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Detecting Strategic Entry Deterrence Empirically: Non-Monotonicity Tests

Bachelor's thesis

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Abstract of bachelor's thesis

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Abstract

Incumbent firms in a market can take action to make entry to the market unprofitable for potential entrants. When this is done from an incentive of actively keeping the entrants at bay and maintaining monopoly position, it is referred to as strategic entry deterrence. Exploiting strategic entry deterrence is in the interest of antitrust authorities, for its adverse effects on the competitive market equilibrium and welfare. In this literature review I am going to review the relevant findings of entry deterrence and attempt to answer to question of how to detect entry deterrence empirically. I will cover a possibly more systematic way of concluding empirical results: non-monotonicity tests. Non-monotonicity tests, a concept introduced by Ellison and Ellison (2011), aims to find differences in the incumbent's behavior when the incumbent's entry deterring incentives are absent or present. It is argued that these incentives are highest when the incumbent's action has a pivotal effect on the entry decision, more specifically at markets of intermediate entry probability. After presenting the theory behind non-monotonicity tests, I will review three empirical papers, which all find some evidence of strategic entry deterrence in the markets of intermediate entry probability.

Keywords strategic entry deterrence, non-monotonicity tests

Contents

1. Introduction

From a perspective of understanding market structure, an industry has firms that are incumbents and entrants. The incumbents are established firms that practice business, and entrants are newcomers entering the industry. In some markets it is natural that only one firm can flourish, due to natural entry barriers. At this point entry is said to be blockaded. When entry barriers are sufficiently small, the probability of entry cannot be ignored by the incumbent. When encountering potential entry, the incumbent faces a decision of practicing entry deterring action. The idea of entry deterring action is to make entry unprofitable for the entrant. (Belleflame and Peitz, 2015)

Wilson's (1992) review of strategic entry deterrence literature up to that point concludes the motives for studying entry deterrence are largely due to understanding the incumbent's path to profits through monopoly power. The main motive for studying entry deterrence is revealing possible strategies for an incumbent to maintain monopoly position. The case often is that entry deterring investments would be important to exploit, but this is difficult due to absence of market opening date and the trouble of distinguishing entry deterring strategies from other profit maximizing strategies (Bokhari and Yan, 2019). Detecting entry deterrence is important for antitrust authorities. This is due to the anti-competitive nature of obstructing ways for entry into a market. Salop and Scheffman (1983, 1987) highlight anti-competitive action in the incumbent acting towards raising the entrants' sunk costs of entering a market. They identify the channels that the incumbent can use as pre-emption in upstream input markets and vertical integration, the abuse of regulatory process, advertising, and product proliferation. Anti-competitive action is strongly tied to welfare, it is often not socially optimal to have extensive market power condensed on one (or a few) incumbents. Chen and Ross (2000) conduct a study on incumbents forming resource sharing alliances that have entry deterring effects and are restricting the efficient market outcome. Espinola-Arredondo and Munoz-Garcia (2013) argue that intervention of antitrust authorities is more necessary in cases where the welfare losses associated to entry deterrence are large. These increase in the absence of learning-by-doing effects, a concept of entry deterrence introduced in Tirole (1988). All in all, the motivation for detecting strategic entry deterrence is obvious through its anticompetitive nature, and welfare reducing aspects.

The research question of this thesis is: *how to detect entry deterrence empirically*, which I will answer with a method pioneered by Ellison and Ellison (2011): non-monotonicity tests. This thesis will be conducted as a literature review. I will first present the relevant empirical papers not using non-monotonicity tests. This literature dates to the 1970's. This will give an overview of how difficult it is to distinguish strategic entry deterrence incentives from a firm's actions. Exploiting strategic entry deterrence often requires data of firms' investments, which is not available for the public, a setting in which an opening of a market is known in time, and a measure of the threat of entry. Empirical papers not using non-monotonicity tests provide some weak evidence of strategic entry deterrence, but often run into problems of designating the incentives of incumbent's action as entry deterrence.

Non-monotonicity tests are proposed as a way of distinguishing the strategic entry deterrence incentive through noticing an increase or decrease of incumbent investment in the markets of intermediate entry probability. The non-monotonicity tests were originally introduced by Ellison and Ellison (2011) and will be presented in more detail in chapter 3. I will cover three empirical papers which use the non-monotonicity test as a form of recognizing entry deterrence: Ellison and Ellison (2011), Bokhari and Yan (2019), and Dafny (2005). Although Ellison and Ellison (2011) pioneer the use of non-monotonicity tests, their study concludes only weak evidence of entry deterrence in pharmaceuticals' detail advertising and product proliferation in the U.S. market. Bokhari and Yan (2019) first conduct a cross-sectional analysis of non-monotonicity, which fails to prove evidence of entry deterrence. This is extended to a panel-data version, which provides some weak evidence of strategic entry deterrence in middle-sized markets. Dafny (2005) finds empirical evidence of incumbents in markets of intermediate probability of entry investing heavily to increase volume, compared to investments in small and large entry probabilities. This can be concluded as evidence for strategic entry deterrence.

This thesis in constructed as follows; in chapter two I will introduce the relevant empirical findings of strategic entry deterrence not using non-monotonicity tests. Non-monotonicity tests, the concept of market attractiveness for entrants and the issues of non-monotonicity tests will be gone through in chapter three. The most relevant empirical papers using non-monotonicity tests will be presented in chapter four. Chapter five concludes.

2. Review of empirical research on entry deterrence not using non-monotonicity tests

Entry deterrence is examined through market structure first by Scherer and Ross (1980), but it is most profoundly studied through applications of game theory investigating the sequential nature of incumbent acting first and the entrant observing. Tirole (1988) constructs the early framework for investigating entry, accommodation and exit of firms through incumbent's action. Theoretical studies on entry deterrence date back to the 70's and 80's when Fundenberg and Tirole (1984) presented the taxonomy of business strategies for the incumbent, Dixit (1980) introduced strategic investments into capacity in entry deterrence and Gilbert (1989) on opening the competition effects of entry deterrence. The theoretical framework is most lately concluded in Belleflame and Peitz (2015). Empirical findings of entry deterring behavior are slim. This is mainly due to the difficulty of distinguishing the entry deterrence incentive. This difficulty stems from not having access to firm-specific data, and the lack of consistent methods of measuring probability of entry. In this section I will cover relevant empirical findings in the subject other than the method of non-monotonicity tests which will be presented in chapter 3.

Wilson (1992) concludes the theoretical literature on entry deterrence thus far. He categorizes models used to study entry deterring behavior into pre-emption, signaling, and predation. Most empirical attempts in detecting entry deterrence fall into the pre-emption category. In pre-emptive models the incumbent has arrived first to the market, holds monopoly power, and attempts the preserve this. Pre-emption models attempt to explain entry deterrence behavior through the incumbent's *pre-emptive* investments into its procedures. This can be for example investments to product proliferation or advertising. Non-monotonicity tests, which will be presented in chapter 3, attempt to find non-monotonic relationships in incumbent's investment pattern in different markets. Signaling models attempt to explain how an incumbent actively conveys information of it having the best qualifications for survival in a market. Finally, predation models attempt to describe how an incumbent prevents entry from future competition by conducting a price war against other firms. These models focus on market's where of multiple incumbents operate. The models attempt to describe the profitability of conducting a price war, with the payoff of preventing future competition due to potential entrants expecting an aggressive response from the incumbent. (Wilson, 1992)

First empirical findings concerning brand proliferation as a form of entry deterrence are captured by Schmalensee (1978) in analysis of the four major ready-to-eat cereal manufacturers in the U.S. from 1950s to 1980s. During this time the four major RTE-cereal manufacturers operated roughly 85% of the market. The minimum efficient firm size in equilibrium, measured by market share, is estimated to be roughly 3-5% (Schmalensee, 1978). By the 1972 complaint filed by the US Federal Trade Commission the six largest manufacturers had introduced 80 different brands to the market between the years 1950-1972. This was thought to be first evidence of incumbents protecting the market against possible entrants through constantly proliferating brands of their own. Product and brand proliferation is difficult to identify as a strategic way of deterring entry, thus many papers focused on excess capacity as the method of entry deterrence.

Early empirical studies on excess capacity as the method include Liebermann (1987), Ghewamat (1984) and Hilke (1984). Liebermann (1987) studies the markets of 39 chemical compounds. Markets are studied through the differences in concentration, with the conclusion that highly concentrated markets had more excess capacity built than unconcentrated markets. However, Liebermann's study fails to prove evidence of capacity being built pre-emptively, rather it was used strategically as a response to entry. Ghewamat (1984) focused on studying 1972-1977 period of U.S. titanium dioxide producer Du Pont, in its attempt of using excess capacity. As ore prices increased in 1972, Du Pont faced a substantial cost advantage to its rivals through having adopted the use of ilmenite chlorite technology earlier, as rivals adopted this technology facing the altered state of prices. Du Pont had 21-23% lower costs than rivals in 1972. Ghewamat (1984) states that the plan was to force a price war through keeping prices low enough for Du Pont to operate but forcing the competitors to exit the market. However, prices ended up increasing heavily from 1972, and the fluctuations in market demand diminished strategic effects. Hilke (1984) studies the regression of increase and decrease of market share of imports on industry specific profits, growth, barriers of entry and excess capacity. The regression shows a weak negative relationship in ex-post entry probability and excess capacity providing weak evidence of entry deterrence.

From the 1990's, most relevant empirical papers on entry deterrence include Mathis and Koscianski (1996), Chevalier (1995), and Kadiyali (1996). Mathis and Koscianski (1996) extend the research on titanium dioxide incumbents having excess capacity prior to entry. They continue with assumptions of excess capacity being an effective entry deterrent if it can credibly threaten the entrant of incumbent engaging in a price war upon entry. Titanium industry is chosen as the candidate through the small number of large firms and high fixed costs creating large entry barriers and homogenous output. Problems arise through minimal sample size and the distinction of strategical use of the excess capacity. The regression they run in fact proves that excess capacity held by the incumbent effectively deters entrants, but it can't be concluded that excess capacity is held for strategic entry deterring incentives.

Chevalier (1995) finds empirical evidence of product-market competition altering after leveraged buyouts (LBOs) of supermarket chains. He measures the number of supermarkets in 85 U.S. metropolitan statistical areas between the years 1985 and 1991. The main conclusion of the study is that when LBOs happen, the rival incumbents in these areas not included in the LBOs, increase their number of supermarkets. The increase is based on softened product-market competition following the LBOs, thus providing an incentive for the rival incumbents to expand. The study only describes the competitive response of the incumbents to the altered state of market but doesn't provide evidence on strategic entry deterrence incentives. Kadiyali (1996) performs a study of entry deterrence and accommodation in the United States photographic film industry in the years 1970-1990. She estimates demand, cost, and market conditions for Kodak and Fuji, two main incumbents of the industry. Kodak had near monopoly position in the market until the year 1980, when Fuji officially entered the market. Kodak held relatively low prices and high advertising levels in the pre-entry period (1970-1979) providing evidence of limit-pricing and limit-advertising[1] used to deter entry. Fuji had more cost-efficient procedures, and Kodak faced an entry that was inevitable. Kodak opted into accommodating Fuji's entry to the market, and the two colluded for larger joint profits had Kodak not accommodated the entry. In the post-entry period (1980-1989) the prices were kept low, and advertising levels high, providing insight of Kodak and Fuji colluding to deter entry of other potential entrants to the market.

To conclude the most relevant empirical findings of entry deterrence, I will showcase more recent papers. Conlin and Kadiyali (2006) investigate excess capacity as a form of entry deterrence in the Texas lodging industry during the years 1991-1997. It is found in the study that idle capacity held by firms is higher in markets of higher concentration and in markets

[1] Limit pricing means keeping prices lower than the profit maximizing price, with the intention of deterring entrants. Limit advertising is a term used by Kadiyali (1996) to describe relatively high advertising levels.

where the firm's presence[2] is larger. This is argued to be an indication of idle capacity being used as strategic entry deterrence. However, the number of alternative hypotheses for excess capacity makes distinguishing entry deterrence difficult. The authors argue that excess capacity could be used to answer for demand fluctuations or excess capacity might be higher in highly concentrated markets as a preparation for expected demand growth. Goolsbee and Syverson (2008) focus on the U.S. airline industry between the years 1993 and 2004. They investigate the incumbent airline's reaction to a threat of Southwest airlines starting transportation on a route the incumbent is already flying. Threat of entry is measured by focusing on Southwest Airlines beginning to operate in an airport, from which there exists a route to another airport where southwest already is operating. It is shown that incumbents lower the fare prices in these "high threat" routes before Southwest starts to fly the route. The authors provide evidence of price cuts in the "high threat" routes but fail to show evidence for the incentives of these. Incumbents not lowering prices on "neutral threat" routes gives weak evidence of deterring entry itself. An alternative hypothesis is that the price cuts today are made to enforce customer loyalty for a longer time span, possibly decreasing the demand for Southwest (Goolsbee and Syverson, 2008).

3. Identifying entry deterrence empirically with non-monotonicity tests

As we have seen, the history for identifying entry deterrence is rather short, and the empirical evidence is limited. In the following section I am going to investigate a method of identifying entry deterrence through non-monotonic relationships between investments and market potential. This concept was introduced by Ellison and Ellison (2011) and has been used empirically to detect incumbents' entry deterring behavior in Dafny (2005), Ellison and Ellison (2011) and Bokhari and Yan (2019). I will cover each of these in more detail later in chapter 4.

3.1 Stylized three-stage sequential game

Ellison and Ellison (2011) develop a stylized three-stage model that describes the sequential nature of the entrant observing the incumbent's action, and then choosing whether to enter a market. For simplicity, the incumbent is assumed to be a sole monopolist in the market before entry, and only one entrant is considered.

[2] Presence = capacity of the firm / total market capacity

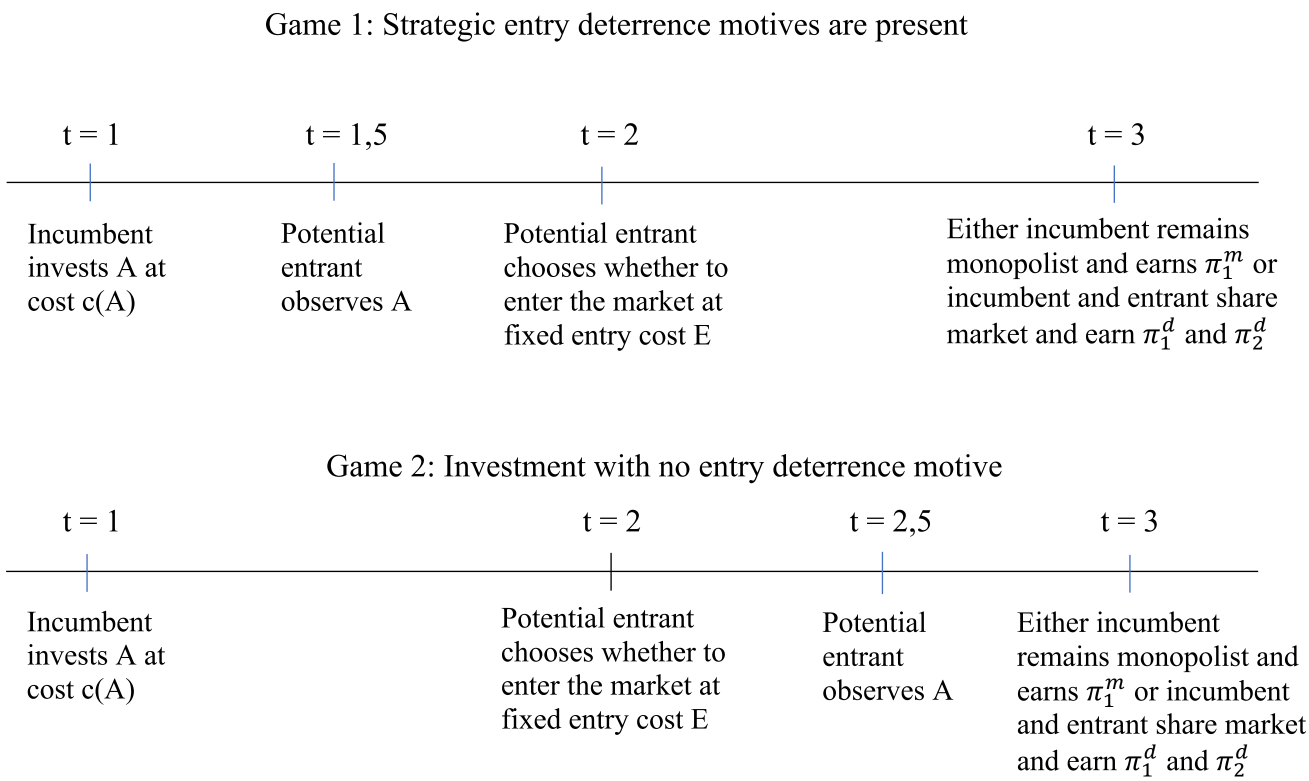

Figure 1. Sequential games of entry deterrence motives from Ellison and Ellison (2011). In game 1 entry deterring incentives are present and in game 2 they are absent.

Following Ellison and Ellison (2011) in describing the idea of the strategic entry deterrence game, we're first in situation t = 1 where the incumbent is a monopolist in a market. Here the incumbent chooses some level of investment into its procedures, for example investments to advertising. In t = 2 the entrant chooses whether to enter the market with a fixed entry cost E. The entrant will naturally enter the market if profits π_2^d(A) are higher than the entry cost E. The subscripts denote 1 = incumbent, 2 = entrant, m = monopoly and d = duopoly. If entry occurs, the incumbent and entrant share the market, earning profits π_1^d(A) and $\pi_2^d(A)$. If entry doesn't occur, the incumbent remains a monopolist in the market, earning monopoly profits $\pi_1^m(A)$. Investment cost c(A) and profits π_1^m(A), $\pi_1^d(A)$, $\pi_2^d(A)$ all depend on initial investment A. I've portrayed two games similarly to Ellison and Ellison (2011). The main takeaway of these is that under an entry deterrence motive (game one), the incumbent notes that the entrant observes the incumbent's investment level A before deciding on entry. In other words, the incumbent understands that investment A can influence entrant's entry decision. Game two describes a situation that would prevail if entry deterrence motives were absent. It provides a neutral benchmark where the incumbent takes the entrant's probability of entry as given and doesn't have an incentive to influence this. The main purpose of game two is to showcase a situation where this absence of an entry deterring motive would happen. Not all situations of incumbent acting without an entry deterring motive require the specific sequence of game two. In the sequential setting of game two, investment A cannot have a causal relationship on entry decision, thus it is chosen as the neutral benchmark here. A neutral benchmark is needed to distinguish the incentive of entry deterrence by comparing the two games. Therefore, it is sensible to consider the case of game two, although it does not always describe the situation before entry realistically.

Ellison and Ellison (2011) make a crucial modification to the entry deterrence models described thus far; the entrant's fixed entry cost E is stochastic. Therefore, the incumbent is uncertain whether investment level A will lead to entry or not. Was this not the case, the model would be deterministic, and the incumbent could choose the level of investment that would successfully deter entry. The probability density function of E is $f(E)$. Ellison and Ellison (2011) assume that the mass of $f(E)$ is concentrated in the intermediate values of E. In other words, it is a unimodal distribution, with the most frequent value arising in the centermost values of E. The cumulative distribution function of E is F(E). Recall that the entrant will enter the market if $E < \pi_2^d(A)$, and it will be indifferent of entry if $E = \pi_2^d(A)$. Thus, the probability of entry can be described by $F(\pi_2^d(A)) = P(E < \pi_2^d(A))$. The incumbent's expected profits as a function of investment A is denoted by $\Pi(A)$. As constructed in Ellison and Ellison (2011), the expected profits are found by considering the probability of entry happening and the probability of staying a monopolist:

$$\Pi(A) = \overbrace{P(entry) * \pi(duopoly)}^{\text{Ending up in duopoly}} + \overbrace{(1 - P(entry)) * \pi(monopoly)}^{\text{Staying as a monopolist}} - \text{costs}$$

$$\Pi(A) = F(\pi_2^d(A))\pi_1^d(A) + (1 - F(\pi_2^d(A)))\pi_1^m(\mathrm{A}) - c(A)$$

Now as described in game one and game two, the incumbent might take the entry probability of an entrant as given (no entry deterrence motive) or it might try to affect this (entry deterrence motive). Following the original paper, the difference between these is described as the strategic entry deterrence incentive. The incentive to deter entry to the market increases when the difference between monopoly profits π_1^m and duopoly profits π_1^d increases. In this stylized game, fixed entry cost is assumed to be larger than the entrant's duopoly profits $(E > \pi_2^d(A))$ in small markets. Ellison and Ellison (2011) argue that this is due to small markets having smaller chance of high profits. Vice versa, in large markets the entrant's fixed entry costs are assumed to be smaller than the entrant's duopoly profits $(E < \pi_2^d(A))$. This is due to large markets having large profits to be attained. The authors argue that the probability of the entrant's fixed entry costs being equal to duopoly profits, $P(E = \pi_2^d(A))$, is largest in intermediate-sized markets. Consequently, the probability mass of entry cost E at $\pi_2^d(A)$, $f(\pi_2^d(A))$, is largest at intermediate-sized markets. This relationship follows directly from the unimodal distribution of E, with probability mass concentrated in the centermost values of E. If this was not the case, for example E being uniformly distributed, then $f(\pi_2^d(A))$ would be the same for all market sizes. Next, following Ellison and Ellison (2011), I will represent the first order conditions of incumbent expected profits with respect to A:

No entry deterrence incentive (subscript N = Neutral):

$$\frac{\mathrm{d}\Pi}{dA}(A_N) = F(\pi_2^d(A_N))\frac{d\pi_1^d}{dA}(A_N) + (1 - F(\pi_2^d(A_N)))\frac{d\pi_1^m}{dA}(A_N) - \frac{dc}{dA}(A_N)$$

Entry deterrence incentive (subscript E = entry deterrence):

$$\frac{d\Pi}{dA}(A_E) = F(\pi_2^d(A_E))\frac{d\pi_1^d}{dA}(A_E) + (1 - F(\pi_2^d(A_E)))\frac{d\pi_1^m}{dA}(A_E) - \frac{dc}{dA}(A_E) + \underbrace{(\pi_1^d(A_E) - \pi_1^m(A_E)) * f(\pi_2^d(A_E))\frac{d\pi_2^d}{dA}(A_E)}_{h(A)}$$

In the neutral case the incumbent maximizes profits by taking entry probability $F(\pi_2^d(A))$ as given. In the case where entry deterring motives are present, profit maximization depends additionally on the strategic entry deterrence incentive denoted by $h(A)$. This is a product of three components: first, the difference between duopoly and monopoly profits $(\pi_1^d(A_E) - \pi_1^m(A_E))$. Second, the probability mass of the entrant's fixed entry cost being equal to equilibrium duopoly profits $f(\pi_2^d(A_E))$. And thirdly, the term $\mathrm{d}\pi_2^d(A_E)/\mathrm{d}A$, which indicates whether the incumbent chooses to strategically under- or overinvest. If investment A decreases the entrant's profits $(\mathrm{d}\pi_2^d(A_E)/\mathrm{d}A < 0)$, the decision is to overinvest. If investment A increases entrant's profits $(\mathrm{d}\pi_2^d(A_E)/\mathrm{d}A > 0)$, the decision is to underinvest.

3.2 Monotonicity and non-monotonicity of investments and entry probability

Ellison and Ellison (2011) identified two possible cases: entry-deterring incentives are present or absent. Ideally, the entry deterrence incentive could be drawn from comparing the level of A in different situations. However, A is difficult to measure empirically. Following the original paper: a new measure, market characteristic z, is introduced. The measure z describes common things between incumbent investment $A(z)$, investment cost $c(A(z))$, and the profits $\pi_1^m(A(z))$, $\pi_1^d(A(z))$, $\pi_2^d(A(z))$. Market characteristic z is a general measure, which can be chosen optimally for each research setting. The measure z is to be interpreted as a proxy for being able to empirically estimate the levels of incumbent investment A in different situations. The measure z is chosen so that the probability of entry follows it. The measure z is not necessarily part of the model structure; however, it is necessary for being able to draw empirical results. For example, market size is chosen as z in Ellison and Ellison (2011). The idea here is that in small markets we might see smaller investments and vice versa in large markets. In the absence of entry deterring motives, the investment size A can't be chosen based on entry probability, because it is not observed. Regardless of the entry deterring incentives being present, in smaller markets incumbent investments are smaller and entry probability is small.

Ellison and Ellison (2011) identify two effects in which z (market size in their study) affects the incumbent's initial investment A. These are the direct effect and the competition effect. Positive direct effect means that increasing z will increase the marginal benefit of investment (A(z)) more than it increases marginal cost of the investment. Thus, when positive direct effect is in place, the incentive is to invest more when z gets higher values (for example, larger markets). Similarly, when the direct effect is negative, the incentive is to invest less when z gets lower values. The competition effect is the effect of z on investment A when going from monopoly to duopoly competition. The competition effect is positive when increasing z, the marginal benefit from investment A is higher in duopoly competition than when the incumbent is a monopolist. Intuitively, when the competition effect is positive, the incentive is to increase investment A when z gets higher values. The authors' conclusion is that incumbent investment A is increasing in z if both effects are positive. If both effects are negative, incumbent investment A should be decreasing in z.

A remarkable suggestion of Ellison and Ellison's (2011) study is that in the absence of entry deterring motives, incumbent investment A should be monotone increasing in z. For example, if A is investment on product proliferation and z is market size, and if both the direct and the competition effects are positive, investments A into product proliferation should grow monotonically when the market size increases. If we are in the second case, where the incumbent has an entry deterring incentive, then this relationship isn't necessarily monotone. As argued earlier, if a non-monotonic relationship is observed, it is due to incumbent's entry deterrence incentives, which show up in the term $h(A)$. Recall that this is a product of three components: the difference in duopoly and monopoly profits to be attained, $(\pi_1^d(A_E) - \pi_1^m(A_E))$, the likelihood of entrant's profits being equal to entrant's entry costs $f(\pi_2^d(A_E))$ and the indicator for under- or overinvestment $\mathrm{d}\pi_2^d(A_E)/\mathrm{d}A$. If z is market size, the hypothesis is that deviations from the monotonic relationship will happen in intermediate sized markets. The likelihood of entrant's entry costs being equal to entry costs $f(\pi_2^d(A_E))$, is largest in the middle values of z.

To conclude the findings so far, z is chosen as a proxy for A and z follows the probability of entry. If the direct- and competition effects of z on A are positive, A should be monotone increasing in z. However, this relationship might be non-monotonic if strategic entry deterrence incentives are in place. Entry deterrence incentives are highest, when the probability mass $f(\pi_2^d(A_E))$, is highest. Due to the assumed distribution of entry cost E, the mass of f is concentrated in the centermost values. Thus, f will be highest in markets of intermediate values of chosen z. Therefore, if larger investments are observed in intermediate values of z, entry deterrence incentives can be concluded. Dafny (2005) describes the risk of entry happening through the notation "market attractiveness". Following Dafny's terminology, markets of intermediate attractiveness[3] leave the most entrants "on the fence" of entering. In very unattractive or very attractive markets, the number of entrants contemplating entry decreases. The relationship of increasing incumbent's investment in market attractiveness is represented visually by Dafny (2005) in Figure 2.

[3] Dafny (2005) describes entrants' entry probability with the term "market attractiveness"

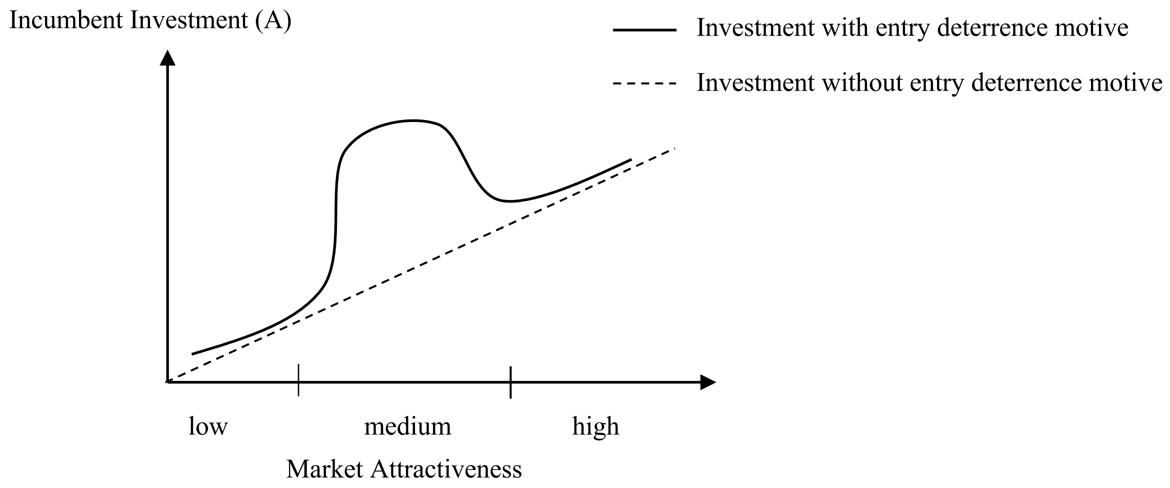

Figure 2. Dafny (2005): The relationship of incumbent's investment A increasing in market attractiveness.

Belleflame and Peitz (2015) conclude the logic of non-monotonicity tests similarly. They state that entry deterrence is unnecessary in markets of small attractiveness and impossible in markets of large attractiveness. When entry probability is low, the number of potential entrants is low, and the incumbent has no use investing to deter entry. When entry probability is large, deterring entry is ineffective due to the inevitability of entry. So, if an incumbent is looking to deter entry, it is most effectively done in markets of intermediate attractiveness. Ellison and Ellison (2011), Bokhari and Yan (2019) and Dafny (2005) all attempt to identify the relationship of incumbent investment A and market entry probability. If this relationship is non-monotonic, where deviations from the monotonically growing relationship are found in the market of intermediate entry probability, entry deterrence incentives might be present.

3.3 Challenges of defining intermediate entry probability

Incumbent investment A should be monotonically increasing in entry probability, which follows market characteristic z, absent of entry deterring incentives (Bokhari and Yan, 2019). In markets of intermediate attractiveness, we might see deviation from this monotonicity due to strategic entry deterrence. This poses two questions; what is an adequate measure for market characteristic z, and how to define a market of intermediate attractiveness? There are no definitive answers to these, but I will present the methods used in the three empirical papers I will cover later in chapter four.

Ellison and Ellison (2011) study the U.S. pharmaceutical market and Bokhari and Yan (2019) study the UK pharmaceutical market. Both papers use the market size as a measure for market entry probability. Market size is measured by market revenue. This is well justified in their works on the U.S. and UK pharmaceuticals due to extensive literature on pre-entry revenues indicating high probability of entry in the field of pharmaceuticals. Scott Morton (2000) and Saha et al. (2006) in the U.S. pharmaceutical industry as well as Appelt (2015) in the German pharmaceutical industry conclude that revenue is the biggest proxy for probability of entry. Scott Morton (2000) states that this is largely due to small marginal costs in pharmaceuticals as they are not necessarily prone to high entry costs. Price elasticities are also found to positively affect the attractiveness of entry in pharmaceuticals as well as FDA restrictions negatively affecting them, this is also found in Saha et al. (2006). The third paper I'm going to go through in chapter 4 is Dafny (2005). Electrophysiological (EP) procedure market is studied here, a costly surgical procedure that experienced a surge in demand in 1989. EP is practiced in hospitals having a designated EP lab, so the entry probability is defined through the number of hospitals nearby not practicing EP, but which meet the pre-requisites of establishing an EP lab (Dafny, 2005).

Measures for market characteristic z can be established depending on the research setting, but defining a market of intermediate attractiveness is more worrisome. The difficulty stems from having to optimally separate the sample into quantiles that would capture the non-monotonic relationship proving the strategic entry deterrence incentive. Dafny (2005) uses a discrete measure of potential entrants and actual entrants which is used to conduct an ex-post analysis of entry probabilities. Different market entry probabilities are quite simple to categorize into small, medium, and large due to the discreteness of chosen z. Ellison and Ellison (2011) split the sample into five quantiles, with the intention of finding evidence in the second quantile. Ex-post analysis of potential and realized entry justify this. Bokhari and Yan (2019) uniformly split the market into three quantiles, with the middle quantile describing medium entry probability. All in all, an ex-post analysis and discrete values for z might alleviate challenges of determining a market of intermediate entry probability.

3.4 Necessary conditions for data to detect non-monotonicity empirically

There are multiple ways of trying to capture the non-monotonic relationship of market attractiveness and incumbent investment. All three empirical studies in this review observe the incumbent's investment immediately prior to a policy change which enables general entry to the market. A known point in time for "market opening" or a surge in demand is ideal for detecting entry deterrence. More specifically, a situation where the market opening date is known, and it is informed beforehand, provides a window for the incumbent to practice entry deterrence. Ellison and Ellison (2011) and Bokhari and Yan (2019) study pharmaceuticals, here the expiration of patents provides a date for market opening. Dafny (2005) chooses EP as the studied market due to a change in EP's reimbursement status. This change increased the demand for EP, which is seen as an event of more general entry to the market.

Another thing to consider is the way regressions are conducted. All three studies include a cross-sectional analysis, but this can pose several challenges. A steeply increasing or decreasing relationship of investment and chosen entry probability characteristic might diminish the effect of non-monotonicity even if entry deterrence incentives are present (Ellison and Ellison, 2011). Substantial heterogeneity in incumbents (Ellison and Ellison, 2011) or market types (Dafny, 2005) might also erode the ability to distinguish non-monotonicity of investment. Pre-existing market trends for different market types is also touched on as a potential diminishing factor in Dafny (2005). Access to panel-data might be beneficial in providing evidence of strategic investment patterns and reducing potential bias or insignificant results of cross-sectional analysis. Data on investment levels before and after general entry allows for examination of the difference, rather than actual investment level. The panel-data approach allows for removing existing non-strategic investment levels and focusing on the "treatment" effect of strategic entry deterrence (Ellison and Ellison, 2011).

The sample size must be large enough to draw statistically significant results from the regression. Smaller samples are more prone to issues of heterogeneity biasing the results (Ellison and Ellison, 2011). Arguably the largest challenge of credibly detecting strategic entry deterring investments is getting access to firms' investment data. Since this is rarely accessible, substitute proxies must be used.

4. Review of empirical studies of non-monotonicity tests in entry deterrence

In the next chapter I will cover three papers, Ellison and Ellison (2011), Bokhari and Yan (2019), and Dafny (2005), which all use non-monotonicity of market attractiveness and incumbent investments as a tool to detect entry deterring behavior.

4.1 Ellison and Ellison (2011): *Strategic Entry Deterrence and the Behavior of Pharmaceutical Incumbents Prior to Patent Expiration*

Beginning the analysis of Ellison and Ellison (2011) study from the perspective of using non-monotonicity tests to exploit entry deterring behavior, I want to emphasize the importance of the study. The authors pioneered non-monotonicity tests for investments increasing or decreasing with previously discussed market characteristic z. The method is crucial in identifying entry deterrence and has been used in other empirical studies alike. Before non-monotonicity tests, there has not been a systematic method for detecting entry deterrence empirically.

The main research question the authors try to answer is can entry deterrence be exploited through a non-monotonic relationship of market size and incumbent investment. Market size, and more specifically market revenue, is used as a proxy for probability of entry happening. This is well justified in the pharmaceutical market as discussed in the previous section. The Authors use data on U.S. pharmaceuticals, which lost their patent between the years 1986-1992. Patent expiration can be thought of "market opening" and is thus an excellent place for investigating entry deterrence. Studied extensively in Grabowski and Vernon (1992), market opening here was due to 1984 Drug Price Competition and Patent Term Restoration Act which permitted general entry into the industry.

As introduced in chapter 3.2, Ellison and Ellison (2011) state that market characteristic z affects the incumbent's investment through the direct- and competition effect. If the direct effect is positive, the incumbent has an incentive to increase investment when z increases. Competition effect is the effect of z on the incumbent's investment level of shifting from monopoly setting to a duopoly setting. If the competition effect is positive, the incumbent has an incentive to increase investment when z increases. If both effects have the same sign, investment should be monotone in z absent of entry deterring incentives. If this relationship is proven non-monotone, we can conclude entry deterrence. Ellison and Ellison (2011) investigate three investment categories: detail advertising, journal advertising and presentation proliferation. Detail advertising means advertising straight to doctors and executives who ultimately prescribe the pharmaceutical to patients. Journal advertising is advertising the pharmaceutical in medical journals, an idea to bring knowledge to the ordinary consumer. Both detail- and journal advertising are measured by per-consumer expenditures. Presentation proliferation means adding additional pack sizes and varieties in the incumbent's line of drugs with the intention of making it difficult for the entrant to match the line of drugs.

Ellison and Ellison (2011) argue that in detail advertising when increasing z (market size in their study) the investments and revenues are likely to be linear. This results in the direct effect being absent. Competition effect is likely to be negative. The idea is that the monopolist benefits more from advertising than the duopolist, thus when facing more competition, the marginal benefits of advertising would decrease. Schmalensee (1983), reached a similar conclusion in his early theoretical analysis of advertising as entry deterrence, where he argues that when in face of guaranteed entry, the incumbent will always want to underinvest in advertising, because advertising benefits the entrant more. Thus, the conclusion the authors make is that incumbent investments to detail advertising are likely to be decreasing in z. Ellison and Ellison (2011) argue that incumbents would have an incentive to reduce advertising to deter entrants by reducing the demand of the pharmaceutical. An early paper from Tirole and Fudenberg (1984) gives similar insight; consumers become more aware of a good only when advertised, thus reducing advertising might be a strategy for entry deterrence. This isn't all so unambiguous, the benefits from deterring enough entrants to overcome the losses from decreased demand leaves a concern. Ellison and Ellison (2011) apply the similar logic of decreasing competition effect in journal advertising. However, in journal advertising the direct effect in predicted to be positive due to expenditure per consumer decreasing in market size (z). Opposite signs of the effects lower the interest for investigating entry deterrence in journal advertising. Ellison and Ellison (2011) predict that investments into journal advertising will be decreasing in z. In presentation proliferation direct and competition effects are thought to be positive. Direct effects are positive because the marginal costs of introducing more presentations by an incumbent are low, therefore the benefits of investing in presentation proliferation increases in z. Competition effect is assumed positive due to duopoly providing the incumbent a niche it wouldn't have had without the entrant. This creates an incentive to proliferate presentations for the incumbent, since monopoly power is achieved through the new presentations (Ellison and Ellison, 2011).

As stated in chapter 3, detecting entry deterrence comes through observing non-monotonicity in investments for different z. Ellison and Ellison (2011) uniformly divide the sample into five quantiles of market size, with the assumption that non-monotonicity would arise in the second quantile. Ex-post analysis of market entry for the five quantiles confirms the second quantile being markets of intermediate entry probability. The probabilities of entry in rising order are: 0%, 43%, 86%, 80% and 92%. The authors take two approaches to represent non-monotonicity: a cross-sectional and a difference-in-difference approach. Two test statistics for non-monotonicity tests are used: modified Hall and Heckman (2000) test statistic and Ellison and Ellison (2000) test statistic. The cross-sectional analysis runs a regression on each of the possible entry deterring investment categories on market revenue (z). The mean value of investment in each investment category per quantile is evaluated. Difference-in-difference (DiD) analysis concentrates on the changes in investment values one year prior to patent expiration and two years after patent expiration. Detail- and journal advertising levels are obtained from data on advertising expenditure of total revenue. Presentation proliferation is simply measured by the average number of presentations for a drug. Next, I will present the results of Ellison and Ellison (2011) study.

In the case of detail advertising, the regression results fail to show evidence of decreasing level of investment in z. The mean values of investment for all five quantiles were low and statistically insignificant. The second quantile had the lowest mean, indicating some non-monotonicity, but the results cannot be concluded due to statistical insignificance. The DiD-approach shows that advertising increased the least in the second quantile, providing weak evidence of non-monotonicity. However, the sample size shrinks in the DiD-approach, and therefore the results are statistically insignificant.

The case of journal advertising gave results of low and statistically insignificant regression coefficients for decreasing investments with market revenue (z). The second quantile had lowest mean in investments to advertising indicating weak non-monotonicity. P-values are however too high to conclude statistical significance. DiD-approach did not give any additional support for non-monotonicity in the second quantile. In fact, investments in advertising increased the least in the first and the third quantiles.

In presentation proliferation a Herfindahl-Hirschman type of index was chosen. This index takes lower values for high number of presentations, while at the same time giving weight on the pharmaceuticals based on their revenues. The regression of revenue and this variable gave large negative coefficients and small p-values providing evidence of strong relationship of increasing presentation proliferation with revenue. The quantile means provide no evidence of presentation proliferation being any larger in intermediate sized markets compared to small or large markets. The DiD-approach provides statistically significant results that presentation proliferation increases in the first, second and third quantiles. This does not give additional support for non-monotonicity in intermediate sized markets.

Ellison and Ellison (2011) pioneer the use of non-monotonicity tests in detecting entry deterring behavior. However, the challenge of finding suitable data for isolating the strategic entry deterring incentive from incumbent investment works as a disadvantage. Only a few weak deductions of non-monotonicity can be concluded from the study. The difference-in-difference approach gave evidence of possible non-monotonic relationship of decreasing advertising investments and market revenue, but the number of observations shrinks. The external validity of the results is rather low due to statistical insignificance.

4.2 Bokhari and Yan (2019): *Product proliferation as entry deterrence: the case of UK pharmaceuticals*

Bokhari and Yan (2019) study product proliferation as a form of entry deterrence in the UK pharmaceutical market. The main idea behind product proliferation is that the incumbent wants to increase the number of products in the product line to make it harder for a potential entrant match the line of products and grasp meaningful profits (Bokhari and Yan, 2019).

The main research questions the authors try to answer are “does more products launched by an incumbent lower the probability of other firms entering the market?” and “does the implementation of product proliferation help the incumbent maintain bigger market share?” (Bokhari and Yan, 2019). The main issue with answering the research questions is identifying strategic investments of entry deterring incentives from the firms’ general profit maximizing investments in product proliferation. This is tackled through non-monotonicity tests on the relationship of the number of products and market size, and measuring the number of products launched by the incumbent before and after market opening. Does lower or higher entry probability affect the number of products launched by incumbents, and is this especially high in markets of intermediate entry probability? The authors also show the effect of product proliferation through preserved market shares of incumbents with the help of hazard rate models. I will not review this part of the study since it does not concern identifying entry deterrence through non-monotonicity. (Bokhari and Yan, 2019)

The paper uses UK pharmaceutical data from molecules that incumbents lost their patents on between the years 1996 and 2016. Bokhari and Yan (2019) have a dataset of 704 unique molecules that had the market for themselves during patent exclusivity period, which of 200 experienced general entry. The data set has more datapoints and is overall richer compared to Ellison and Ellison (2011) dataset, with which they ran into issues of statistical significance. Each molecule is identified with an ATC3-code; thus, each ATC3-code describes a market of its own. Some crucial modifications have had to been done to the data for it to suit non-monotonicity tests. Some pharmaceuticals face protection from authorities, thus their entry probabilities are distorted and must be excluded from the analysis. Only molecules that have one molecule as the main compound of the pharmaceutical can be included due to distinction of markets being based on this. (Bokhari and Yan, 2019)

The strategic product proliferation investment is simply measured with the number of products. This is split into three more specific alternatives for proxying the magnitude of product proliferation practiced by the incumbent. First one is the number of important products, which is calculated through considering the sum of squares of market shares per product, giving larger weight to products which have a greater market share. Second alternative is the number of unique formulations by firm. Lastly the different pack sizes for all different formulations are considered. An interesting finding is done in the raw data: on average, the number of products by an incumbent is rising until the date of patent expiration and after this it stays constant or is decreasing at times. This observation is not directly related to non-monotonicity tests but gives motivation to investigate the data before and after market opening. (Bokhari and Yan, 2019)

In Bokhari and Yan (2019) entry probability is described with market size. Market size is proxied with market revenues, which has been concluded as an excellent way to describe entry probabilities in the pharmaceutical market in Scott Morton (2000). The number of products is projected to increase monotonically with market size absent of entry deterring incentives. Non-monotonicity focus is on splitting the market size to quantiles, to find deviations in the market of intermediate entry probability. Market size is split up uniformly into three quantiles at 33 and 66 percentage points marking the small, medium, and large markets. According to non-monotonicity theory, if the strategic entry deterrence incentive is present, it would arise from middle-sized markets increasing the number of products prior to market opening relatively more than other sized markets. (Bokhari & Yan, 2019)

In my opinion, optimal dividing of the sample into different quantiles must be considered carefully. For example, if the substantial differences were achieved at say the quantile ranging from 20 to 40 percentage points, splitting the market at 33 and 66 percentage points might not capture relevant evidence due to misspecification in small, medium, and large entry probability of markets. This could be addressed with an ex-post analysis of entry occurrence.

The authors conduct two types of analysis for revealing the entry deterrence incentive of product proliferation by incumbents: first a cross-sectional analysis and second a panel-data analysis. The cross-sectional analysis is done by regressing the number of products on revenue, and the square of deviation from the mean value of revenue. The authors state that non-monotonicity is found if the coefficient of the deviation term takes an opposite sign compared to the linear term. The intuition here is that as market size increases, so does the number of products per incumbent. The deviation from the mean revenue should be larger in small and large markets if product proliferation increased monotonically. Therefore, non-monotonicity can be concluded if the deviation term is negative when the linear term is positive. The authors state that omitted variable bias is not an issue in this regression. This is due to possible omitted variables affecting the coefficients in the same direction. The cross-sectional tests fail to reveal any evidence of non-monotonicity. The cross-sectional case is extended to a similar panel-data version, where different years before market opening are observed. No non-monotonic pattern is to be found in the panel-data regression either, thus they do not provide evidence of entry deterrence. A pattern of increasing product proliferation in market size is detected in both cases. The cross-sectional and panel-data non-monotonicity tests are also executed with semi-parametric tests using the Hall and Heckman (2000) test-statistic.[4] The non-parametric tests reveal weak non-monotonicity in the panel-data and give no evidence in the cross-sectional case.

Bokhari and Yan (2019) further exploit the panel-data, to a test for product launch rate before and after market opening. The authors conduct an ex-post analysis, where they analyze the number of products launched as the dependent variable. Independent variables are years until patent expiration, a dummy for entry happening and an interaction term of these, which reveals whether higher entry threat will indicate more products launched. Calculations are conducted for years before and after market opening. The conclusion is that incumbents

[4] Non-parametric tests found in appendix D, pp. 37 in Bokhari and Yan (2019).

launch more products, when entry threat is high (entry takes place) than when it's low. This is statistically significant for all but one measurement category (important products). Markets that faced entry, reduced product launches after entry, which suggests evidence for an entry deterring strategy of launching products just before market opening. This analysis is extended to the different sized quantiles of small, medium, and large markets. Medium sized markets reduced product launches substantially more than small, and large markets. This suggests a pattern of markets that experience entry, practicing product proliferation strategically prior to market opening, particularly in intermediate sized markets, providing further proof of strategic entry deterrence. (Bokhari and Yan, 2019)

Bokhari and Yan (2019) use a richer dataset than Ellison and Ellison (2011), to find more statistically significant results. Although initial cross-sectional and panel-data regressions fail to provide evidence of product proliferation being higher in markets of intermediate entry, the ex-post analysis does. Analyzing the differences in periods before and after market opening, exploits product proliferation as a strategic way to deter entry. When comparing the launch rate of products before and after market opening, evidence of larger reductions in launch rate are found in the middle-sized markets. This is consistent with the theory of incentives being most prominent in the market of intermediate attractiveness. The results cannot be generalized since the study focuses solely on the pharmaceutical market of UK.

4.3 Dafny (2005): *Games Hospitals Play: Entry Deterrence in Hospital Procedure Markets*

The final paper I'm going to study in more in detail is Leemore S. Dafny's (2005) research on hospital procedure markets. Non-monotonicity tests are used in a similar way in the study as Ellison and Ellison (2011)[5] and Bokhari and Yan (2019). The main method is exploiting non-monotonicity in the increasing relationship of the volume of electrophysiological (EP) procedures and market entry probability. Pattern to be detected is similar: if entry deterring motives are present, one would expect markets with intermediate probability of entry to experience relatively higher investments into hospital procedures.

[5] Dafny (2005), cites Ellison and Ellison (2000) which is the same study as Ellison and Ellison (2011) but had not been published in the *American Journal of Microecomics* before 2011.

Data used in the study is based on the electrophysiological (EP) procedure market in the U.S. EP is a costly surgical procedure that requires highly skilled professionals for successful outcomes, specialized EP labs which imply high fixed costs and additional referral by cardiologists, who choose the hospital where the procedure is performed. EP is chosen as the surgical procedure of interest, specifically based on these qualities. It is shown that hospitals with higher volume generate better outcomes for a specific procedure. The causality relationship of this is debated, and Dafny (2005) identifies two alternative explanations for such relationship. One alternative is high learning by doing effects; large experience on a procedure creates better outcomes. This is backed up by evidence from Ho (2002). The second explanation comes from reverse causality; better outcomes in procedures increase the volume. Mukamel and Mushlin (1998) provide evidence for this pattern. Since it is not in the interest of Dafny (2005) to pick sides on this debate, both effects are accounted for through cumulative volume and patient demand. Hospital quality L is introduced as the variable which sums these effects. Through increasing L, higher profits can be achieved, thus it is in the incumbent's incentive to increase volume to increase competitiveness. (Dafny, 2005)

EP is also chosen due to a shock of increasing demand for the procedure. Original reimbursement values for EP procedures in 1988 were at \$1800 to \$2700. Based on a decision by the U.S. Health Care Finance Administration (HCFA) in 1989, the reimbursement values we're significantly increased for the year 1990 from \$6500 to \$26700. This created additional interest for hospitals not practicing EP, to start doing so. In an entry deterrence perspective, this creates a two-year window for incumbents to deter the entry of potential entrants. A Market is defined as a Health Service Area (HSA) containing hospital(s) that practice EP. Potential entrants are hospitals that practice cardiac catherization and open-heart surgery, but do not practice EP. This is due to these procedures being prerequisites for setting up an EP lab. (Dafny, 2005)

The usual number of potential entrants ranges from 0 to 4. Dafny (2005) opts into describing market entry probability as a function of potential entrants. An ex-post analysis is conducted. This yields that entry probability is at 9 % for markets with 0 potential entrants, 49 % for markets with 1 potential entrant and 77-85 % for markets with 2+ potential entrants. This concludes that market entry probability is at intermediate levels for markets with 1 potential entrant, hence here we would expect to see strategic investments of entry deterrence. Dafny (2005) assumes an increasing relationship between procedure volume and market entry probability. Intuitively this feels ambiguous. Dafny (2005) explains this with the number of potential entrants giving a good measure of unmet EP demand in a market. More unmet demand undeniably results in increasing market attractiveness for the potential entrant.

Having data on incumbents' investments in EP volume would reveal more accurate measures of entry deterrence, but this is not available. However, measuring the actual levels of volume is. Difference in volume levels 1988 and 1989, before and after the revealed information of the new reimbursement status, is used as a proxy for the investment. When graphing the unadjusted volume growth on entry probability, it is seen that volume grew substantially more in markets with 1 potential entrant than 0 or 2+ potential entrants, giving initial evidence of entry deterrence. Cross-sectional and panel-data regressions are conducted to give further proof of the result.

Starting off with the cross-sectional approach, Dafny (2005) uses the natural logarithm of volume growth as the dependent variable and an indicator independent variable, which indicates the number of potential entrants. The regression is conducted four times, with increasing number of controls for each round (years of EP experience, teaching status, existing catheterization lab, etc.). Regression results show that incumbents in markets of intermediate entry probability, meaning markets with 1 potential entrant, increased their volume of EP procedures significantly more than other market types. This result hold for all four regressions, even with included controls. On average the increase is 35 %-points more than markets with 0 potential entrants, denoting the low entry probability markets. For the markets of 4+ potential entrants, the markets of high entry probability, the increase is 26 to 49 %-points more. The coefficients are statistically significant at $p < 0,1$ level for three of the four rounds of regressions, providing strong evidence of investments into EP volume as entry deterrence. Issues of possible bias rise with cross-sectional analysis due to difficulties of identifying the strategic investments out of incentives of profit maximization in general. Panel-data regression is conducted to provide a solution to this issue. (Dafny, 2005)

The panel-data regression attempts to remove biases of the cross-sectional analysis caused by differences in market growth trends for different types of markets. This panel-data set is constructed by regressing the volume of EP per hospital for each year between 1985 and 1989. The panel-data regression introduces a dummy variable, which captures the different trends per market type. Recall that different market types are denoted by the number of potential entrants. An indicator variable for the year 1989 is introduced. The idea is that the indicator variable for 1989 captures the additional incumbent investment to EP volume, caused by the reimbursement status change, per different market type. This way the differences in growth trends per market type can be controlled. The panel-data regression results show that incumbents' EP volume increased significantly more for markets with 1 potential entrant compared to 0 or 2+ potential entrants. For example, for the rounds of adding controls, EP volume increased 55-62 %-points more for markets with 1 potential entrant compared to markets which had 4+ potential entrants. These results are all statistically significant on the $p < 0,05$ level. Panel-data analysis provides even stronger evidence of incumbents facing intermediate probability of entry, investing strategically in EP procedure volume to deter entry from potential entrants. (Dafny, 2005)

Dafny (2005) goes further to test the cross-sectional case for monopolist incumbents (HSA's with only 1 Hospital offering EP), and the non-monotonic relationship of EP volume and entry probability is even stronger. However in this case the sample size reduces, and only markets with 0, 1 or 2 potential entrants are observed. All in all, the paper concludes statistically significant results of incumbents investing heavily into volume of electro physiological procedures ahead of general entry to the market. These investments are substantially larger in markets of intermediate attractiveness, even after controlling for a variety of alternative causes. This can be concluded as strategic entry deterrence. Due to the distinct qualities of the EP procedure, generalizing the results is not very sensible.

5. Conclusion

Strategic entry deterrence has been studied extensively in theoretical research since the 1970's. Concluding findings of entry deterrence empirically often runs into problems of distinguishing the action of incumbent originating from entry deterring incentives. Empirical findings of entry deterrence are limited to mostly observing the response of the markets to the investments made by incumbents. The absence of a systematic way of empirically recognizing when incumbent investments are made of entry deterring incentives rises demand for such a method. This is especially in the interest of antitrust authorities. Incumbents succeeding in deterring entry affect the competitive equilibrium.

Ellison and Ellison (2011) suggest a method of non-monotonicity tests to distinguish investments made from entry deterrence incentives. I've reviewed three empirical studies, Ellison and Ellison (2011), Bokhari and Yan (2019) and Dafny (2005), which all use non-monotonicity tests. The bigger picture to be drawn from these is that when measuring incumbents' investment values before general entry to the market, some non-monotonicity can be found in markets of intermediate entry probability. If entry probability can be distinctively categorized to different quantiles of the data, the non-monotonicity of investments can be easier to conclude, as seen in Dafny (2005). Data on investments before and after general entry to the market provides more statistically significant results, as seen in Ellison and Ellison (2011) and Bokhari and Yan (2019). Empirical research using the non-monotonicity tests rely heavily on having data of an optimal market[6], accurate estimates for entry probability and sufficiently large data sets.

The test is a step closer to finding a systematic way of empirically exploiting firms practicing entry deterrence. However, multiple aspects erode the generality of non-monotonicity tests. The difficulty of determining accurate measure of market entry probability remains a concern. Ex-post analysis of possible and realized entry provides some solutions but concluding entry deterrence years later is not too much help for the antitrust authorities. Non-monotonicity tests require splitting a market into different quantiles of entry probability, with the intent of determining a market of intermediate entry probability. This distinction is all but unambiguous due to differences in markets.

An ideal research-setting for using non-monotonicity tests would require knowledge of a distinct date of market opening and knowledge of the entrant's entry probability. For this ideal situation access to information on incumbent's profits, incumbent's investment levels and entrant's entry costs, would be provided. With information on the distribution of entry costs, and the different entry probabilities, it would be possible to identify the markets, where entrants are most likely to be just unsure of entry. For non-monotonicity tests, it would be ideal, that higher incentives of entry deterrence would be prominent in some bounded region of the entry probability spectrum, and non-prominent elsewhere. This would be caused by a unimodal distribution of entry cost. Having data of a similar market, which doesn't inhabit

[6] An optimal market for detecting entry deterrence has a known date for general market opening (or a known date for a surge in demand). This provides a timeframe for the incumbent to practice entry deterrence.

the incentives for entry deterrence, provides a useful "neutral" benchmark. Through comparing these markets, investments made from entry deterrence incentives could be concluded. The direct- and competition effects of entry probability on incumbent investment must be of the same sign. If these are of opposite signs, the ability to detect strategic entry deterrence with non-monotonicity tests declines.

From the perspective of antitrust authorities, it would be beneficial to detect the cases in which incentives to deter entry are large before entry happens. This way antitrust authorities could sharpen their focus on observing entry deterring investments from incumbents before entry takes place. This is difficult in practice. Ideally market opening would be anticipated in advance, and the distribution of entry costs could be known or estimated. If this was the case, focus should be at markets of intermediate entry probability, where entry costs are likely to be equal to the entrant's profits. Measuring entry probability beforehand is always an estimate of what will happen. Scott Morton (2000) concludes that market revenue is the best proxy for entry probability in the U.S. pharmaceutical market. Future research on proxies for entry probability in other markets would be beneficial for the antitrust authorities. With this information, the authorities' focus could be allocated in markets of intermediate probability of entry, where the market opening date is known in advance.

The issue of entry deterrence investments being in line with general profit maximization investments remains a problem for the antitrust authorities. How to provide enough credible evidence, that an investment is made specifically from an entry deterrence incentive, and not from a general profit maximizing incentive. My policy suggestion for antitrust authorities in this, would be a requirement for the incumbent firms to provide a statement of larger investments when approaching the market opening. The justification for the investments would appear from this statement. This policy might be easier to implement in markets where the incumbent is a monopolist, due to added correctness to legislative competitive aspects. If monopoly position is acquired through grants from legislatures, this might be even easier.

In the future I would like to see more empirical research done using non-monotonicity tests. I think that there is great potential in the method, and with some additional controls it could be generalized further. Measuring market entry probability accurately and having access to broad data sets might provide more statistically significant results.

References

Bokhari, F. A., and Yan, W. (2019). Product proliferation as entry deterrence: the case of UK pharmaceuticals. [Working paper]

Belleflame, P., and Peitz, M. (2015). *Industrial Organization: Markets and Strategies* (2nd ed.). Cambridge University Press. Cambridge, UK.

Chevalier, J. A. (1995). Capital structure and product-market competition: Empirical evidence from the supermarket industry. *The American Economic Review*, *85*(3), 415-435.

Conlin, M., and Kadiyali, V. (2006) Entry-Deterring Capacity in the Texas Lodging Industry. *Journal of Economics & Management Strategy, 15*(1), 167-185.

Dafny, L. S. (2005). Games hospitals play: Entry deterrence in hospital procedure markets. *Journal of Economics & Management Strategy*, *14*(3), 513-542.

Dixit, A. (1980). The role of investment in entry-deterrence. *The economic journal*, *90*(357), 95-106.

Ellison, G., and Ellison, S. F. (2000). A simple framework for nonparametric specification testing. *Journal of Econometrics*, *96*(1), 1-23.

Ellison, G., and Ellison, S. F. (2011). Strategic entry deterrence and the behavior of pharmaceutical incumbents prior to patent expiration. *American Economic Journal: Microeconomics*, *3*(1), 1-36.

Fudenberg, D., and Tirole, J. (1984). The fat-cat effect, the puppy-dog ploy, and the lean and hungry look. *The American Economic Review*, *74*(2), 361-366.

Ghemawat, P. (1984). Capacity expansion in the titanium dioxide industry. *The Journal of Industrial Economics*, *33*(2), 145-163.

Gilbert, R. J. (1989). The role of potential competition in industrial organization. *Journal of Economic Perspectives*, *3*(3), 107-127.

Goolsbee, A., and Syverson, C. (2008). How do incumbents respond to the threat of entry? Evidence from the major airlines. *The Quarterly journal of economics*, *123*(4), 1611-1633.

Hall, P., and Heckman, N. E. (2000). Testing for monotonicity of a regression mean by calibrating for linear functions. *Annals of Statistics*, *28*(1), 20-39.

Hilke, J. C. (1984). Excess capacity and entry: some empirical evidence. *The Journal of Industrial Economics*, *33*(2), 233-240.

Ho, V. (2002). Learning and the evolution of medical technologies: the diffusion of coronary angioplasty. *Journal of health economics*, *21*(5), 873-885.

Kadiyali, V. (1996). Entry, its deterrence, and its accommodation: A study of the US photographic film industry. *The Rand Journal of Economics*, *27*(3), 452-478.

Lieberman, M. B. (1987). Postentry investment and market structure in the chemical processing industries. *The Rand Journal of Economics*, *18*(4), 533-549.

Mathis, S., and Koscianski, J. (1996). Excess capacity as a barrier to entry in the US titanium industry. *International Journal of Industrial Organization*, *15*(2), 263-281.

Scott Morton, F. M. (2000). Barriers to entry, brand advertising, and generic entry in the US pharmaceutical industry. *International Journal of Industrial Organization*, *18*(7), 1085-1104.

Mukamel, D. B., and Mushlin, A. I. (1998). Quality of care information makes a difference: an analysis of market share and price changes after publication of the New York State Cardiac Surgery Mortality Reports. *Medical care*, *36*(7), 945-954.

Neven, D. J. (1989). Strategic entry deterrence: recent developments in the economics of industry. *Journal of economic surveys*, *3*(3), 213-233.

Salop, S. C., and Scheffman, D. T. (1983). Raising rivals' costs. *The American Economic Review*, *73*(2), 267-271.

Salop, S. C., and Scheffman, D. T. (1987). Cost-raising strategies. *The Journal of Industrial Economics*, *36*(1), 19-34.

Scherer, F. M., and Ross, D. (1980). *Industrial Market Structure and Economic Performance* (2nd ed.). Rand McNally. Chicago.

Schmalensee, R. (1978). Entry deterrence in the ready-to-eat breakfast cereal industry. *The Bell Journal of Economics*, *9*(2), 305-327.

Schmalensee, R. (1983). Advertising and entry deterrence: an exploratory model. *Journal of political Economy*, *91*(4), 636-653.

Tirole, J. (1988). *The Theory of Industrial Organization*. MIT press. Cambridge, Mass.

Wilson, R. (1992). Strategic models of entry deterrence. In: Aumann, R. and Harts, S.(Eds) *Handbook of Game Theory with Economic Applications*, *1*, 305-329.