

Advanced Industrial Organization II

Empirical Analysis of Predation

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1 Plan

Predatory behaviour = strategies adopted by firms to drive competitors out of business or prevent entry. The reason firms may have an incentive to behave like this is that less competition implies higher profits - i.e. this is a way of increasing rents.

This lecture will focus on the following paper:

Ellison, Glenn and Sara Fisher Ellison (2007). "Strategic Entry Deterrence and the Behaviour of Pharmaceutical Incumbents Prior to Patent Expiration". Mimeo: MIT.

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This is a long paper and, at times, a bit technical. But the overall objective and testing strategy of the paper are very clear. Focus on that when reading the paper.

2 Entry Deterrence in the Pharmaceutical Industry: Background to the Research

- Basic assumption: the less entry the better from the point of view of the incumbent - for instance because competition in the market is Cournot. So if incumbent firms feel there is a way of stopping new entry, it may be rational for them to do so.
- Goal of empirical work: Establish whether incumbent firms behave strategically in order to prevent entry of new firms; learn how much of a threat to new entry is posed by predatory behaviour.

- Empirical research in this area can be tricky. Your first instinct as an empirical researcher might be to run a regression of the following kind:

$$entry = \alpha + \beta \times predation + \varepsilon$$

where *predation* is a variable measuring the extent of predatory behaviour, or entry deterrence (ED), and *entry* measures the rate of entry in a market. Intuition suggests β should be negative: stronger predatory behavior leads to lower entry. To illustrate why this approach may not work in practice, suppose *predation* is a binary "tool" for entry deterrence. Suppose *predation* = 1, which is costly, reduces the likelihood of entry of new firms.

- Suppose there are 2 types of markets in your dataset:
 - Market A: High likelihood of entry of new firms

- Market B: Very low likelihood of entry of new firms
- Remember implementing the ED tool is costly. Quite possibly, the incumbent firm may find it rational to deter entry - i.e. worthwhile to incur the cost of predation - in market *A*, since the likelihood of entry is high here. However, since the likelihood of entry is low in market *B* it may not bother attempt to deter entry there.
- If this is so, your data is divided up into 2 groups:
 - Market *A*: Some entry; predatory behavior (note predatory tool is not perfect; hence entry rate doesn't go to zero)
 - Market *B*: Very little or no entry; no predatory behavior

- If this is what your data look like, then if you run the regression

$$entry = \alpha + \beta \times predation + \varepsilon$$

you will obtain $\beta > 0$, suggesting predatory behavior **increases** entry! You don't seem to have learned much about the effect of predatory behavior on entry.

- What's gone wrong? In this particular example, the problem is that we didn't control for the fact that predation is **endogenous**. That is, it may well be that *predation* depends on expected entry in the market. That is, we didn't think carefully enough about the strategic behaviour of incumbent firms - we hadn't done our homework on economic theory before setting out to test empirically for predation.

- Ellison and Ellison (2007) is a nice example of a paper where the hypotheses tested empirically link clearly to an interesting theoretical model of entry deterrence.
- These authors use data from the pharmaceutical industry. Using a panel of 63 drugs that lost their U.S. patent protection between 1986-1992, they recognize that the risk of entry may be high once the patent protection has disappeared. They then investigate whether the incumbent firms behave strategically in order to deter entry.
- Potential tools for entry deterrence that the incumbent firm can use:
 - Advertising (two types: "detail advertising" = one-to-one conversations, sales representative & doctor; "journal advertising" = advertisements in medical journals).

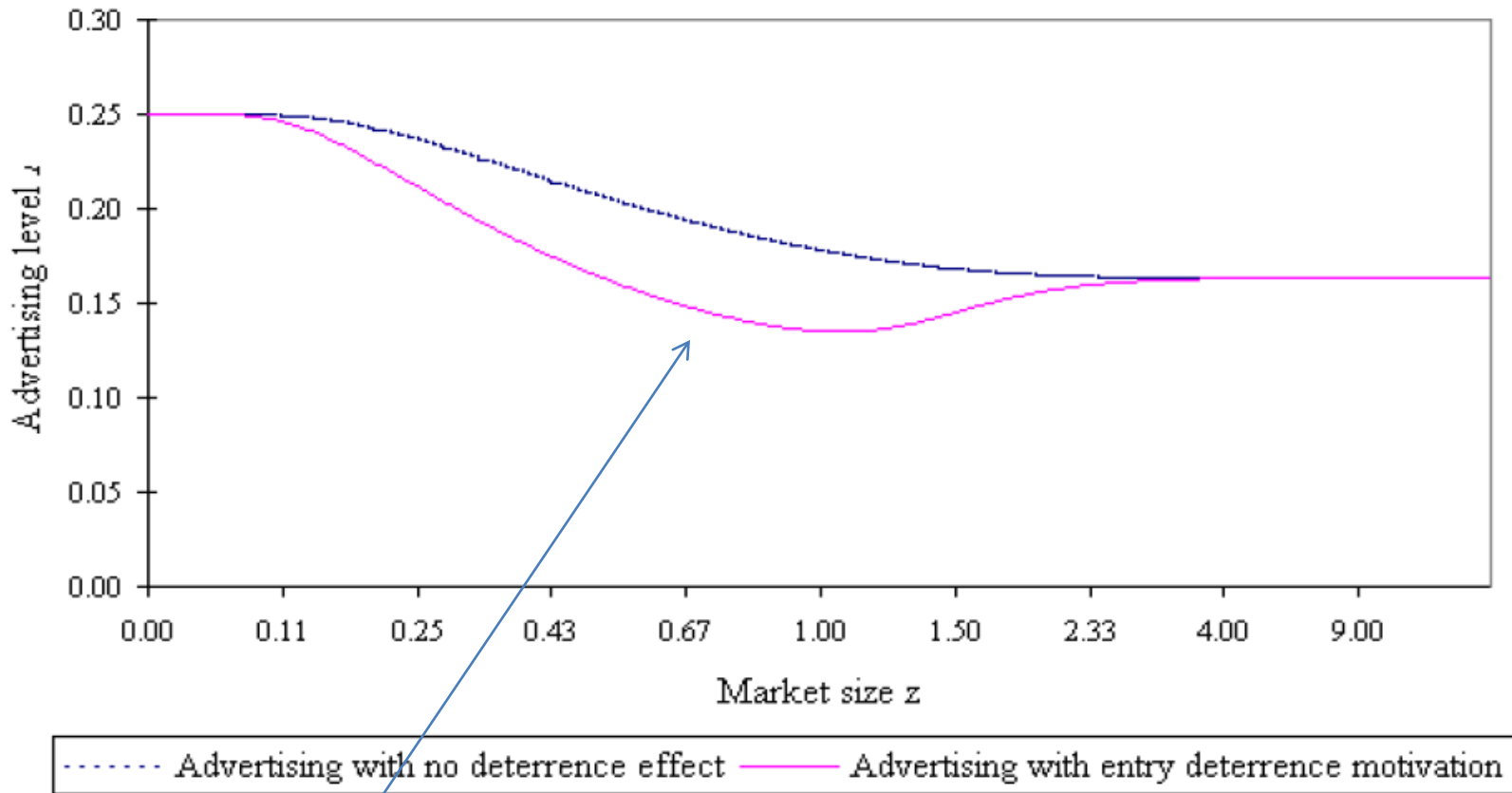
- Product proliferation (number of presentations, e.g. drug is available 100mg tablets, 200mg tablets etc.)
- Pricing
- Focus on advertising. Note that advertising for a particular drug will benefit **all** producers of that drug, to some extent. For example, advertising by an incumbent raises consumer awareness of the drug, which will make benefit generic rivals as well.
- Thus, Ellison and Ellison assume that advertising by an incumbent today will **help** tomorrow's generic entrant. Hence, if the incumbent wants to deter entry, it may find it optimal to advertise **less** than it would if there were no entry deterrence motive.

- Key feature of their theoretical model: The incentive to deter entry will be **stronger** in intermediate-sized markets than in very small or very large markets.
 - Very small markets: No strategic investments are needed to deter entry
 - Very large markets: Deterring entry is too costly or impossible
- Key prediction: Advertising (and other tools for entry deterrence) will **not** be monotonically related to market size *if an entry deterrence motive exists*. In this case, as market size increases from small to intermediate and then to large, you will see an increase in the extent of predation as you go from small to intermediate size, and then a decrease as you go from intermediate to large size.

- In contrast, in a version of their model in which an entry deterrence motive does not exist, the relationship between advertising and market size will be monotonic (more specifically, advertising will fall as market size increases).
- What do we mean by monotonicity?

[Figure 2 here.]

Model of Advertising with Spillovers



For intermediate sized markets, advertising is much lower if there is an entry deterrence than if not

H_0 : No entry deterrence motive. Monotonic relationship between market size and advertising.

H_1 : There exists an entry deterrence motive. Non-monotonic relationship between market size and advertising.

- Two empirical tests: one based on cross-section differences, one being a Difference-in-differences approach, drawing on data on actions immediately prior to patent expiration and actions in earlier years.
- Main results:
 - Some evidence of nonmonotonicity for journal advertising - i.e. journal advertising unusually low in intermediate-sized markets.

- Some evidence of nonmonotonicity for behaviour changing and market size in detail advertising - most likely to be reduced in intermediate-sized markets.

3 Modelling framework

3-stage game. A model in which the incumbent has an incentive to deter entry.

- Stage 1: Incumbent (firm 1) chooses an investment level A at a cost $c(A)$, where $c'(A) > 0$, $c''(A) \geq 0$. That is, investment cost is convex. Think of A as representing the level of advertising.
- Before stage 2: Potential entrant (firm 2) observes the incumbent's choice of A .
- Stage 2: Firm 2 chooses whether to enter the market, which requires paying an entry cost E .

- Stage 3: Production - either firm 1 is a monopolist (firm 2 chose not to enter), or firms 1 and 2 compete as duopolists (firm 2 chose to enter).

- If firm 1 is a monopolist: firm 1 chooses some action $x_1^m(A)$ and earns profits

$$\pi_1^{m*}(A) = \pi_1(x_1^m(A), A)$$

- If duopoly: The two firms choose actions $x_1^*(A)$ and $x_2^*(A)$ and receive profits

$$\pi_i^{d*}(A) = \pi_i(x_1^*(A), x_2^*(A), A),$$

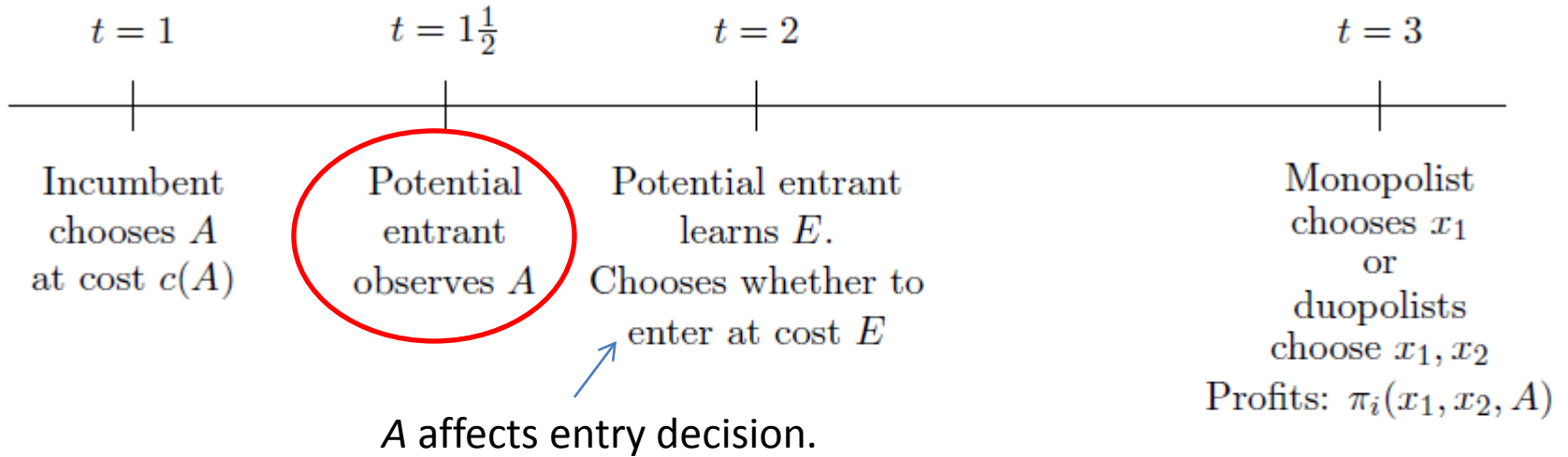
$$i = 1, 2.$$

- Assumptions: profit functions are concave, solutions for optimal choices are always interior and described by first-order conditions.

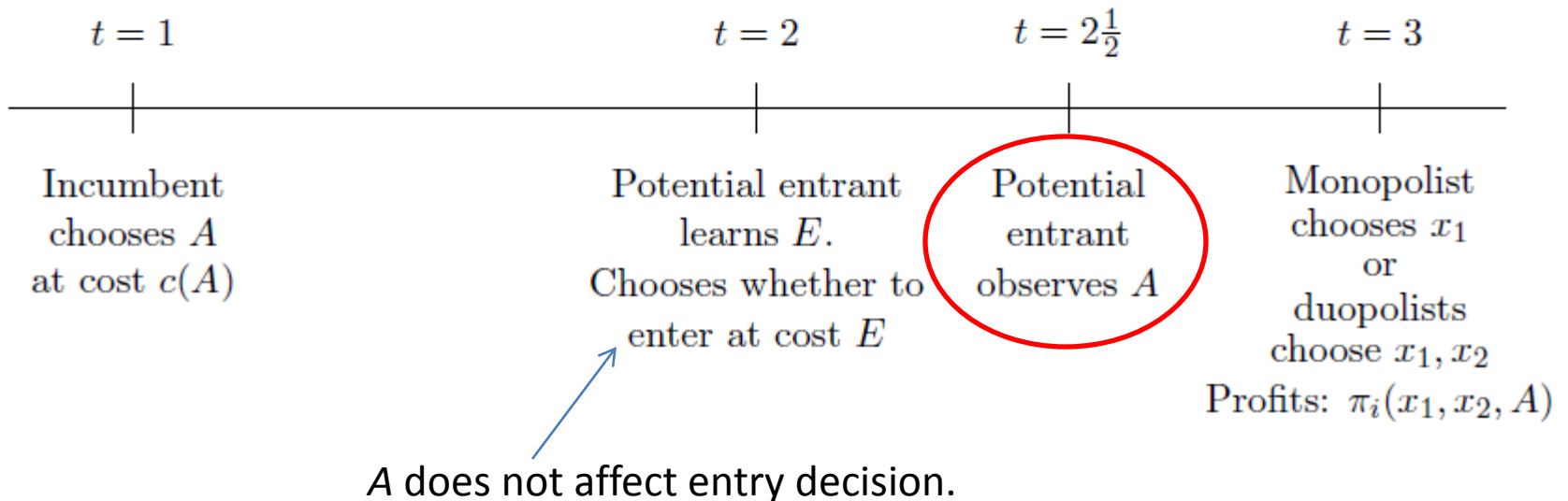
To get a model in which an entry deterrence does **not** exist, we make one small change to the above model: Firm 2 observes A **after** having entered rather than before. This means A cannot directly affect the entry decision of firm 2.

[Figure 1 here]

Strategic Entry Deterrence Model



Investment With No Entry Deterrence Motive



Definitions:

A_{ED}^* = equilibrium choice of advertising by firm 1, in model where entry deterrence exists.

A_{ND}^* = equilibrium choice of advertising by firm 1, in model where entry deterrence does not exist

F = probability that firm 2 will enter. The entry cost E is stochastic.

Firm 1's expected profit, at stage 1:

$$E(\pi_1(A)) = F \left[\pi_2^{d*}(A) \right] \times \pi_1^{d*}(A) + \left(1 - F \left[\pi_2^{d*}(A) \right] \right) \times \pi_1^{m*}(A) - c(A).$$

Now let's think about optimal levels of advertisement.

Model with strategic entry deterrence motive First-order condition: take into account direct effect of A on profits, **and** the indirect effect operating through the probability of entry:

$$\begin{aligned}
 c'(A_{ED}^*) &= F[\pi_2^{d*}(A_{ED}^*)] \times \frac{\partial \pi_1^{d*}(A_{ED}^*)}{\partial A} \\
 &+ (1 - F[\pi_2^{d*}(A_{ED}^*)]) \times \frac{\partial \pi_1^{m*}(A_{ED}^*)}{\partial A} \\
 &+ [\pi_1^{d*}(A_{ED}^*) - \pi_1^{m*}(A_{ED}^*)] \\
 &\times \frac{d\pi_2^{d*}(A_{ED}^*)}{dA} \frac{\partial F[\pi_2^{d*}(A_{ED}^*)]}{\partial \pi_2^{d*}}.
 \end{aligned}$$

Since F is a probability, or a cumulative density function, we obtain the probability density function, denoted $f(\pi_2^{d*}(A_{ED}^*))$ when differentiating F with

respect to its argument:

$$\begin{aligned}
 c'(A_{ED}^*) &= F[\pi_2^{d*}(A_{ED}^*)] \times \frac{\partial \pi_1^{d*}(A_{ED}^*)}{\partial A} \\
 &+ \left(1 - F[\pi_2^{d*}(A_{ED}^*)]\right) \times \frac{\partial \pi_1^{m*}(A_{ED}^*)}{\partial A} \\
 &+ \left[\pi_1^{d*}(A_{ED}^*) - \pi_1^{m*}(A_{ED}^*)\right] \\
 &\times \frac{d\pi_2^{d*}(A_{ED}^*)}{dA} f[\pi_2^{d*}(A_{ED}^*)].
 \end{aligned}$$

The last term here, i.e.

$$\left[\pi_1^{d*}(A_{ED}^*) - \pi_1^{m*}(A_{ED}^*)\right] \frac{d\pi_2^{d*}(A_{ED}^*)}{dA} f[\pi_2^{d*}(A_{ED}^*)]$$

is called the "strategic entry deterrence" incentive. Focus on the role of the probability density function $f(\cdot)$. First, notice that $f[\pi_2^{d*}(A_{ED}^*)]$ measures the likelihood of drawing an entry cost E such that firm 2 is indifferent between

a) not entering; and

b) entering, earning duopoly profit π_2^{d*} and paying entry cost E .

Now consider 3 markets of differing size

- Very small market. This means the duopoly profit π_2^{d*} will be rather low. This means the entry cost E would have to be extremely low for firm 2 to be indifferent between not entering and entering (almost no matter what happens it will not enter). This means $f(\cdot)$ will be **low** (close to zero). Left tail of the probability density function.
- Very large market. This means the duopoly profit π_2^{d*} will be rather high. This means the entry cost E would have to be extremely high for firm 2 to

be indifferent between not entering and entering (almost no matter what happens it will enter). This means $f(\cdot)$ will be **low** (close to zero). Right tail of the probability density function.

- Intermediate sized market. This means the duopoly profit π_2^{d*} will be fairly high. This means that firm 2 will be indifferent between not entering and entering at an intermediate - and rather likely - value of the entry cost E . This means $f(\cdot)$ will be **high**.
- So you see how this particular mechanism - the effect of market size on the likelihood of entry - implies that the strategic entry deterrence is non-monotonic in market size: first increasing, then decreasing. This, essentially, is the source of the monotonicity result in this model.

Model with no strategic entry deterrence motive First-order condition: take into account direct effect of A on profits, but no direct effect of A on the likelihood of entry:

$$c'(A_{ND}^*) = F[\pi_2^{d*}(A_{ND}^*)] \times \frac{\partial \pi_1^{d*}(A_{ND}^*)}{\partial A} + (1 - F[\pi_2^{d*}(A_{ND}^*)]) \times \frac{\partial \pi_1^{m*}(A_{ND}^*)}{\partial A}.$$

- You see how this expression does not contain the strategic entry deterrence term.
- Let's now look at the role of market size by means of a numerical example.
Assumptions:

- Market i has z_i potential customers
- Cost of advertising: $c(A) = z_i A^2 / 2$
- Advertising raises utility for consumers, and consumers are heterogeneous with respect to this effect.
- Utility from buying the (branded) good from firm 1: $\theta A - p_1$
- Utility from buying the (generic) good from firm 2: $\frac{\theta A}{2} - p_2$
- The parameter θ is distributed uniformly on $[0, 1]$ - this is the heterogeneity
- Utility from not buying the good: 0
- Choice variables in final stage: price (p_1, p_2)

- Suppose firm 1 remains a monopolist in the last stage. Define q_1 as the number of consumers buying the product. Profits:

$$\pi_1 = p_1 q_1$$

$$\pi_1 = p_1 \Pr(\theta A - p_1 > 0) z_i.$$

Remember θ stochastic; hence:

$$\pi_1 = p_1 \Pr\left(\theta > \frac{p_1}{A}\right) z_i$$

$$\pi_1 = p_1 \left[1 - \Pr\left(\theta \leq \frac{p_1}{A}\right)\right] z_i$$

$$\pi_1 = p_1 \left[1 - \frac{\frac{p_1}{A} - 0}{1 - 0}\right] z_i$$

$$\pi_1 = p_1 \left[1 - \frac{p_1}{A}\right] z_i.$$

(recall cumulative density function for uniform distribution). Interpretation: A high price raises revenues through the price effect but reduces

profits through negative demand effect. First-order condition:

$$\begin{aligned} 1 &= \frac{2p_1}{A} \\ p_1 &= \frac{A}{2}, \end{aligned}$$

is the optimal price (notice advertising is predetermined at this stage).

Profits:

$$\begin{aligned} \pi_1 &= \frac{A}{2} \left[1 - \frac{\frac{A}{2}}{A} \right] z_1 \\ \pi_1 &= \frac{A}{4} z_i. \end{aligned}$$

Note higher profits in larger markets.

- Duopoly prices and profits are as follows:

$$p_1^* = \frac{2}{7}A$$
$$p_2^* = \frac{1}{14}A$$
$$\pi_1^{d*} = \frac{8}{49}Az_i = 0.163 \times Az_i$$
$$\pi_2^{d*} = \frac{1}{49}Az_i = 0.020 \times Az_i.$$

Don't worry about the derivation of these. Just note that: profits increase with market size; and that the duopoly price and profits for firm 1 are lower than under monopoly.

- Based on this, firm 1 chooses the optimal level of advertising as indicated by the first-order conditions above. The relationship we care about is that between advertising and price.

- For the model with no entry deterrence motive, inspecting the f.o.c. is informative. With profits and costs as in the above example, the general f.o.c.

$$c'(A_{ND}^*) = F[\pi_2^{d*}(A_{ND}^*)] \times \frac{\partial \pi_1^{d*}(A_{ND}^*)}{\partial A} + \\ + \left(1 - F[\pi_2^{d*}(A_{ND}^*)]\right) \times \frac{\partial \pi_1^{m*}(A_{ND}^*)}{\partial A}$$

becomes

$$z_i A = F[\pi_2^{d*}(A_{ND}^*)] \times 0.163 z_i + \left(1 - F[\pi_2^{d*}(A_{ND}^*)]\right) \times \frac{1}{4} z_i,$$

and so if we divide through by z_i we get

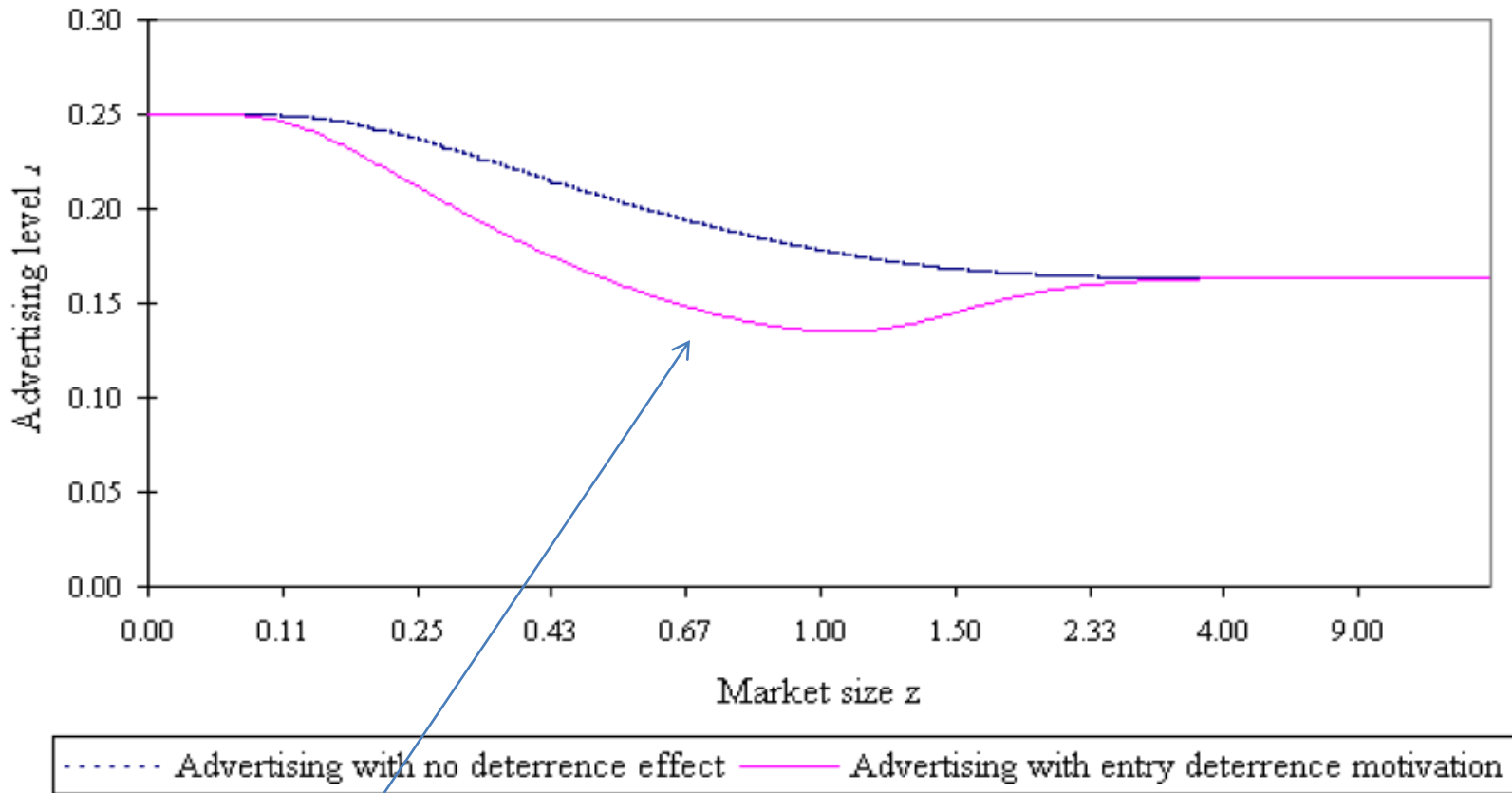
$$A = F[\pi_2^{d*}(A_{ND}^*)] \times 0.163 + \left(1 - F[\pi_2^{d*}(A_{ND}^*)]\right) \times \frac{1}{4}.$$

Now think about the effect of market size on the optimal level of advertising under no predatory behaviour. The likelihood of entry F increases as π_2^{d*}

increases; and π_2^{d*} increases with market size z_i . This means as z_i increase more weight will be given to 0.163 and less weight to $(1/4)$, i.e. A will decrease. This relationship is monotonic.

- Figure 2 shows what this relationship looks like when the distribution of entry costs is log normal with mean 0.0025 and variance 0.0015, for the models with and without an entry deterrence incentive.
- [Figure 2 again]

Model of Advertising with Spillovers



For intermediate sized markets, advertising is much lower if there is an entry deterrence than if not

4 Summary of the Empirical Analysis

- "Reduced-form approach": identify where competing theoretical models make different predictions, and test those predictions.
- Null hypothesis: investments are not influenced by the strategic entry deterrence motive. This translates into a null hypothesis that is empirically testable: advertising is monotonic in market size.

4.1 Cross-sectional patterns in incumbent behaviour

- Consider a regression model as follows:

$$A_i = A^*(z_i) + \epsilon_i,$$

where $A^*(z_i)$ is an unknown function. Your goal is to investigate if the data support the idea that A^* is either monotonically increasing or decreasing in market size.

- Probably the simplest way of doing this is to run a regression of the following kind:

$$A_i = \beta_0 + \beta_1 z_i + \beta_2 z_i^2 + \epsilon_i.$$

With this specification, how do you go about testing the null hypothesis?

- The authors use this approach but don't find very strong results. Indeed, little evidence of any patterns at all - key coefficients are insignificant and R^2 is low (except in Col. 3).
- [Table 6 here].

- The authors also use other, more sophisticated methods for testing for nonmonotonicity. These methods - one devised by Hall and Heckman, one by the authors themselves - are not very common in the applied literature, and you can skip the technical details. Just be clear on one thing: the reported p -values are associated with the null hypothesis that the relationship is monotonic. That is, high p -values imply you do not reject a monotonic relationship - no evidence then in favour of entry deterrence motives.
- [Table 7: How advertising and proliferation vary with market size]

- Why, given that we are interested in the effects of predatory behaviour on entry, are we focussing on the relationship between market size (revenue) and advertising?
- The idea is that entry will be higher in large markets. This is strongly supported by the data - see Table 5.
- [Table 5: Modelling the probability of entry as a function of revenue]

Table 5: Entry versus pre-expiration revenues

Dependent variable for probit is <i>Entry3Yr</i>		
Variable		
$\log(\text{Revenue3})$	0.70 (0.17)	0.76 (0.20)
<i>HospFrac</i>		1.01 (0.78)
<i>Chronic</i>		0.60 (0.54)
$\log(\text{TherSubs})$		0.01 (0.29)
Constant	-6.39 (1.94)	-7.60 (1.94)
Number of Obs.	63	63
<i>PseudoR</i> ²	0.40	0.43

The table presents estimates of probit models. The dependent variable is a dummy for whether entry occurs within three years of patent expiration. The explanatory variables are average revenue in the three years prior to patent expiration, the fraction of sales which are through hospitals (as opposed to drugstores), a measure of whether the drug treats a chronic or acute condition, and the number of other drugs in the therapeutic class. The observations are 63 drug molecules which lost patent protection at some point between 1986 and 1992.

4.2 Changes in behaviour as expiration approaches

- One nice feature of the economic environment used in this paper is that entry is prohibited until a known point in time.
- Further in advance of this date, the entry deterrence motive should be weaker than closer to the point in time where entry will be allowed.
- Define the date of patent expiration as $t = 0$.
- Authors examine the difference between firm behaviour in the year immediately prior to patent expiration, i.e. at $t = -1$, and firm behaviour in the preceding two years ($t = -2, t = -3$).

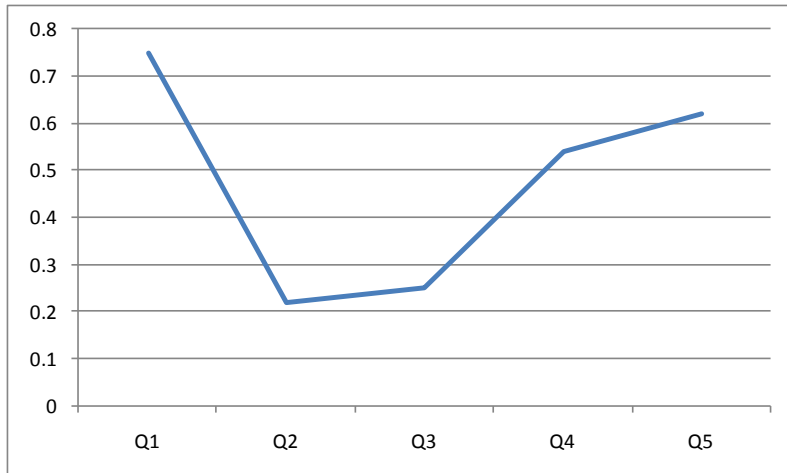
- Is there any evidence that changes in advertising and the other strategic investment are non-monotonic in market size? You may want to refer back to Fig. 2 again - the biggest change in advertising predicted by the model is for intermediate sized markets.
- The dependent variable measures whether advertising etc. has increased or decreased. Results in Table 8.

[Table 8]

Table 8: Changes in incumbent behavior as expiration approaches: quintile means and monotonicity tests

	Fraction increasing by quintile					Monotonicity test p-value	
	Q 1	Q 2	Q 3	Q 4	Q 5	H-H Test	E-E Test
<i>Detail3</i>	0.75 (4)	0.22 (9)	0.25 (12)	0.54 (13)	0.62 (13)	0.307	0.031
<i>Journal3</i>	0.50 (2)	0.43 (7)	0.17 (12)	0.29 (14)	0.31 (13)	0.321	0.696
<i>PresHerf</i>	0.33 (6)	0.42 (12)	0.38 (13)	0.50 (14)	0.62 (13)	0.083	0.217
<i>DPrice</i>	0.70 (10)	0.58 (12)	0.75 (12)	0.54 (13)	0.92 (13)	0.430	0.601
<i>HPrice</i>	0.50 (8)	0.50 (12)	0.54 (13)	0.77 (13)	0.73 (11)	0.573	0.854

This table reports the fraction of drugs in each revenue quintile for which the investment variable was higher in the year immediately prior to patent expiration than it was on average in the previous two years. The number of observations in each cell is in parentheses below the quintile means.



Pattern is roughly consistent with entry-deterrence: for most drugs in small & large markets, advertising is increasing as you get closer to date of expiration; the opposite is true for intermediate sized markets.

5 Conclusions

- The expiration of a pharmaceutical patent is an important event for pharmaceutical firms.
- This paper examines how a number of firms have set prices, chosen advertising levels, and adjusted their presentation-level product mix at this time.
- Paper finds some evidence of nonmonotonic patterns, suggesting that incumbents' actions may be motivated in part by a desire to deter generic entry.

- More generally, this is a paper about the testing of strategic entry-deterrence theories. Empirical analysis should be useful for diverse reasons: from a behavioral perspective one could wonder

whether firms have figured out the sometimes subtle effects; and regulators may be interested in whether firms are actively trying to deter entry.