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Abstract

This study investigates the relationship between market transparency and economic welfare in a mixed duopoly in which a welfare-maximizing public firm competes with a profit-maximizing private firm. We find that the private firm's market share, consumer surplus, and welfare increase with market transparency. Further, the relationship between the private firm's profit and market transparency has an inverted U shape. This result suggests that profit-maximizing firms may have incentives to improve market transparency, especially when the degree of market transparency is low, which is in sharp contrast to the results under a private duopoly.

Keywords: market transparency, mixed oligopoly, product differentiation, unconstrained Hotelling model, profit-enhancing market transparency, crowding out

JEL classification: L13; L15; L33; R32

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1. Introduction

We investigate how consumer-side market transparency affects market performance in a mixed duopoly. One is a state-owned public firm that maximizes welfare, and the other is a private firm that maximizes profits. To this end, we use a location-price model with a linear city (Hotelling line) and endogenize the degree of product differentiation and prices. We consider the effects of market transparency on firms' locations and prices, consumer surplus, welfare, and private firms' profits.

We find that a decrease in market transparency shifts the public (private) firm's location toward the center (edge) of the linear city, which leads to a location choice distortion. Consequently, the private firm's market share, consumer surplus, and economic welfare increase with market transparency. However, an increase in market transparency lowers the private firm's price and increases its market share; thus, the effect of market transparency on the private firm's profit is ambiguous. Specifically, we demonstrate that the relationship between a private firm's profit and market transparency is non-monotonic (inverted U-shaped relationship) in a mixed duopoly. Notably, this non-monotonic relationship does not appear if firms are profit maximizers in a private oligopoly (Schultz, 2004), suggesting an important implication from an antitrust perspective. Our results suggest that profit-maximizing private firms may have an incentive to improve market transparency in a mixed duopoly, which is not the case in a private duopoly.[1]

There are two streams of related research. The first refers to market transparency. Since the seminal work of Varian (1980), the literature on public economics and industrial organization has intensively discussed how market transparency affects welfare and competition structure. Market transparency has attracted broad attention from the viewpoint of public policy, especially competition and consumer protection (Gu and Hehenkamp, 2014; Gu and Wenzel, 2011, 2012; Schultz, 2004, 2005, 2009, 2017). The price system is complex in

[1] The Japanese electricity and gas market is a mixed oligopoly for which the comparison of fees among firms is difficult because the fee system is complicated. In this sense, market transparency may be low. Enerchange Ltd. runs a platform that suggests the best electric or gas company for each consumer, depending on several consumer-specific conditions, improving market transparency. Several electric and gas companies, both public and private firms, commit to and financially support Enerchange Ltd. This suggests that even private firms have an incentive to improve market transparency. Conversely, the Japanese gasoline retail market is a private oligopoly. GOGO Labs Inc. provides a similar service in the gasoline retail market, and there is no significant financial commitment by gasoline companies. Our results explain these facts adequately.

many markets. Thus, for consumers, firms' prices and product positions may not be transparent, which is why discussing market transparency is significant.

Schultz (2004) incorporates market transparency into a location-price model with the unconstrained Hotelling line formulated by Tabuchi and Thisse (1995) and Lambertini (1997). Schultz (2004) shows that an improvement in market transparency reduces the degree of product differentiation and private firms' profits but improves economic welfare and consumer surplus. Schultz (2009) further investigates a free-entry market, and finds that an improvement in market transparency reduces the number of entering firms and improves consumer surplus if the number of firms is greater than or equal to two. Conversely, Gu and Hehenkamp (2014) and Gu and Wenzel (2011, 2012) demonstrate that an increase in market transparency may reduce welfare under plausible conditions because it distorts firms' entry decisions. Schultz (2017) states that increasing (decreasing) transparency on the producer (consumer) side facilitates collusion. However, all these studies investigate private oligopolies, in which all firms are profit maximizers. We deviate from these discussions by investigating a mixed duopoly in which one of the players is a welfare maximizer.

The second research stream refers to mixed oligopolies. Although the privatization of state-owned public enterprises has been observed globally, many public enterprises owned by the public sector remain active, and a considerable number of these public enterprises compete with private enterprises in numerous industries.[2] Public enterprises may affect private enterprises' product positioning and pricing strategies. This topic has been extensively discussed since Cremer et al. (1991).

Specifically, Cremer et al. (1991) investigate a location-price model on the Hotelling line, and show that the equilibrium location pattern is optimal for welfare in a mixed duopoly. Matsumura and Matsushima (2004) confirm that this result is robust to any exogenous cost differences between public and private firms. They endogenize the cost structure by introducing R&D competition and show that a mixed duopoly distorts R&D competition and yields welfare loss. Lu (2006) discusses the conditions for the existence of pure strategy equilibrium. Inoue et

[2] The literature on mixed oligopolies is rich and diverse. See Cho et al. (2022), Xu and Matsumura (2022), Yang and Huang (2023), and the papers cited therein.

al. (2009) find that multiple equilibrium location patterns exist if a public firm is owned by the local government. Ogawa and Sanjo (2011) extend their analysis to investigate the effect of market integration. Moreover, Li and Zhang (2011) formulate a model in which a public and a private firm enter a market sequentially over an infinite time horizon. Kitahara and Matsumura (2013) and Matsumura and Tomaru (2015) show that the price-dependent demand and shadow costs of public funds yield distortions in location choices, respectively. Furthermore, Zhang and Li (2013) investigate endogenous timing in the presence of demand uncertainty. Additionally, Ma et al. (2021) introduce a costly product differentiation. However, no studies have hitherto investigated market transparency in mixed oligopolies.

The remainder of this paper is organized as follows. Section 2 describes the model formulation, and Section 3 examines the equilibrium outcomes. Subsequently, Section 4 presents the main results. Finally, Section 5 concludes the study.

2. The model

We consider a Hotelling model with a unit-length line in a mixed duopoly. Firm 0 is a public firm that maximizes welfare and firm 1 is a private firm that maximizes its profits. We assume that both firms have a common constant marginal cost normalized to zero. Suppose firm i $(i = 0, 1)$ is located at point l_i. Without loss of generality, we assume $l_0 \leq l_1$. A consumer living at $z \in [0, 1]$ incurs transportation cost $t(l_i - z)^2$ when purchasing a product from firm i. Parameter $t > 0$ can be interpreted as a measure of the intensity of production differentiation. Each consumer derives a surplus from consumption (gross price and transportation costs) equal to s. We assume that s is sufficiently large such that every consumer consumes one unit of the product.[3]

Following Schulz (2004), we assume two types of consumers: informed and uninformed. Informed consumers observe firms' locations and prices and choose whether to purchase products from firms 0 or 1. Uninformed consumers do not observe firms' locations and prices and choose whether to purchase a product based on expectations. Let φ be the fraction of

[3] The model formulation is the same as in Schultz (2004), except for firms' payoff function. Following Schultz (2004), we allow firms to locate outside the linear city. In other words, we adopt the unconstrained Hotelling model formulated by Tabuchi and Thisse (1995) and Lambertini (1997). We briefly discuss the constrained Hotelling model in which $l_i \in [0, 1]$ in Proposition 2 at the end of Section 4.

informed consumers, while $(1-\varphi)$ of them are uninformed. Parameter $\varphi \in (0,1]$ denotes the degree of market transparency. The higher φ is, the more transparent is the market.

For an informed consumer living at $x = \frac{l_0+l_1}{2} + \frac{p_1-p_0}{2t(l_1-l_0)}$, the total cost of buying from either firm is the same. For an uninformed consumer living at $y = \frac{l_0^E+l_1^E}{2} + \frac{p_1^E-p_0^E}{2t(l_1^E-l_0^E)}$, the total cost of buying from either firm is the same, with superscript E denoting the expectation. Following the literature, such as Schulz (2004), we assume that uninformed consumers rationally expect firms' choices. Thus, the demand of firm 0, D_0, and that of firm 1, D_1, are given, respectively, by:

$$D_0 = \varphi x + (1-\varphi)y,$$
$$D_1 = 1 - D_0. \quad (1)$$

Welfare, W, is given by:

$$W = s - t[\varphi(\int_0^x (z-l_0)^2 dz + \int_x^1 (z-l_1)^2 dz) + (1-\varphi)(\int_0^y (z-l_0)^2 dz + \int_y^1 (z-l_1)^2 dz)]. \quad (2)$$

The profit of firm i $(i = 0, 1)$ is:

$$\pi_i = p_i D_i. \quad (3)$$

The game proceeds as follows. In the first stage, each firm i $(i = 0, 1)$ chooses location l_i simultaneously. For expositional simplicity, we assume that the two firms choose different locations and that $l_0 \leq l_1$. In the second stage, each firm i $(i = 0, 1)$ chooses price $p_i \in [0, \infty)$ simultaneously. We use the subgame perfect Nash equilibrium as the equilibrium concept. Thus, we solve the game using backward induction.

3. Equilibrium analysis

3.1. Price competition

We first discuss the second-stage subgame in which firms' locations are given exogenously. Firm 0 (1) chooses p_0 (p_1) to maximize welfare (profit), given y, l_0, l_1, and p_1 (p_0). The first-order conditions are as follows:[4]

$$\frac{\partial W}{\partial p_0} = \frac{\phi(p_1-p_0)}{2t(l_1-l_0)},$$

[4] All second-order conditions are satisfied in this study.

$$\frac{\partial \pi_1}{\partial p_1} = \frac{t(l_1-l_0)(2(1-y)+\phi(2y-l_0-l_1))+\phi(p_0-2p_1)}{2t(l_1-l_0)}. \quad (4)$$

Let R_0 (R_1) be the reaction function of firm 0 (1) in the second stage.

$$R_0 = p_0(p_1) = p_1,$$

$$R_1 = p_1(p_0) = \frac{t(l_1-l_0)(2(1-y)+\phi(2y-l_0-l_1))}{2\phi} + \frac{1}{2}p_0. \quad (5)$$

From (5), we observe that an increase in p_1 (p_0) increases p_0 (p_1)—the strategies in the second stage are strategic complements. Additionally, firm 0's price is independent of ϕ and y, whereas firm 1's price decreases with ϕ and y. Firm 0 tries to choose the same price as firm 1 because this pricing strategy minimizes transport costs and, thus, maximizes welfare.

The common equilibrium price in the second stage is:

$$p_i = \frac{t(l_1-l_0)(2(1-y)+\phi(2y-l_0-l_1))}{\phi}, \text{ where } i = 0, 1. \quad (6)$$

The resulting profit of firm 1 and welfare are, respectively:

$$\pi_1 = \frac{t(l_1-l_0)(2(1-y)+\phi(2y-l_0-l_1))^2}{2\phi},$$

$$W = s - \frac{t(4(1-3y(y-l_0)l_0-3(1-y)(1+y-l_1)l_1)-3\phi(2y-l_0-l_1)^2(l_1-l_0))}{12}. \quad (7)$$

3.2. Location choice

In the first stage, firm 0 (1) chooses l_0 (l_1) to maximize welfare (profit) in (7). The first-order conditions are as follows:

$$\frac{\partial W}{\partial l_0} = \frac{t(4y(y-2l_0)-\phi(2y-l_0-l_1)(2y-3l_0+l_1))}{4} = 0,$$

$$\frac{\partial \pi_1}{\partial l_1} = \frac{t(2(1-y)+\phi(2y+l_0-3l_1))(2(1-y)+\phi(2y-l_0-l_1))}{2\phi} = 0. \quad (8)$$

We have the following reaction function for firm *i* in the first stage:

$$l_0(l_1) = \frac{2\sqrt{y^2(4-5\phi+\phi^2)+\phi l_1(2y-2y\phi+\phi l_1)}-4y(1-\phi)-\phi l_1}{3\phi},$$

$$l_1(l_0) = \frac{2(1-y+y\phi)}{3\phi} + \frac{1}{3}l_0. \quad (9)$$

From (9), we have the following locations:

$$l_0 = \frac{3\sqrt{1+8y^2(1-\phi)}-(1+8y(1-\phi))}{8\phi} \text{ and } l_1 = \frac{\sqrt{1+8y^2(1-\phi)}+(5-8y(1-\phi))}{8\phi}. \quad (10)$$

3.3. Rational expectation

Finally, we derive equilibrium y. Owing to the rational expectation assumption, $p_0 = p_0^E$,

$p_1 = p_1^E,\ l_0 = l_0^E,\ l_1 = l_1^E$, and $y = \frac{l_0^E + l_1^E}{2} + \frac{p_1^E - p_0^E}{2t(l_1^E - l_0^E)}$ must hold. Substituting the locations in (10) and the resulting prices into $y = \frac{l_0 + l_1}{2} + \frac{p_1 - p_0}{2t(l_1 - l_0)}$, we obtain $y = \frac{1}{1+\phi}$. Subsequently, the two firms' equilibrium locations are:

$$l_0^* = \frac{1}{2(1+\phi)} \text{ and } l_1^* = \frac{3}{2(1+\phi)}, \tag{11}$$

where superscript $*$ denotes the equilibrium outcomes. From (11), we obtain the following result.

Lemma 1.

(i). $l_0^* < \frac{1}{2}$ and l_0^* decreases with ϕ;

(ii). $l_1^* \geq \frac{3}{4}$ and l_1^* decreases with ϕ.

Lemma 1(ii) suggests that firm 1 chooses the location closer to the center of the city when ϕ is larger. The intuition is as follows. An increase in ϕ implies that more consumers observe firm 1's location. Therefore, a decrease in l_1 increases firm 1's market share more effectively when ϕ is larger. Consequently, firm 1 has a stronger incentive to locate closer to the city center to obtain a larger market share when ϕ is larger.

Lemma 1(i) suggests that firm 0 has the opposite incentive (i.e., firm 0 chooses the location further to the center of the city when ϕ is larger). We explain the intuition as follows. A pair of the best locations is $(l_0^*, l_1^*) = (\frac{1}{4}, \frac{3}{4})$. When $\phi < 1,\ l_1^* > \frac{3}{4}$. In other words, firm 1 dares to choose a location closer to the edge than the socially optimal location to mitigate price competition. Responding to this rival's location, firm 0 dares to choose a location closer to the center than the first best location to reduce total transport and improve welfare. As an increase in ϕ makes firm 1's location closer to the first best location, firm 0 chooses the location closer to the first best location, responding to the change in firm 1's location.

The equilibrium price of each firm is:

$$p_i^* = \frac{2t}{(1+\phi)^2}, \text{ where } i = 0, 1. \tag{12}$$

The demands of the firm are, respectively:

$$D_0^* = \frac{1}{1+\phi} \text{ and } D_1^* = \frac{\phi}{1+\phi}. \tag{13}$$

Finally, the resulting profit of firm 1 and welfare are, respectively:

$$\pi_1^* = \frac{2t\phi}{(1+\phi)^3} \text{ and } W^* = s - \frac{t(1+3\phi-6\phi^2+4\phi^3)}{12(1+\phi)^3}. \quad (14)$$

4. Results

Here, we discuss the implications of market transparency in a mixed duopoly. As a benchmark, we first present the results for a private duopoly, following Schultz (2004).

Result 1. (Schultz, 2004)

Consider a private duopoly in which both firms maximize their profits, where:

(i). welfare and consumer surplus increase with ϕ;

(ii). each firm's profit decreases with ϕ;

(iii). each firm's market share is independent of ϕ.

In a private duopoly, each firm chooses a location closer to the center of the city when ϕ is larger. The intuition is similar to that behind Lemma 1(ii). This economizes the transport costs and accelerates competition. Additionally, an increase in ϕ directly accelerates price competition in the last stage. These arguments lead to Proposition 1.

We present our main results for a mixed duopolistic market in the following proposition:

Proposition 1.

Consider a mixed duopoly, where:

(i). welfare and consumer surplus increase with ϕ;

(ii). the private firm's profit increases (decreases) with ϕ if $\phi < (>)\frac{1}{2}$;

(iii). the public firm's market share decreases with ϕ.

Proof of Proposition 1.

(i). $\frac{dW^*}{d\phi} = \frac{3t(1-\phi)\phi}{2(1+\phi)^4} > 0$. Additionally, consumer surplus can be obtained by $CS^* = W^* - \pi_0^* - \pi_1^* = s - \frac{t(25+27\phi-6\phi^2+4\phi^3)}{12(1+\phi)^3}$. Then, we obtain $\frac{dCS^*}{d\phi} = \frac{t(8+11\phi-3\phi^2)}{2(1+\phi)^4} > 0$;

(ii). $\frac{d\pi_1^*}{d\phi} = \frac{2t(1-2\phi)}{(1+\phi)^4} \gtreqless 0$ when $\phi \lesseqgtr \frac{1}{2}$;

(iii). $\frac{dD_0^*}{d\phi} = -\frac{1}{(1+\phi)^2} < 0$. Q.E.D.

Proposition 1(i) indicates that increasing market transparency on the consumer side leads

to greater welfare and consumer surplus. A decrease in market transparency moves the private location toward the right side of the linear city (Lemma 1(ii)); in response to this private firm's choice, the public firm also moves toward the right side of the linear city (Lemma 1(i)). Such relocations increase transportation costs and reduce welfare. Additionally, a decrease in market transparency increases prices. Changes in both location and price reduce consumer surplus.

Proposition 1(ii) states that the effect of market transparency on the private firm's profit depends on the degree of market transparency. When ϕ is lower than $\frac{1}{2}$, a decrease in market transparency reduces the private firm's profit. A decrease in market transparency raises the equilibrium price of the private firm, which, in turn, increases its profits. However, a decrease in market transparency affects location and reduces private firms' market share, which, in turn, reduces their profits. The latter effect dominates the former when ϕ is small. Therefore, an increase in market transparency may increase the private firm's profit, which does not occur in a private duopoly. Figure 1 shows the profit of the private firm when $t = 1$. In Figure 1, the vertical axis represents π_1^* and the horizontal one ϕ.

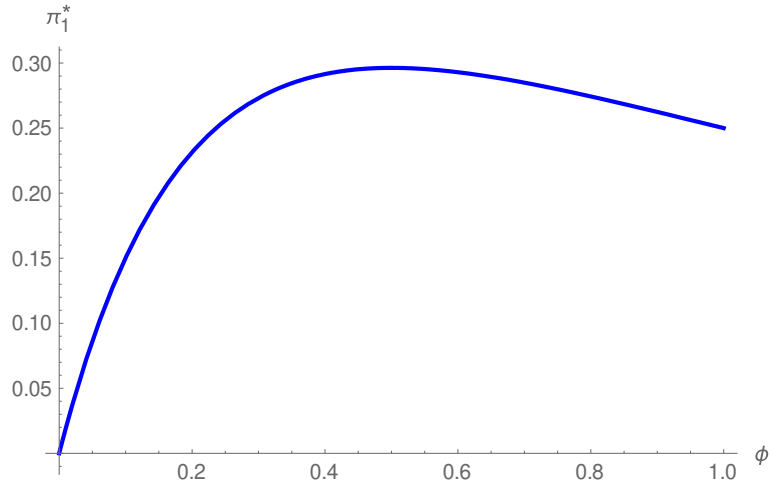

Figure 1. The private firm's profit ($t = 1$)

As previously mentioned, a decrease in market transparency induces the relocation of the firms, which increases the public firm's market share. In other words, an improvement in market transparency induces production substitution from public to private firms.[5]

[5] If we allow a cost difference between public and private firms such as like in the study by Matsumura and Matsushima (2004), this production substitution has an additional welfare-improving effect. Therefore, Proposition 1 (i) is strengthened if we assume that the public firm's marginal cost is higher than the private firm's marginal cost. The model with the public firm's cost disadvantage is popular in the literature on mixed oligopolies. See Pal (1998), Mujumdar and Pal (1998), and Haraguchi and Matsumura (2020).

Finally, we discuss the outcomes of adopting a Hotelling model with location restriction and assume $l_i \in [0,1]$. As Schultz (2004) shows, both firms locate outside the linear city, regardless of ϕ. Therefore, in this constrained Hotelling model, one firm chooses point 0 and the other chooses point 1, regardless of ϕ. Consequently, welfare is independent of ϕ. However, an increase in ϕ reduces equilibrium prices, which improves consumer surplus but reduces firms' profits. The following results are derived directly from Schultz (2004).

Result 2. (Schultz, 2004)

Consider the private duopoly with a constrained Hotelling model, where:

(i). welfare is independent of ϕ;

(ii). consumer surplus increases with ϕ;

(iii). each firm's profit decreases with ϕ;

(iv). each firm's market share is independent if ϕ.

In the mixed duopoly, (11) yields $0 < l_i^* < 1$ when $\phi > \frac{1}{2}$. Therefore, when $\phi > \frac{1}{2}$, the firms choose locations within the city. Therefore, constraint $l_i \in [0,1]$ is not binding, and the same results hold for both the constrained and unconstrained Hotelling models. Nevertheless, when $\phi < \frac{1}{2}$, constraint $l_1 \leq 1$ binds. Therefore, the equilibrium location is $(l_0^*, l_1^*) = (\frac{1}{3}, 1)$ if $\phi < \frac{1}{2}$. By replacing this equilibrium location with the above equilibrium locations, we obtain Proposition 2.

Proposition 2.

Consider the mixed duopoly with a constrained Hotelling model, where:

(i). welfare is non-decreasing in ϕ and is increasing in ϕ for $\phi > \frac{1}{2}$;

(ii). consumer surplus increases with ϕ;

(iii). the private firm's profit is non-increasing in ϕ and is decreasing in ϕ for $\phi > \frac{1}{2}$;

(iv). the public firm's market share is non-increasing in ϕ and is decreasing in ϕ for $\phi > \frac{1}{2}$.

The most interesting result of Proposition 1—the private firm's profit may increase with ϕ—does not hold in the constrained Hotelling model. However, in the mixed duopoly, we obtain one important implication of the constrained Hotelling model: welfare is independent of ϕ in the private duopoly but may increase with ϕ in the mixed duopoly. Therefore, in both

the unconstrained and constrained Hotelling models, the mixed duopoly yields implications different from those for the private duopoly.

5. Concluding remarks

This study investigates a mixed duopoly in which a welfare-maximizing public firm competes against a profit-maximizing private firm with consumer-side market transparency. We discuss how market transparency affects firms' locations and pricing strategies, as well as the resulting profits and economic welfare. We find that an increase in market transparency reduces location distortions and induces production substitution from both the public and private firms, which improves welfare. Moreover, the private firm's profit may increase with market transparency in a mixed duopoly, which is never the case in a private duopoly.

However, there remains a need to extensive future research due to the following limitations. In this study, we do not consider factors such as price-dependent demand, the shadow cost of public funds, R&D investments that affect quality and/or production costs, and various externalities. These factors may affect location patterns and, thus, the welfare implications of market transparency. Incorporating of these elements into our analysis remains a topic for future research. Furthermore, we use a location-price model in the Hotelling line as an endogenous product differentiation model. Extending our analysis to different endogenous product differentiation models is another significant direction for future research.[6]

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[6] For example, Matsushima and Matsumura (2003, 2006) investigate a location-quantity model in mixed oligopolies, while Liu et al. (2020) consider endogenous product differentiation in a mixed duopoly using an alternative non-spatial model.

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