, we can not neglect the properties of technology and the market when we consider technical innovation. We must know the properties of technology and the market for the effective management of technology.

We have to investigate more cases to refine these hypotheses and to derive some other hypotheses about the influence of organizational properties, of social conditions, and so on. A comparison of the experiences of different industries, of different companies in the same industry, or of different countries in the same industry may be useful for these purposes. Then we should try empirical tests to verify the hypotheses. In this way, we can probably establish a useful theory of technical innovation for the management of technology.

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