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Equilibrium locations in a mixed duopoly with sequential entry in real time☆

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ABSTRACT

We investigate a mixed duopoly model where a public firm and a private firm enter a market sequentially over an infinite time horizon, with and without uncertainty over the follower's entry date. We assume that there is a unit-length linear city and show that, if the public firm moves first, equilibrium location falls inside the second and third quartiles. The later the follower is expected to enter, the closer the two firms are. However, if the private firm acts first, it moves aggressively to locate at the middle point (one-half), forcing the public firm to locate nearer the periphery (one-sixth), to minimize consumers' transportation cost. In addition, social welfare is strictly greater when the public firm moves as the leader.

1. Introduction

In many countries, public and private firms compete against each other in a wide range of industries such as banking, education, automotive, steel, liquor, and food processing. The theoretical discussion of such mixed oligopolies mainly focuses on the case where firms move simultaneously,[1] and thus neglects the influence of time over firms' decisions. However, due to government regulations and the difference in technical capabilities, firms seldom enter the same market simultaneously. One example is related to the process of opening up market by the WTO members. According to the WTO agreements, each developing country is offered some flexibility in implementing its commitments. That is, after a country's accession to the WTO, wholly foreign-owned enterprises may not be permitted for a given period. As a result, the local firms move earlier and the foreign firms move later in this domestic market. Another example is related to patent protection, which enables a patent holding firm to prevent its rivals from entering the market over a time period. For instance, in 2008, IBM received 4196 U.S. patents from the United States Patent and Trademark Office (USPTO).[2] Due to the brand protection, firms must enter the market one by one over an infinite time horizon.

In making its location and time-of-entry decisions, a firm must consider both the decisions of its rivals and the nature of competition. A firm's decision affects not only its own expected profits, but also the expected profits of its rival firms. Moreover, a change in the order of moves gives rise to different welfare implications within the context of mixed oligopolies. Thus it is quite important to understand firms' behaviors and then examine desirable roles within a framework of oligopolistic markets.

In this paper, we develop a mixed oligopoly model where a public firm and a private firm enter a linear market sequentially (from Hotelling (1929), originally). The sequential nature of the game is captured by the assumption that firms move one by one over an infinite time horizon. For the first mover, any relocation after its rival's entry is prohibited. The game structure of the present paper is thus a multi-period dynamic model rather than a single-period static model. Our analysis is carried out in two alternative settings where the earlier mover either (1) perfectly anticipates the later mover's entry date, or

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[1] There are some exceptions, for example, Pal (1998), Matsumura (2003a,b) and Matsumura and Matsushima (2003). However, those models assume a single-period framework where the sequential nature of the game is captured by the assumption that the first mover acts as a Stackelberg leader, while the second mover acts as a Stackelberg follower.

[2] http://en.wikipedia.org/wiki/List_of_top_United_States_patent_recipients. This website provides a list of the top ten recipients of patents issued by the USPTO in the year indicated.

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(2) attaches a constant instantaneous probability (hazard rate) to the event of entry at any date.

Our analysis shows that, under a well-known transformation of the hazard rate into the expected entry date, the two models yield the same equilibrium outcomes. If the public firm is the first mover, equilibrium location falls inside the second and third quartiles. As the expected entry date shifts farther into the future, the public firm locates closer to the center of the market. This forces the private firm to move away from the middle point. This, in turn, leads to the fact that the later the second firm is expected to enter, the closer the two firms locate. Conversely, if the entry is expected to be early, the public firm locates away from the market center, which induces the private firm to locate close to the middle point. Thus firms are apart from each other.

However, if the private firm moves first, equilibrium location becomes $(\frac{1}{6}, \frac{1}{2})$. This result does not rely on the second mover's expected entry date. When the private firm acts as the leader, it has a first-mover advantage over its rival firm. Thus the private firm takes an aggressive action to locate at the market center. Such aggressive behavior forces the public firm to locate far away from the middle point so as to economize transportation cost for consumers.

Another result derived from our analysis is that, from the social welfare perspective, the public firm should be the leader. When choosing its location, a private firm considers (i) the *market share effect*, which entails achieving a larger market share, and (ii) the *competitive effect*, which entails fiercer competition. The market share effect induces the private firm to locate close to the middle point, while the competitive effect encourages the private firm to locate far away from its opponent. But a public firm hopes to establish an adequate distance from its rival firm so as to minimize the transportation cost. The distance between the two firms is larger when the public firm acts as a market leader than when it acts as a follower. Thus social welfare is greater when the public firm is the leader.

Not surprisingly, the issue of location choice has been the subject of many studies over the last 20 years, and some important results have been established. One strand of the literature examines the validity of Hotelling's principle of minimum differentiation. Some papers tend to overturn Hotelling's traditional view (e.g., D'Aspremont et al., 1979; Neven, 1985), but other models seem to support Hotelling's standard result (Hamilton et al., 1989; Anderson and Neven, 1991; Irmen and Thisse, 1998). Still other papers find a mix of outcomes (Economides, 1986; Harter, 1993; Mai and Peng, 1999; Matsumura and Matsushima, 2003; Piga and Poyago-Theotoky, 2005). While these studies offer valuable insights, they analyze either Cournot-type or Bertrand-type simultaneous games and thus assume away sequential entries.

This paper is closely related to spatial competition models that emphasize sequential moves. One avenue of the literature takes a single-period approach and describes the sequential nature of the game by assuming that firms compete in a Stackelberg fashion (see, for example, Pal, 1998; Matsumura, 2003a,b; Matsumura and Matsushima, 2003). Another segment of the literature uses a multi-period approach and explicitly examines the influence of time in determining firms' equilibrium locations. Examples include Zhou and Vertinsky (2001) and Lambertini (2002). By considering entry costs in a private duopoly model, Zhou and Vertinsky (2001) study firms' optimal locations and times of entry. Assuming that the follower's entry date is exogenously given, Lambertini (2002) analyzes firms' location behavior under the assumption that the leader knows the follower's entry date with and without uncertainty.[3]

The second strand of the literature examines the desirable role of the public firm. Pal (1998) shows that, in the absence of spatial competition, a public firm should be a follower, from the social welfare perspective. However, Matsumura (2003a) argues that the public firm should be the leader, in the presence of a foreign competitor. By using a two-period production model, Matsumura (2003b) investigates endogenous roles in a mixed duopoly and finds that several equilibria exist. Matsumura and Matsushima (2003) use a sequential location-choice model and show that the public firm should be the follower (leader) if a price regulation is (is not) imposed.[4] Anam et al. (2007) use a stochastic model and show that the equilibrium outcome hinges upon the level of uncertainty and public ownership.

The rest of the paper is organized as follows. Section 2 presents the basic model. Section 3 studies the game where the leader knows the follower's entry date without uncertainty. Section 4 extends the model in Section 3 by introducing in uncertainty over the follower's entry date. Section 5 gathers our conclusions. The proofs are presented in the Appendix.

2. The basic model

Suppose that there is a Hotelling-type linear market. The market is unit-length and exists over $t\in[0,+\infty)$. Two firms, indexed by 0 and 1, produce the same physical good. Unit production cost is assumed to be constant, which is normalized to be zero without loss of generality. Firm 0 is a welfare-maximizing public firm, whereas firm 1 is a profit-maximizing private firm. Firms sequentially choose their locations, y_0 and y_1, and compete against each other *a la* Bertrand as soon as both are in the market, $y_i\in[0, 1]$. Because of the symmetry of the model, it is reasonable to assume that $y_0\le y_1$. It is assumed that location is chosen once, for all, at the time of entry. In other words, any relocation is impossible. Before the entry of the follower, the leader is the sole seller in the market, and thus it acts as a monopoly. Throughout the time horizon, both firms have the same discounted rate $\rho\in(0, 1)$.

Without loss of generality, we assume that the market leader enters at $t=0$, and the market follower enters at $\tau\in[0,+\infty)$. Following Lambertini (2002), our analysis is carried out in two alternative cases:

Case 1 τ is certain and known to both firms.
Case 2 τ is not known *ex ante*. The follower enters at any $\tau\in[0,+\infty)$, with a fixed instantaneous probability (hazard rate) $h\in[0,+\infty)$.

As argued by Lambertini (2002), firms' sequential entry over a time horizon can be interpreted as a result of either unsuccessful R&D activity by the follower over the period $[0, \tau]$, or as brand protection, which shelters the monopoly power of the leader over the same time span. Case 2 supposes that the follower's entry date is stochastic, and hence that firm experiences a constant instantaneous probability that its R&D activity will produce a usable new technology.

Consumers are uniformly distributed with unit density along the interval [0, 1]. The population is normalized to one. Each consumer demands at most one unit of the product. A consumer located at $y\in[0, 1]$, who will buy from firm i, pays a transportation cost, $d(y-y_i)^2$,[5] and obtains the following net surplus:

$$S-p_i-d(y-y_i)^2, i=0,1, \tag{1}$$

where $S>0$ is the consumer's reservation price, p_i is firm i's mill price and $d>0$ is the transportation cost rate. To ensure that each consumer consumes one unit of the product, we assume that S is large enough ($S\ge 3d$).

[3] The model used by Lambertini (2002) is a fully private duopoly.

[4] Matsumura and Matsushima (2003) is an extension of Cremer et al. (1991), who study how the present of public firms affects social welfare and how the results depend on the total number of firms and their relative positions.

[5] The quadratic cost function guarantees the existence of equilibrium at the pricing stage (D'Aspremont et al., 1979). It can be alternatively interpreted as the marginal disutility of purchasing a good that is not the consumer's preferred good (see, Neven, 1985; Harter, 1993; Piga and Poyago-Theotoky, 2005).