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THE ROLE OF FIXED ENTRY COSTS IN AN EVOLUTIONARY ENTRY GAME WITH BERTRAND PLAYERS

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Abstract

This paper analyzes the role of fixed costs in an evolutionary entry game with Bertrand players. A stable state fails to exist when entry is free, regardless of whether capacity constraints are present or not. When a fixed entry cost is introduced, there is a unique evolutionarily stable strategy (ESS) identical to the ESS outcome of Soytas and Becker (2003) and resembling the separating equilibrium of Milgrom and Roberts (1982). The unique ESS emerges even when capacity constraints are imposed. However, the fixed cost must be sufficiently large for the ESS to prevail if the incumbent has capacity limitations.

Keywords: Fixed costs, capacity constraints, entry, Bertrand competition, ESS.

Öz

Bertrand Oyunculu Evrimsel Piyasaya Giriş Oyununda Sabit Maliyetlerin Rolü

Bu makalede fiyat bazlı rekabet eden oyuncuların bulunduğu evrimsel bir piyasaya giriş oyununda sabit maliyetlerin rolü incelenmiştir. Kapasite kısıtlamaları olsun veya olmasın, giriş serbest iken popülasyonun kararlı bir dengesi yoktur. Sabit maliyetler modele eklendiğinde ise tek bir evrimsel kararlı stratejiler vektörü ortaya çıkmaktadır. Bu evrimsel kararlı stratejiler Soytas ve Becker (2003) de bulunan evrimsel kararlı stratejilere ve Milgrom ve Roberts'ın (1982) ortaya koyduğu ayrıştırılabilir dengedeki stratejilere benzeşmektedir. Fakat kapasite kısıtlamaları söz konusuyken bulunan dengenin kararlı olabilmesi için sabit maliyetlerin yeterince büyük olması gerekmektedir.

Anahtar Sözcükler: Sabit maliyetler, kapasite kısıtları, giriş, Bertrand rekabeti, evrimsel kararlı stratejiler.

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INTRODUCTION

When we assume Bertrand competition with identical firms, even a duopoly yields the perfectly competitive outcome. However, when the players have to sink even a small amount of cost, the Bertrand Nash equilibrium yields negative payoffs for both players. When we allow free entry in the presence of sunk costs, we see that entry is deterred because the entrant conjectures that the Bertrand Nash equilibrium will hold upon entry. Hence, he chooses to stay out. Entry deterrence arises as a result of the existence of sunk costs and the belief structure of the players.

Microeconomic theory tells us that the monopolist chooses an output or price level at which marginal revenue equals marginal cost, and enjoys monopoly profit. This is due to the implicit assumption that there are significant entry barriers in the industry that protect the monopolist. In other words, the existence of entry barriers is taken for granted. The relaxation of this assumption, by the emergence of industrial organization as a field, was one of the main contributions to the study of imperfect competition. Therefore, most of the interest in the entry deterrence literature that followed was on analyzing the strategic interaction of the incumbent and the potential entrant when the main assumption underlying the Bain-Sylos postulate is abandoned (Kreps, 1990). Furthermore, the potential entrant's decision will depend on how he perceives the post entry game. However, the results may change when the information structure of the players can be modeled differently. For example, Milgrom and Roberts (1982) show that in the face of incomplete information limit pricing may be possible. They also point out how potential entrants may treat pre-entry output of incumbents as signals for post-entry competition. Soytas and Becker (2003) show that in an evolutionary game with Cournot players and where the potential entrant must pay a fixed amount upon entry, limit pricing strategy of the low cost incumbent is an evolutionarily stable strategy (ESS). An ESS is an equilibrium strategy that survives the invasion of mutant strategies. Strategy α^* is an ESS for all $\alpha \neq \alpha^*$ if the following conditions are satisfied (Samuelson; 1997: p.38).

i) if $\pi(\alpha^*, \alpha^*) \geq \pi(\alpha, \alpha^*)$ and

ii) if $\pi(\alpha^*, \alpha^*) = \pi(\alpha, \alpha^*)$, then $\pi(\alpha^*, \alpha) > \pi(\alpha, \alpha)$.

Baumol, Panzar, and Willig (1982) have developed the concept of perfectly contestable markets, in which there are no sunk costs, and entry and exit is free. Another assumption underlying the contestable market setting is that the potential competitors have identical cost structures with incumbents.

The potential entrants can enter and exit before the incumbents can respond to entry by changing prices.

The sustainability-contestability approach may best be applied to an industry with a homogeneous product and increasing returns to scale to analyze the efficiency in that natural monopoly industry. Indeed, Becker (1986) shows that in an industry with fixed costs and free entry the profit-maximizing incumbent prefers a quantity setting strategy rather than a price setting strategy, and establishing as the von Stackelberg quantity leader. Therefore, he argues that there may be an inconsistency between the contestability theory and profit maximization hypothesis. Furthermore, according to von Weizsacker (1980), quantity competition with free entry may result in higher than socially optimal number of firms in the industry. Hence, Becker's (1986) example adds to the doubts about the relevance of the contestability theory to efficiency considerations.

The criticisms do not invalidate the contestable market outcome being a benchmark result. The interesting question to ask becomes what kind of strategic interactions may yield the perfectly contestable outcome. It is easy to see that in a Cournot setting the perfectly contestable outcome is an extreme case that can be achieved only in the limit (as number of firms approaches infinity). Furthermore, in the Bertrand game existence of two firms is enough to reach the contestable outcome. When we allow entry into the Bertrand setting with fixed costs, even one firm in the industry gives us the benchmark result as long as there is at least one potential entrant standing by.

Indeed, the unique Nash equilibrium of the game is that the incumbent pursues an average cost pricing strategy; whereas, the potential entrant stands by, ready to enter and charge a price equal to the average cost. In the equilibrium, price equals average cost, both players have zero payoffs, and the outcome corresponds to the perfectly contestable outcome. Hence, firms rationally choosing strategies among their strategy sets can achieve the perfectly contestable outcome.

A variation of the Bertrand game is when firms are constrained by their capacities, such that the low price firm fails to meet the entire demand. Hence, the high price firm has a positive residual demand. Here, one can assume efficient rationing in the sense that the consumers who value the good most are served first by the low price firm (Church and Ware, 2000, p. 265). If the two firms have the same cost structure and sufficient capacity, then the outcome is Bertrand equilibrium, when competition is in prices. On the other hand, if the two firms have different cost structures and sufficient capacity, then the low cost firm charges a price equal to the marginal cost of the rival and serves the entire market. However, if both capacity constraints are binding, then they produce to capacity and the market demand is simply the sum of the capacities of the two firms when we assume identical firms. In the case of only one firm constrained by its capacity, we observe an Edgeworth cycle, such that there is no equilibrium in pure strategies and firms continuously switch from low to high prices and vice versa. Dixit (1980) reports that the capacity level may be used as a precommitment device by the incumbent firm to deter entry. However, he also acknowledges that his study needs to be extended by including several firms and periods into the game.

Recently, there have been several studies on Bertrand competition. Elberfeld and Wolfstetter (1999) show that in a repeated game of simultaneous entry and pricing, the probability that the market breaks down gets higher as the number of potential entrants exceed two. They also point out that the social welfare declines with more competition. Thomas (2002) on the other hand studies a Bertrand game when entrants have asymmetric entry costs. He finds that the welfare must rise when a sufficiently small cost competitor enters the market. Boccard and Wauthy (2000) analyze a game with imperfect commitment to capacity and find that a range of prices may emerge under the equilibrium. Paech (1998) shows that in a contestable market, for the threat of entry by the potential entrant to work, there must be exit barriers in the industry. Hence, in the literature some studies examine Bertrand competition with asymmetric entry costs when entry is observed, whereas some studies are concerned with the outcome when firms learn the type of the rival after simultaneously setting prices. However, the models discussed above assume rational players and suffer from the multiple equilibria problem.

In a recent study, Rhode and Stegeman (2001) apply Darwinian dynamics to a symmetric, differentiated duopoly and find that on the average the Darwinian price is lower than the Bertrand Nash equilibrium price. Their game involves rational decision makers as well as imitators and the strategy space is infinite. The resulting non-Nash equilibria are stable and unique. They argue that pure imitation is an unrealistic approximation of behavior; however, they also report that when rational and imitative decision makers are mixed a purely imitative outcome may emerge. Soytas and Becker (2003) show that in an evolutionary entry game with Cournot competition and asymmetric information, limit pricing is observed in the stable state of the population.

In this paper, using the same game structure in Soytas and Becker (2003) I analyze the role of fixed costs in an evolutionary entry game with Bertrand players. I first conjecture that entry is free and then introduce a fixed entry cost and compare the results. Furthermore, capacity limitations are imposed with both free entry and a fixed entry cost. I assume that the players change their strategies via imitating the strategies that yield strictly higher payoffs. Hence, the game does not require fully rational players. In that respect, this paper utilizes a complementary approach to traditional game theory in the entry deterrence literature.

I find that in the absence of fixed entry costs the game does not have an evolutionary stable strategy (ESS) outcome whether the firms face capacity limitations or not. Therefore even the outcome that implies the contestable market result is not immune to invasion by rare mutant strategies (different rules adopted or imitated by the players). When a fixed entry cost is introduced, the ESS outcome resembles the separating equilibrium of Milgrom and Roberts (1982) such that the low cost incumbents play the limit output in the first stage and the potential entrants that observe limit output choose to stay out, whereas the high cost incumbents adopt the monopoly output in the first stage and potential entrants that observe monopoly output enter the market. The ESS outcome is identical to the stable state in Soytas and Becker (2003). When the potential entrant has capacity limitations, for the ESS to prevail, the fixed entry cost must be sufficiently large.

The organization of the paper is as follows. The evolutionary entry game and solution methodology is introduced in section 2. Section 3 introduces capacity constraints into the picture and compares the results. Section 4 provides a brief summary of the results and concludes.

I. THE EVOLUTIONARY ENTRY GAME

The first mover is a trivial player, the Nature. Nature randomly chooses one incumbent and one potential entrant from their respective populations to play the two stage entry game. The population of incumbents is divided into two: The low cost incumbents and the high cost incumbents with marginal costs c_L and c_H respectively. The proportion of low cost incumbents is δ and the proportion of high cost incumbents is $(1 - \delta)$. In the first stage, the incumbent chooses either the limit pricing strategy or the monopoly price. The limit price refers to the highest price that is believed to deter entry.

The proportions of low cost incumbents and high cost incumbents that play limit price are p_1 and p_2 respectively. Hence, $(1 - p_1)$ of low cost and $(1 - p_2)$ of high cost incumbents follow the monopoly price strategy in the first stage. In the second stage, the potential entrant with a marginal cost of c_E (where $c_L < c_E < c_H$) decides whether to enter or not. The incumbent is aware of its cost structure, whereas the potential entrant does not know the type of the incumbent. I assume that the potential entrant cannot tell the cost structure of the incumbent regardless of the first stage price choices since a monopoly price in the first stage by either type of incumbent firm will indicate the lack of an entry deterring signal. Each potential entrant also follows a simple rule. The p_3 proportion of potential entrants play Enter when they observe limit pricing, and $(1 - p_3)$ proportion play Stay out when limit price is observed. Likewise, p_4 proportion of potential entrants play Enter when monopoly price is charged in the first stage, and $(1 - p_4)$ play Stay out given monopoly price. Another assumption I have to make is that all strategies are represented with positive probabilities in the initial populations. The game tree is represented in Figure 1.

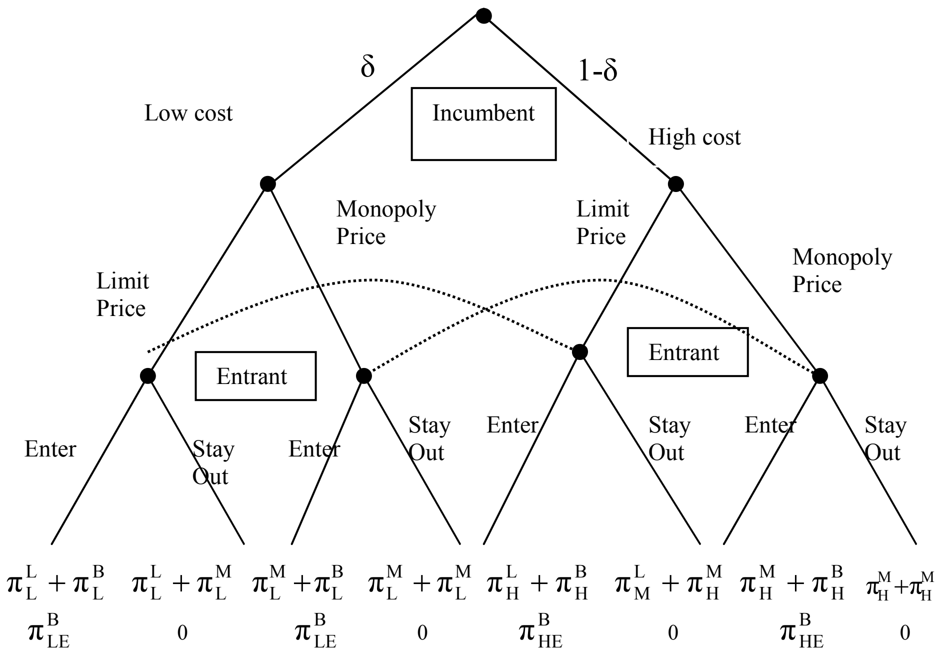

Figure-1: The Game Tree

Where the superscripts L, B, and M refer to limit price, Bertrand, and monopoly; subscripts L, H, LE and HE refer to low cost incumbent, high cost incumbent, entrant that faces a low cost incumbent and entrant that faces a high cost incumbent, respectively.

In the first stage, the incumbent earns either a monopoly profit or a limit price profit (loss if high cost). Upon entry firms compete in prices by simultaneously setting their strategies. If entry does not occur, the incumbent enjoys monopoly profits in the second stage and the potential entrant receives a payoff of zero. Since I assume that the limit price is equal to c_E and the Bertrand equilibrium price charged by the low cost incumbent is slightly lower than c_E, it follows that the limit price profit is higher than the Bertrand profit for the low cost incumbent if the demand is inelastic. The reverse is true for the high cost incumbent, because the limit price generates a loss, whereas the Bertrand price competition yields 0 profits. Furthermore, the monopoly profits are higher than the limit price profits for both types of incumbents. The payoff to the incumbent firm is the sum of the payoffs in each stage.

Schlag (1997) shows that when players change their strategies only through simple imitation the limiting case of the learning process resembles the replicator dynamics. Furthermore, the relative insensitivity of stable states to the specification of the dynamic system is noted by Samuelson (1997). He also points out that replicator dynamics may emerge as a result of a learning process that involves simple imitation.

Taylor and Jonker (1978) was first to introduce the following replicator dynamics.

$$dp_i/dt = [\pi(a_i, p) - \pi(p_i, p)]p_i \qquad (1)$$

where $a_i \in A_i$, $\pi(a_i, p)$ is the payoff to player type i (i = 1, 2, 3, 4), when he plays strategy a_i against the population state $p = \{(p_1, 1 - p_1), (p_2, 1 - p_2), (p_3, 1 - p_3), (p_4, 1 - p_4)\}$, and $\pi(p_i, p)$ is the payoff to p_i when he faces the population state p, thus representing the average payoff to type i in the population. If the strategy a_i yields a more than average payoff, more players will imitate it and the population proportion of the players that follow strategy a_i would rise. If the strategy yields a less than average payoff, then players will imitate a relatively more successful strategy and the proportion of players who adopt a_i would be wiped out and will not be observed in the population ever again, since the replicator dynamics is based on "reproduction" of the existing strategies (Samuelson, 1997, p. 67).

Hence, following the steps of Gardner and Morris (1991) the replicator dynamics may be rewritten as in (2):

$$\frac{\partial p_i}{\partial t} = p_i(1 - p_i)F_i(p) \qquad (2)$$

where i = 1, 2, 3, 4 and

$$F_1(p)=[(p_3(\pi_L^L + \pi_L^B)+(1- p_3)(\pi_L^L + \pi_L^M)) - (p_4(\pi_L^M + \pi_L^B) + (1 - p_4)(\pi_L^M + \pi_L^M))]$$

$F_2(p)=[(p_3(\pi_H^L + \pi_H^B)+(1–p_3)(\pi_M^L + \pi_H^M)) - (p_4(\pi_H^M + \pi_H^B) + (1 – p_4)(\pi_H^M + \pi_H^M))]$

$F_3(p) = [P_L\, p_1\, \pi_{LE}^B + (1 – P_L)p_2\, \pi_{LE}^B]$

$F_4(p) = [P_L\,(1 - p_1)\, \pi_{HE}^B + (1 – P_L)\,(1 - p_2)\, \pi_{HE}^B]$.

where the superscripts L, B, and M refer to limit price, Bertrand, and monopoly; subscripts L, H, LE and HE refer to low cost incumbent, high cost incumbent, entrant that faces a low cost incumbent and entrant that faces a high cost incumbent, respectively. The four replicator equations in this game constitute a system of autonomous differential equations that are Lipschitz continuous (Samuelson, 1997, p.67), as in Soytas and Becker (2003).

If $p^* = \{(p_1^*, 1 – p_1^*), (p_2^*, 1 – p_2^*), (p_3^*, 1 – p_3^*), (p_4^*, 1 – p_4^*)\}$ is an ESS, then p* is a dynamic stable equilibrium of the system, according to a Liapunov theorem (Gardner and Morris, 1991). Selten (1980) shows that mixed strategies cannot be ESS of asymmetric games. Therefore, it suffices to study all possible population states for which the p_i (i = 1, 2, 3, 4) are either 1 or 0. The Jacobian of the system of equations is as in (3):

$$J(p) = \begin{pmatrix} \partial\varphi_1/\partial p_1 & \partial\varphi_1/\partial p_2 & \partial\varphi_1/\partial p_3 & \partial\varphi_1/\partial p_4 \\ \partial\varphi_2/\partial p_1 & \partial\varphi_2/\partial p_2 & \partial\varphi_2/\partial p_3 & \partial\varphi_2/\partial p_4 \\ \partial\varphi_3/\partial p_1 & \partial\varphi_3/\partial p_2 & \partial\varphi_3/\partial p_3 & \partial\varphi_3/\partial p_4 \\ \partial\varphi_4/\partial p_1 & \partial\varphi_4/\partial p_2 & \partial\varphi_4/\partial p_3 & \partial\varphi_4/\partial p_4 \end{pmatrix} \quad (3)$$

where $\varphi_i = dp_i/dt$.

An equilibrium point p* is asymptotically stable if all the characteristic roots of the Jacobian of the system of equations in (2) evaluated at p^* have negative real parts (see Gandolfo (1996)). As Weibull (1995) and Samuelson (1997) point out, since ESS and dynamic stability imply each other in asymmetric games, the same conditions apply to ESS.

I.1. Free Entry

If entry is costless, then there is no ESS. This implies that even the outcome that resembles the contestable market outcome is not stable. That is, the population state in which, low cost incumbents playing the limit pricing strategy in the first stage and potential entrants playing stay out is subject to invasion by incumbents and/or potential entrants that try out a new rule or strategy (mutants). Furthermore, the absence of ESS also implies that limit pricing is not an ESS, contradicting the results of Milgrom and Roberts (1982) and Soytas and Becker (2003). The non-existence of a stable state is due to the fact that, the potential entrants that are matched against a low cost incumbent receive a payoff of zero regardless of their enter or stay out choice. Therefore, for $p_2 = 0$ or $p_2 = 1$, at least one of the eigenvalues of the Jacobian has a non-real part. Hence, there is no ESS under free entry.

I.2. Fixed Entry Cost

When I introduce a fixed entry cost, there exists a unique ESS. The low cost incumbents play limit price and the potential entrants that observe the limit price stay out. The low cost incumbents that play the monopoly price in the first stage and the potential entrants that play enter given limit price are wiped out. As for the high cost incumbents, bluffing or sending a wrong signal by playing the limit price does not survive the replicator dynamics. Hence, in the stable state of the population all high cost incumbents play the monopoly price pre-entry, and all potential entrants that play stay out given monopoly price are also wiped out. The population state $p = \{(1, 0), (0, 1), (0, 1), (1, 0)\}$ is the only state at which all the eigenvalues of the Jacobian matrix has negative real parts.

II. FREE ENTRY WITH CAPACITY CONSTRAINTS

The Bertrand games that take place upon entry in the evolutionary entry game assumed that firms do not have capacity constraints. When there are capacity constraints the outcome of the Bertrand game may change, and hence the stable state of the entire game may be subject to change. Note that the same Bertrand Nash equilibrium will prevail if the capacities of both firms are non-binding. Hence, here I will discuss 3 scenarios where at least one of the firms' capacities is binding. Also note that, in the presence of capacity constraints the monopoly price of the incumbent in the first stage refers to the maximum price at which the firm can sell to its capacity. Also at the limit price the incumbent can sell only up to its capacity.

II.1. When both Firms are Capacity Constrained

When the capacities of both firms are constrained, then in equilibrium both firms will charge prices such that the demand for each individual firm equals that firm's capacity. Hence, even the entrants will have positive residual demands even if they are matched against the low cost incumbents. However, the possible stable states under these settings call for payoff structures that are counter intuitive (monopoly profit less than limit price profit, negative profit to the entrant etc.). Hence, I conclude that even if capacity constraints are introduced, there is no ESS. Once again, all possible states of the population may be subject to invasion by rare mutants.

II.2. When the Incumbent is Capacity Constrained

The capacity limitation on the part of the incumbent allows the entrant to earn positive profits, regardless of the type of the incumbent. Indeed, the potential entrant will be more advantageous against the high cost incumbent than in the previous scenario. That is, the entrant can cut price and serve the market alone, leaving 0 profits for the high cost incumbent. Under these capacity and cost settings there is no ESS either.

II.3. When the Potential Entrant is Capacity Constrained

When the entrant cannot meet the market demand, the high cost incumbent can earn positive profits. However, if the entrant is matched against a low cost incumbent whose choices are unconstrained, the low cost incumbent can capture the market by cutting price slightly below c_E. Hence, upon entry the potential entrant always receives 0 profits when playing against a low cost incumbent. Therefore, an ESS does not exist, for at least one characteristic root of the Jacobian has a non-negative part.

Hence, in the absence of a fixed entry cost the game does not have a stable state even if capacity constraints are accounted for. That is, neither state of the population is immune to invasion. This outcome is similar to the unconstrained result with free entry. Both types of incumbents in the population will continuously try different prices (limit price and monopoly price).

II.4. Capacity Constraints with Fixed Entry Cost

Here, I introduce a fixed cost that an entrant must incur to enter the industry.

II.4.1. When both Firms are Capacity Constrained

Once again, the fixed entry cost plays an important role in determining the stable state. As long as the fixed cost exceeds the Bertrand profits of the entrant when it faces a low cost incumbent, there is a unique ESS outcome. The stable state of the population is equivalent to the ESS outcome of the unconstrained game with fixed costs.

II.4.2. When the Incumbent is Capacity Constrained

In the presence of fixed entry costs, similar arguments hold for this case. The fixed cost must be sufficiently high to ensure negative profits to the entrant when matched with a low cost incumbent in order the population state p = {(1, 0), (0, 1), (0, 1), (1, 0)}to be stable.

II.4.3. When the Potential Entrant is Capacity Constrained

The mere presence of a fixed entry cost ensures the same unique stable state, regardless of the size of the fixed cost.

Hence, when I introduce capacity constraints, in order for the game to have a stable state, a fixed cost must exist, and it must be sufficiently large if the potential entrant is unconstrained or when both firms face capacity constraints. The ESS is such that all low cost incumbents that play monopoly price and all potential entrants that play enter when they observe limit price are wiped out. Furthermore, all high cost incumbents play the monopoly price and all potential entrants that observe monopoly price enter.

CONCLUSIONS

In this paper, I investigate the role of fixed entry costs in an evolutionary entry game similar to Soytas and Becker (2003), but with Bertrand players. I also consider the case in which there are capacity constraints. I find that in the absence of fixed entry costs there is no stable state, regardless of whether capacity constraints are imposed or not. Potential entrants switch between entering and staying out when they observe a limit or monopoly price in the first stage. Likewise, the incumbents alternate between the limit price and the monopoly price strategies as if in an Edgeworth cycle with two prices.

When fixed costs are introduced into the picture, a unique ESS outcome emerges. Regardless of whether the firms are capacity constrained or not, the population state p* = {(1, 0), (0, 1), (0, 1), (1, 0)} is stable. However, if the only firm with capacity constraints is the incumbent or both firms have capacity constraints, the fixed entry cost must be higher than the Bertrand equilibrium profit of the potential entrant for p* to be the ESS. If the fixed entry cost is sufficiently small, then an ESS does not exist.

In the stable state, the low cost incumbents play limit price, and potential entrants that observe limit price play stay out. The high cost incumbents, on the other hand, play monopoly price as if they have given up advertising themselves as strong incumbents. The potential entrants that observe the monopoly price in the first stage play enter in the stable state. The stable state of the game is identical to the stable state of Soytas and Becker (2003) and resembles the separating equilibrium of Milgrom and Roberts (1982). Soytas and Becker (2003) find that the limit pricing strategy is a part of the equilibrium when firms are Cournot competitors. I confirm their finding in a similar game with Bertrand players. Also note that, the results of this paper do not depend on either the rationality or the common knowledge of rationality assumptions.

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