Herding versus Hotelling:

Market Entry with Costly Information

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Abstract

Why do businesses such as fast-food restaurants, coffee shops, and hotels cluster? In the classic analysis of Hotelling, firms cluster to attract consumers who have travel costs. We present an alternative model where firms cluster because one firm is free riding on another's information about market demand. One consequence of this free riding is that an informed firm might forego a market that it knows to be profitable. Furthermore, an uninformed firm might earn higher profits when research costs are high, because it can credibly commit to ignorance.

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1 Introduction

Why do businesses such as fast-food restaurants, coffee shops, and hotels cluster? In the classic analysis of Hotelling (1929), firms cluster to attract consumers that want to minimize travel costs when making a purchase. We present an alternative model where an informed firm's entry into a market provides its rival with a noisy signal about market demand. The uninformed rival will blindly mimic the informed leader when research costs are higher than expected losses from sometimes following the leader into unprofitable markets. One consequence of this free riding is that an informed firm might forego a market that it knows to be profitable for only one firm. Since the leader is avoiding markets that are profitable for one firm, the follower will sometimes enter when the leader does not. Furthermore, an uninformed firm's profits might be higher when research costs are higher, because it can avoid the research cost knowing that it can blindly follow the informed firm when it enters.

Hotelling (1929) provided valuable insight into the optimal strategies for profit-maximizing firms and vote-maximizing politicians. Hotelling's results have been described as "invalid," however, when firms choose both price and location, because firms have an incentive to move apart to decrease price competition (D'Aspremont, Gabszewicz, and Thisse, 1979). Hotelling assumed that competitors set prices without reference to their rivals. Nevertheless, Hotelling provided at least two important insights. First, spatial competition is inherently oligopolistic, because firms tend to compete directly with only a few neighbors. Second, businesses tend to locate near rivals, despite price pressures.

Alternative explanations for firm agglomeration can be categorized as demand side or supply side. On the demand side, firms cluster because consumers prefer businesses in certain locations. Firms cluster to attract consumers searching for optimal product characteristics (Wolinsky, 1983; Fischer and Harrington, 1996; Konishi, 2005), to provide a credible commitment to low prices (Dudey, 1990), to locate near consumers attracted by the marketing or reputation of rivals (Chung and Kalnins, 2001), and because consumers (residences, workplaces, or entertainment) are concentrated (Neven, 1986). On the supply side, firms cluster to decrease the costs of labor and other inputs (Marshall, 1920), to learn from other firms how to improve productivity (Glaeser et al., 1992; Shaver and Flyer, 2000; Furman et al., 2006), and because spinoffs sometimes locate near parent firms (Buenstorf and Klepper, 2005; Klepper, 2007).[1] Furthermore, firms cluster when they are forced together by zoning regulations (Ridley, Sloan, and Song, 2007).

Another explanation for agglomeration can be seen in the entry behavior of fast-food restaurants and coffee shops. Firms cluster because one firm has better information and its rival free rides. According to *The Wall Street Journal*, "In the past, many restaurants...plopped themselves next to a McDonald's to piggyback on the No. 1 burger chain's market research"(Leung, 2003). Likewise, Browning and Zupan (2001) report that "After McDonald's statistically determines that a location will be profitable and begins operations on that site, Burger King opens up its own franchise nearby." Coffee shops exhibit the same behavior. "The Tully's goal is simple: a shop across the street from every Starbucks, around the world"(Mulady, 2001). "The reason we want to open across the street from every Starbucks is they do a great job at finding good locations," said Tom O'Keefe, Chairman and CEO of Tully's Coffee Corporation (Goll, 2000). According to data from Dun and Bradstreet, in California in 2004, the mean driving distance from a Tully's to a Starbucks was 0.6 miles, and 12 of 13 Tully's were located in the same zip code as a Starbucks.

The aforementioned behavior suggests a model of positive information externalities, such as in the herding literature (Banerjee, 1992; Bikhchandani, Hirshleifer, and Welch, 1998) or in Caplin and Leahy (1994, 1998). In contrast to much of the herding literature which assumes the follower's actions are neutral or helpful to the leader (e.g., a following investor

[1] Other studies focused not on geographic agglomeration, but temporal agglomeration of scheduled flight departure times (Borenstein and Netz, 1999) and movie release dates (Corts, 2001; Einav, 2007).

bidding up the share price of a stock held by the leader), here the follower's free riding hurts the leader. Stahl and Varaiya (1978), Gal-Or (1987), Hirokawa and Sasaki (2001), and Toivanen and Waterson (2005) modeled both positive information externalities and the adverse consequences for first movers. In these models, however, it is generally assumed that information about demand is conferred by entry or by a rival's entry, and additional information is infinitely costly. On the other hand, Cooper (1997) models optimal market research by firms and shows that in equilibrium only one firm chooses to collect data, but he does not model the entry decision. Our paper presents a model in which both entry and research decisions are modeled for both the leader and follower.

Free riding based on entry information has both efficiency and distributional consequences. First, markets that can support only one firm might not be entered by any firms, when the uninformed second mover's profit-maximizing strategy is to always follow the first.[2] Second, since the leader is avoiding markets that are profitable for one firm, the follower will sometimes enter when the leader does not. [3] Third, a firm might earn higher profits when research costs are high, because it can credibly commit to ignorance. If the second firm's research costs fall the first firm can expect the second to be informed so the first can safely enter markets that support only one firm.Because free riding can lead to socially excessive or insufficient entry, the paper also relates to the literature on entry efficiency (Mankiw and Whinston, 1986).

[2]The model is motivated using examples of business clustering in local markets, but the model can be applied to entry into global markets (such as developing nations) or even to children playing. Consider a young child who wants to play with the same toy as an older child, not because sharing is fun, but because the younger child believes that the older is more knowledgable about which toy is fun. The older child might be wise to bypass toys that they cannot enjoy together such as a single doll. The older child might like to find a toy for which sharing is not entirely unpleasant such as a large set of Legos.

[3]Consider a small town in the state of Washington that does not have a Starbucks. Tully's knows the town exists and that the town has no Starbucks, but Tully's doesn't know whether demand in the market is small (not even enough demand for one chain coffee shop) or medium (enough demand for only one chain coffee shop), because Tully's has not investigated demand (preferences, demographics, traffic patterns) in that town. If entry costs are low and research costs are high, Tully's might blindly enter the market, even though it risks losses if the market is too small.

Section 2 contains the basic model in which research is free for firm 1 and infinitely costly for firm 2. In section 3 research is costly for both firms. Section 4 contains the conclusion.

2 Basic Model

2.1 Set Up

Two firms are considering entry into a market. Each firm can open one or zero stores in the market.[4] Each knows that market demand θ is distributed $F(\theta), \theta \in [\underline{\theta}, \bar{\theta}]$. Each decides whether to enter a market with $a_i = 1$ if firm i enters and $a_i = 0$ otherwise.

The timing of the game is as follows:

1. Firm 1 observes θ.

2. Firm 1 makes its entry decision.

3. Firm 2 observes firm 1's entry decision and forms a belief about θ. Denote this belief by the probability distribution $\mu_2(\theta, a_1) \geq 0$ where $\int_{\underline{\theta}}^{\bar{\theta}} \mu_2(\theta, a_1) d\theta = 1$.

4. Firm 2 makes its entry decision.

Payoffs for each firm depend on the firm's entry decision, its rival's entry decision, and market demand. Each firm must pay entry cost K. After paying entry costs, the payoff for firm i is $\pi_i(\theta, a_j)$, where a_j is the action of the rival firm. The following assumptions are made regarding the payoff function:

Assumption 1 $\pi_i(\theta, I) = \pi(\theta, I)$, $\forall i$ and $\forall I \in \{0, 1\}$.

[4] There are several reasons why a firm might locate only one store in a market large enough to support both the firm and its rival. First, there might be lower demand for two stores of the same type than one store of each type. Second, firms might have diseconomies of scale. Third, firms might be financially constrained. Firms often prefer financing from internal retained earnings because the internal cost of capital is lower than the market rate of interest or because they prefer secrecy. For a more extensive discussion of why firms might not open multiple stores in a market see Prescott and Visscher (1977).

Assumption 2 If $\theta' < \theta$ then $\pi(\theta', I) < \pi(\theta, I)\ \forall\theta$.

Assumption 3 $\pi(\theta, 1) < \pi(\theta, 0)\ \forall\theta$.

Assumption 4 There exists θ such that $\pi(\theta, 1) > K$ and θ' such that $\pi(\theta', 0) < K$.

Assumption 1 establishes that the payoff functions are the same for both firms. Assumption 2 establishes that the payoffs are monotonically increasing in market demand θ. Assumption 3 establishes that the payoffs are higher if the rival firm does not enter. Assumption 4 establishes the existence of some markets in which duopoly profit is positive and others in which monopoly profit is negative. Given these assumptions, the market can be divided into three regions.

Lemma 0. *There exist values θ_d and θ_m such that:*

a. For all $\theta < \theta_d, \pi(\theta, 1) < K$ and for all $\theta' > \theta_d, \pi(\theta, 1) > K$.

b. For all $\theta < \theta_m, \pi(\theta, 0) < K$ and for all $\theta' > \theta_m, \pi(\theta, 0) > K$.

c. $\theta_d > \theta_m$.

Markets are labeled large when duopoly profit is positive, medium when monopoly profit is positive but duopoly profit is negative, and small when duopoly and monopoly profit is negative. Firms without full information might enter small markets, but a fully-informed profit-maximizing firm will never enter a market it knows to be small, so such strategies for fully-informed firms will be ignored. Large markets are profitable and small markets are unprofitable, regardless of whether a rival firm enters. Hence, medium markets are the most interesting.

The extensive form of the game is illustrated in Figure 1. Nature determines market size θ which firm 1 observes and then makes its entry decision. Firm 2 observes firm 1's decision to enter or not, but does not observe θ as indicated by the dotted curves connecting firm 2's nodes.

Consider a simple example in which inverse demand is $p = \theta - Q$, θ is distributed uniformly on $[\underline{\theta}, \bar{\theta}]$, total output is the sum of the output from each firm $Q = q_1 + q_2$, the only cost is the entry cost K, and firms compete a la Cournot. Hence, equilibrium duopoly profit is $\pi_i(\theta, 1) - K = \frac{1}{9}\theta^2 - K$ and equilibrium monopoly profit is $\pi_i(\theta, 0) - K = \frac{1}{4}\theta^2 - K$. Figure 2 illustrates payoffs as a function of market size θ and whether the rival has entered the market. In this figure as in others, $\underline{\theta} = 15$ and $\bar{\theta} = 100$.

In the simple example, the value at which duopoly profit is zero is $\theta_d = 3\sqrt{K}$ and the value at which monopoly profit is zero is $\theta_m = 2\sqrt{K}$. Entry costs must be above $\underline{K}$ for the existence of small markets (defined as negative monopoly profits) and below $\overline{K}$ for the existence of large markets (defined as positive duopoly profits). Hence, the boundaries of small, medium, and large markets are functions of K. With fixed values for $\underline{\theta}$ and $\bar{\theta}$, increases in K increase the space of small markets fastest (at a rate of $1/\sqrt{K}$), medium markets grows slowly (at a rate of $1/(2\sqrt{K})$), and large markets shrink (at a rate of $3/(2\sqrt{K})$). Hence, when entry costs are high, more markets are small, for given values of $\underline{\theta}$ and $\bar{\theta}$.

2.2 Equilibria when Leader's Research Is Free

With free research for the leader and infinitely costly research for the follower, there are three lemmas. The notation is as follows: (firm 1's strategy, firm 2's strategy given that firm 1 enters, firm 2's strategy given that firm 1 does not enter). For example, (L, E, E) in Lemma 1 below indicates that firm 1 enters only large markets, if firm 1 enters firm 2 enters, and if firm 1 does not enter firm 2 still enters. While "L" indicates entry into only large markets, "M" indicates entry into both medium and large markets (firms never forego markets they know to be large).

In Lemma 1 below we find conditions such that firms cluster in large markets but not other markets. Entry cost is low, so firm 2 always enters. Given that firm 2 is always entering, firm 1 only enters markets large enough to support two firms.

Lemma 1 (L,E,E)**.** *There is a unique perfect Bayesian equilibrium where firm 1 only enters large markets and firm 2 always enters if the following hold:*

1a. $K \leq \frac{F(\theta_d)-F(\theta_m)}{F(\theta_d)} E\pi(\theta_d > \theta > \theta_m, 0) + \frac{F(\theta_m)}{F(\theta_d)} E\pi(\theta < \theta_m, 0)$*. (Converse of 2a.)*

1b. $K \leq \frac{1-F(\theta_d)}{1-F(\theta_m)} E\pi(\theta > \theta_d, 1) + \frac{F(\theta_d)-F(\theta_m)}{1-F(\theta_m)} E\pi(\theta_d > \theta > \theta_m, 1)$*. (Converse of 3a.)*

The beliefs that support this equilibrium are

$$\mu_2(\theta, 1) = \begin{cases} \frac{f(\theta)}{1-F(\theta_d)} & \text{for } \theta > \theta_d \\ 0 & \text{otherwise} \end{cases}$$

$$\mu_2(\theta, 0) = \begin{cases} \frac{f(\theta)}{F(\theta_d)} & \text{for } \theta < \theta_d \\ 0 & \text{otherwise} \end{cases}$$

Proof of Lemma 1 (L,E,E). Consider firm 2's best response. If firm 1 enters, firm 2 believes the market is large so it will enter by Lemma 1. Condition *1b* requires that expected duopoly gains in large markets exceed duopoly losses in medium markets by more than the entry cost, so firm 2 will always follow firm 1, even if firm 1 is believed to enter both medium and large markets. Consider firm 1's best response. If firm 2 always follows then firm 1 only enters large markets. Given that firm 1 only enters large markets, if firm 1 does not enter, firm 2 believes the market is small or medium. Condition *1a* states that expected monopoly gains in medium markets exceed monopoly losses in small markets by more than the entry cost, so firm 2 also enters when firm 1 does not enter.[5] □

When entry costs rise, however, it is no longer profitable for firm 2 to enter when firm 1 does not enter, because losses in small markets become relatively greater than gains in

[5] It is assumed that firm 2 believes that if firm 1 is not present in a market it is because firm 1 observed market demand and chose not to enter. Alternatively, firm 1 might not be aware of market demand or might not even be aware that the market exists. Presumably, firm 1 has not researched a market or is not aware of it because it is on average smaller. The possibility that the market might be undiscovered terrain would lower the threshold value of θ, but it would not change the qualitative results of the model.

medium markets. Hence, firm 2 only enters when firm 1 enters. In Lemma 2 below we find conditions such that sequential entry decisions can lead firm 2 to mimic firm 1.

Lemma 2. *(L,E,N) There is a unique perfect Bayesian equilibrium where firm 1 only enters large markets and firm 2 only enters if firm 1 enters if the following conditions are met:*

2a. $K > \frac{F(\theta_d)-F(\theta_m)}{F(\theta_d)} E\pi(\theta_d > \theta > \theta_m, 0) + \frac{F(\theta_m)}{F(\theta_d)} E\pi(\theta < \theta_m, 0)$. *(Converse of 1a.)*

2b. Same as condition 1b. (Converse of 3a.)

The beliefs that support this equilibrium are the same as in Lemma 1.

Proof of Lemma 2 (L,E,N). Consider firm 2's best response. If firm 1 enters, firm 2 believes the market is large so firm 2 will enter. In fact, firm 2 would enter even if it believed the market was medium or large by condition *1b* which requires that expected duopoly gains in large markets exceed duopoly losses in medium markets by more than the entry cost. Consider firm 1's best response. If firm 2 always follows then firm 1 only enters large markets. Given that firm 1 only enters large markets, if firm 1 does not enter, firm 2 believes the market must be small or medium. Condition *2a* states that expected monopoly losses in small markets plus monopoly gains in medium markets are less than entry costs (in contrast to Lemma 1), so firm 2 will not enter if firm 1 does not enter. □

Hence, firm 1 foregoes medium markets because firm 2 is following and medium markets are not profitable for two firms. This leads to a proposition.

Proposition 1. *Under the conditions in Lemma 2 there are markets that are identified by one firm as profitable, but no firms enter.*

When entry costs are low, firm 2 sometimes blindly follows firm 1, leading firm 1 to forego markets that support only one firm. When entry costs are high, however, firm 1 knows that firm 2 will not find it profitable to blindly follow firm 1 into medium and large markets. In Lemma 3 below we find conditions such that the leader enters markets that are profitable for at least one firm (medium and large) while the other firm never enters.

Lemma 3. *(M,N,N) There is a perfect Bayesian equilibrium where firm 1 enters medium or large markets and firm 2 never enters if the following condition is met:*

3a. $K > \frac{1-F(\theta_d)}{1-F(\theta_m)} E\pi(\theta > \theta_d, 1) + \frac{F(\theta_d)-F(\theta_m)}{1-F(\theta_m)} E\pi(\theta_d > \theta > \theta_m, 1)$. *(Converse of 1b.)*

The beliefs that support this equilibrium are

$$\mu_2(\theta, 1) = \begin{cases} \frac{f(\theta)}{1-F(\theta_m)} & \text{for } \theta > \theta_m \\ 0 & \text{otherwise} \end{cases}$$

$$\mu_2(\theta, 0) = \begin{cases} \frac{f(\theta)}{F(\theta_m)} & \text{for } \theta < \theta_m \\ 0 & \text{otherwise} \end{cases}$$

(The beliefs differ from Lemma 1 and 2 in that θ_m replaces θ_d.)

Proof of Lemma 3 (M,N,N). Consider firm 2's best response. If firm 1 enters, firm 2 will sustain losses by entering, because condition *3a* ensures that expected duopoly gains in large markets are less than duopoly losses in medium markets plus entry costs. Consider firm 1's best response. Since firm 2 is not following, firm 1 will enter medium and large markets. If firm 1 does not enter, firm 2 believes the market is small with negative payoffs, so it will not enter. □

Proposition 2. *Given the parameter values of θ and K, there is a unique equilibrium characterized by Lemmas 1-3.*

Using the conditions in Lemmas 1-3, it is straightforward to show that the equilibrium is unique and has full coverage. For each condition in each lemma, there is a corresponding converse in another lemma.

In summary, when firm 1 is informed it avoids being the second firm in unprofitable medium and small markets, so only large markets ever have two firms. Firm 2, on the other hand, is not informed if research costs are high, so profitable medium markets can be foregone (L,E,N) and unprofitable small markets can be entered (L,E,E).

2.3 Welfare and Profit when Leader's Research Is Free

Entry costs affect social welfare and profit directly through costs and indirectly through firm strategies. Recall from the simple example that as entry costs increase, small markets grow fastest, medium markets grow slowly, and large markets contract. If the entry costs are low, $K \in (\underline{K}, K_a)$, then firm 2 will always enter and firm 1 will enter only large markets (L,E,E). If entry costs rise to $K \in (K_a, K_b)$ then the space of small markets becomes bigger relative to the space of medium markets so firm 2 does not enter when firm 1 does not enter (L,E,N). If the entry costs are high ($K \in (K_b, \overline{K})$) then medium markets become greater relative to large markets so firm 2 changes to not enter when firm 1 enters medium markets (M,N,N). (Figure 3 illustrates both the boundaries described above and welfare described below.)

Having examined how entry costs affect strategy, we can consider the implications for social welfare. Social welfare losses result from 1) entry costs, 2) research costs (assumed zero in section 2 but positive in section 3), 3) consumers unserved because no firms enter their market, and 4) consumers unserved because sales are limited by monopolists (and to a lesser extent duopolists) in order to increase prices.

We can write expected social welfare as the sum of profits and consumer surplus. In the simple linear example, profit is $p(\theta, Q)Q$ less entry cost, and consumer surplus is $(1/2)(\theta -$

$p(\theta, Q))Q$, so expected welfare is:

$$EW = \int_{\theta_a}^{\theta_b} \frac{(\theta + p(\theta, Q))Q}{2(\theta_b - \theta_a)} d\theta - N_k K \quad (1)$$

where $N_k \in (0, 1, 2)$ is the number of firms paying entry cost K.

The social optimum is never Lemma 2 (L,E,N), because medium markets are unserved. Firm 1 avoids medium markets knowing that firm 2 is free riding and that medium markets are not profitable for two firms. Lemma 2 (L,E,N) is socially inferior to Lemma 1 (L,E,E) when entry costs are low ($K < K_a$) and socially inferior to Lemma 3 (M,N,N) when entry costs are high ($K > K_a$) (Figure 3).

Likewise, profit tends to be lower in Lemma 2 (L,E,N) since large markets have two competitors and other markets are not entered. Profit is higher in Lemma 3 (M,N,N), because the leader earns monopoly profits. At high entry cost, the follower is deterred from entering, thus securing monopoly profits for the leader and being socially optimal in that redundant entry costs are avoided.

At higher entry costs ($K > K_a$), it is more profitable to be the leader. At lower entry costs ($K < K_a$), there is a slight advantage to being the follower, because firm 2 enters medium and small markets, and the gains from medium markets exceed the losses from small markets when entry costs are low ($K < K_a$).

3 Costly Research

3.1 Equilibria where Leader and Follower Research

Now assume that it costs $R_i \geq 0$ for both firms to obtain information about market demand. Equilibria 1-3 are maintained, though with additional conditions (in the appendix). For example, Lemma 2 (L,E,N) has six conditions illustrated in Figure 4. Furthermore, seven new lemmas are added as described below.

In Lemma 4 firms cluster in large markets, and only firm 1 enters medium markets, because firm 2 pays for research about market demand before following firm 1. Firm 2 pays for research when firm 1 enters, because firm 1 not only enters large markets, but also medium markets.

Lemma 4 (M,L,N)**.** *There is a perfect Bayesian equilibrium where firm 1 researches and enters medium and large markets, firm 2 researches then enters only large markets if firm 1 enters, and firm 2 does not enter if firm 1 does not enter, if the following conditions hold:*

4a. $R_2 \leq \frac{F(\theta_m)-F(\theta_d)}{1-F(\theta_m)}[E\pi(\theta_d > \theta > \theta_m, 1) - K]$. *(Converse of 1c.)*

4b. $R_2 \leq \frac{1-F(\theta_d)}{1-F(\theta_m)}[E\pi(\theta > \theta_d, 1) - K]$. *(Converse of 3b.)*

4c. Same as condition 3c (appendix). (Converse of 7d.)

4d. Same as condition 3d (appendix). (Converse of 10b.)

The beliefs that support this equilibrium are the same as in Lemma 3.

Proof of Lemma 4 (M,L,N). Consider firm 2's best response. If firm 1 enters, firm 2 believes that the market is medium or large. Firm 2 will research by condition *4a* and only enter large by condition *4b*. If firm 1 does not enter, firm 2 believes the market is small, so it neither enters nor conducts research. Consider firm 1's best response. Firm 1 will research and enter medium or large by conditions *3c* and *4d*. Firm 1 knows that firm 2 will research and only enter large markets when it enters, so firm 1 can enter both medium and large markets without fear of duopoly losses. □

Although firm 2 can now purchase information about market size, it will still free ride under certain conditions. If firm 1 enters only large markets, then firm 2 can follow firm 1 without purchasing information. Given firm 1's strategy, if firm 1 does not enter, then firm

2 believes the market is medium or small. In this case, purchasing information might be cost effective. In Lemma 5 firm 2 free rides on firm 1's information when firm 1 enters, and firm 2 purchases information when firm 1 does not enter. Hence, the firms cluster in large markets, and only firm 2 enters medium markets.

Lemma 5 (L,E,M)**.** *There is a perfect Bayesian equilbrium where firm 1 researches and enters large markets, firm 2 enters blindly if firm 1 enters, and firm 2 researches and enters medium if firm 1 does not enter when the following hold:*

5a. Same as condition 1b (appendix). (Converse of 3a.)

5b. Same as condition 1c (appendix). (Converse of 4a.)

5c. $R_2 \leq \frac{-F(\theta_m)}{F(\theta_d)}[E\pi(\theta < \theta_m, 0) - K]$. *(Converse of 1d.)*

5d. $R_2 \leq \frac{F(\theta_d)-F(\theta_m)}{F(\theta_d)}[E\pi(\theta_d > \theta > \theta_m, 0) - K]$. *(Converse of 2d.)*

5e. Same as condition 1e (appendix). (Converse of 8b for $R_i = R_1$*.)*

5f. Same as condition 1f (appendix). (Converse of 6f.)

The beliefs that support this equilibrium are the same as in Lemma 1.

Proof of Lemma 5 (L,E,M). Consider firm 2's best response. If firm 1 enters, firm 2 believes the market is large and will enter blindly. Furthermore, conditions *1b* and *1c* ensure that firm 2 enters even if firm 1 enters medium or small. If firm 1 does not enter, then firm 2 believes the market is small or medium. Firm 2 will prefer to research and enter medium by conditions *5c* and *5d.* Consider firm 1's best response. Firm 1 will research and enter large markets by conditions *1e* and *1f.* Firm 1 won't deviate to medium because of conditions *1b* and *1c* which ensure that firm 2 enters blindly regardless of firm 1's strategy for medium markets. □

Figure 5 summarizes the first five lemmas. These are the only lemmas under the special case where research is free for firm 1 and costly for firm 2. Regions in the figure are shaded according to whether entry is "excessive" or "insufficient." Entry is excessive in the sense that firms enter markets in which returns are less than entry costs, such as when the market size is small but firm 2 enters anyway, as in Lemma 1 (L,E,E). There is excess entry because firm 2 is uninformed when research costs are high and entry costs are low (dark region).

When research and entry costs are both high there is "insufficient" entry (lightly-shaded region), in the sense that firms forego markets in which returns exceed entry costs, such as when firm 1 foregoes medium markets, as in Lemma 2 (L,E,N).

When research costs are low, however, both firms purchase research when it has positive value. Research does not have positive value, for example, if your rival enters only large markets and you observe your rival entering. For both Equilibria 4 and 5, there are two firms in large markets, one firm in medium markets, and no firms in small markets.

Lemmas 4 and 5 are alike in that entry is neither excessive nor insufficient, but there are interesting distributional differences between them.

If research costs rise so that strategies change from Lemma 4 (M,L,N) to Lemma 5 (L,E,M), then firm 2 benefits at the expense of firm 1. Firm 2's profits rise because now firm 2 receives monopoly profits in medium markets rather than firm 1. Furthermore, firm 2 switches from researching when firm 1 enters to researching when firm 1 does not enter.

Proposition 3. *When the follower's research costs rise, its profit can rise too, because it can credibly commit to free riding on its rival.*

We can show that under the conditions for Lemma 5 (L,E,M), the expected profit for firm 2 from Lemma 5 is greater than the expected profit for firm 2 from Lemma 4 (M,L,N). The former is $E\Pi^2_{MLN} = (1-F(\theta_d))(E\pi(\theta > \theta_d, 1) - K - R_2) + (F(\theta_d) - F(\theta_m))(-R_2) + F(\theta_m)(0)$.

The latter is $E\Pi^2_{LEM} = (1 - F(\theta_d))(E\pi(\theta > \theta_d, 1) - K) + (F(\theta_d) - F(\theta_m))(E\pi(\theta_d > \theta > \theta_m, 0) - K - R_2) + F(\theta_m)(-R_2)$. The difference in profits is $E\Pi^2_{LEM} - E\Pi^2_{MLN} = (F(\theta_d) - F(\theta_m))(E\pi(\theta_d > \theta > \theta_m, 0) - K) - R_2F(\theta_d) + R_2(1 - F(\theta_m))$. Clearly, the third term, $R_2(1 - F(\theta_m))$, is positive. The sum of the first two terms is positive, too, by Condition *5d*.

We examine the effect of research costs on profit and social welfare in greater detail in section 3.3.

3.2 Equilibria where Leader is Uninformed

We now consider lemmas in which firm 1 is uninformed prior to entry because it chooses not to pay research cost R_1.

In Lemma 6 below firm 1 does not enter and firm 2 researches then enters medium and large markets. Firm 1 does not enter, because if it did so firm 2 would blindly follow.

Lemma 6 (N,E,M)**.** *There is an equilibrium where firm 1 does not enter, firm 2 enters if firm 1 enters, and firm 2 enters medium and large markets if firm 1 does not enter if the following conditions hold:*

6a. $R_2 \leq -F(\theta_m)[E\pi(\theta < \theta_m, 0) - K]$. *(Converse of 7d for* $R_i = R_2$*.)*

6b. $R_2 \leq [1 - F(\theta_d)][E\pi(\theta > \theta_d, 0) + (F(\theta_d) - F(\theta_m))[E\pi(\theta_d > \theta > \theta_m, 0) - K]$. *(Converse of 10b for* $R_i = R_2$*.)*

6c. Same as condition 1b (appendix). (Converse of 3a.)

6d. Same as condition 1c (appendix). (Converse of 4a.)

6e. Same as condition 1e (appendix). (Converse of 8b for $R_i = R_1$*.)*

6f. $R_1 > [1 - F(\theta_d)][E\pi(\theta > \theta_d, 1) - K]$. *(Converse of 1f.)*

The beliefs that support the equilibrium are:

$$\mu_2(\theta, 1) = \begin{cases} \frac{f(\theta)}{1-F(\theta_d)} & \textit{for } \theta > \theta_d \\ 0 & \textit{otherwise} \end{cases}$$
$$\mu_2(\theta, 0) = f(\theta)\forall\theta$$

Proof of Lemma 6 (N,E,M). Consider firm 2's best response. If firm 1 does not enter and is uninformed, then firm 2 will do research and enter medium and large markets by conditions *6a* and *6b*. If firm 1 is informed and enters, then firm 2 will enter by conditions *1b* and *1c*, even if firm 1 is entering medium as well as large markets. Consider firm 1. Firm 1 prefers to research and enter large markets rather than entering blindly by condition *1e*. Firm 1 does not enter medium markets since firm 2 will always follow firm 1 when firm 1 enters by conditions *1b* and *1c*. Hence, if firm 1 enters it will research first and enter only large markets, consistent with firm 2's beliefs. Firm 1 prefers, however, to not enter rather by condition *6f*. □

In Lemma 7 below firms cluster in large markets, and only firm 1 enters medium markets, because firm 2 pays for research about market demand before following firm 1. Firm 2 pays for research when firm 1 enters, because firm 1 not only enters large markets, but also medium and even small markets where firm 1 sustains losses.

Lemma 7 (E,L,E)**.** *There is an equilibrium where firm 1 enters without research, firm 2 researches and enters large markets if firm 1 enters, and firm 2 enters if firm 1 does not enter if the following conditions hold:*

7a. Same as condition 4a. (Converse of 1c.)

7b. $R_2 \leq [F(\theta_m) - F(\theta_d)][E\pi(\theta_d > \theta > \theta_m, 1) - K] - F(\theta_m)[E\pi(\theta < \theta_m, 1) - K]$. *(Converse of 8b for* $R_i = R_2$*.)*

7c. $R_2 \leq [1 - F(\theta_d)][E\pi(\theta > \theta_d, 1) - K]$. *(Converse of 9c.)*

7d. $R_i > -F(\theta_m)[E\pi(\theta < \theta_m, 0) - K] \forall i$. *(Converse of 3c for* $R_i = R_1$ *and 6a* $R_i = R_2$*.)*

The beliefs that support this equilibrium are $\mu_2(\theta, 1) = \mu_2(\theta, 0) = f(\theta)\ \forall\theta$.

Proof of Lemma 7 (E,L,E). Consider firm 2's best response. If firm 1 enters without being informed, firm 2 believes the market offers duopoly profits in small, medium, or large markets. Firm 2 prefers to research and enter large markets by conditions *7b* and *7c.* Conditions *4a* and *7c* ensure that firm 2 researches then enters large markets, even if firm 1 researches and enters medium markets. If a firm has no information and expects to be a monopolist in medium markets, as is the case for firm 1 and for firm 2 when firm 1 is out, then the firm prefers to enter without information by conditions *7c* and *7d.* Note that by combining *7c* and *7d* we get $K \leq [1-F(\theta_d)]E\pi(\theta > \theta_d, 1)+[F(\theta_d)-F(\theta_m)]E\pi(\theta_d > \theta > \theta_m, 0)+F(\theta_m)E\pi(\theta_m > \theta, 0)$. □

In the previous seven lemmas, at least one firm has been informed of market demand prior to entering. Research can, however, be so costly that no firms are informed, as in Equilibria 8-10 (appendix). In Lemma 8 both firms always enter without first conducting research (E,E,E). In Lemma 9 there is a monopolist and neither firm is informed before entering (E,N,E). In Lemma 10 research and entry costs are so high that no firms enter (N,N,N).

Proposition 4. *Given the parameter values of* θ*,* K*, and* $R_1 = R_2$*, there is a unique equilibrium characterized by Lemmas 1-10.*

Using the conditions in Lemmas 1-10, it is straightforward to show that the equilibrium is unique and has full coverage. For each condition in each lemma, there is a corresponding converse in another lemma. The equilibrium is illustrated in Figure 6. When research costs are high and entry costs are low, firms sometimes enter markets in which returns do not cover the entry costs (dark shade). When research costs and entry costs are both high, firms sometimes forego markets in which returns would cover entry costs (light shade). For example, in Lemma 9 (E,N,E) only one firm enters, even though large markets are profitable for two.

3.3 Welfare and Profit when Research Is Costly

Recall that welfare losses result from 1) entry costs, 2) research costs, 3) consumers unserved because no firms enter their market, and 4) consumers unserved because sales are limited by monopolists (and to a lesser extent duopolists) in order to increase prices. In section 2.3 we focused on the effect of entry costs on welfare. Here we focus on the effect of research costs on welfare. We revise equation 1 to include research cost R.

$$EW = \int_{\theta_a}^{\theta_b} \frac{(\theta + p(\theta, Q))Q}{2(\theta_b - \theta_a)} d\theta - N_k K - N_r R \tag{2}$$

where $N_r \in (0, 1, 2)$ is the number of firms paying the research cost R.

Figure 7 illustrates the effect on social welfare and expected profits of changes in research costs. Entry costs are fixed (using the simple example with $K = 400$). When research costs are low, firm 1 enters medium markets and firm 2 researches before following (M, L, N). Consistent with Proposition 3, when firm 2's research costs are lower, firm 2's profits are lower, because firm 2 can no longer credibly commit to ignorance and thus can no longer free ride on firm 1.

When research costs (and fixed entry costs) are moderate, firm 2 strictly follows firm 1 (L, E, N). Consistent with Proposition 1, medium markets are not entered by either. This free riding leads to lower social welfare. Furthermore, firm 2's profits exceed firm 1's profits.

When research costs are high, neither firm purchases information (E, E, E). Hence, welfare and profit functions are horizontal because further increases in research costs affect neither firm.

4 Conclusion

The classic explanation for agglomeration offered by Hotelling is that firms locate near one another because they believe that they will attract all consumers located on their side. An alternative explanation is that firms cluster because one firm is free riding on the information of another.

Entry into a market by an informed firm provides its rival with a noisy signal about market demand. This is similar to the result from the literature on herd behavior, except that the first firm is harmed by the entry of the second. Hence, the first firm must account for the reaction of its rival when it decides whether to enter a market. The first firm might forego a market that it knows to be profitable.

Due to advances in technology, information has become less costly to obtain in recent years. The model predicts that there will be less free-riding behavior. This is not necessarily beneficial to all firms, however, as the second firm can no longer credibly commit to ignorance. If the second firm is informed, it will not follow the first firm into markets that support only one firm. Hence, the first firm can capture markets that support only one firm, rather than having those captured by its rival.

5 Appendix

Proof of Lemma 0. First consider Lemma 0a. By Assumption 4 there exists some $\theta < \theta_d$ such that $\pi(\theta, 0) < 0$ and by Assumption 3 $\pi(\theta, 1) < \pi(\theta, 0)$, so $\pi(\theta, 1) < \pi(\theta, 0) < 0$. Likewise, by Assumption 4 there exists some $\theta > \theta_d$ such that $\pi(\theta, 1) > 0$. By Assumption 2, there exists some θ_d such that Lemma 0a holds. Likewise, by Assumption 4 there exists some $\theta > \theta_d$ such that $\pi(\theta, 1) > 0$. By Assumption 2, there exists some θ_d such that Lemma 0a holds. Second consider Lemma 0b. By Assumption 3 $\pi(\theta, 1) < \pi(\theta, 0)$ $\forall\theta$ and by Assumption 4 there exists some θ such that $\pi(\theta, 1) > 0$, so there exists some θ such that $\pi(\theta, 0) > \pi(\theta, 1) > 0$. Likewise, by Assumption 4 there exists some θ such that $\pi(\theta, 0) < 0$. By Assumption 2, there exists some θ_m such that Lemma 0b holds. Third consider Lemma 0c. If $\theta_m > \theta' > \theta_d$ then by Lemma 0a $\pi(\theta', 1) > 0$ and by Lemma 0b $\pi(\theta', 0) < 0$. Hence, $\pi(\theta', 1) > 0 > \pi(\theta', 0)$, but by Assumption 3 $\pi(\theta', 1) < \pi(\theta', 0)$. This is a contradiction so it is not the case that $\theta_m > \theta' > \theta_d$. Likewise, $\theta_m = \theta_d$ would lead to a contradiction because it would require that $\pi(\theta, 0) = \pi(\theta, 1)$. Consider instead if $\theta_m < \theta' < \theta_d$ then by Lemma 0a $\pi(\theta', 1) < K$ and by Lemma 0b $\pi(\theta', 0) > K$. Hence, $\pi(\theta', 1) < K < \pi(\theta', 0)$ which corresponds with Assumption 3 $\pi(\theta', 1) < \pi(\theta', 0)$. □

Equilibria 1-3 are the same as in section 2 except new conditions are added to examine cases in which $R_i \geq 0$.

Lemma 1 (L,E,E)**.** *There is a unique perfect Bayesian equilibrium where firm 1 researches and only enters large markets and firm 2 always enters if the following hold:*

1a. $K \leq \frac{F(\theta_d)-F(\theta_m)}{F(\theta_d)} E\pi(\theta_d > \theta > \theta_m, 0) + \frac{F(\theta_m)}{F(\theta_d)} E\pi(\theta < \theta_m, 0)$. *(Converse of 2a.)*

1b. $K \leq \frac{1-F(\theta_d)}{1-F(\theta_m)} E\pi(\theta > \theta_d, 1) + \frac{F(\theta_d)-F(\theta_m)}{1-F(\theta_m)} E\pi(\theta_d > \theta > \theta_m, 1)$. *(Converse of 3a.)*

1c. $R_2 > \frac{F(\theta_m)-F(\theta_d)}{1-F(\theta_m)} [E\pi(\theta_d > \theta > \theta_m, 1) - K]$. *(Converse of 4a.)*

1d. $R_2 > \frac{-F(\theta_m)}{F(\theta_d)}[E\pi(\theta < \theta_m, 0) - K]$. *(Converse of 5c.)*

1e. $R_1 \leq [F(\theta_m) - F(\theta_d)][E\pi(\theta_d > \theta > \theta_m, 1) - K] - F(\theta_m)[E\pi(\theta < \theta_m, 1) - K]$. *(Converse of 8b for $R_i = R_1$.)*

1f. $R_1 \leq [1 - F(\theta_d)][E\pi(\theta > \theta_d, 1) - K]$. *(Converse of 6f.)*

The beliefs that support the equilibrium are:

$$\mu_2(\theta, 1) = \begin{cases} \frac{f(\theta)}{1-F(\theta_d)} & \text{for } \theta > \theta_d \\ 0 & \text{otherwise} \end{cases}$$

$$\mu_2(\theta, 0) = \begin{cases} \frac{f(\theta)}{F(\theta_d)} & \text{for } \theta < \theta_d \\ 0 & \text{otherwise} \end{cases}$$

Proof of Lemma 1 (L,E,E). Consider firm 2's best response. If firm 1 enters, it believes the market is large so it will enter by lemma 1. Conditions *1b* and *1c* ensure that firm 2 enters blindly even if firm 1 enters medium and large. If firm 1 does not enter, firm 2 believes the market is medium or small. It will decide to enter without research if *1a* and *1d* hold because gains from a medium monopoly are expected to be positive. Consider firm 1's best response. Firm 1 is aware of beliefs and strategy for firm 2. Since firm 2 always enters blindly, firm 1's best response is to research and only enter large by *1e* and *1f*. Medium will bring in losses and not entering forfeits profits. □

Lemma 2 (L,E,N)**.** *There is a unique perfect Bayesian equilibrium where firm 1 researches and only enters large markets and firm 2 only enters when firm 1 enters if the following conditions are met:*

2a. $K > \frac{F(\theta_d)-F(\theta_m)}{F(\theta_d)} E\pi(\theta_d > \theta > \theta_m, 0) + \frac{F(\theta_m)}{F(\theta_d)} E\pi(\theta < \theta_m, 0)$. *(Converse of 1a.)*

2b. Same as condition 1b. (Converse of 3a.)

2c. Same as condition 1c. (Converse of 4a.)

2d. $R_2 > \frac{F(\theta_d)-F(\theta_m)}{F(\theta_d)}[E\pi(\theta_d > \theta > \theta_m, 0) - K]$. *(Converse of 5d.)*

2e. Same as condition 1e. (Converse of 8b for $R_i = R_1$*.)*

2f. Same as condition 1f. (Converse of 6f.)

The beliefs that support the equilibrium are:

$$\mu_2(\theta, 1) = \begin{cases} \frac{f(\theta)}{1-F(\theta_d)} & \text{for } \theta > \theta_d \\ 0 & \text{otherwise} \end{cases}$$

$$\mu_2(\theta, 0) = \begin{cases} \frac{f(\theta)}{F(\theta_d)} & \text{for } \theta < \theta_d \\ 0 & \text{otherwise} \end{cases}$$

Proof of Lemma 2 (L,E,N). Consider firm 2's best response. If firm 1 enters it believes the market is large, so it will enter by lemma 1. Conditions *1b* and *1c* ensure that the firm enters blindly even if firm 1 enters medium and large. If firm 1 does not enter, firm 2 believes the market is medium or small. It will decide to not enter and research by conditions *2a* and *2d*. Consider firm 1's best response. Conditions *1e* and *1f* ensure that it wants to do research and enter large markets. Given the beliefs and strategy of firm 2, firm 1 will have to enter only large markets (it can't deviate to medium and large because 2 enters blindly). □

Lemma 3 (M,N,N)**.** *There is an equilibrium where firm 1 researches and enters medium and large markets, and firm 2 never researches or enters, if the following hold:*

3a. $K > \frac{1-F(\theta_d)}{1-F(\theta_m)}E\pi(\theta > \theta_d, 1) + \frac{F(\theta_d)-F(\theta_m)}{1-F(\theta_m)}E\pi(\theta_d > \theta > \theta_m, 1)$. *(Converse of 1b.)*

3b. $R_2 > \frac{1-F(\theta_d)}{1-F(\theta_m)}[E\pi(\theta > \theta_d, 1) - K]$. *(Converse of 4b.)*

3c. $R_1 \leq -F(\theta_m)[E\pi(\theta < \theta_m, 0) - K]$. *(Converse of 7d for* $R_i = R_1$*.)*

3d. $R_1 \leq [1 - F(\theta_d)][E\pi(\theta > \theta_d, 0) - K] + [F(\theta_d) - F(\theta_m)][E\pi(\theta_d > \theta > \theta_m, 0) - K]$. *(Converse of 10b.)*

The beliefs that support the equilibrium are:

$$\mu_2(\theta,1) = \begin{cases} \frac{f(\theta)}{1-F(\theta_m)} & \textit{for } \theta > \theta_m \\ 0 & \textit{otherwise} \end{cases}$$

$$\mu_2(\theta,0) = \begin{cases} \frac{f(\theta)}{F(\theta_m)} & \textit{for } \theta < \theta_m \\ 0 & \textit{otherwise} \end{cases}$$

Proof of Lemma 3 (M,N,N). Consider firm 2's best response. If firm 1 enters, condition *3a* ensures that firm 2 does not enter the market blindly. Furthermore, condition *3b* ensures that there is no benefit from researching and entering a large duopoly market. If firm 1 does not enter, then firm 2 believes that the market is small and will decide not to enter by lemma 1. Consider firm 1's best response. Since firm 2 is not entering, firm 1 will research and enter by *3c* and *3d* above. It will always enter medium or large because it will have a monopoly in both which implies positive profits. Switching from this strategy would result in negative or forfeited profits. □

In Equilibria 8-10, research costs are sufficiently high that neither firm is informed of market demand before entering.

Lemma 8 (E,E,E)**.** *There is an equilibrium where firm 1 enters without research and firm 2 always enters if the following hold:*

8a. $K \leq [1 - F(\theta_d)][E\pi(\theta > \theta_d, 1)] + [F(\theta_d) - F(\theta_m)][E\pi(\theta_d > \theta > \theta_m, 1)] + F(\theta_m)E\pi(\theta < \theta_m, 1)$. *(Converse of 9b.)*

8b. $R_i > [F(\theta_m) - F(\theta_d)][E\pi(\theta_d > \theta > \theta_m, 1) - K] - F(\theta_m)[E\pi(\theta_m > \theta, 1) - K] \forall i$. *(Converse of 1e for $R_i = R_1$ and 7b for $R_i = R_2$.)*

The beliefs that support this equilibrium are $\mu_2(\theta, 1) = \mu_2(\theta, 0) = f(\theta)\ \forall\theta$.

Proof of Lemma 8 (E,E,E). Consider firm 2's best response. Firm 2 believes that firm 1's actions provide no new information because firm 1 is uninformed by condition *8b.* If firm 1 enters, firm 2 enters because expected duopoly profits across all market sizes are positive by condition *8a* and research is too costly by condition *8b.* Likewise, if firm 1 does not enter, firm 2 finds it more profitable to enter; obviously if duopoly profit is high, then monopoly profits must be even higher. Finally, it follows that firm 1's profit-maximizing strategy is to enter by the same conditions *8a* and *8b.* □

Lemma 9 (E,N,E)**.** *There is an equilibrium where firm 1 enters, firm 2 does not enter when firm 1 enters, and firm 2 enters when firm 1 does not enter if the following conditions hold:*

9a. $K \leq [1 - F(\theta_d)]E\pi(\theta > \theta_d, 0) + [F(\theta_d) - F(\theta_m)]E\pi(\theta_d > \theta > \theta_m, 0) + F(\theta_m)E\pi(\theta_m > \theta, 0)$. *(Converse of 10a.)*

9b. $K > [1 - F(\theta_d)]E\pi(\theta > \theta_d, 1) + [F(\theta_d) - F(\theta_m)]E\pi(\theta_d > \theta > \theta_m, 1) + F(\theta_m)E\pi(\theta < \theta_m, 1)$. *(Converse of 8a.)*

9c. $R_2 > [1 - F(\theta_d)][E\pi(\theta > \theta_d, 1) - K]$. *(Converse of 7c.)*

9d. Same as condition 7e. (Converse of 3c for $R_i = R_1$ *and 6a for* $R_i = R_2$*.)*

The beliefs that support this equilibrium are $\mu_2(\theta, 1) = \mu_2(\theta, 0) = f(\theta)\ \forall\theta$.

Proof of Lemma 9 (E,N,E). Consider firm 2's best response. If firm 1 enters blindly, then firm 2 will prefer to stay out by conditions *9b* and *9c.* If firm 1 does not enter and is uninformed, then firm 2 will prefer to enter blindly by conditions *9a* and *9d.* Given that firm 2 does not follow, firm 1 enters blindly by conditions *9a* and *9d.* □

Lemma 10 (N,N,N)**.** *There is an equilibrium where neither firm 1 nor firm 2 enter if the following conditions hold:*

10a. $K > [1 - F(\theta_d)]E\pi(\theta > \theta_d, 0) + [F(\theta_d) - F(\theta_m)]E\pi(\theta_d > \theta > \theta_m, 0) + F(\theta_m)E\pi(\theta_m > \theta, 0)$. *(Converse of 9a.)*

10b. $R_i > [1 - F(\theta_d)][E\pi(\theta > \theta_d, 0) - K] + [F(\theta_d) - F(\theta_m)][E\pi(\theta_d > \theta > \theta_m, 0) - K]$. *(Converse of 6b when $R_i = R_2$.)*

The beliefs that support this equilibrium are $\mu_2(\theta, 1) = \mu_2(\theta, 0) = f(\theta) \forall \theta$.

Proof of Lemma 10 (N,N,N). Consider firm 2's best response. If firm 1 enters or does not enter, firm 2 does not enter by condition *10a* and does not research by condition *10b*. Firm 1's entry provides no information since firm 1 is uninformed, except converting the market from monopoly to duopoly. Whether the market is monopoly or duopoly, entry and research are so costly as to make expected returns negative. Likewise, entry and research are not expected to be profitable by firm 1 due to conditions *10a* and *10b* respectively.

□

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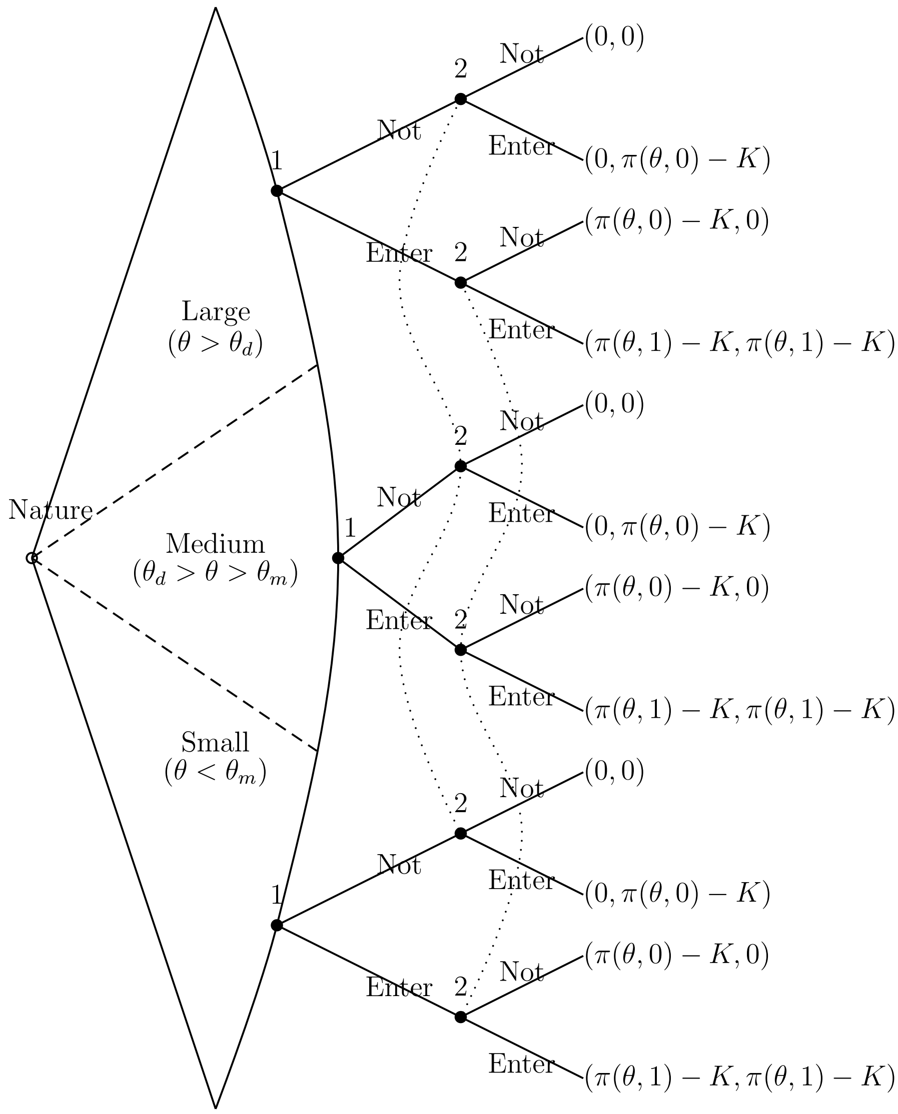


Figure 1: Extensive form of the game when research about market size θ is free for the leader and infinitely costly for the follower. Payoffs for firms 1 and 2 are (Π_1,Π_2).

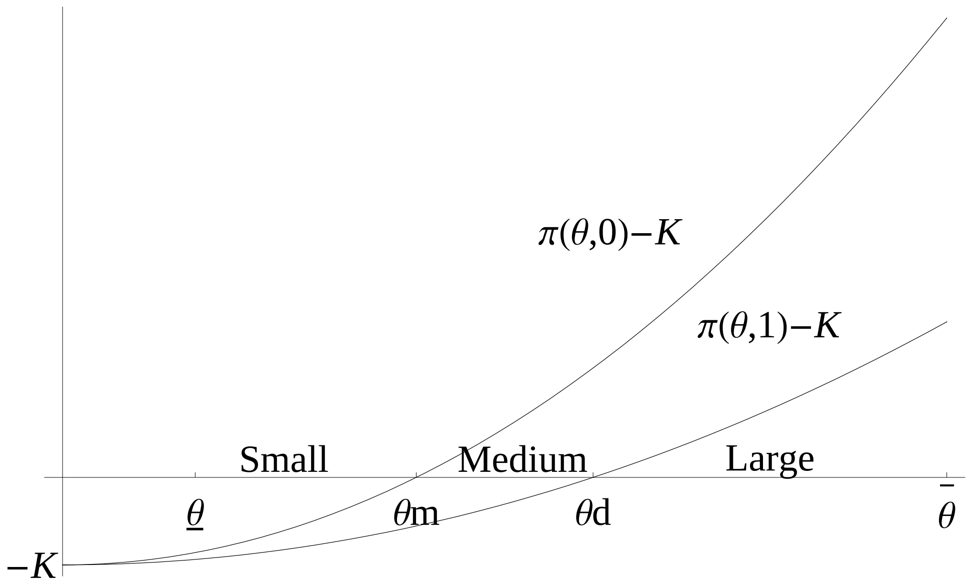


Figure 2: Monopoly and duopoly profit as a function of market size θ where small, medium, and large markets support 0, 1, and 2 firms respectively.

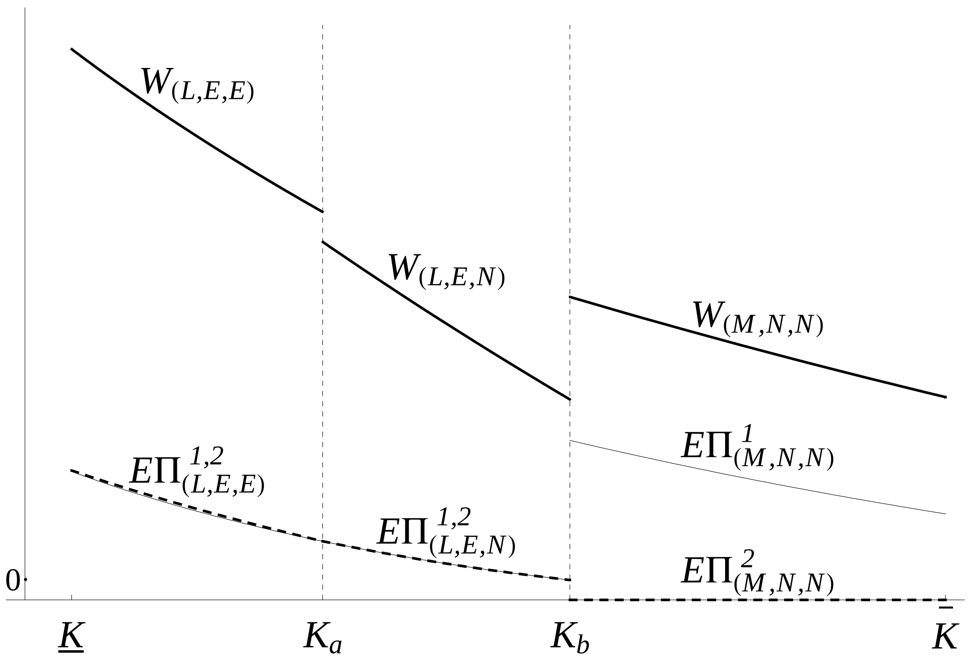
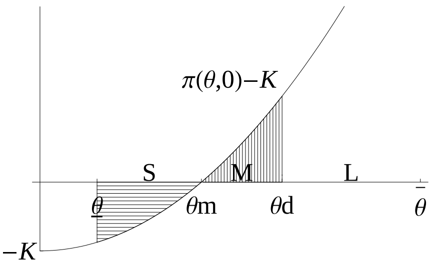
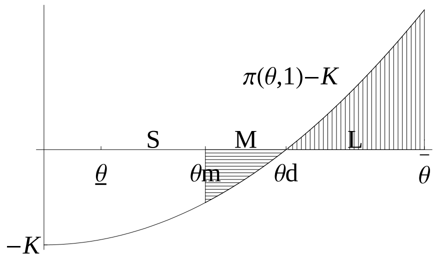


Figure 3: Social welfare W and expected profit $E\Pi^i$ for firm i depend on the entry cost K and firm strategies. In this example, research is free for firm 1 and infinitely costly for firm 2.

<table>
<tr><td colspan="2">Lemma 2 (L,E,N)
$K = 450,\ R_i = 200,\ \underline{\theta} = 15,\ \bar{\theta} = 100$</td></tr>
<tr><td>2a. Expected monopoly profits are negative when markets are small or medium

</td><td>1b. Expected duopoly profits are positive when markets are medium or large

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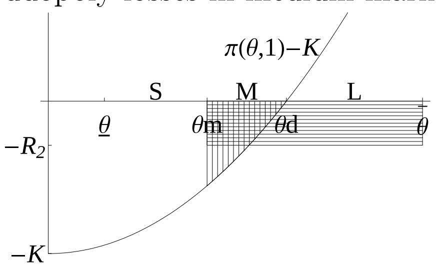
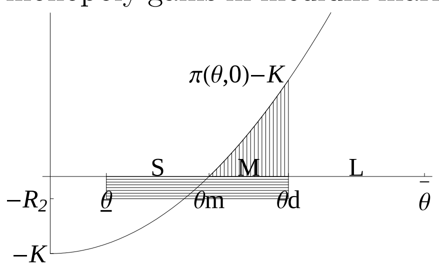
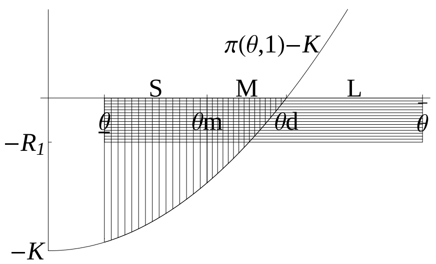
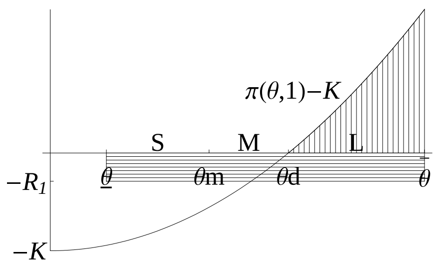

</td><td>2d. Research costs exceed expected monopoly gains in medium markets

</td></tr>
<tr><td>1e. Expected duopoly losses in small and medium markets exceed research costs

</td><td>1f. Expected duopoly gains in large markets exceed research costs

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Figure 4: Profit is a function of market size θ, entry cost K, research cost R_i, and whether the rival entered the market. This example illustrates the six conditions for Lemma 2 (L,E,N).

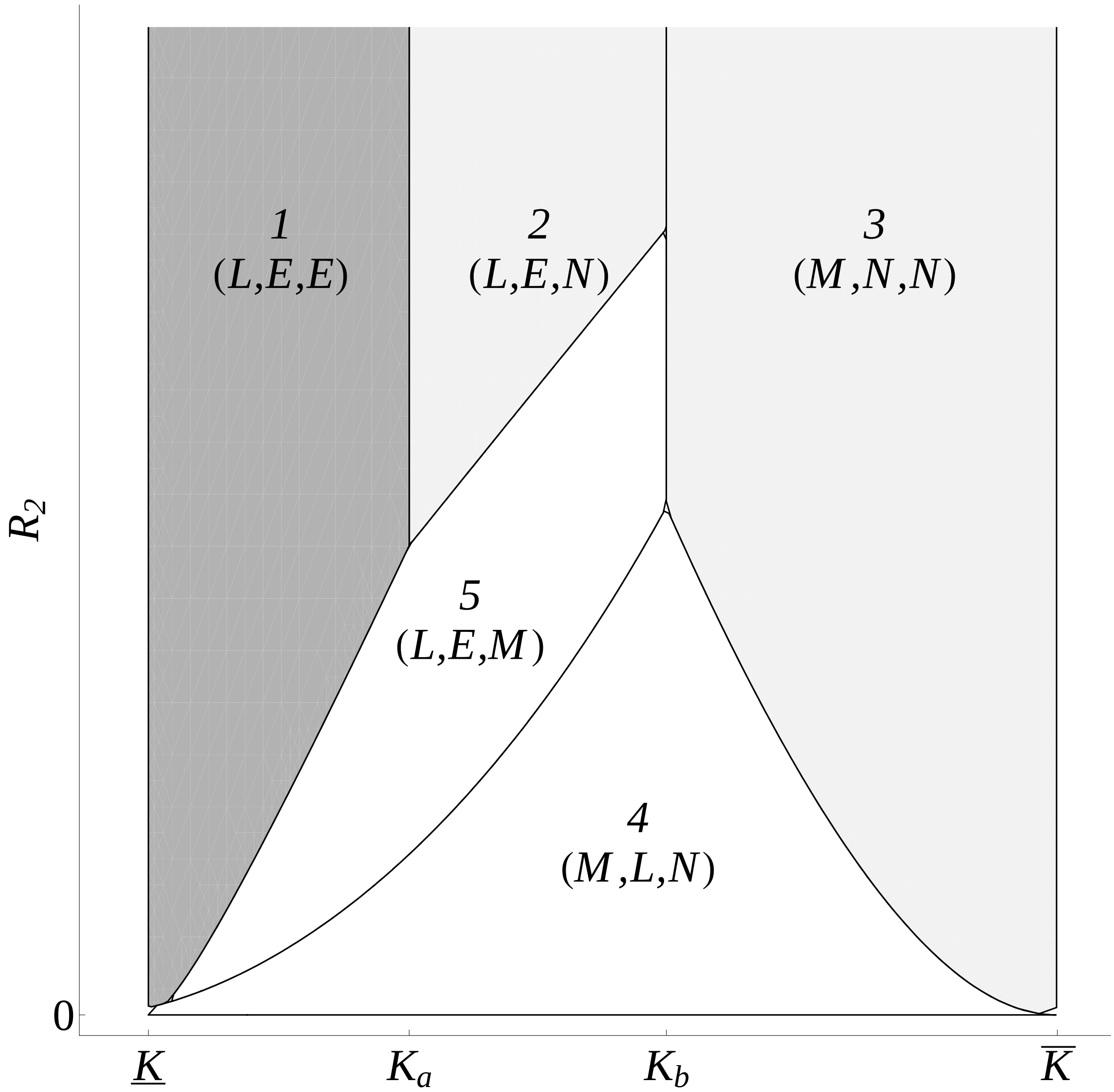

Figure 5: When firm 2's research cost ($R_2 > R_1 = 0$) is high and entry cost K is low, firms sometimes enter markets in which returns do not cover entry cost (dark shade). When research and entry costs are both high, firms sometimes forego markets in which returns would cover entry cost (light shade).

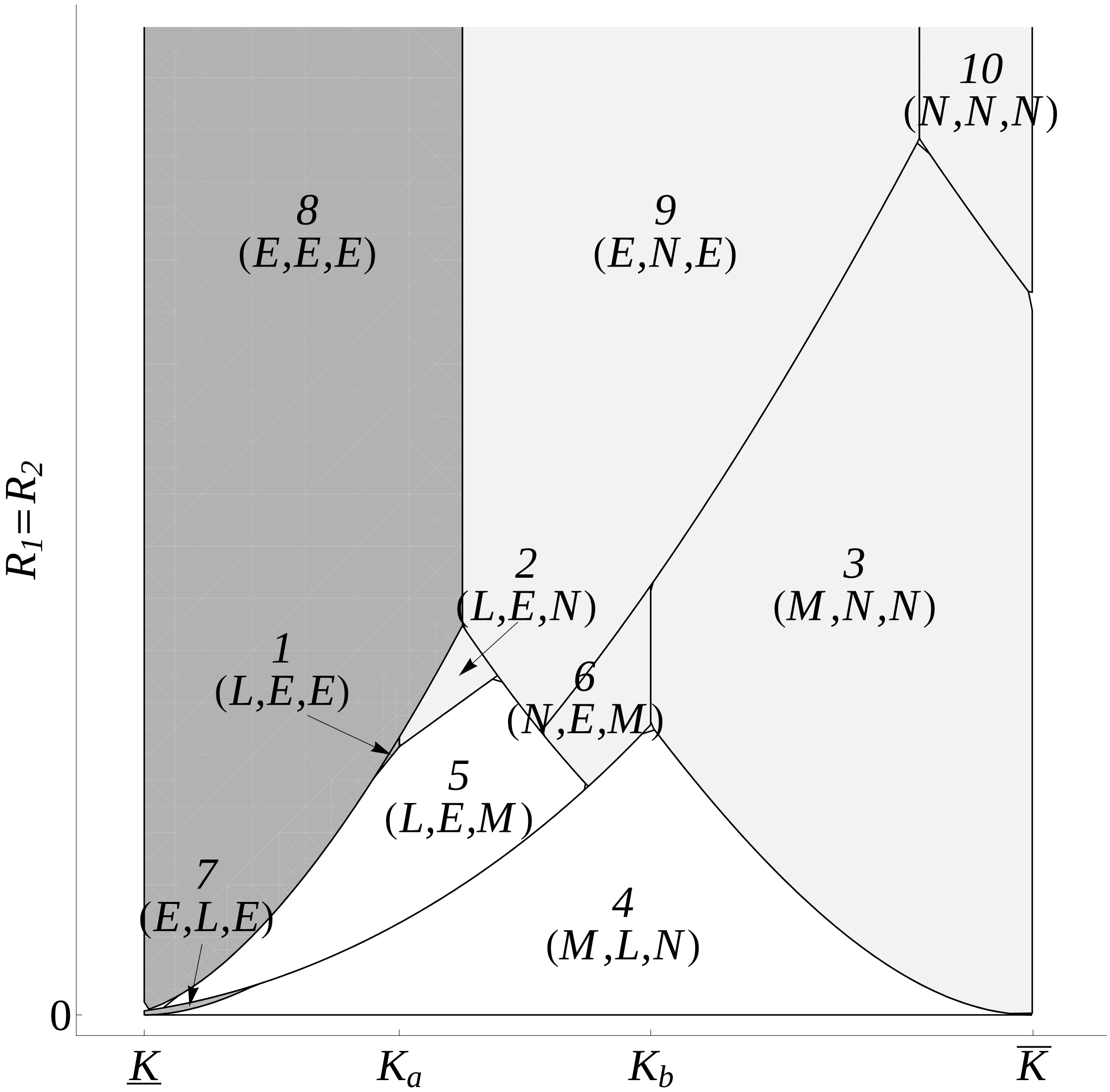

Figure 6: When research cost R_i is high and entry cost K is low, firms sometimes enter markets in which returns do not cover entry costs (dark shade). When research and entry costs are both high, firms sometimes forego markets in which returns would cover entry costs (light shade).

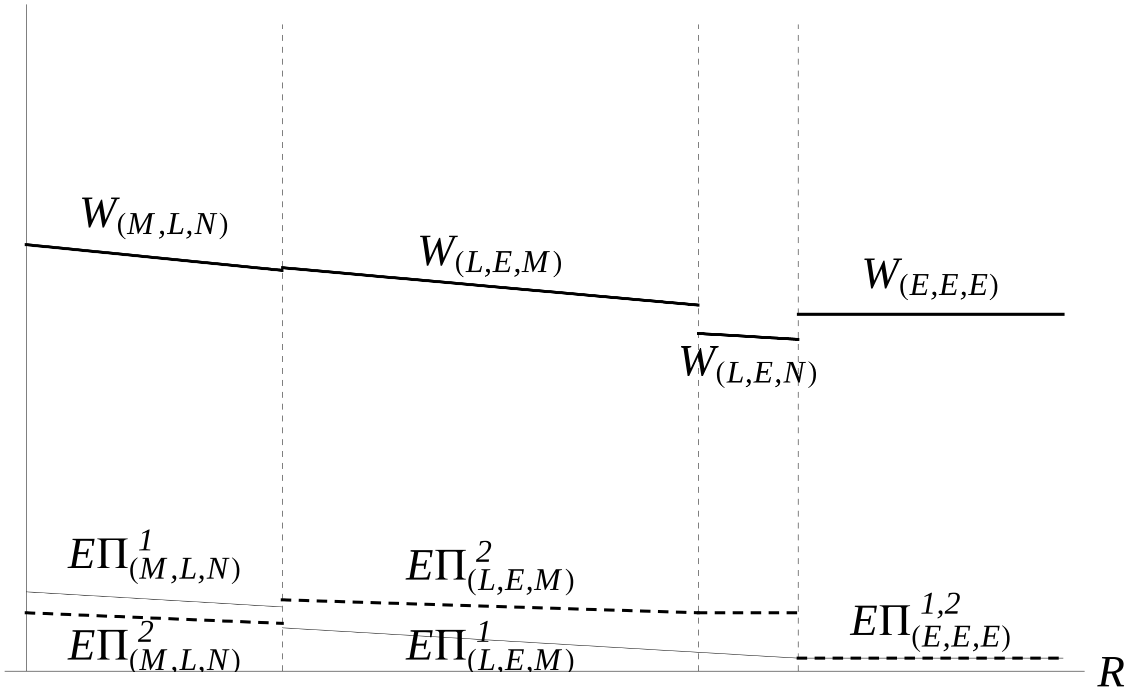

Figure 7: Social welfare W and expected profit $E\Pi^i$ for firm i depend on the research cost $R_1 = R_2$ and firms' strategies. Entry cost K is fixed.