Predatory pricing under uncertainty: revisiting the deep pocket argument

Maria N. Lavrutich[1] and Jacco J.J. Thijssen[2]
[1] *CentER, Department of Econometrics and Operations Research, Tilburg University, Post Office Box 90153, 5000 LE Tilburg, The Netherlands*
[2] *The York Management School, University of York, Freboys Lane, Heslington, York YO10 5DD, United Kingdom*

February 1, 2016

Abstract

In this paper we develop a stochastic dynamic model of predatory pricing. When profits evolve stochastically, a negative demand shock can lead to bankruptcy for firms, which cannot immediately raise external capital. An assumption that firms are able to hoard liquidity creates incentives for market incumbents to use the predatory pricing strategies in order to keep the new players out of the industry. Applying game theoretic and dynamic programming techniques, we show that an incumbent firm may use a large cash reserve as a war chest to initiate a price war that could drive the entrant out of the market. Because of uncertainty the entrant may wish to take a chance and enter based on the probability of success. Therefore, realised market structure may be different for different sample paths of the stochastic process.

1 Extended abstract

Recent empirical literature on capital markets suggests that there exists strategic reasoning behind cash hoarding. In particular, large cash reserves of established firms may be used as a war chest to discourage the entry of potential competitors (Fresard (2010), Boutin *et al.* (2013), Morellec *et al.* (2014)).

In the early literature this phenomenon is explained in two ways. The first one is known as the "deep pocket argument" introduced by McGee (1958) and later studied by Telser (1966) and Benoit (1983). In their models a more resourceful incumbent is able to drive a financially constrained entrant out of the market by the means of aggressive pricing. Their main conclusion is, however, that under perfect information no price war will be observed in equilibrium due to the temporary nature of price cuts. The second explanation is associated with the so called, chain store paradox. In a formulation of Selten (1978) incumbent's incentives to predate come from reputational considerations. Namely, by initiating a price war when facing the first out of potentially many entrants an incumbent establishes reputation as an aggressive firm in order to prevent further entries. Selten (1978) presents an unintuitive result, which is also known as the chain store paradox, that price war is not a viable strategy from the perspective of standard game theoretic approach.

Thus, even though contentions that firms use aggressive pricing to drive the opponents out are not uncommon, the early literature failed to explain the rationality behind such behavior. More recent studies bridge the gap between theory and practice by incorporating market imperfections into the analysis. For example, Milgrom and Roberts (1982), Kreps and Wilson (1982) and Benoit (1984) find that incomplete (or imperfect) information about firms' payoffs resolves the chain store paradox. According to Fudenberg and Tirole (1985a) and Poitevin (1989) asymmetric information in financial markets can trigger predatory pricing behavior due to the fact financiers are typically not aware of true entrant's profitability. Alternatively, the entrant may be able uncertain about its own costs and thus, is not able to perfectly predict its future profits. In Fudenberg and Tirole (1986) entrant's inference about its future profitability is based on the current profits and, as a result, incumbent may "jam" this signal using predatory pricing strategy. In Saloner (1987) under asymmetric information about costs, an informed firm is willing to signal low-cost type using output expansions in order to facilitate better merger terms. Bolton and Scharfstein (1990) show that mitigating agency problems between the firm and its financiers creates incentives for predatory behavior.

In this paper we go back to a complete information setting and the traditional 'deep pockets" hypothesis. We investigate if this result still holds in a dynamic setting where firms are capital constrained and their profits are subject to stochastic shocks. In our model an entrant becomes active in the existing market by undertaking an irreversible investment given the uncertainty about its future profit stream. An incumbent may use its cash reserve as a war chest to initiate a price war that could

drive the entrant out of the market or prevent from entering the market in the first place. The focus of our analysis is whether the entrant would exercise its option to invest given the predation threat.

In this regard, this paper is also related to the real options theory and contributes to this strand of the literature in two ways. Firstly, we enhance the existing body of research by providing a more general model of predatory pricing under uncertainty. Even though a large bulk of real options studies focuses on entry deterrence strategies (e.g. Spence (1977), Smets (1991), Boyer *et al.* (2004) and Huisman and Kort (2015)) or exit games (Lambrecht (2001), Murto (2004)), predatory pricing has gained a rather limited attention. Among the few real options contributions that explicitly use the notions of either aggressive pricing or predation are Gryglewicz (2009), that considers a stochastic limit pricing model under asymmetric information, and Bayer (2007), where predation is defined as forcing the entrant out of the market by installing a large capacity. We present a complete information model, where the firm-specific uncertainty is the rationale for aggressive pricing.

This brings us to the second contribution, which is more of a methodological nature. In this model we depart from the assumption of the perfectly correlated shocks for market participants. In the standard real options models, where firms are subject to the same uncertainty regarding the future profits, their deterministic actions allow to predict the outcome of the game. In our model deterministic actions change the probabilistic environment.

More precisely, we consider two risk neutral profit maximizing firms. One firm is already operating in the market as a monopolist. The other firm faces a possibility to enter this market by undertaking an irreversible investment that creates a revenue stream. When active, firms transfer their profits to cash reserves. In other words, net revenues accumulated over time form each firm's cash hoard. Firms are assumed to be financially constrained, implying that a firm goes bankrupt when its cash reserves are depleted. Additionally, given that firms are subject to potential future losses, the instantaneous cash inflow is exposed to firm-specific uncertainty. Therefore, the cash flow process of firm i denoted by X_t^i is modeled as an Arithmetic Brownian Motion. Then the instantaneous cash inflow for firm i satisfies the following differential equation

$$dX_t^i = \hat{\pi}_i dt + \sigma_i dB_t^i, \tag{1}$$

where $\hat{\pi}_i$ is firm's current profit, σ_i is volatility parameter and B_t^i is a Weiner process. Similarly to Morellec *et al.* (2014) this formulation implies that the drift of the Brownian motion is controlled by the incumbent, while the volatility is not. We assume shocks to be firm-specific, i.e. B_t^1 and B_t^2 are uncorrelated. In this setting an incumbent firm cannot guarantee that initiating price war will eventually lead to exit of its opponent. Instead, aggressive pricing alters the probability of staying alive. Thus, the outcome of the game is determined by the paths of the underlying stochastic process. Depending on the amount of cash reserves available for the firms, this may create incentives for an established firm to take a chance to initiate a price war, while for a new firm to enter despite that.

References

Azevedo, A. and D. Paxson (2014). Developing real option game models. *European Journal of Operational Research*, 327, 909–920.

Bayer, C. (2007). Investment timing and predatory behavior in a duopoly with endogenous exit. *Journal of Economic Dynamics and Control*, 31, 3069–3109.

Benoit, J. (1984). Constrained entry in a game with incomplete information. *The RAND Journal of Economics*, 15, 490–499.

Benoit, J. P. (1983). Entry with exit: An extensive form treatment of predation with financial constraints. *Technical Report 405*, Stanford University.

Bolton, P. and D. S. Scharfstein (1990). A theory of predation based on agency problems in financial contracting. *American Economic Review*, 80, 93–106.

Boutin, X., G. Cestone, C. Fumagalli, G. Pica, and N. Serrano-Velarde (2013). The deep-pocket effect of internal capital markets. *Journal of Financial Economics*, 109, 122–145.

Boyer, M., P. Lasserre, T. Mariotti, and M. Moreaux (2004). Preemption and rent dissipation under price competition. *International Journal of Industrial Organization*, 22, 309–328.

Ching, W. K., J. Gu, and H. Zheng (2014). On correlated defaults and incomplete information. Working Paper.

Decamps, J.-P., T. Mariotti, and S. Villeneuve (2006). Irreversible investment in alternative projects. *Economic Theory*, 28, 425–448.

DeMarzo, P. M. and Y. Sannikov (2006). Optimal security design and dynamic capital structure in a continuous-time agency model. *Journal of Finance*, 61, 26812724.

Dixit, A. K. (1980). The role of investment in entry-deterrence. *The Economic Journal*, 90, 95–106.

Dixit, A. K. (1993). Choosing among alternative discrete investment projects under uncertainty. *Economics Letters*, 41, 265–268.

Fresard, L. (2010). Financial strength and product market behavior: The real effects of corporate cash holdings. *Journal of Finance*, 65, 1097–1122.

Fudenberg, D. and J. Tirole (1985a). Predation without reputation. Working Paper, Massachusetts Institute of Technology, United States.

Fudenberg, D. and J. Tirole (1985b). Preemption and rent equalization in the adoption of new technology. *The Review of Economic Studies*, 52, 383–401.

Fudenberg, D. and J. Tirole (1986). A "signal-jamming" theory of predation. *The RAND Journal of Economics*, 17, 366–376.

Gedge, C., J. W. Roberts, and A. Sweeting (2014). A model of dynamic limit pricing with an application to the airline industry. NBER Working Paper.

Gryglewicz, S. (2009). Signaling in a stochastic environment and dynamic limit pricing. Working Paper,Erasmus University Rotterdam, The Netherlands.

He, H. (1998). Double lookbacks. *Mathematical Finance*, 8, 201–228.

Huisman, K. J. M. (2001). *Technology Investment: A Game Theoretic Real Options Approach*. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Huisman, K. J. M. and P. M. Kort (2015). Strategic capacity investment under uncertainty. *The RAND Journal of Economics*, 46, 217–460.

Kreps, D. and R. Wilson (1982). Reputation and imperfect information. *The Journal of Economic Theory*, 27, 253–279.

Lambrecht, B. M. (2001). The impact of debt financing on entry and exit in a duopoly. *Review of Financial Studies*, 14, 765804.

Mason, R. and H. Weeds (2010). Investment, uncertainty and pre-emption. *International Journal of Industrial Organization*, 28, 278–287.

McGee, J. (1958). Predatory price cutting: The Standard Oil (N.J.) case. *The Journal of Law and Economics*, 1, 137–169.

Metzler, A. (2010). On the first passage problem for correlated Brownian motions. *Statistics and Probability Letters*, 80, 277–284.

Milgrom, P. and J. Roberts (1982). Predation, reputation, and entry deterrence. *The Journal of Economic Theory*, 27, 280–312.

Morellec, E., B. Nikolov, and F. Zucchi (2014). Competition, cash holdings and financing decisions. Working Paper.

Murto, P. (2004). Exit in duopoly under uncertainty. *The RAND Journal of Economics*, 35, 111–127.

Poitevin, M. (1989). Financial signalling and the "deep-pocket" argument. *The RAND Journal of Economics*, 20, 26–40.

Rogers, L. C. G. and L. Shepp (2006). The correlation of the maxima of correlated brownian motions. *Journal of Applied Probability*, 43, 880–883.

Sacerdote, L., M. Tamborrino, and C. Zucca (2015). First passage times of two-dimensional correlated diffusion processes: analytical and numerical methods. Working Paper.

Saloner, G. (1987). Predation, mergers, and incomplete information. *The RAND Journal of Economics*, 18, 165–186.

Selten, R. (1978). The chain-store paradox. *Theory and Decisions*, 9, 127–159.

Smets, F. (1991). Exporting versus FDI: The effect of uncertainty, irreversibilities and strategic interactions. Working Paper, Yale University, New Haven, Connecticut, United States of America.

Spence, A. M. (1977). Entry, capacity, investment and oligopolistic pricing. *The Bell Journal of Economics*, 8, 534–544.

Telser, T. (1966). Cutthroat competition and the long purse. *The Journal of Law and Economics*, 9, 259–277.

Weeds, H. (2002). Strategic delay in a real options model of R-D competition. *The Review of Economic Studies*, 69, 729–747.

Zhou, C. (2001). An analysis of default correlations and multiple defaults. *The review of Financial Studies*, 14, 555–576.