Quality-improving R&D and merger policy: Technological proximity and technological alienation

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Abstract

This paper combines the equality-improving R&D model and the technological spillover function with the consept of technological distance, and provides examinations for horizontal merger policy for duopolistic market with equality-improving R&D. As main results, we have three points. First, when the degree of product differentiation is sufficiently small, then the criterion under Cournot duopoly is stricter than that under Bertrand duopoly. By contrast, when the degree of product differentiation is moderate or large, then the criterion under Bertrand duopoly is stricter than that under Cournot duopoly. Second, when the technological distance is small sufficiently, then, in both duopoly cases, the merger between two firms should be invariably allowable. Third, when the degree of product differentiation is sufficiently small, then, in both duopoly cases, the merger should be invariably allowable, irrespective of technological distance.

JEL classification: D43; K21; L40; O32

Keywords: Product R&D; Cournot Duopoly; Merger policy; Technological proximity; Technological alienation; Spillover effect.

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1 Introduction

In recent years, many consumers tend to pay a higher price for higher quality products than for lower ones. Many firms develop high-quality goods to survive market competition. As examples of goods produced from product R&D (quality-improving R&D), one might suggest markets for LED lights, electric automobiles, advanced safety vehicles, home air-conditioners, refrigerators, digital cameras, water purifiers, organic soap, detergents, anti-aging cosmetics, foods for specified health use (e.g., high-catechin beverages), and rare sugar (e.g., D-Psicose). Studies of product R&D in oligopolistic markets have been made by Motta (1993), Symeonidis (2003), and Yakita and Yamauchi (2011).

On the other hand, to survive the fierce market competition, firms cooperate with their rivals in R&D and production stages, and also merges with rivals. In the existing literature, many studies assumes that the values of spillover effect and product differentiation are exogenous. However, Zhao (2015) and Flach and Irlacher (2018) proposed the convincing definition of technological spillover that is linked with the degree of product differentiation. Thus, we have the fundamantal question for merger policy. When should the government allow the duopolistic firms with quality-improving R&D horizontal merger?

To examine that point, this paper combines the equality-improving R&D model developed by Symeonidis (2003) and by Yakita and Yamauchi (2011) and the spillover effect with the new consept of technological distance proposed by Zhao (2015) and Flach and Irlacher (2018), and provides examinations for merger policy for duopolistic market with equality-improving R&D.

This paper is organized as follows. The next section introduces the model. Section 3 presents solutions for the two-stage game under three alternative scenarios presented in Table 1. In Section 4, in the presence of product R&D and new spillover function proposed by Zhao (2015) and Flach and Irlacher (2018), we investigate the two comparisons: "Cournot duopoly v.s. merger case" and "Bertrand duopoly v.s. merger case". The final section presents policy implications and conclusions.

Table 1: Three alternative scenarios.

Scenarios	R&D stage	Production stage
Differentiated Cournot duopoly (case C)	Competition	Competition
Differentiated Bertrand duopoly (case B)	Competition	Competition
Full collusion (case M)	Collusion	Collusion

2 The model

We combine the product R&D model and the consept of technological property formulated by Zhao (2015). We specifically examine symmetric equilibrium.

2.1 Market and consumer

First, we consider an industry comprising two firms with the same cost structure and R&D technology, firm i and firm j, engaging in quantity competition. Then, $x_i(>0)$ denotes the quantity of variety i. Production costs are $C_i(x_i) = cx_i, (0 < c < 1)$.

We assume $S(>0)$ identical individuals exist in the market. Each consumer's income is captured by $Y(>0)$. The price of variety i is given as $p_i(>0)$. Then, $M = Y - (p_i x_i + p_j x_j)$ represents expenditure on outside goods. The utility function of each is given as:

$$U(x_i, x_j, M) = x_i + x_j - \frac{x_i^2}{u_i^2} - \frac{x_j^2}{u_j^2} - 2\sigma \frac{x_i}{u_i}\frac{x_j}{u_j} + M.$$

Therein, u_i $(i, j = 1, 2; i \neq j)$ represents the quality of variety i. Higher u_i increases consumers' willingness to pay for the firm i product, although it requires R&D expenditures. The exogenous parameter $\sigma \in (0, 1)$ denotes the degree of horizontal product differentiation between two varieties. As $\sigma \to 0$ (1), then the goods become independent (perfect substitutes) when $u_i = u_j$. We assume that an individual consumer spends only a small part of her income on the industry's product. Under that assumption, an interior solution of utility maximization is ensured. In addition, that assumption enables us to ignore the income effects on the industry examined here and to apply partial-equilibrium analysis.

The inverse demand of each consumer for variety i is derived as

$$p_i = 1 - \frac{2x_i}{u_i^2} - \frac{2\sigma}{u_i}\frac{x_j}{u_j} \ (i, j = 1, 2; i \neq j), \tag{1}$$

for the region of quantity spaces in which prices are positive.

The direct demand for variety i is

$$x_i = \left(\frac{u_i(1-p_i) - \sigma u_j(1-p_j)}{2(1-\sigma)^2} \right) u_i, \tag{2}$$

for the region of price spaces in which quantities are positive. It is readily apparent that $dx_i/du_i > 0, dx_i/dp_i < 0, dx_i/du_j < 0$, and $dx_i/dp_j > 0$.

The quality level of variety i depends on the level of R&D activities. The relation between the quality level and R&D expenditures is specialized as

$$u_i = \alpha \Big(R_i^{1/4} + \rho R_j^{1/4} \Big), \tag{3}$$

where $R_i(>0)$ represents firm i's R&D expenditures. Technological spillover effects are captured by $\rho \in [0, 1]$. A positive constant $\alpha(>0)$ is the efficiency parameter of R&D cost.

2.2 Technological spillover

As a novel feature of this model, we introduce the concepts of technological proximity and technological alienation into the product R&D model with merger policy. In line with Zhao (2015, equation (6)) and Flach and Irlacher (2018, equation (28)) that formulates those consepts, the relationship between the spillover parameter and the degree of product differentiation is defined by the following hypothesis.

$$\rho(\sigma, h) \equiv \sigma^h, \ h > 0. \tag{4}$$

Therein, h determines both the sensibility of the R&D spillover to the degree of product differentiation and the degree of spillovers for a given value of differentiation (see Zhao (2015)). More precisely, $h(>0)$ is the parameter that denotes technological distance between two firms. As illustrated in Figure 1, when $0 < h < 1$, that presents technological proximity. In contrast, when $h > 1$, that means technological alienation. As h increases, the technological difference between two firms expands. In contrast, when h is small enough, then each firm has a similar produaction technology each other, and locates in a nearby place (e.g., identical industrial zone). As pointed out by Zhao (2015) and Flach and Irlacher (2018), equation (4) describes that firms share similar technologies and production processes, and one firm can recieve more positive externality from the rival's R&D effort if products are less differentiated.

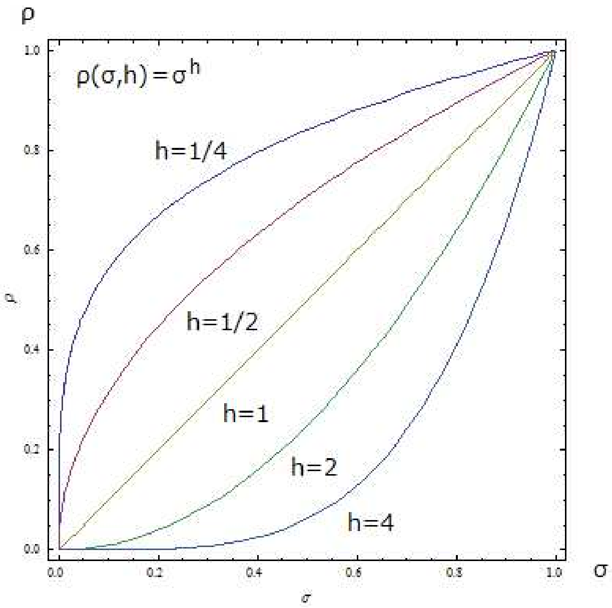

Figure 1: Spillover effect under Hypothesis 1.

2.3 Profit, social welfare, and timing of the game

Firm i's profit from the sale of products is expressed as $\pi_i = S(p_i - c)x_i$. Additionally, firm i's net profit is $\Pi_i \equiv \pi_i - R_i$. Consumer surplus is denoted as $CS \equiv S\{U(x_i, x_j, M) - U(0, 0, M) - p_i x_i - p_j x_j\}$. Social welfare W is defined as $W \equiv CS + \Pi_i + \Pi_j$.

In the case of differentiated Cournot duopoly, the time structure of this model is the following.

Stage 1: Firm i determines the quality level u_i simultaneously.
Stage 2: Firm i determines its own output level x_i simultaneously.

On the other hand, the time structure of differentiated Bertrand duopoly case is the following.

Stage 1: Firm i determines the quality level u_i simultaneously.
Stage 2: Firm i determines the price p_i simultaneously.

3 Equilibrium outcomes

As analyzed by d'Aspremont and Jacquemin(1988) and Zhao (2015), full collusion in all stages is considered as the monopoly case after merger. Furthermore, each firm always has some private incentives for merger. We investigate the three scenarios shown in Table 1. The solution concept that is used is the subgame-perfect Nash equilibrium (SPNE). The two-stage game is solved by backward induction. Consequently, we summarize the existence of SPNE as Lemma 1.

Lemma 1. *Unique equilibrium outcomes exist for each of these three cases.*

4 Main Results: Two duopoly cases versus full collusion

We investigate when full collusion is superior to full competition.

4.1 Consumer surplus

Next, we compare consumer surplus among three cases. The results are obtained as follows.

$$CS_{\mathrm{C}} - CS_{\mathrm{M}} = \frac{S^2\alpha^4(1-c)^4(1+\sigma^h)^3 C_3(\sigma,h)}{128(1+\sigma)^2(2+\sigma)^4(2-\sigma)}, \tag{5}$$

$$CS_{\mathrm{B}} - CS_{\mathrm{M}} = \frac{S^2\alpha^4(1-c)^4(1+\sigma^h)^3 B_3(\sigma,h)}{128(1+\sigma)^2(2-\sigma)^4(2+\sigma)}, \tag{6}$$

where $C_3(\sigma,h) \equiv 16(1+\sigma)^3(2-\sigma(\sigma^h)) - (2+\sigma)^4(2-\sigma)(1+\sigma^h)$ and $B_3(\sigma,h) \equiv 16(2-\sigma(\sigma^h)-\sigma^2) - (2-\sigma)^4(2+\sigma)(1+\sigma^h)$. Results of these comparisons are summarized as Proposition 1.

Proposition 1. *It holds that*

Region III_1 $CS_{\mathrm{C}} > CS_{\mathrm{M}}$ *and* $CS_{\mathrm{B}} > CS_{\mathrm{M}}$,
Region III_2 $CS_{\mathrm{C}} < CS_{\mathrm{M}}$ *and* $CS_{\mathrm{B}} > CS_{\mathrm{M}}$,
Region III_3 $CS_{\mathrm{C}} < CS_{\mathrm{M}}$ *and* $CS_{\mathrm{B}} < CS_{\mathrm{M}}$,
Region III_4 $CS_{\mathrm{C}} > CS_{\mathrm{M}}$ *and* $CS_{\mathrm{B}} < CS_{\mathrm{M}}$.

Proof: See Figure 2. □

When we assume that the government uses consumer surplus as the merger criterion, then we obtain the following three points. First, when the degree of product differentiation is small sufficiently, then the criterion under Cournot duopoly (case C) is stricter than that under Bertrand duopoly (case B). By contrast, when the degree of product differentiation is moderate or large, then the criterion under case B is stricter than that under case C. Second, when the parameter of technological distance is small enough, then, in both cases, the merger between two firms should be invariablely allowable. Third, when the degree of product differentiation is small sufficiently, then, in both cases, the merger should be invariablely allowable, irrespective of the parameter of technological distance.

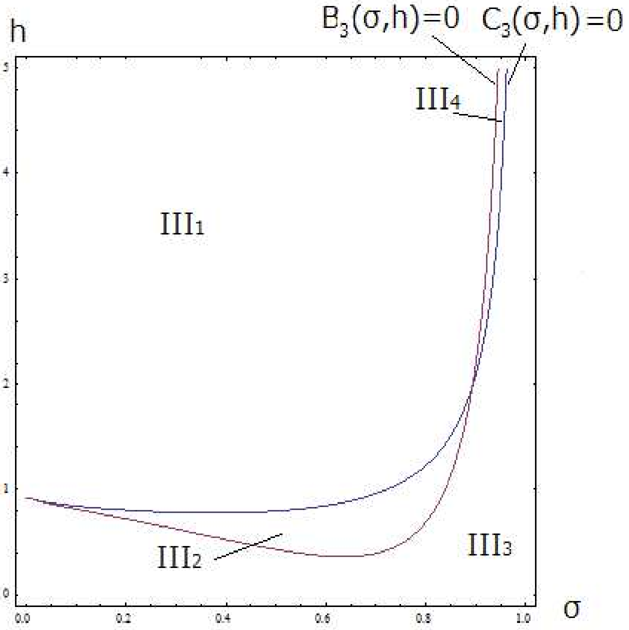

Figure 2: Consumer surplus.

4.2 Social welfare

We compare the three equilibrium values of social welfare. After some manupilation, the results are derived as shown below.

$$W_{\mathrm{C}} - W_{\mathrm{M}} = \frac{S^2\alpha^4(1-c)^4(1+\sigma^h)^2 C_4(\sigma,h)}{64(1+\sigma)^2(2+\sigma)^4(2-\sigma)^2}, \quad (7)$$

$$W_{\mathrm{B}} - W_{\mathrm{M}} = \frac{S^2\alpha^4(1-c)^4(1+\sigma^h)^2 B_4(\sigma,h)}{64(1+\sigma)^2(2-\sigma)^4(2+\sigma)^2}, \quad (8)$$

where $C_4(\sigma,h) \equiv 8(1+\sigma)^2(2-\sigma(\sigma^h))[(1+\sigma^h)(2-\sigma)(3+\sigma)-(2-\sigma(\sigma^h))]-(2+\sigma)^4(2-\sigma)^2(2-\sigma(\sigma^h))$ and $B_4(\sigma,h) \equiv 8(2-\sigma(\sigma^h)-\sigma^2)[4-\sigma-\sigma^2+2\sigma^h(3-\sigma^2)]-(2-\sigma)^4(2+\sigma)^2(1+\sigma^h)$. Results of these comparisons are summarized as Proposition 2.

Proposition 2. *It holds that*

Region IV_1 $\quad W_{\mathrm{C}} > W_{\mathrm{M}}$ *and* $W_{\mathrm{B}} > W_{\mathrm{M}}$,
Region IV_2 $\quad W_{\mathrm{C}} < W_{\mathrm{M}}$ *and* $W_{\mathrm{B}} > W_{\mathrm{M}}$,
Region IV_3 $\quad W_{\mathrm{C}} < W_{\mathrm{M}}$ *and* $W_{\mathrm{B}} < W_{\mathrm{M}}$,
Region IV_4 $\quad W_{\mathrm{C}} > W_{\mathrm{M}}$ *and* $W_{\mathrm{B}} < W_{\mathrm{M}}$.

Proof: See Figure 3. □

We assume that the government uses social welfare as the merger criterion. Then, Proposition 2 states the following three points. First, similarly to the discussion of consumer surplus criterion, when the degree of product differentiation is small sufficiently, then the criterion under case C is stricter than that under case B. By contrast, when the degree of product differentiation is moderate or large, then the

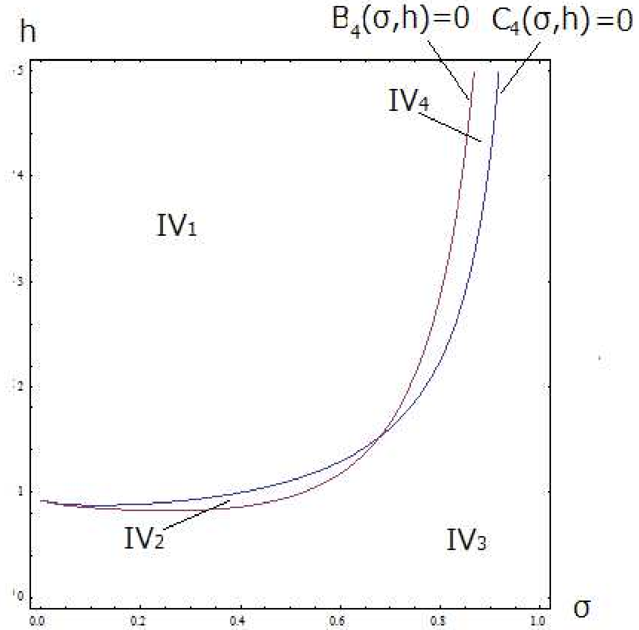

Figure 3: Social welfare.

criterion under case B is stricter than that under case C. Second, when the parameter of technological distance is small enough, then, in both cases, the merger between two firms should be always allowable. Third, when the degree of product differentiation is sufficiently small, then, in both cases, the merger should be always allowable, irrespective of the parameter of technological distance.

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