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HOW MUCH SHOULD MY SOFTWARE DIFFER FROM YOURS [CASE STUDY]

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ABSTRACT

This paper analyzes an optimal differentiation between two competing application software products when one of the two is produced by a monopolist of a base software. The so called 'minimum differentiation principle' by Hotelling (1929) is inappropriate in this market category. One can see the example of our 'optimal differentiation principle' in a web browser market, where Microsoft's Internet Explorer and Netscape Navigator have a certain degree of differentiation.

1. INTRODUCTION

This paper analyzes an optimal differentiation between two competing application software products when one of the two is produced by a monopolist of a 'base software' – a software which is required to be installed first to run these application software. Hotelling (1929) has studied the issue of endogenous choice of differentiation in his spatial competition model. The famous result of his paper is the so-called "Principle of Minimum Differentiation," a tendency of a firm to minimize the differentiation against the other firm.[1]

Meanwhile, d'Aspremont et al. (1979) modify Hotelling's model and show that slightly different model specification brings different results. In fact, they show that there may exist a tendency for both firms to maximize product differentiation. Contrary to those works, we find that neither the minimal nor maximal differentiation propositions are appropriate in an application software market.

Application software provides no consumption benefits unless some other products are purchased in advance and used in conjunction. First of all, consumers need to have hardware. Some software products like operating system (OS) are also essential and prerequisite to other application software products. In this complementary relationship, we define 'base good' as one of the two complementary goods that must be purchased and installed prior to use application software products. Examples are hardware and OS. We also define 'supplemental good' as the other complementary good that provides consumption benefit when only used in conjunction with a base good. Any application software is a supplemental good. A base good may

1 This principle has been applied in many fields of other social sciences as well as economics. In political science, for example, the principle is adopted to explain why two political parties' platforms tend to converge at the median voter's preference.

give consumption benefit without a specific supplemental good but a supplemental good always requires a base good.

We narrow our focus in this paper and consider the competition between two application software products one of which is provided by the monopolist of a base good market. For example, Microsoft is a monopolist of OS market, and has major competitors in various application software markets; word processor market, spreadsheet market, web browser market, and so on.

The main question of this paper is whether minimal differentiation principle is still appropriate in this category of market. This principle does not seem true in the application software market. Let's consider the web browser market. Microsoft's Internet Explorer (IE) and Netscape Navigator share many common features. In terms of core Internet capabilities, i.e., browsing, e-mail, and newsgroups, two are almost identical. Each displays HTML pages, including those scripted with the new Dynamic HTML. Each handles multimedia content. Each accepts JavaScript and Java applets.[2]

However, there exist apparent differences in the details. Netscape Navigator is extensible through plug-ins while Internet Explorer is through ActiveX controls. Netscape Navigator uses bundled Composer for its built-in mini editor while IE supplies FrontPad, a stripped-down version of Microsoft's FrontPage HTML editor. Netscape's initial implementation of Dynamic HTML involves a Netscape-specific layer tag, combined with JavaScript Accessible Style Sheets (JASS). The tag allows positioning and overlapping of segments of HTML files, and JASS modifies those segments on the fly when the page loads and in response to user interaction. Meanwhile, Microsoft proposes extending Cascading Style Sheets (CSS), which already exist as an HTML standard. With CSS, a Web page designer can redefine HTML tags using either a linked external CSS file (which, like HTML, is a plain-text file), or employing the new style tag embedded within the HTML file's Header section. Netscape Navigator is said to be more end-user friendly while new features of IE 5.0 are targeting developers.[3]

Therefore, we can say that there exists a certain degree of differentiation between Microsoft's IE and Netscape Navigator. This is also true to Microsoft's other application software products and their major rivals (like MS Word and WordPerfect). Neither Hotelling's minimal differentiation nor d'Aspremont et al.'s maximal differentiation can explain this degree of differentiation.

While Hotelling and d'Aspremont et al. consider a market with horizontal competition, we consider a vertically related base-supplemental goods market, where one of the competitors in the supplemental goods market is the base good monopolist. A change in product differentiation alters not only the profitability from the competing application software market but also the profitability from the monopolized base good market. This strategic effect did not occur in Hotelling's single good competition model.

The paper consists of four sections. In section 2, we briefly review Hotelling's (1929) minimal differentiation principle and the d'Aspremont et al. (1979) maximal differentiation principle. In section 3, we analyze an optimal differentiation between two competing application software products. We show that neither the minimal nor maximal differentiation principle is appropriate in this market category. In section 4, we summarize and conclude.

2. HOTELLING'S MINIMUM DIFFERENTIATION PRINCIPLE

This section reviews the purpose of Hotelling's (1929) paper and the principle of minimum differentiation. Customers are evenly distributed along the unit interval,[4] and have unit demand for products. He analyzes

[2] Johnson, Amy Helen, "Smooth Surfing for Casual Browsers with Internet Explorer 4.0," *Windows Magazine*, June 1997, v.8, n.6, p.134.

[3] See Fiedler, David, "Casting a Developer's Eve on Internet Explore 5.0," *Internet World*, June 29, 1998, v4, n.23, p.26.

4 In Hotelling's original paper, the length of the line is *l*. Without loss of generality, we normalize the length to one.

the optimal choice of location in his linear city model. Each location represents each consumer's preference, and the choice of location stands for the choice of product differentiation. Two sellers (1 and 2) of a homogenous product, with zero production cost, are located at *a* and *b* from the left-end point and the right-end point, respectively. A consumer incurs transportation cost, *t* per distance between her and a firm's location. Denote firm 1's price and 2's price as p_1 and p_2. Let π_1 and π_2 denote profits for firm 1 and firm 2 respectively.

The marginal consumer who is indifferent between buying 1 and 2 determines the demand functions for two products. Let the location of the marginal consumer be *x*, then the demand for firm 1's product is $x(p_1, p_2 ; a,b)$ and the demand for 2's product is $1 - x(p_1, p_2; a,b)$.

Two firms set prices simultaneously, and the optimal prices are

$$p_1^* = t(3+a-b) / 3$$

$$p_2^* = t(3-1+b) / 3$$

The profit functions under the optimal prices can be expressed in terms of *a* and *b*:

$$\pi_1(p_1^*, p_2^*) = t(3+a-b)^2 / 18$$

$$\pi_2(p_1^*, p_2^*) = t(3-a+b)^2 / 18.$$

Now, one can easily see that $\partial\pi_1/\partial a$ and $\partial\pi_2/\partial b$ are strictly positive. This implies that both firms have a tendency to move toward the center. Or, if we suppose firm B's location is fixed but that firm 1 is free to move, then 1 will choose adjacent of firm B.[5] Hence, there exists a tendency for minimum differentiation of the products.

Even though Hotelling's proposition provides a lot of intuition about product differentiation in oligopolistic competition, Hotelling's linear-cost model is not very tractable, because the demand function is not continuous if firms are located inside the interval. When a firm lowers its price to the point that it just attracts all consumers located between the two firms, it also attracts the consumers located on the other side of the rival. Consequently, the price competition problem is not well behaved. D'Aspremont et al (1979) discover the problem and show that the Hotelling's equilibrium outcome exists if, and only if the following two conditions are satisfied:

$$(3+a-b)^2 \geq 4(a+ 2b) / 3 \text{ and}$$

$$(3+b-a)^2 \geq 4(b+ 2a) / 3.$$

These conditions imply that the two firms should not be located too close together. If two firms get too closer, then these conditions are violated, hence the equilibrium will no longer exist.[6] Therefore, a tendency of the minimal differentiation works only when two firms are located far enough apart.

D'Aspremont et al (1979) modified Hotelling's example by considering quadratic transportation costs with respect to distance instead of linear costs. Therefore, for any distance x, the transportation costs are tx^2. Under this assumption, the demand for firm 1's product is:

$$D_1(p_1, p_2) = x = a + \frac{1-a-b}{2} + \frac{p_2 - p_1}{2t(1-a-b)}.$$

The Nash equilibrium in prices and profits always exist:

[5] Close enough, but not the same location as firm B. If the two are in the same location (i.e., $a+b=1$), then all prices and profits are zero.

[6] For instance, if we consider symmetric locations around the center (i.e., $a=b$), then the necessary and sufficient conditions for the equilibrium outcome to exist reduce to $a = b < 1/4$. In other words, both firms should not locate inside the quartiles to have a price equilibrium.

$p_1^* = t\,(1\text{-}a\text{-}b)\,(3+a\text{-}b)\,/\,3$

$p_2^* = t\,(1\text{-}a\text{-}b)\,(3+b\text{-}a)\,/\,3$

$\pi_1^* = t\,(1\text{-}a\text{-}b)\,(3+a\text{-}b)^2\,/\,18$

$\pi_2^* = t\,(1\text{-}a\text{-}b)\,(3+b\text{-}a)^2\,/\,18.$

D'Aspremont et al (1979) show that the derivative function of firm 1's profit with respect to *a* is strictly negative:

$$\frac{d\pi_1}{da} = -\frac{t(3a+1+b)(a-b+3)}{18} < 0$$

Similarly, $d\pi_2 / db < 0$. This suggests that firm 1 always wants to move leftward and firm 2 always wants to move rightward. Therefore, there exists a tendency of 'maximal differentiation' for the products.

3. AN OPTIMAL DIFFERENTIATION IN APPLICATION SOFTWARE MARKET

Now, let's consider two competing application software products which require a common base good like OS. The base good market is monopolized, and the monopolist and the rival firm enter the application software market. Consumers are distributed along the unit interval according to their tastes for application software product and they have unit demand. We denote the monopolist to be firm 1 and the rival firm to be firm 2. Let S_1 and S_2 be firm 1's and firm 2's software products, respectively. The monopolist's base good software is denoted as *B*.

The game consists of three stages. In the first stage, the base good monopolist and the rival firm choose their products' differentiation. We denote the monopolist's choice of product type to be $a \in [0,1]$, and the rival firm's choice of product type to be $1\text{-}b \in [0,1]$, where $a \le 1\text{ -}b$. '$a = b = 0$' indicates the maximal differentiation and '$a=1\text{- }b$' suggests the minimal differentiation. In the second stage, the base goods are traded and in the last stage, the application software products are traded.

If we consider the marginal consumer who is indifferent between purchasing firm 1's and firm 2's product, then the marginal consumer's location *x* is given by equating the costs for two products, i.e., $u(S_1)$ - p_{S1} - $t(x\text{-}a)$ -$p_B = u(S_2)$ - p_{S2} - $t(1\text{-}b\text{-}x)$ - p_B. We assume that $u(S_1) = u(S_2) \equiv u$. The demand function for S_1 becomes $D_1 = x(p_B, p_{S1}, p_{S2}; a, b)$.[7] However, the solutions for this demand function are not the optimal strategy for the monopolist. The problem is that the monopolist is not able to act as a Stackelberg leader.

As a Stackelberg leader, the monopolist sets the base good price such that the marginal consumer is indifferent to buying *B* and S_1, buying *B* and S_2, or buying nothing. We consider two kinds of transportation cost. One is linear cost as in Hotelling's original model, and the other one is the quadratic cost as in d'Aspremont et al.'s model. We first consider the linear cost. The demand functions for each firm are:

$$D_1 = a + (u\text{-}p_B\text{ -}p_1)\,/\,t$$
$$D_2 = b + (u\text{-}p_B\text{ -}p_2)\,/t \qquad (1)$$
$$s.t.\ \ D_1 + D_2 = 1.$$

Since the product specification is decided at the first stage, we may consider the second and the third stage by assuming the value of *a* and *b* is given. The rival firm is a Stackelberg follower with a response function

7 In the linear city model, it is possible that not all the consumers purchase the products, i.e., the market may be uncovered. However, the uncovered market is of little interest in this endogenous choice of differentiation. If a market is uncovered in equilibrium, then the two supplemental goods are already differentiated enough and a price change of a supplemental good does not affect the price of the other supplemental good. The analysis of a firm's product differentiation choice against competing firm's product is not meaningful. Therefore, we focus on the case of covered market.

of $p_2(p_B) = (u-p_B+bt) / 2$. We also constraint the total demand to equal to one ($D_1 + D_2 = 1$), so p_1 becomes a function of p_B and $p_2(p_B)$. The optimal prices and profits are expressed in the reduced form of a and b:

$$
\begin{aligned}
&p_B(a, b) = u - (2/3)t + (1/3)(a + 2b)t \\
&p_1(a, b) = (1/2)(a - b)t \\
&p_2(a, b) = (1/3)t - (1/6)(a - b)t \qquad (2) \\
&\pi_1(a, b) = u + (1/6)(4a - ab + 2b)t + (1/12)(a^2 + b^2)t - (2/3)t \\
&\pi_2(a, b) = (1/36)(a - b - 2)^2.
\end{aligned}
$$

Once the reduced form of profit is derived, the firms choose the value of a and b for maximization. We see that π_1 and π_2 are increasing functions of a and b respectively, which suggests the minimum differentiation principle. However, we should note that $u - p_B(a,b) - p_1(a,b) - t|x-a| \geq 0$ if a consumer located at x buys good S_1, and $u - p_B(a,b) - p_2(a,b) - t|x-1+b| \geq 0$ if a consumer located at x buys good 2. The consumer who incurs the highest transportation cost for S_1 in equilibrium is located at the left-end point and the consumer who incurs the highest transportation cost for S_2 is located at the right-end point. Therefore, the highest possible values of a and b which satisfy $u - p_B(a,b) - p_1(a,b) - t\,a \geq 0$ and $u - p_B(a) - p_2(a,b) - t\,b \geq 0$ are 7/20 and 3/20, respectively. The final outcomes are as follows:

$$
\begin{aligned}
&a^* = 7/20 \\
&b^* = 3/20 \\
&p_B^* = u - (9/20)t \\
&p_1^* = (1/10)t \qquad (3) \\
&p_2^* = (3/10)t.
\end{aligned}
$$

This equilibrium outcome satisfies the two conditions of d'Aspremont et al. (1979), hence this equilibrium exists. The monopolist will take *7/10* portion of the market and the rival firm has the remaining *3/10* of the market. Thus, the minimal differentiation principle is inappropriate and there exists an optimal degree of differentiation.

Now, let's consider the case of a quadratic transportation cost function. For any distance x, transportation costs are given by tx^2 and the demand functions are:

$$D_1 = a + \sqrt{\frac{u - p_B - p_1}{t}}, \qquad D_2 = b + \sqrt{\frac{u - p_B - p_2}{t}}. \tag{4}$$

For mathematical convenience, we assume that b is equal to zero without loss of generality. If $b=0$, then $a=0$ is the maximal differentiation and $a=1$ is the minimal differentiation. Since we want to show the optimal differentiation principle, we need to check whether $a \neq 0$ and $a \neq 1$.

The response function of firm 2, in this case, is: $p_2(p_B) = (2/3)(u-p_B)$. We also have the market size constraint, $D_1 + D_2 = 1$. The profit function, $\pi_1 = p_1 D_1 + p_B(D_1 + D_2)$ can be expressed as $\pi_1[p_1(p_B, p_2(p_B)), p_2(p_B), p_B; a]$. Recalling that all prices are decided by a differentiation choice, a, we take the derivative of π_1 with respect to a:[8]

$$\frac{d\pi_1}{da} = \frac{\partial \pi_1}{\partial a} + \frac{\partial \pi_1}{\partial p_B}\frac{\partial p_B}{\partial a} + \frac{\partial \pi_1}{\partial p_2}\frac{\partial p_2}{\partial p_B}\frac{\partial p_B}{\partial a} + \frac{\partial \pi_1}{\partial p_1}\left(\frac{\partial p_1}{\partial p_B} + \frac{\partial p_1}{\partial p_2}\frac{\partial p_2}{\partial p_B}\right)\frac{\partial p_B}{\partial a} \tag{5}$$

[8] We can substitute the reduced form price functions into the profit function. The profit will be expressed as a function of only a, explicitly. Then we can take the derivative of π_1 with respect to a more directly. However, the decomposition of the derivative as in equation (5) is more intuitive.

The first term is the direct effect of a change in a. The second term is the indirect effect of a change in a through p_B. The third term is an indirect effect of a change in a through p_2, and the last term is an indirect effect of a change in a through p_1. The second term is zero due to the envelope theorem. The third term is also zero because $D_1 + D_2 = 1$, so π_1 does not contain the p_2 term in the function. Therefore, equation (5) reduces to the equation with the first and last term.

The first term is what Tirole (1988) has called: "the market-share effect" which clearly has a positive sign. The last term is called "the strategic effect". Let's look at the sign of this effect part by part. First, we need to check the sign of $\partial\pi_1 / \partial p_1$. One may think this is zero by the envelope theorem because the monopolist sets p_1 and p_B to maximize π_1. However, the total market size constraint ($D_1+D_2=1$) makes it impossible for both prices to have internal solutions.

The monopolist's best strategy is setting p_B to make $\partial\pi_1 / \partial p_B$ equal zero and setting p_1 to satisfy $D_1+D_2=1$. Hence, $\partial\pi_1 / \partial p_1$ is positive. Now, consider the inside of the bracket. When there is a change in p_B, p_1 will be affected by two routes. If p_B increases, then p_1 decreases because the base good and supplemental good are complements and the monopolist has to set p_1 to satisfy the market size constraint. The increased p_B also lowers p_2, which makes the monopolist decrease competing price p_1 once again. Therefore, this has the negative sign. Finally, $\partial p_B / \partial a > 0$ is not difficult to see. If a increases from a small value, then the monopolist is able to charge higher prices on the base good because a consumer's transportation cost decreases. Therefore, the last term in equation (5) is negative.

We have shown that the first term is positive and the last term is negative. Now, which effect is larger? In d'Aspremont et al.'s (1979) paper, the strategic effect dominates the market share effect and there exists a tendency for 'maximal differentiation'. In our paper, the computations show that the market share effect dominates the strategic effect, i.e., $d\pi_1 / da > 0$. This looks like a result as the minimal differentiation principle instead of d'Aspremont et al.'s maximal differentiation. However, once again, we should note that $u - p_B(a) - p_1(a) - t(x-a)^2 \geq 0$ if a consumer located at x buys good 1 and $u - p_B(a) - p_2(a) - t(1-x)^2 \geq 0$ if a consumer located at x buys good 2. Therefore the optimal choice of a^*,is the highest possible value which satisfies these two inequalities. We can show that $a^* \in (0,1)$ (neither 0 nor 1). Therefore, we can claim the following proposition.

<*Proposition*> There exists a certain degree of product differentiation between two competing application software products when a base good monopolist produces one of which. Neither the minimal nor maximal differentiation is appropriate in this market category.

What makes out principle different from Hotelling's (1929) or d'Aspremont et al.'s (1979)? While Hotelling and d'Aspremont et al. consider one market with horizontal competition, we consider a base-supplemental goods market, a vertically related market. The difference arises since one of the competitors in the application software market is the base good monopolist. A change in product differentiation alters not only the profitability from the competing supplemental goods market but also the profitability from the monopolized base good market. Reducing the transportation cost (or transportation cost), enables the monopolist to derive higher surplus from consumers by charging a higher base good price, thus increasing the profit from the monopolized base good. Reduction of transportation cost is key to increasing the profit of the monopolist. This strategic effect does not occur in Hotelling's single market competition model. Obviously, neither minimal nor maximal differentiation minimizes the transportation cost. Our optimal product differentiation can minimize the transportation cost and increase the monopolist's profit.

4. CONCLUSION

We show that neither the minimal nor maximal differentiation principle is appropriate in two competing application software market. There exists an optimal differentiation in two competing supplemental products. The difference arises since one of the competitors of the application software market is a base good monopolist. A change in product differentiation alters not only the profitability from the competing application software market but also the profitability from the monopolized base good market. By reducing the transportation cost, the monopolist can charge a higher price on base good, thus increase the monopolized base good profit. This strategic effect does not occur in Hotelling's single market competition model.

We apply our analysis to the web browser market. Microsoft enters the web browser market that had been dominated by Netscape. While Microsoft's IE has a lot of common features with Netscape Navigator, in some details, Microsoft has chosen quite different technology and format from Netscape. Therefore, there exists a certain degree of differentiation between these two products and our model may explain this differentiation.

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APPENDIX: TECHNICAL PROOF OF THE PROPOSITION

As in equations (3), we have already shown the proposition is true when the transportation cost is linear. All we need to show is that the optimal choice a^* is inside the unit interval under quadratic transportation cost, i.e., $a^* \in (0,1)$. Since the consumer who incurs the highest transportation cost is located at the left-end point in equilibrium, we need to show $u - p_B(a) - p_1(a) - t\, a^2$ becomes negative as a approaches 1. Let $W(a) \equiv u - p_B(a) - p_1(a) - ta^2$. Since $p_B(a)$ and $p_1(a)$ are the functions of a, we can express $W(a)$ as a function of only a. Then $W(a) = (1/54)\ t\ [\ 108 + 21a^2 - 180a - 2aV + 3V + 6\sqrt{3}(a-1)\ (108+42a^2-144a-4aV+6V)^{1/2}$, where $V \equiv \sqrt{3}(30a^2-108a+81)^{1/2}$. It is easy to see that $W(a)$ is a continuous function of $a \in [0,1]$. Now, we find that $W(0) = (2-\sqrt{3})t/2 > 0$ and $W(1) = -(8/9)t < 0$. By the mean value theorem, there exists a value of $a^* \in (0,1)$ which makes $W(a^*)=0$. Therefore, the optimal product differentiation is neither minimal nor maximal.

Q.E.D.