Games and Economic Behavior 111 (2018) 250–273

Contents lists available at ScienceDirect

Games and Economic Behavior

www.elsevier.com/locate/geb

Multilateral limit pricing in price-setting games ☆

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ARTICLE INFO

Article history:
Received 21 June 2017
Available online 17 July 2018

JEL classification:
L11
L13
C72

Keywords:
Bertrand
Supermodularity
Market entry and exit
Limit pricing
Stackelberg

ABSTRACT

In this paper, we characterize the set of pure strategy undominated equilibria in differentiated Bertrand oligopolies with linear demand and constant unit costs when firms may prefer not to produce. When all firms are active, there is a unique equilibrium. However, there is a continuum of non-equivalent Bertrand equilibria on a wide range of parameter values when the number of firms (n) is more than two and $n^* \in [2, n-1]$ firms are active. In each such equilibrium, the firms that are relatively more cost or quality efficient limit their prices to induce the exit of their rival(s). When $n \geq 3$, this game does not need to satisfy supermodularity, the single-crossing property, or log-supermodularity. Moreover, the best responses might have negative slopes. Our main results extend to a Stackelberg entry game where some established incumbents first set their prices, and then a potential entrant sets its price.

1. Introduction

In several markets, some firms may not be able to actively participate, and many decide to shut down. A large amount of literature has studied entry or exit decisions that are induced by information-based (i.e., signaling-based) limit pricing[2] and predatory pricing[3] practiced by other firms. However, the entry and exit behavior of firms might also be efficiency-based in

☆ This paper originates from Cumbul (2013). An earlier version was circulated under the title “Non-supermodular Price Setting Games.” We are grateful to the editor Marco Battaglini and two anonymous referees for providing very useful comments to different versions of the paper. We thank seminar participants for valuable discussions at the 2nd Brazilian Game Theory Society World Congress 2010, SED 2011 at the University of Montréal, Midwest Economics Theory Meetings 2011 at the University of Notre Dame, Stony Brook Game Theory Festival 2011, the 4th World Congress of Game Theory 2012, Bilgi University, Istanbul, University of Rochester 2010, 2011, and 2013, University of Toronto 2013, International Industrial Organization Conference 2014, EARIE 2014, Canadian Economic Theory Conference 2014, IESE-Barcelona 2014, Stony Brook Game Theory Festival 2014, and Koç University Winter Workshop 2017. We also thank Victor Aguirregabira, Alp Atakan, Paulo Barelli, Eric Van Damme, Pradeep Dubey, Manuel Mueller Frank, Alberto Galasso, Srihari Govindan, Thomas D. Jeitschko, Martin Osborne, Romans Pancs, Greg Shaffer, Ron Siegel, Tayfun Sönmez, Adam Szeidl, William Thomson, Mihkel M. Tombak, Utku Ünver, and Xavier Vives for their useful comments and suggestions.

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1 I thank Tubitak for their financial support.

2 The earlier limit pricing literature assumed that a low pre-entry price might deter entry because potential entrants would view the price as implying that low prices would be set post-entry (e.g., Gaskins, 1971; Kamien and Schwartz, 1971; Baron, 1973). Milgrom and Roberts (1982), Bagwell and Ramey (1988), Bagwell (2007), and Gedge et al. (2016) address this issue by introducing asymmetric information between the incumbents and the potential entrant.

3 Predatory pricing means that a firm charges a price that is below the firm’s average costs with the sole intention of driving an existing rival out of the market.

https://doi.org/10.1016/j.geb.2018.06.008
0899-8256/

highly competitive markets. Competitors' cost-reducing innovations, the inability to adapt to changing market conditions, a cost-efficient merger among rival firms, or firms' strategies to raise rivals' variable costs may induce an existing firm to exit or a potential entrant not to enter. Nevertheless, an inactive firm might still be efficient enough to lead the active firm(s) to engage in efficiency-based limit pricing but not strong enough to enter the market.

In this paper, we study traditional static price-setting games among firms that have different levels of quality or cost efficiencies. The differences between these levels might be due to one of the factors above. Our main aim is to identify the set of active and inactive firms in any pure strategy *undominated* Bertrand equilibrium and to provide a full characterization of the equilibrium behavior of firms.[4] There are two types of equilibrium in this game. An equilibrium is either *unconstrained* or *constrained* (i.e., limit pricing/kinked demand) if the price decisions of the set of active firms are unconstrained or constrained, respectively, by the presence of inactive firm(s). We show that when all firms are active, there is a unique equilibrium. However, if the marginal inactive firm is sufficiently inefficient, then there is a continuum of equivalent unconstrained equilibria when the number of firms (n) is greater or equal to two. If otherwise, there is a continuum of non-equivalent constrained equilibria and the Bertrand best responses have negative slopes in a region for a wide range of parameter values when $n \geq 3$ and $n^* \in [2, n-1]$ firms are active. In each such equilibrium, the firms that are relatively more cost or quality efficient limit their prices to induce the exit of their rival(s). We also provide an iterative algorithm to find the set of active firms in any equilibrium and show that this set is the same in all equilibria. These results are very different from the existing literature on Bertrand models with differentiated products, where uniqueness holds under a linear market demand assumption and the best response functions slope upward.[5]

To explain our results, consider a symmetric three-firm differentiated product Bertrand oligopoly where the marginal cost levels are $c_i = \xi$ for $i = 1, 2, 3$. All firms are active; that is, their equilibrium production levels are all strictly positive. Suppose that a process innovation is available for firms 1 and 2. Accordingly, their cost levels reduce to $\widehat{\xi} = \widehat{c}_1 = \widehat{c}_2 < \widehat{c}_3 = \xi$. If the initial cost level ξ is high enough, then there are two cutoff levels for $\widehat{\xi}$, say $\widehat{\xi}_1$ and $\widehat{\xi}_2$ with $0 < \widehat{\xi}_1 < \widehat{\xi}_2$, such that the firms' equilibrium strategies are qualitatively different when $\widehat{\xi}$ lies in the region $[0, \widehat{\xi}_1]$, $(\widehat{\xi}_1, \widehat{\xi}_2)$, or $[\widehat{\xi}_2, \xi)$. More specifically, if $\widehat{\xi} \in [\widehat{\xi}_2, \xi)$, then the level of innovation is not too high, and all three firms continue to be active in the market. At the other extreme, if $\widehat{\xi} \in [0, \widehat{\xi}_1]$, then firm 3 becomes very inefficient compared to firms 1 and 2 and leaves the market. Accordingly, firms 1 and 2 charge unconstrained duopoly prices. The most interesting region is the intermediate region here, $\widehat{\xi} \in (\widehat{\xi}_1, \widehat{\xi}_2)$. This region involves efficiency-based limit pricing induced by firms 1 and 2 to keep firm 3 out of the market. If they ignored firm 3 and charged unconstrained duopoly prices, then firm 3 would continue to be active in the market.

In the case of linear demand, limit pricing takes a particularly simple form. Consider any price combination of firms 1 and 2 such that $p_1 + p_2 = M$ where M is uniquely determined by the parameters of the model. If either firm 1 or firm 2 charges a higher price, then firm 3 would start to produce, and the market would become a triopoly market. On the other hand, when either firm decreases its price, the market is a duopoly market. For this reason, the profit functions of firms 1 and 2 exhibit kinks at price combinations where $p_1 + p_2 = M$. Moreover, the fact that demand is more sensitive to a change in the price that a firm sets in the region where all three firms are active[6] implies that the right-hand derivative of the profit of firm 1 with respect to p_1 is more negative (or less positive) than the left-hand derivative if $p_1 + p_2 = M$ as the demand drop is accelerated for prices where the third firm is active. At such price combinations, the optimality conditions for firm 1 require the left-hand derivative of the profit function to be positive and the right-hand derivative to be negative, which can be satisfied by multiple combinations of p_1 and p_2 satisfying $p_1 + p_2 = M$. As a result, there is a host of equilibria in our price-setting game. Relatedly, the kink implies that the best response for firm 1 when firm 2 sets p_2 satisfies $p_1 = M - p_2$, so the price choices of firms 1 and 2 are strategic substitutes at such a point.

Our model has been extensively studied in a two-firm set-up. For example, Muto (1993), Erkal (2005), and Zanchettin (2006) show that when there are two firms, there is a unique limit pricing equilibrium, in which the efficiency gap between the two firms is sufficiently high to rule out an interior equilibrium, where both firms are active, but not high enough to allow the most efficient firm to engage in (unconstrained) monopoly equilibrium. This paper generalizes the Bertrand equilibrium characterization results to an n-firm set-up when firms have any degree of cost and quality asymmetries. The generalization of the limit pricing equilibrium unveils a set of novel results such as the multiplicity of the limit pricing equilibria. There are several applications of the findings in the contexts of market exit after a cost-reducing process innovation or a cost-efficient merger[7] and of the comparisons of Cournot and Bertrand equilibria. For example, Zanchettin (2006) shows that the efficient firm's and industry profits can be higher under Bertrand competition than under Cournot competition in the limit pricing equilibrium region. This finding reverses Singh and Vives' (1984) ranking. It is clear from these arguments that the possibility of limit pricing and multiple equilibria might give rise to unexpected results in various contexts.

[4] Such a characterization in static quantity-setting games is trivial. In particular, standard existence and uniqueness results for the Cournot equilibrium extend to environments where firms may prefer not to be active (Novshek, 1985; Gaudet and Salant, 1991, and Cumbul, 2013).

[5] For instance, Friedman (1977) shows that when the best response functions are contractions, costs are nondecreasing, and all firms produce imperfectly substitutable products, then there is a unique Bertrand equilibrium.

[6] The reason is that when firm 1 changes its price in the duopoly region (i.e., where $p_1 + p_2 < M$), the firm's quantity responds relatively mildly because there is only one other firm (firm 2), to which customers divert. In the region where $p_1 + p_2 \geq M$, any increase in p_1 makes customers divert to firms 2 and 3.

[7] Motta (2007) considers the possibility of a market exit after a cost-efficient Bertrand merger. Although a limit pricing region exists, it has not been pointed out (Cumbul and Virág, 2018b).