E c o n o m i c s B u l l e t i n

Partial Compatibility and Vertical Differentiation

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Abstract

In this paper we construct a game-theoretic model to analyze firms¡¦ partial compatibility choices. The quality of a hybrid system depends on the minimum of the compatibility levels chosen by firms. We find that, depending on the investment cost, the compatibility level could be incompatibility or partial compatibility. When the investment cost is very small, firms¡¦ optimal compatibility levels are partial. If the investment cost is relatively large, then firms will choose incompatibility. These results offer an explanation for why firms do not produce components which are fully compatible with their rivals¡¦.

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1. Introduction

A “system” can be viewed as a composite good made up of components that are of little or no value separately to consumers. We often observe that components of a system have different terms of lives, e.g., printer and toner. This paper calls the component with a longer duration as the durable component and the component with a shorter duration as the non-durable component.

In the literature, there are many pioneering works including Farrell and Saloner (1986), Matutes and Regibeau (1988), Economides (1989), Chou and Shy (1990) utilizing different approaches to investigate firms’ compatibility decisions and related issues. The issues relating partial compatibility have not got much attention up until now, with Chou and Shy (1993) being the first to investigate partial compatibility. They defined a partial compatibility degree as the proportion of the software written for one hardware technology which can be used on the other hardware technology. de Palma et al. (1999) endogenized the compatibility degree and defined it as the proportion of consumers joined the same network who only used the other brand’s product.

Different from the above literature, this paper defines compatibility level from the viewpoint of quality. Although a hybrid system (a system made up of different brands’ components) can bring consumers utilities under compatibility, it is easy to observe that there are often some unexpected problems in using hybrid systems. This means that there is vertical differentiation between purebred (a system made up of components with the same brand) and hybrid systems. The quality difference between hybrid and purebred systems intuitively depends on the compatibility level between brands. The higher the compatible level is between brands, the smaller the quality difference will be between purebred and hybrid systems. From this point of view, compatibility level choices are equivalent to the quality choices of hybrid systems.

In this paper we consider a duopolistic market where firms produce the durable components and the non-durable components. The durable components bring some utilities for consumers. In contrast, the non-durable components alone are useless for consumers, but they can be used to upgrade the durable components. An example that fits the previous description is an all-in-one printer. An all-in-one printer can be used as a printer, a scanner, a fax machine, and a copier. Consumers can use it as a scanner and a sending-fax machine without a toner. A toner alone is useless for consumers, but it can be used to upgrade an all-in-one printer. We find that firms' optimal compatibility levels are partial when the investment cost is very small. If the investment cost is relatively large, firms will choose incompatibility. These results offer an explanation for why firms do not produce components which are fully compatible with their rivals' components.

The paper is organized as follows. We introduce the model in the second section. The third and fourth sections analyze the consumers' and firms' behaviors in the second and first periods, respectively. Section 5 investigates firms' optimal compatibility level choices. Section 6 concludes.

2. The Model

If firm $i(i=1,2)$ chooses its unilateral compatibility levels to be k_i $(0 \le k_i \le 1)$, the quality of the hybrid system is[1]

$$Q_h = kQ_p,$$

$$k = \min[k_1, k_2],$$

where Q_p and Q_h are the corresponding qualities of the purebred and hybrid systems respectively and k is the compatibility level between brands.

The quality of a hybrid system is determined by the minimum of the unilateral compatibility levels chosen by the firms. If any firm makes its components to be less compatible with its rival's components, then the compatibility level between brands and hence the quality of a hybrid system decrease.

Full compatibility occurs only upon both firms' agreements ($k = k_1 = k_2 = 1$), the quality of the hybrid system is the same as that of the purebred system. Another extreme case is that when one of the two firms uses a secret technology in producing components ($k_1 = 0$ or $k_2 = 0$), the components produced by the different firms cannot be used together. Incompatibility occurs. When $0 < \min[k_1, k_2] < 1$, the quality of the

[1] A similar assumption appeared in Economides (1999). The quality of a composite good is assumed to be the minimum of the qualities of the components when the components are produced by different firms.

hybrid system is positive, but smaller than that of the purebred one, and this is partial compatibility.

The quality of a purebred system is assumed to be 1 in this paper and the quality of the hybrid system is therefore equal to the compatibility level between brands.

Durable component 1 and durable component 2 reside at points 0 and 1, respectively. Consumers (in the first period) are uniformly distributed on the interval [0,1] with density 1. Let t denote consumers' preferences to durable components. A consumer located at t has the following utility function for durable components.

$$u_1(t) = \begin{cases} u_0 - p_d^1 - t & \text{if he purchases durable component 1,} \\ u_0 - p_d^2 - (1-t) & \text{if he purchases durable component 2.} \end{cases} \quad (1)$$

Here, u_0 is the basic utility of using a durable component, and p_d^i is the price of durable component i. Besides, u_0 is assumed to be sufficiently large such that the market of the durable component is covered.

In the second period, consumers decide whether to buy a non-durable component to upgrade their durable components. Consumers (in the second period) are heterogeneous in their valuations on the qualities of upgraded systems. Let r denote the index of such a consumer's valuation. We assume that r is uniformly distributed on the interval [0,1] with density 1. A consumer (in the second period) indexed with r gains the following additional utility when upgrading his durable component.

$$u_2(r) = r\theta - p_{nd}, \quad (2)$$

where θ ($\theta = 1$ for a purebred system; $\theta = k \le 1$ for a hybrid system) denote the quality parameter and p_{nd} is the price of the non-durable component.

We assume that firms (in the second period) can distinguish consumers into groups of durable component 1 and durable component 2 owners so that they are able to exercise price discrimination.[2] Under this assumption, firms are motivated to offer a lower non-durable component price so as to promote the acceptance of hybrid systems.

There is no production cost in producing the durable component and the non-durable

[2] Because two symmetric firms will set the same non-durable component price and a hybrid system's quality can not be higher than that of the purebred system, hybrid systems could be purchased only if firms

component. Firms incur investment cost, fk, if they choose k as their unilateral compatibility levels, where $f > 0$.

The game proceeds in two periods. In the first period, firms decide their compatibility levels first and then price their durable components. Consumers purchase durable components finally. In the second period, firms price their non-durable components first and then consumers purchase the non-durable components. In the following we will use backward induction to derive the subgame perfect equilibrium.

3. Consumers' and Firms' Optimal Choices in the Second Period

Since the compatibility level is determined as the lower unilateral compatibility level chosen by one of the two firms and a higher unilateral compatibility level would result in a higher investment cost, the two firms choose the same unilateral compatibility level, so that $k = k_1 = k_2$.

Given the compatibility level is k, the second period utility function of a consumer who owns durable component 1 in the first period is

$$U = \max[r - p_{nd}^1, rk - (p_{nd}^2 - s_2), 0],$$

where p_{nd}^i (i=1,2) is the price of the non-durable components produced by firm i and s_2 is firm 2's special discount for the consumers who own durable component 1.

According to the utility function, the consumers owning durable component 1 with $r \geq (p_{nd}^1 - p_{nd}^2 + s_2)/(1-k)$ will buy non-durable component 1 in the second period (let us call such consumers the loyal consumers), consumers owning durable component 1 with $(p_{nd}^2 - s_2)/k \leq r < (p_{nd}^1 - p_{nd}^2 + s_2)/(1-k)$ will buy non-durable component 2 (let us call such consumers the switching consumers), and consumers owning durable component 1 with $r < (p_{nd}^2 - s_2)/k$ do not buy a non-durable component. Similarly, the loyal (switching) consumers of firm 2 have quality valuations that satisfy $r \geq (p_{nd}^2 - p_{nd}^1 + s_1)/(1-k)$ ($r \geq (p_{nd}^1 - s_1)/k$), where s_1 is firm 1's special discount for the consumers who own durable component 2.

offer consumers special discounts.

From the previous analysis, given that firm 1's market share in the first period is σ, firms' second period profits functions are:

$$\pi_1 = \sigma[p_{nd}^1(1-\frac{p_{nd}^1 - p_{nd}^2 + s_2}{1-k})] + (1-\sigma)[(p_{nd}^1 - s_1)(\frac{p_{nd}^2 - p_{nd}^1 + s_1}{1-k} - \frac{p_{nd}^1 - s_1}{k})],$$

$$\pi_2 = (1-\sigma)[p_{nd}^2(1-\frac{p_{nd}^2 - p_{nd}^1 + s_1}{1-k})] + \sigma[(p_{nd}^2 - s_2)(\frac{p_{nd}^1 - p_{nd}^2 + s_2}{1-k} - \frac{p_{nd}^2 - s_2}{k})].$$

Solving the first-order conditions of the above profit functions yield the firms' optimal pricing stated as follows.

***Proposition* 1** *Given that the compatibility level is* k, *a firm's optimal non-durable component prices are as follows.*

(1) *The price of the non-durable component to the loyal consumers is* $2(1-k)/(4-k)$ *;*

(2) *The price of the non-durable component to the switching consumers is* $k(1-k)/(4-k)$.

When the compatibility level is higher, the non-durable component price competition becomes more severe, and the non-durable component price to the loyal consumers decreases.

From [Proposition 1], firms' optimal pricing under full compatibility and incompatibility are also quite clear. Firstly, the non-durable component price is 0 under full compatibility. Because the two brands' non-durable components are homogenous under this situation, a perfect Bertrand competition occurs. Secondly, the non-durable component price is $1/2$ under incompatibility. This means that firms would charge a monopoly price to their loyal consumers if the rival's non-durable component cannot be used together with its durable component.

By [Proposition 1], firms' second period profit functions are:

$$\pi_1^2 = \frac{4\sigma(1-k)}{(4-k)^2} + \frac{k(1-k)(1-\sigma)}{(4-k)^2}, \tag{3.1}$$

$$\pi_2^2 = \frac{4(1-\sigma)(1-k)}{(4-k)^2} + \frac{k(1-k)\sigma}{(4-k)^2}. \tag{3.2}$$

4. Consumers' and Firms' Optimal Choices in the First Period

Note that firms offer the same price scheme in the second period (as stated in [Proposition 1]). A consumer is hence going to face the same scenario in the second period no matter which brand's durable component he buys. This implies that consumers' purchase decisions of durable components are independent of the (expected) second period outcome. The first period utility function of a consumer located at t is

$$U = \max[u_o - p_d^1 - t, u_0 - p_d^2 - (1-t)].$$

Firm 1's market share in the first period is therefore $\sigma = (1 - p_d^1 + p_d^2)/2$.

Substitute the market share into equation (3.1) and (3.2), the firms' second period profit functions are:

$$\Pi_1 = \frac{p_d^1(1 - p_d^1 + p_d^2)}{2} + \frac{k(1-k)(1 + p_d^1 - p_d^2)}{2(4-k)^2} + \frac{2(1-k)(1 - p_d^1 + p_d^2)}{(4-k)^2} - fk, \qquad (4.1)$$

$$\Pi_2 = \frac{p_d^2(1 - p_d^2 + p_d^1)}{2} + \frac{k(1-k)(1 + p_d^2 - p_d^1)}{2(4-k)^2} + \frac{2(1-k)(1 - p_d^2 + p_d^1)}{(4-k)^2} - fk. \qquad (4.2)$$

Solving the first-order conditions of the profit functions simultaneously, the prices of the durable components are

$$p_d^1 = p_d^2 = \frac{3}{(4-k)}. \qquad (5)$$

Durable component prices increase in compatibility level. Because the non-durable component price competition becomes more severe, the profits from selling the non-durable component to the loyal consumers decrease in compatibility level. This reduces a firm's incentive to strive for higher market share in the first period.

5. Firms' Compatibility Decisions

Inserting the optimal durable component prices into (4.1) and (4.2), firms' profit functions are:

$$\Pi_1(f,k) = \Pi_2(f,k) = \frac{16 - 6k - k^2}{2(4-k)^2} - fk.$$

Solving the first-order conditions of the above profit function yields firms' optimal compatibility level choices stated as [Proposition 2].

***Proposition* 2** (1) *If* f *is almost zero, the firms' optimal compatibility level choices are nearly* $4/7$;

(2) *If* $f > 1/16$, *the firms choose incompatibility.*

From the previous analysis, raising the compatibility level results in a softer durable component price competition and a tougher non-durable component price competition. Full compatibility result in the highest durable component price,[3] but there is, nevertheless, perfect Bertrand competition in the non-durable component market. On the other hand, incompatibility will help firms to lock-in those consumers who purchased their durable component in the first period, but the toughest durable component price competition would occur under this situation. Firms face the above tradeoff as they make compatibility level decisions. [Proposition 2] indicates that firms' optimal compatibility levels are partial when the investment cost is very small. This implies that choosing full compatibility is always unprofitable for firms. If the investment cost is relatively large, firms will choose incompatibility. These results offer an explanation for why firms do not produce components which are fully compatible with their rivals' components.

6. Conclusion

This paper proposes a model to analyze firms' compatibility level choices in the markets of durable components and non-durable components.

We find that firms' optimal compatibility levels are partial when the investment cost is very small. If the investment cost is relatively large, then firms will choose incompatibility. These results offer an explanation for why firms do not produce components which are fully compatible with their rivals' components.

[3] From equation (5), the price of the durable component is the highest when firms choose full compatibility.

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