Firm Location Choice in the Presence of a Free Rider Problem

Elie Appelbaum* and Eliakim Katz†

November 2003

Abstract

In this paper we show that, in the presence of an investment that provides all firms in an industry with positive externalities, a firm may choose an 'extreme policy'. Specifically, within the context of a locational game, we show that a firm may make a positive profit by locating outside a city, if in doing so it manages to induce other firms to undertake investments that they would not undertake if the first firm was located within the city. Our finding is likely to have implications for similar locational issues such as ones facing political parties.

Key Words: Free Rider, Location, Multi-Stage Game.

*York University, Toronto, Canada.

†Northern Illinois University, Illinois, USA.

1 Introduction:

The purpose of this paper is to examine the nature of the equilibria in a market with a free rider problem and strategical interaction. Specifically, the market's existence/emergence requires an initial "investment" in infrastructure. The market can operate after such investment was made to to. For example, suppose that in order to be able to sell a particular product in a new market, it is necessary to undertake an initial advertising campaign. Without advertising demand is zero, but once, "general", advertising has been undertaken, *any* firm can produce the product and sell it in this market. From the perspective of firms, therefore, investment in advertising is a public good. Once any firm has paid for advertising, other firms cannot be excluded from the market, and will therefore enter the market, if they finds it profitable to do so. It is clear that under these circumstances, a firm's incentive to make the initial investment is reduced. In turn, this potentially affects all the firm's decisions, such as type/quantity of the product.

While we focus on the example described above, a similar analysis will be applicable in other contexts. For example, consider two firms that wish to deter entry of (further) potential entrants: each of these two firms will try to free ride on each others' entry deterrence activities. Similarly, firms competing in a market where R&D might be profitably undertaken,to but where there are no exclusive intellectual property rights, will face a similar problem. Essentially, in these cases, firms compete in their investment in the public good and in other dimensions: quantity, price, type of product, location, etc. It is clear that in order to mitigate the cost of free riding, firms will change their choices in those other dimensions. In fact, it is possible that in order to entice its rivals to provide the public good, a firm may have to amend its other choices to such an extent that they may appear "extreme". In the case considered in this paper, for example, we show that in a market where firms compete in "locations", a firm may locate "outside the city" in order to entice its rival to provide the public good. If we re-interpret the location game in terms of a political game, this suggests that a political party may choose an extreme position, in order to entice another party to provide a mutually needed public service[1].

The model discussed in this paper is related to the large literature that, starting with the seminal paper by Hotelling (1927), considered locational choice (or, equivalently, product differentiation) in markets (or politics).[2] The focus in many of these papers was the degree to which product differentiation would be exercised and, consequently, the degree to which it would tend to increase price competition.[3] One of

[1] For example, acting to undermine a common current governing rival. See Appelbaum and Katz (2003).

[2] These studies examined the role of locational choice in determining price competition, entry deterrence, product selection, etc. See for example d'Aspremont, et. al. (1979), de Palma, et.al., (1985), Bonano, G., (1987), Dasgupta, P. and E. Maskin, (1986), Donnenfeld and Weber, (1992). See also Tirole (1988), for a general discussion.

[3] In their important paper, d'Aspremont, et. al. (1979), show that in a market in which firms compete in prices and locations,

the standard results (see Hotelling (1927)) in this literature, is that without price competition product differentiation would be minimal, but with price competition it may even be maximal.[4] While our paper also examines locational choice, its focus is the strategic role of location in the face of a free rider problem. Unlike the standard result in the product differentiation literature, we show that the existence of free riders will lead to product differentiation even in the absence of price competition. Moreover, as we mentioned above, strategic considerations may lead a firm to choose an extreme position, in order to entice its rival to invest in a public good.

Strategic behavior in the face of free riding is also addressed in the deterrence literature, where it is shown that multiple incumbents may give rise to the possibility that a firm will "free-ride" on the entry deterring investments of its rivals (Bernheim (1984), Gilbert/ Vives (1986) and Waldman (1987) Appelbaum and Weber (1993)). As a result, rivals may under-invest or over-invest in deterrence activities depending on the nature of the interactions among firms. The sequential nature of the game in our model, however, enables a firm to use its choice of location strategically, in order to force its rival to invest in the public good.

2 The Location/Advertising Game

Consider a linear city situated on the $[0,1]$ interval, whose population is distributed along its length. Two firms that produce a homogeneous product wish to enter this market, but the initial demand for the product is zero. In order to generate demand for the product an indivisible advertising campaign costing c must be undertaken.[5] If this is done, an individual who resides a distance z from the nearest firm would be willing to pay $p(z) \equiv 1 - t\ g(z)$ for one unit (but will not buy more than one unit) of the product, where t is the transportation cost per unit of distance and $g(z)$ is an increasing and convex cost function. The cost of producing the product is zero. We also assume that the choice of location is costless. Consequently, the entry decision itself does not play a role in the model.

We examine a sequential game in location and advertising choices. Let the choices of location and advertising by firm i be given by: $y_i \in [0,1]$ and $c_i = \{c, 0\}$, $i = 1, 2$, respectively. Throughout this paper we assume that the all the parameters are known to both players and that both players are informed of any decision as soon as it is made. The order of play is as follows:

product differentiation will be maximal, hence reducing price competition. On the other hand, De Palma et. al. (1985) and Economides (1986) show that under certain cost and preferences conditions, it is possible to get less than maximal, or even minimal product differentiation. Clearly, the optimal degree of product differentiation will be determined by the trade-off between the desire to reduce price competition (by greater differentiation) and the wish to be "near" the center of market.

[4] See reference in footnotes 2 and 3.

[5] Alternatively, an investment in some public "infrastructure" in the amount of c must be made. Any investment whose benefits are not strictly private will play a similar role in the model.

1. Firm 1 (enters and) costlessly chooses y_1.
2. Firm 2 (enters and) costlessly chooses y_2.
3. Firm 1 irrevocably decides whether to advertise.
4. Firm 2 irrevocably decides whether to advertise.

Without loss of generality we assume that $y_1 \geq \frac{1}{2}$.

Let the firms' gross profit functions be given by: $\pi^1(y_1, y_2; t) \geq 0$ and $\pi^2(y_1, y_2; t) \geq 0$. We assume that the firms enter the market if and only if, in equilibrium, their net profits, $\pi^i(y_1, y_2; t) - c_i$, are non-negative. Moreover, given that a firm earns zero profits, it prefers that a market exists to a situation where a market does not exist.

3 The Equilibria of the Game

Using backward induction, we now find the subgame perfect Nash Equilibrium of this sequential game. Consider the last stage of the game. The firms' locations (y_1, y_2) are now given and Firm 1's advertising decision (c_1) has been made. Firm 2's advertising decision in the last stage of the game is given by:

$$\max_{c_2}\{\pi^{n2}(y_1, y_2, c_1, c_2; c, t) : \; c_2 = c, 0\} \equiv J^2(y_1, y_2, c_1; c, t) \tag{1}$$

where, $\pi^{n2}(\cdot)$, is its net profit, defined by:

$$\pi^{n2}(y_1, y_2, c_1, c_2; c, t) = \begin{cases} \pi^2(y_1, y_2; t) - c \; if \; c_2 = c \;\; and \;\; c_1 = 0 \\ 0 \; if \; c_2 = 0 \;\; and \;\; c_1 = 0 \\ \pi^2(y_1, y_2; t) \; if \; c_2 = 0 \; and \;\; c_1 = c \\ \pi^2(y_1, y_2; t) - c \; if \; c_2 = c \; and \;\; c_1 = c \end{cases} \tag{2}$$

Let the solution to problem (1) be given by, c_2^*:

$$c_2^* \equiv \arg\{\max_{c_2}\{\pi^{n2}(y_1, y_2, c_1, c_2; c, t) : \; c_2 = c, 0\}\} = c_2^*(y_1, y_2, c_1; c, t) \tag{3}$$

Consider now Firm 1's advertising choice. At this stage, locations y_1 and y_2 have already been determined and Firm 2's advertising rule is known to be given by (3). Firm 1's problem is, therefore, given by:

$$\max_{c_1}\{\pi^{n1}(y_1, y_2, c_1, c_2; c, t) : \; c_1 = c, 0, \; c_2 = c_2^*(y_1, y_2, c_1; c, t)\} \equiv J^1(y_1, y_2; c, t) \tag{4}$$

where $\pi^{n1}(\cdot)$is its net profit, defined by:

$$\pi^{n1}(y_1, y_2, c_1, c_2; c, t) = \begin{cases} \pi^1(y_1, y_2; t) \quad if \; c_2 = c \;\; and \;\; c_1 = 0 \\ 0 \;\; if \; c_2 = 0 \;\; and \;\; c_1 = 0 \\ \pi^1(y_1, y_2; t) - c \;\; if \; c_2 = 0 \;\; and \;\; c_1 = c \\ \pi^1(y_1, y_2; t) - c \;\; if \; c_2 = c \;\; and \;\; c_1 = c \end{cases} \tag{5}$$

Let the solution to problem (4) be given by, c_1^*:

$$c_1^* \equiv \arg\{\max_{c_1}\{\pi^{n1}(y_1, y_2, c_1, c_2; c, t) : \; c_1 = c, 0, \; c_2 = c_2^*(y_1, y_2, c_1; c, t)\}\} = c_1^*(y_1, y_2; c, t) \tag{6}$$

Going backwards, consider now the choice of location for Firm 2. Location y_1 is given and the two firms' advertising rules are defined by (4),(1). Firm 2's net profits are now given by: $J^2(y_1, y_2, c_1^*(y_1, y_2; c, t); c, t)$ and its location choice problem is:

$$\max_{y_2} J^2(y_1, y_2, c_1^*(y_1, y_2; c, t); c, t) \equiv H^2(y_1; c, t) \tag{7}$$

where its optimal location, y_2^* is:

$$y_2^* \equiv \arg\{\max_{y_2} J^2(y_1, y_2, c_1^*(y_1, y_2; c, t); c, t)\} = y_2^*(y_1; c, t) \tag{8}$$

Finally, Firm 1's first stage location choice is given by:

$$\max_{y_1} J^1(y_1, y_2^*(y_1; c, t); c, t)) \equiv H^1(c, t) \tag{9}$$

where its optimal location, y_1^* is:

$$y_1^* \equiv \arg\{\max_{y_1} J^1(y_1, y_2^*(y_1; c, t); c, t))\} = y_1^*(c, t) \tag{10}$$

The subgame perfect Nash equilibrium is, therefore, given by:

$$NE(c, t) = \left\{ \begin{array}{c} y_1^*(c, t) \\ y_2^*(y_1^*(c, t); c, t) \\ c_1^*[y_1^*(c, t), y_2^*\{y_1^*(c, t); c, t\}; c, t] \\ c_2^*[y_1^*(c, t), y_2^*\{y_1^*(c, t); c, t\}, c_1^*\{y_1^*(c, t), y_2^*\{y_1^*(c, t); c, t\}; c, t\}; c, t] \end{array} \right. \tag{11}$$

From the solution above, i.e., (11), it is clear that the nature of the equilibrium (including the question of existence) depends on the parameters of the problem, namely, c, t. However, rather than looking at the nature of equilibrium in general, we consider the possibility of a special type of equilibrium. Specifically, we examine whether there exist "reasonable" values of c, t, for which the equilibrium is such that: (i) one of the firms (say, Firm1) locates *outside* the city and make positive profits, and (ii) Firm 2 locates inside the city, pays the cost of advertising, c, and make zero profit. The following result indicates that for commonly used specifications of the underlying distribution and demand functions, there exist (reasonable) values of c (and t) that give rise to such an "out of city" equilibrium.

To demonstrate this we assume:

Assumption 1: The population is uniformly distributed along the interval $[0, 1]$.

Assumption 2: Consumers' demand (willingness to pay) is given by the quadratic function: $p(z) = 1 - d^2$ (that is: $t = 1$ and $g(d) = d^{2\cdot}$).

These are standard assumptions in the location/product differentiation literature[6]

Definition 1 *Define the interval:* $A \equiv \{c : 0.7346938776 < c < 0.8628190892\}$.

Then we have the following proposition:

Proposition 2 *Given assumptions 1 and 2, if* $c \in A$*, a subgame perfect Nash equilibrium, as given by (11), exists and is such that Firm 1 locates outside the city and makes positive profits, and firm 2 locates inside the city and makes zero profit.*

Proof. Available upon request. ∎

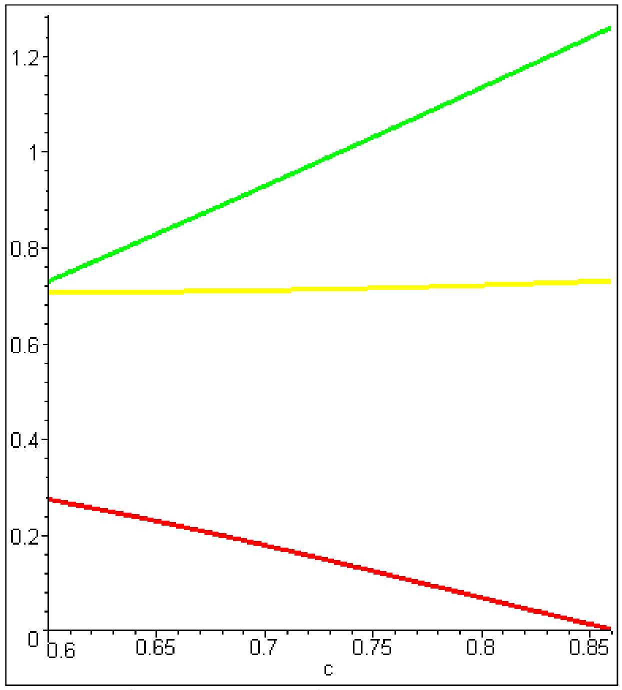
3.1 Other Equilibria:

The nature of the equilibrium depends on the parameter, c. In choosing its location, firm 1 balances two effects. On the one hand, to increase its market share, firm 1 has to move as close as possible to the centre. On the other hand, to entice firm 2 to (enter and) pay the cost c, it has to give firm 2 "more space" (by moving far enough from the centre), so that firm 2 will break even by entering and paying c. How far it needs to move away depends on c. As c decreases, firm 2 needs "less space" to be enticed to enter and pay c. Thus, as c decreases, firm 1 moves back toward the city and below some value ($c < 0.7346938776$), it will be back in the city. On the other hand, for sufficiently high values of c ($c > 0.8628190892$), firm 1 cannot move away far enough outside the city, while still making profits, and enticing firm 2 to enter and pay the cost, c.

The effects of c on the Nash Equilibrium values of y_1, y_2 and H^1 are shown in Figure 1[7].

[6] See Tirole (1988).

[7] Calculated using Maple 6.



Optimal Locations and Firm 1's Profit as Function of $c:$ y_1- green line, y_2- yellow line, $H^1(c)$ - red line, $H^2(c) = 0$.

For intermediate values of c, the equilibrium is as described in Proposition 1. As c increases, Firm 1 moves further outside of the city, for a while still making positive profits. In response to Firm 1's move to the right, Firm 2 also moves further out, but it remains within the city. As c increases, Firm 1's profits decrease (eventually reaching zero), since it has to move further to be able to entice Firm 2 to enter and pay (the higher) c.

Finally, it should be noted that although the results above were derived for and specific distribution and demand functions, these were functions that are very commonly used in this literature. Moreover, the principle that drives these results will still be true for alternative specifications (e.g., a different demand function), so that the free rider problem may lead a firm to choose an extreme position "outside the city".[8]

4 Conclusion

In this paper we show that, in the presence of an investment that provides all firms in and industry with positive externalities, a first player may choose an 'extreme policy'. Specifically, we show that a firm may make a positive profit by locating outside a city, if in doing so it manages to induce other firms to undertake investments that they would not undertake if the first firm was located within the city. Our finding is likely to have implications for similar locational issues such as ones facing political parties.

[8] For example, a distribution with a lower spread (or a lower t), will mitigate the distance required to enable firm 2 to earn a given profit. Consequently, firm 1's location may be less extreme. Nonetheless, depending on the distribution (or, the value of t), firm 1 may still locate outside the city.

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