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January 2023

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JEL classification: D21, L13

Keywords: Hotelling model, differentiation, imitation, standardization

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1. Introduction

Is the distance between the product characteristics of firms in an industry getting closer or not in competition? On the one hand, firms increase the distance through product differentiation or innovations for profit maximization. On the other hand, they reduce

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the distance through imitation or social learning to incorporate their competitors' superior product characteristics into their own products for profit maximization.[1] As a result, the distance continues to change in competition. Therefore, we examine how competition affects the distance through differentiation and imitation.

Numerous studies have been conducted on either differentiation or imitation to date. Primarily, product differentiation has long been studied as a kind of imperfect competition (Thisse and Norman eds., 1994). While Chamberlin (1933) studied a variety of products as monopolistic competition, Hotelling (1929) formulated the degree of differentiation of interest in this study as a location or address model. Hotelling not only showed the result of minimum differentiation in his model settings but also provided the foundation for subsequent studies on differentiation under various settings. Contrary to his result, d'Aspremont et al. (1979) indicated the result of maximum differentiation with a two-stage game by choosing not only locations but also prices, and Kou and Zhou (2015) showed the impact of relative performance on the degree of differentiation. Moreover, Matsumura and Matsushima (2012) showed that the range of possible locations affects research and development (R&D) investments. Hence, our understanding of the degree of differentiation has been developed from multiple perspectives.

Next, imitation and its related concepts have been focused particularly since the late 20th century in economics. First, they have attracted scholarly attention along with the growing interest in technological progress for economic growth. Imitation has become explicitly investigated as the diffusion, social learning, or spillover process of new technologies, knowledge, or innovations (Griliches, 1957; Kapur, 1995; Mansfield, 1961; Stiglitz and Greenwald, 2014). While innovations and R&D are often emphasized as a source of economic growth, imitation and its related concepts have also played an equally large role through technological catching up.

Second, imitation has also come to attention concerning the growing interest in the firm's strategic behavior. As a firm cannot protect its competitive advantage if its competitors can easily imitate the firm's differentiation or innovations, ways should be devised to increase impediments to imitation (Besanko et al., 2017). In particular, the conditions of imitation or social learning are thriving in studies on business administration (Lieberman and Asaba, 2006; Örtenblad ed., 2019). It has also been analyzed which competitors a leader should imitate in a multi-competitor environment (Sharapov and Ross, 2019). Thus, differentiation and imitation that change the product

[1] Regarding learning, it can be divided into learning by doing based on one's own experiences and social learning based on others' ones. It is the latter that is of interest in this study.

characteristic distance have been individually analyzed in depth so far.

However, because differentiation and imitation have not been analyzed within the same framework, the difference between the compositions of similarities and differences of products in each industry is not explicit. If comparing a composition of larger degrees of similarities and differences and that of smaller degrees of both, even though the relative difference between the compositions is the same, the contents of them are quite different. Looking at real products in an industry, they generally contain the aspects of both similarities and differences in comparison with other products in the same industry, so unless the balance of both differentiation and imitation can be analyzed, the differences of real products cannot be explicitly shown. However, previous studies on differentiation showed the degree of differences between products in the same industry but not directly another aspect of similarities. Similarly, previous studies on imitation showed a process where product characteristics become similar but not directly another aspect of differentiation. Therefore, we need to analyze differentiation and imitation in a unified way to show both the aspects of actual products and examine how firms change the product characteristic distance in competition.

As one way to solve it, this study introduces the concept of imitation into a Hoteling model on differentiation and analyzes imitation after differentiation. Specifically, we suppose that after determining the degree of differentiation in the first period, two firms can expand their product characteristics toward the other by imitation from each other in the second period. In doing so, we show that although firms are more profitable if they maintain differentiation, they face a prisoner’s dilemma in imitation in certain settings. Therefore, they are forced to imitate as much as possible from each other, which decreases their profits. Thus, the distance between the average product characteristics of the firms becomes closer.

Moreover, the analysis of differentiation and imitation in a unified way has enabled us to explicitly show the composition between similarities and differences that characterize actual products in an industry. If the product characteristics of both firms become partially or almost commonalized, then the products become standardized within the industry to the degree of commonalization. Hence, the standardization of product characteristics in the industry leads to newly industrial differentiation from existing industries and the diversification of industries in an economy. This study shows the process of industrial development through interactions at the firm level.

The remainder of this paper is structured as follows. Section 2 presents a model to analyze differentiation and imitation. Section 3 analyzes how profits change as a result of imitation after differentiation. Finally, Section 4 concludes the study.

2. Model: Differentiation and Imitation

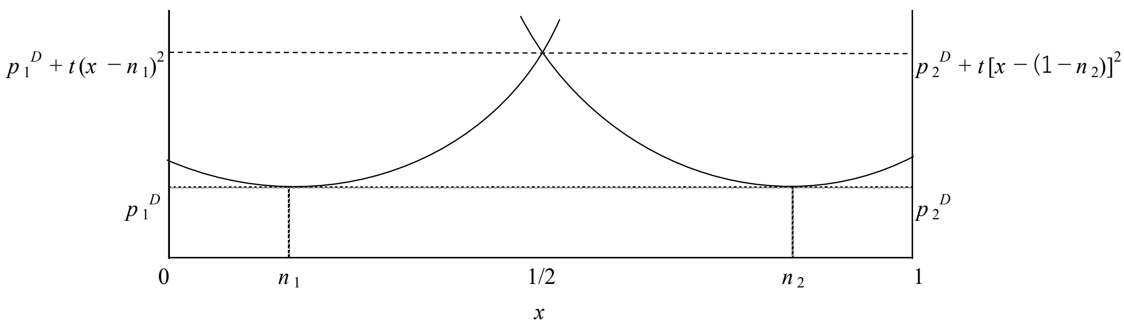
2.1. Differentiation

This subsection introduces a model of differentiation based fundamentally on d'Aspremont et al. (1979).[2] The model is basic in the research field on differentiation. However, it is here developed in relative detail because we introduce imitation into the model in the next subsection and analyze imitation in a similar way to analyzing differentiation in the next section.

Consumers with different preferences are uniformly distributed on a linear city of the unit interval [0, 1], and each consumer buys a product that is close to each preference (Figure 1). There are two firms, Firm i (i = 1, 2), and Firms 1 and 2 locate at location n_i ($0 \leq n_i \leq 1/2$). In detail, Firm 1 locates at n_1 from the left end 0 to 1/2 and Firm 2 locates at location n_2 from the right end 0 to 1/2. Therefore, if $n_1 = n_2 = 0$, then the locations represent maximum differentiation. On the other hand, if $n_1 = n_2 = 1/2$, then the locations represent minimum differentiation. Next, let x and $1 - x$ be demands for Firms 1 and 2, respectively, and let $t > 0$ be the coefficient of a transportation cost or a disutility for the consumers because of the difference between Firm i's product differentiation n_i and the consumers' preferences. Then, the sum of Firm 1's product price p_1^D and its transportation cost and that of Firm 2's product price p_2^D and its transportation cost are equal at x as follows:

$$p_1^D + t(x - n_1)^2 = p_2^D + t(1 - n_2 - x)^2. \tag{1}$$

Figure 1: Locations of n_i



Source: The author.

Next, Firms 1 and 2 choose n_1 and n_2 to maximize their profits π_1^D and π_2^D as

[2] The specific formulation is also based on Tirole (1988).

follows, respectively:

$$\pi_1^D = (p_1^D - c)x - h^D\left(\frac{1}{2} - n_1\right)^2 \tag{2}$$

and

$$\pi_2^D = (p_2^D - c)(1 - x) - h^D\left(\frac{1}{2} - n_2\right)^2, \tag{3}$$

where c is the marginal cost and $h^D > 0$ is the coefficient of a differentiation cost for the firms. Although the cost does not make an essential difference compared with the results of previous studies on differentiation, it brings a diversity of degrees of differentiation.

Solving Eq. (1) for x and substituting that x into Eqs. (2) and (3), Firm 1's and Firm 2's equilibrium prices ${p_1^D}^*$ and ${p_2^D}^*$ that maximize their profits are obtained as follows, respectively:

$${p_1^D}^* = c + t(1 - n_1 - n_2)\left(1 + \frac{n_1 - n_2}{3}\right) \tag{4}$$

and

$${p_2^D}^* = c + t(1 - n_1 - n_2)\left(1 + \frac{n_2 - n_1}{3}\right). \tag{5}$$

If $n_1 = n_2 = 0$ (maximum differentiation), then ${p_1^D}^* = {p_2^D}^* = c + t$. On the other hand, if $n_1 = n_2 = 1/2$ (minimum differentiation), then ${p_1^D}^* = {p_2^D}^* = c$.

Substituting Eqs. (4) and (5) into Eq. (1) and solving for x, the demands for Firms 1 and 2 are obtained as follows, respectively:

$$x = \frac{1}{2} + \frac{n_1 - n_2}{6} \tag{6}$$

and

$$1 - x = \frac{1}{2} + \frac{n_2 - n_1}{6}. \tag{7}$$

Finally, substituting Eqs. (4) and (6) into Eq. (2) and substituting Eqs. (5) and (7) into Eq. (3), n_1 and n_2 for maximizing profits are obtained as follows:[3]

$$n_1 = n_2 = \frac{-t + 6h^D}{4(t + 3h^D)}.$$

Firm 1's and Firm 2's locations and profits depend on the value of h^D. If $0 < h^D \leq t/6$, then $n_1 = n_2 = 0$ and $11t/24 \leq \pi_1^D = \pi_2^D < t/2$, which is less than $t/2$ when $h^D = 0$. On the other hand, if $t/6 < h^D < \infty$, then $0 < n_1 = n_2 < 1/2$ and $0 < \pi_1^D = \pi_2^D < 11t/24$. Therefore, the smaller the h^D, the farther the product characteristic distance and the larger the profits.

2.2. Imitation

This subsection introduces our settings on imitation into the model of differentiation. Imitation is defined as one firm's incorporation of some or all of the other firm's product characteristics differentiated in the first period into its own product characteristics in the second period.

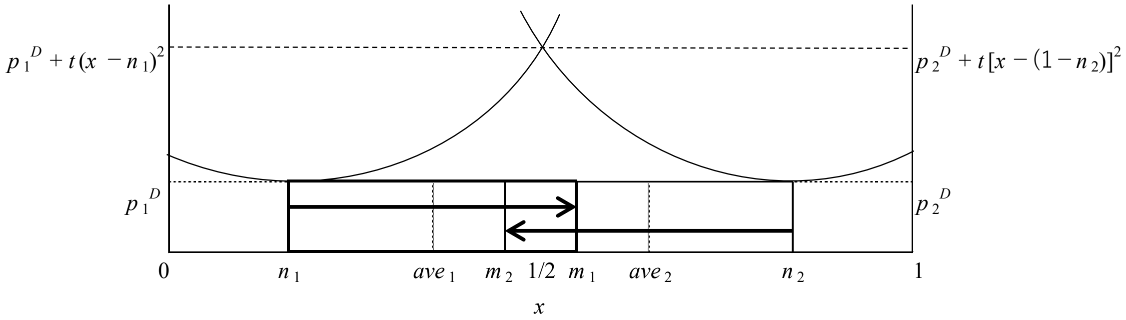
First, we suppose that Firm i can expand its product characteristics from n_i toward m_i ($0 \leq m_i \leq 1$) by imitation the other's n_j ($j \neq i$) to increase its profit (Figure 2). In other words, imitation here means adding adjacent product characteristics that are closer to the other's location to its product characteristics. Therefore, its product characteristics are no longer a point at n_i but have a width between n_i and m_i. Assuming average product characteristics ave_i of the width, the greater the m_i, the closer the distance between ave_i and ave_j. Additionally, Firm 1's m_1 and Firm 2's m_2 are 0 at the right end closer to Firm 2's n_2 and at the left one closer to Firm 1's n_1, respectively. If the product characteristics of the firms overlap through imitation, we assume that consumers in the overlapping areas near 0 and 1 buy Firm 1's and Firm 2's products, respectively.

[3] There are two more pairs of solutions as follows:

$$n_1 = n_2 = \frac{-2t - 9h^D \pm 3\sqrt{t^2 + 12th^D + 18h^D}}{2t}.$$

However, they are excluded here because h^D becomes negative.

Figure 2: Locations of m_i



Source: The author.

Second, we suppose that the firms can expand product characteristics through imitation while maintaining $p_i^{D^*}$ in Eqs. (4) and (5) even if the average or overall product characteristics from n_i to m_i become similar between firms. Specifically, it is assumed that the product characteristics established in the first period become the core features of each firm's product or the source of a strong brand. In other words, their product uniqueness is maintained even though new characteristics are added to their own products through imitation. Although this is a strong assumption, this study focuses on a fact that even if the prices are maintained, the behavior of firms has a significant impact on each other's profits through the introduction of imitation.[4]

3. Analysis: Differences and Similarities

3.1. No Imitation: Benchmark

To compare the results of imitation in this section, first, this subsection shows the profits when both firms do not imitate from each other in the second period as a benchmark, selling the products which are differentiated in the first period. Firm 1's and Firm 2's profits π_1^{DD} and π_2^{DD} are as follows, respectively:

$$\pi_1^{DD} = \left(p_1^{D^*} - c\right)\frac{1}{2} \tag{8}$$

[4] If imitation causes the average product characteristics distance to decrease and their prices to fall, then the firms would be better off maintaining differentiation without imitation unless we add another assumption to our model settings.

and

$$\pi_2^{DD} = \left(p_2^{D^*} - c\right)\frac{1}{2}. \tag{9}$$

To focus attention on the comparison, we assume that both firms take the same behavior, that is, $n_1 = n_2$ in Eqs. (6) and (7), and therefore, the demands for both firms are 1/2.

Substituting Eqs. (4) and (5) in Eqs. (8) and (9), respectively, Firm 1's and Firm 2's profits π_1^{DD} and π_2^{DD} are as follows, respectively:

$$\pi_1^{DD} = \frac{t(3 + n_1 - n_2)(1 - n_1 - n_2)}{6} \tag{10}$$

and

$$\pi_2^{DD} = \frac{t(3 - n_1 + n_2)(1 - n_1 - n_2)}{6}. \tag{11}$$

The profits depend on the values of n_1 and n_2. If the differentiation cost is small and $n_1 = n_2 = 0$, then $\pi_1^{DD} = \pi_2^{DD} = t/2$; if it is large and $n_1 = n_2 = 1/2$, then $\pi_1^{DD} = \pi_2^{DD} = 0$.

3.2. Imitation by Only One Firm: Optimal Behavior

Second, this subsection shows the profits when only one of the two firms imitates. We first derive the profits of the firms that imitate and then those that do not.

First, Firm 1's and Firm 2's profits π_1^{ID} and π_2^{ID} are as follows, respectively, when only that firm imitates and the other does not:

$$\pi_1^{ID} = \left(p_1^{D^*} - c\right)\left(\frac{1}{2} + \frac{1 - m_1 - n_1}{2}\right) - h^I(1 - m_1 - n_1)^2 \tag{12}$$

and

$$\pi_2^{ID} = \left(p_2^{D^*} - c\right)\left(\frac{1}{2} + \frac{1 - n_2 - m_2}{2}\right) - h^I(1 - n_2 - m_2)^2. \tag{13}$$

The demand for the firms that imitate is 1/2 plus half of the expansion of product characteristics from Firm i's n_i to m_i. On the other hand, the firm has to bear an imitation cost depending on the coefficient of the imitation cost $h^I > 0$ and the degree of imitation.

Substituting Eqs. (4) and (5) in Eqs. (12) and (13), respectively, m_1^* and m_2^* that maximize each profit equation are obtained as follows, respectively:

$$m_1^* = 1 - n_1 - \frac{t(3 + n_1 - n_2)(1 - n_1 - n_2)}{12h^I} \tag{14}$$

and

$$m_2^* = 1 - n_2 - \frac{t(3 - n_1 + n_2)(1 - n_1 - n_2)}{12h^I}. \tag{15}$$

The third term on the right side of both equations is positive or 0 because $0 \leq n_i \leq 1/2$ and $h^I > 0$. Therefore, the smaller the h^I, the closer the m_i to the competitor's n_j. To focus attention on the h^I, we assume that $n_1 = n_2 = 0$. If $h^I \leq t/4$, then $m_1 = m_2 = 0$. In this case, the width length of product characteristics is 1. On the other hand, if $h^I = \infty$, then $m_1 = m_2 = 1$. In this case, the width length of product characteristics is 0.

Although $0 \leq m_i \leq 1$ by definition, because m_i can be negative depending on the value of h^I, it can be divided by cases as follows. In the first case, if $t\,(3 + n_1 - n_2)\,(1 - n_1 - n_2)\,/\,12\,(1 - n_1) \leq h^I \leq \infty$ for m_1^*, then $0 \leq m_1^* \leq 1$; if $t\,(3 - n_1 + n_2)\,(1 - n_1 - n_2)\,/\,12\,(1 - n_2) \leq h^I \leq \infty$ for m_2^*, then $0 \leq m_2^* \leq 1$. In the second case, if $h^I < t\,(3 + n_1 - n_2)\,(1 - n_1 - n_2)\,/\,12\,(1 - n_1)$ for m_1^*, instead of being negative, $m_1^* = 0$; if $h^I < t\,(3 - n_1 + n_2)\,(1 - n_1 - n_2)\,/\,12\,(1 - n_2)$ for m_2^*, similarly, $m_2^* = 0$.

In the first case, substituting Eqs. (4) and (14) in Eq. (12) and substituting Eqs. (5) and (15) in Eq. (13), Firm 1's and Firm 2's profits π_1^{LD} and π_2^{LD} are as follows, respectively:

$$\pi_1^{ID} = \frac{t(3 + n_1 - n_2)(1 - n_1 - n_2)}{6} + \frac{[-t(3 + n_1 - n_2)(1 - n_1 - n_2)]^2}{144h^I} \tag{16}$$

and

$$\pi_2^{ID} = \frac{t(3 - n_1 + n_2)(1 - n_1 - n_2)}{6} + \frac{[-t(3 - n_1 + n_2)(1 - n_1 - n_2)]^2}{144h^I}. \quad (17)$$

As a result, the firm's profit is more by the second term on the right side, as long as it is not zero, than Eqs. (10) and (11). The smaller the h^I, the larger the profits over the benchmark. If $n_1 = n_2 = 0$ and $h^I = t/4$, then $\pi_1^{ID} = \pi_2^{ID} = 3t/4$; if $n_1 = n_2 = 0$ and $h^I = \infty$, then $\pi_1^{ID} = \pi_2^{ID} = t/2$.

In the second case, substituting Eq. (4) and $m_1^* = 0$ in Eq. (12) and substituting Eq. (5) and $m_2^* = 0$ in Eq. (13), Firm 1's and Firm 2's profits π_1^{ID} and π_2^{ID} are as follows, respectively:

$$\pi_1^{ID} = \frac{t(2 - n_1)(3 + n_1 - n_2)(1 - n_1 - n_2)}{6} - h^I(1 - n_1)^2 \quad (18)$$

and

$$\pi_2^{ID} = \frac{t(2 - n_2)(3 - n_1 + n_2)(1 - n_1 - n_2)}{6} - h^I(1 - n_2)^2 \quad (19)$$

Therefore, the smaller the h^I, the larger Eqs. (18) and (19) are than Eqs. (16) and (17), respectively. If $n_1 = n_2 = 0$ and $h^I < t/4$, then $\pi_1^{ID} = \pi_2^{ID} > 3t/4$.

Next, we derive the profits of the firms that do not. Firm 1's and Firm 2's profits π_1^{DI} and π_2^{DI} are as follows, respectively, when only that firm does not imitate and the other does:

$$\pi_1^{DI} = \left(p_1^{D^*} - c\right)\left(\frac{1}{2} - \frac{1 - n_2 - m_2^*}{2}\right) \quad (20)$$

and

$$\pi_2^{DI} = \left(p_2^{D^*} - c\right)\left(\frac{1}{2} - \frac{1 - m_1^* - n_1}{2}\right). \quad (21)$$

The demand for the firms decreases by half of another firm's expansion of product characteristics.

Substituting Eqs. (4) and (14) in Eq. (20) and substituting Eqs. (5) and (15) in

Eq. (21), Firm 1's and Firm 2's profits π_1^{DI} and π_2^{DI} are as follows, respectively:

$$\pi_1^{DI} = \frac{t(3+n_1-n_2)(1-n_1-n_2)(n_2+m_2)}{6} \tag{22}$$

and

$$\pi_2^{DI} = \frac{t(3-n_1+n_2)(1-n_1-n_2)(n_1+m_1)}{6}. \tag{23}$$

The smaller the competitor's m_j, the smaller Eqs. (22) and (23). If $n_1 = n_2 = m_1 = m_2 = 0$, then $\pi_1^{DI} = \pi_2^{DI} = 0$.

Therefore, imitation as much as possible is a rational choice for both firms, even at a cost. On the other hand, if only one firm does not imitate, then its profit may decrease or even disappear.

3.3. Imitation by Both Firms: Prisoner's Dilemma

Finally, this subsection shows the profits when both firms imitate from each other. Firm 1's and Firm 2's profits π_1^{II} and π_2^{II} are as follows, respectively:

$$\pi_1^{II} = \left(p_1^{D^*} - c\right)\frac{1}{2} - h^I(1-m_1^*-n_1)^2 \tag{24}$$

and

$$\pi_2^{II} = \left(p_2^{D^*} - c\right)\frac{1}{2} - h^I(1-n_2-m_2^*)^2. \tag{25}$$

Similarly in the previous subsection, this subsection also divides the value of h^I into the two cases. In the first case, substituting Eqs. (4) and (14) in Eq. (24) and substituting Eqs. (5) and (15) in Eq. (25), Firm 1's and Firm 2's profits π_1^{II} and π_2^{II} are as follows, respectively:

$$\pi_1^{II} = \frac{t(3+n_1-n_2)(1-n_1-n_2)}{6} - \frac{[-t(3+n_1-n_2)(1-n_1-n_2)]^2}{144h^I}$$

and

$$\pi_2^{II} = \frac{t(3 - n_1 + n_2)(1 - n_1 - n_2)}{6} - \frac{[-t(3 - n_1 + n_2)(1 - n_1 - n_2)]^2}{144h^I}.$$

The firm's profit is less by the second term on the right side, as long as it is not zero, than Eqs. (10) and (11). If $n_1 = n_2 = 0$ and $h^I = t/4$, then $\pi_1^{II} = \pi_2^{II} = t/4$; if $n_1 = n_2 = 0$ and $h^I = \infty$, then $\pi_1^{ID} = \pi_2^{ID} = t/2$.

In the second case, substituting Eq. (4) and $m_1^* = 0$ in Eq. (24) and substituting Eq. (5) and $m_2^* = 0$ in Eq. (25), Firm 1's and Firm 2's profits π_1^{II} and π_2^{II} are as follows, respectively:

$$\pi_1^{II} = \frac{t(3 + n_1 - n_2)(1 - n_1 - n_2)}{6} - h^I(1 - n_1)^2$$

and

$$\pi_2^{II} = \frac{t(3 - n_1 + n_2)(1 - n_1 - n_2)}{6} - h^I(1 - n_2)^2.$$

The firm's profit is less by the second term on the right side than Eqs. (10) and (11). If $n_1 = n_2 = 0$ and $h^I < t/4$, then $\pi_1^{II} = \pi_2^{II} > t/4$.

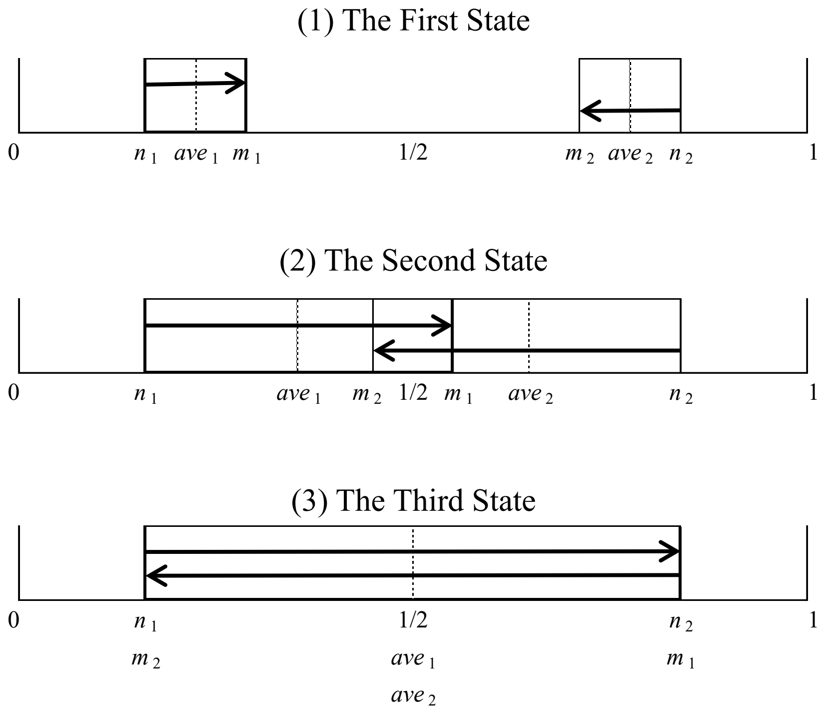
Therefore, both firms are facing a prisoner's dilemma over whether or not to imitate. If both do not imitate, they will earn a profit based on the degree of differentiation. On the other hand, if only one imitates the product characteristics of the other, such a firm will earn a much larger profit. However, the other firm that does not imitate will have a reduced profit. Therefore, both firms must choose to imitate as much as possible. Consequently, their average product characteristics become similar, and profits are reduced more than the benchmark. Through the analysis of imitation after differentiation in this section, we have shown how the average product characteristics distance changes.

3.4. Composition Between Similarities and Differences: Three States

The analysis of differentiation and imitation in a unified way has enabled us to explicitly show, in addition to the average product characteristics, the composition between similarities and differences that characterize actual products in an industry. As the composition can be in various states based on the industry, we can classify it into the following three broad states. However, because the similarities and differences in product characteristics are extremely relative, notably, how consumers identify them also depends on what they are comparing.

The first is a state in which differentiation is maintained without commonalization or overlap of product characteristics between firms (Figure 3 (1)). In this case, even if products are in the same industry and their product characteristics are slightly broadened through narrower imitation, the product concepts are still different or independent. Similar to personal digital assistants and smartphones before the first-generation iPhone appeared in 2007, major mobile-phone firms have introduced next-generation handsets in a wide variety of styles. Therefore, this is probably a state that often occurs in the early stages of market emergence.

Figure 3: Composition Between Similarities and Differences



Source: The author.

The second is a state in which some product characteristics are commonalized between firms, whereas some areas of differentiation remain (Figure 3 (2)). In this case, the products have both similarities and differences, which is often the case in real industries. As with the launch of the first iPhone, the basic concept of smartphones has been standardized, even if they use different operating systems and have different product specifications. Therefore, the product characteristics shared across an industry become the standard in the industry.

The third is a state in which product characteristics are fully commonalized after completely imitation from each other (Figure 3 (3)). In this case, products in the industry share the same product characteristics and become fully standardized between firms, although they still maintain product uniqueness based on the core features or the brand. Therefore, this is probably a state that often occurs in the late stages of market emergence.

4. Conclusion

This study introduced the concept of imitation into the Hotelling model on differentiation. We showed that although it is rational for firms to maintain differentiation for profit maximization, they are faced with a prisoner's dilemma in imitation. Consequently, they are forced to imitate from each other as much as possible, which decreases their profits. Therefore, competition brings the average product characteristics distance closer by imitation from each other. Then, based on the decrease of differentiation and the increase of similarity, we classified the composition between similarities and differences in product characteristics into three broad states, and showed the standardization of product characteristics.

The standard of an industry characterizes and differentiates that industry from other industries in an economy. As an industry is generally a set of firms with similarities as well as differences in products, the standard explicitly identifies where the products of the industry are more similar to each other than products in other industries. Therefore, the formation of a standard indicates a new industrial differentiation or specialization of that industry from the existing division of labor among industries in an economy, increasing the variety of industries. While industries in industrial classifications are generally defined a priori, this study showed the process of industrial development through the interactions at the firm level.

However, actual compositions between the similarities and differences of products must vary from industry to industry. Moreover, the background behind the different compositions and their impact on competition and performance in the industry may differ from industry to industry. Therefore, more industry cases should be accumulated for a better understanding of the backgrounds and impacts of the compositions.

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