Predatory Advertising: Theory and Evidence in the Pharmaceutical Industry *

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Abstract

In this paper, we investigate the strategic interaction between competing pharmaceutical firms after one firm, Crestor, suffers bad news and faces the threat of exit. A game theoretical analysis shows that its competitor, having superior information about the market condition, advertise at a higher level than the normal competitive level, with the intention of inducing Crestor to exit. Moreover, such up-ward distortion only happens in those markets where the demand for Crestor prior to the bad news event is neither too high nor too low. We empirically test our prediction using physician-level data. Our major finding is that Crestor's main competitor, Lipitor, increased its advertising intensity the most among those physicians with whom Crestor already had a median market share of total prescriptions. The change in Lipitor's detailing pattern is consistent with the theoretical prediction of predation.

Keywords: Predatory advertising, Exit, Incomplete information

JEL Classification: D43, L11, L13

1 Introduction

The basic idea of predation is that a firm may sacrifice part of the profits that could be earned under competitive circumstances in order to induce the exit of an opponent, with an eye towards gaining additional profits in the future.

However, a careful examination of predation strategy leads one to question whether predation should emerge at all as a rational choice in the equilibrium. On the one hand, beginning in the 1950s, "Chicago School" economic analysis, assuming complete information, rightfully pointed out the irrationality of monopolizing a market through predation (McGee (1958, 1980)). On the other hand, using the tools of incomplete information game theory, modern strategic analysis have resurrected the logic of predatory practice. The key assumption is that there is an absence of perfect information; under such conditions, predation becomes a rational strategy, even for a predator without efficiency or financial advantages over its prey. Many intrinsic incentives have been identified in favor of predation. For example, there is the "reputation effect", whereby a firm constructs a "tough" reputation (Milgrom and Roberts (1982), Kreps and Wilson (1982)); "signal jamming," whereby a firm might interfere with an entrant's inference problem (Fudenberg and Tirole (1986)); "signaling on a low cost", with the intent of convincing an entrant that it will only achieve subnormal profits (Roberts (1986)), and predation for the purpose of achieving better takeover terms (Saloner (1987)).

In spite of the fact that predation and its rationality has become the center of economic debate, the empirical study of predation, even to the extent of detecting its existence, has remained very limited.

In this work, we empirically test the predication of predation models using an interesting case from the pharmaceutical industry. Crestor, a brand that belongs to a therapeutic class of Statin drugs, first entered the market in August 2003. Shortly after its entry, several cases of severe side effects occurred from the use of this brand. Alarmed by the potential risk, on March 4, 2004, Public Citizen, a very influential consumer advocacy group, submitted a petition to the Food and Drug Administration (FDA) to formally remove the brand from the market. This bad news was immediately picked up by the major news networks, such as CBS. Interestingly, a different Statin brand, Baycol, was also petitioned by Public Citizen in 2001. As a consequence of a similar bad news event, Baycol had withdrawn from the market.

A natural question to ask is whether Crestor's competitors tried to induce Crestor's exit following the news event. As advertising, in the forms of detailing,[1] is the main competition method in the pharmaceutical industry, we focus on changes in firms' detailing strategies after the news event. In the period immediately following the bad news, all firms in the market increased their detailing levels. Comparing the number of sales visits at physician's office in the four weeks before and after the news event, we find that the average number of visits increased by 26.5%. However, a simple comparison of detailing level before and after the news event may not provide any evidence of predation. One could argue that the increase in advertising activity constituted a natural competitive response following the event of a rival suffering bad news. In other words, it was simply aimed at grabbing a larger market share, without caring about if Crestor would exit or not. On the other hand, it may be the case that Crestor's competitors advertised more than their

[1]Detailing is the term used in the pharmaceutical industry referring to visit of pharmaceutical sales representatives at physicians' office.

normal competitive level, in order to drive down the demand for Crestor and ultimately induce Crestor to exit. The difficulty in detecting predation has to do with the fact that a predatory strategy looks like an innocent competitive strategy, one without any predatory intent, inasmuch as both allow for an increase in advertising.

In order to obtain a testable hypothesis for predatory intent, we begin with a theoretical analysis of predation. Since Lipitor is the dominant brand, accounting for around 50% of the total sale of Statin drugs, we focus on the strategic interaction between Lipitor and Crestor. Our theoretical model emphasis the importance of asymmetric information in explaining predation intent, as we feel that it is the most plausible explanation for this particular case. Treating each physician as a market, we argue that there exists uncertainty about the change in demand for Crestor in each market.[2] In addition, Lipitor has superior information over Crestor as to how each market will respond to such a bad news event.[3] In this case, there exists an incentive for predation, as Lipitor is able to signal Crestor about the market condition, or to interfere with Crestor's inference of the market condition.

After the shock occurred, Crestor remained active in the market in order to infer information about its future profitability — that is, to determine whether staying on was still profitable or if in fact it should exit. At the same time, Lipitor had an incentive to either convince Crestor of the inherently bad market situation, or to interfere with its inference

[2]As we focus on the strategic interaction between firms, we do not model explicitly the reason why the change in demand at each physician's office may differ.

[3]Lipitor has been active in the market and interacted with physicians for a much longer period than Crestor. Moreover, it is Crestor's first time experiencing such bad news event, while Lipitor has witnessed a similar shock on Baycol three years ago. For more details of the Statin market and news event, see Section 3.

procedure so that Crestor would be unable to learn anything new; the upshot is that for Crestor, exiting became the optimal strategy. Note that our notion of exit is different from the conventional one. We consider each physician as a market; hence, we consider Crestor as having exited if it forewent relationship building with a physician by ceasing to send a sales representative to that physician. As long as Crestor's opponents preferred that it exit (that is, that it stops advertising to a physician) rather than stay on, the underlining incentives for predation still held.[4]

More specifically, we construct a three-period game of incomplete information between Crestor and Lipitor following the bad news. In period one, Crestor stays in the market and determines its advertising strategy simultaneously with Lipitor. At the end of period one, Crestor observes its own demand and profit but does not observe Lipitor's advertising or profit. In period two, Crestor updates its prior belief about the nature of the news event and chooses whether to exit or stay in the market. If it stays, in period three, the real effect of the shock is revealed to Crestor and competition happens again between Crestor and Lipitor under symmetric information. The solution concept we use is Perfect Baysian Nash Equilibrium, with a multiplicity of equilibria refined by intuitive criteria in Cho and Kreps (1987).

An important feature of our model is that we allow for heterogeneity in the demand for Crestor prior to the news event, this gives Lipitor different incentive in predation. We argue that, predation is either unnecessary or impossible in those markets where the demand for Crestor prior to the news event is too strong or too weak. More specifically,

[4]One could argue that the reentry cost may be low in this case. However, as we show in the theoretical model that the reentry cost does not necessarily prevent firms from using predatory strategies.

following the bad news, the demand in markets that had a very weak demand for Crestor is so low, such that Crestor will choose to exit regardless of how severe the shock was. Similarly, Crestor will always stay in markets that had a very strong demand before the shock. Consequently, a predatory intent can only exist for Lipitor in markets where a prior demand for Crestor falls in the median range.

We find that in those markets with median level demand for Crestor, Lipitor advertises more in order to drive down the demand for Crestor, either with the purpose of convincing Crestor that there exists truly unprofitable market circumstances under a severe shock (in the case of a separating equilibrium), or in order to disenable Crestor's inference of the true effect of the shock where it was actually mild (in the case of a pooling equilibrium). For either of these equilibria, we find that, Lipitor is trying to induce Crestor to exit by advertising at a level higher than what would be the case at a normal competitive level.

We then empirically test if the change in Lipitor's advertising is consistent with the prediction of the theoretical model using physician-level data on the detailing intensity for each Statin drug brand for the periods preceding and following the bad news. Our main testable finding then is that, as a result of predation, Lipitor's advertising is distorted upward relative to a pure competitive scenario in markets where the demand for Crestor falls in the median range.[5] We use lagged Crestor's share of a physician's total prescriptions as an approximation of the demand for Crestor at a physician's office. We argue that, if change in Lipitor's advertising from before to after the news event is a purely competitive response, it normally should be monotonic with respect to Crestor's market share.[6] Conversely, where predation is present, Lipitor specifically increases its

[5] Our method is analogous in essence to Ellison and Ellison (2000).

[6] We show that a number of standard demand functions, such as Logit demand function, satisfies this

advertising to physicians with which Crestor has a median market share. Thus our main test hypothesis is that after the news event, there is non-monotonicity in the change of Lipitor's advertising with respect to Crestor's market share. The increase in advertising intensity should be the highest to physicians where Crestor has median market share.

A natural question to ask is why normal competitive response can not cause the non monotonic increase in Lipitor's advertising. Although we explain in the theory part that, under regular conditions, competitive response should be monotonic in Crestor's market share, we can not rule out other possible competitive response explanations.

As a robustness check, we use two additional tests to provide evidence against competitive response explanation. Our second test looks at the changes in detailing intensity of the two smaller competitors, Zocor and Pravachol. As Lipitor is the dominant brand in the market, the predation incentive should be the strongest for Liptior. In addition, Zocor and Pravachol's patents expires much sooner than Lipitor.[7] We expect the incentive to engage in predation by Zocor and Pravachol (if exists at all) to be much weaker than that for Lipitor. As such, it is more likely for Lipitor to choose advertising level strategically, while the changes in Zocor and Pravachol detailing level should mainly capture the effects of normal competitive response. If Zocor and Pravachol do not exhibit similar pattern of increase in advertising to physicians with median Crestor market share, it will provide indirect evidence that the change in Lipitor's advertising may be driven by predatory intent.

Our third test checks whether Lipitor has non monotonic changes in advertising towards other drugs in the market. Since the news only affects Crestor but not other drugs in

property.

[7]Zocor and Provachol's patents expire in 2006, while Lipitor's expire in 2010.

the market, we expect that the non-monotonic change in detailing only happens to physicians with median Crestor market share but not to physicians with median market share for other drugs.

We use three methods to carry out the empirical test: a Difference in Difference estimator, a parametric regression model and a nonparametric regression model. All three methods give us consistent findings. Firstly, after the bad news, Lipitor demonstrated a significantly larger increase in its advertising among physicians with which Crestor had a median market share, relative to the changes in its advertising among other physicians. This is true when controlling for more market-related characteristics. Secondly, such a pattern is not found with the Zocor and Pravachol, the two smaller competitors in the market. Finally, Lipitor doesn't have the same change in detailing pattern towards other products similar to Crestor in the market. Our findings suggest that the changes in Lipitor's advertising strategies are consistent with the theoretical prediction of predation.

Our paper contributes to the existing empirical literatures in the following ways. First, most of the existing studies look at the predatory pricing behaviors. Since predatory pricing is illegal in most modern market economy, researchers often have to look at either historical data or some unique markets where predation is allowed. Yet predation behavior may exist in many markets in the forms of non-price competition. Our paper test predation theory by looking at non-price competition in the forms of advertising.

Second, our paper offers an alternative approach for detecting predatory intent relative to normal competitive responses. The existing studies on predation either use a direct method, which requires comparing prices to different measures of costs, or an indirect method, which compares the change in prices after the entry of new firms. The direct method has to estimate cost, which in most cases is very difficult; while the indirect method need to assume that entry is exogenous. If entry is endogenous, the estimates are biased in the same way as Heckman's classical selection bias problem. Our approach is based on the "natural experiment" method developed in the program evaluation literature. We argue that the news event is an exogenous change in the market, and predation becomes possible after the news event. Thus we can identify the predation intent by comparing the changes in firm's strategy before and after the news across different markets in which predation intent should be different.

The rest of the paper is organized as follows: Section 2 reviews the literature; Section 3 introduces some background regarding the bad news event; Section 4 describes the theoretical model and its results; Section 5 provides the empirical model, together with our major findings; and Section 6 concludes.

2 Literature Review

The theoretical part of our work is most closely related to the literature on predation where there exists asymmetric information. Milgrom and Roberts (1982), and Kreps and Wilson (1982) show that the "reputation effect" justifies predation as an equilibrium, since preying against a rival fosters a "tough" reputation that discourages future challenges. Fudenberg and Tirole (1986) use "signal jamming" to illustrate that when a new entrant is uncertain with regard to its future profitability and needs to infer from its current profit, a predator is able to interfere with the entrant's inference problem as a means of encouraging its exit. Roberts (1986) shows that preying entails an upward distortion in the predator's quantity in the context of Cournot competition; that is, the predator signals a bad market situation when there exists incomplete information regarding its cost. Another literature relevant to the theoretical part of this paper is that dealing with models on oligopoly advertising competition (Friedman (1983)); advertising signaling demand and product quality (Albæk and Overgaard (1992)), Orzach, Overgaard and Tauman (2002)). In particular, Bagwell and Ramey (1988) find that pre-entry demand-enhancing advertising is upwardly distorted as a part of a sequence aimed at signaling the incumbent's low cost in order to deter entry.

Our work is also related to the large empirical literature on entry and exit in the market. The majority of empirical studies on entry and exit belong to the class of "equilibrium entry/exit models" pioneered by the influential studies of Bresnahan and Reiss (1988) and Berry (1992). A common feature of those studies is their assumption that the observed market structure is at equilibrium. Consequently, it must be profitable for existing firms to stay in the market, but not profitable for an additional firm to enter the market. Interestingly, even though the studies try to understand entry and exit, no actual entry or exit needed to be observed in the data. In addition, equilibrium entry/exit models often ignore how firm strategies – such as price and advertising – affect entry and exit.

Relatively few studies have looked at strategic entry/exit models. Most of the papers study entry deterrence. In a manner closely related to our work, Ellison and Ellison (2000) examine the behavior of pharmaceutical incumbents in the period prior to the expiration of their patents. They identify evidence of entry deterrence by investigating whether the incumbent's behavior is non-monotonic relative to the size of the market. Large markets are so attractive that deterring entry is never optimal; while small markets inherently defy entry, making entry-deterring investment unnecessary. Morton (2000) tests whether incumbents facing generic entry increase advertising in order to deter entry, and finds no evidence supportive of brand advertising as constituting an entry barrier. Goolsbee and Syverson (2004) use data from major airlines to study how incumbent carriers responded to the threat of the entry of Southwest Airlines. They find evidence consistent with theories claiming that incumbents try to construct longer-term loyalty before entry occurs.

Very few studies empirically tested predation theory. Morton (1997) studies the response of the British shipping cartel to the entry of new shipping lines. Incumbent cartels are found to be more likely to start a price war after the entry of “weaker" firms. This provides support for the “long purse" theory of predation. Genesove and Mullin (2006) study entry into the American sugar refining industry. They find that the price wars following entry were predatory by first comparing the price to the marginal cost and then comparing the predicted competitive price cost marginal to the observed margins.

3 Background

3.1 The Statin Drug Market

Statins are drugs that help lower cholesterol levels. With at least 12 million Americans taking cholesterol-lowering drugs — most of them statins — and experts recommending that another 23 million take them, Statin drugs are certainly very important to the pharmaceutical industry. In many cases, Statin drugs are the number one seller of their company. With sales for 2004 reaching US $10.8 billion and 5.2 billion respectively, the top two brands in the market, Lipitor and Zocor, are not only the largest seller for their maker, Pfizer and Merck & Co, but also the largest two selling drugs in the world.

Table 1 tabulates for major brands, chemical content, production method, generic availability, makers and market share in 2004. Based on chemical content, there are six competing products in the market[8]: Crestor (rosuvastatin), Lescol (fluvastatin), Lipitor (atorvastatin), Pravachol (pravastatin), Zocor (simvastatin) and lovastatin. Only lovastatin has a number of generic products. Lovastatin was first produced under the brand name of Mevacor, the first generation of statin drug that started this market. During our study period, although generic brands are available, the market is dominated by the branded drug. The four main brands in the market are Lipitor, Zocor, Pravachol and Crestor. Their makers are Pfizer, Merck, Bristol-Myers Squibb and Astra Zeneca respectively. Among them, Lipitor and Crestor are considered closer substitutes as they use the same production method (Synthetic).

Pharmaceutical companies mainly compete through advertising and marketing promotions. Excepting direct to consumer advertising, the most commonly used marketing methods are pharmaceutical sales representatives' visits to physicians' offices, referred to as "detailing". Detailing is widely viewed as a means of building a relationship with a particular physician. During the office visit, a sales representative will show the physician various findings that support the use of the relevant drug. The sales representative will also leave free samples for the physician to distribute to patients. According to industry convention, each sales representative is only allowed to visit the same physician

[8]If two drugs have the same chemical content, they should be considered the same product from a chemical point of view. Of course consumers may have different preference towards drugs of the same content. This difference may be caused by various reasons, such as brand image effect, advertising and different ways of packaging the product, etc.

once a month. However, if a firm wants to have more than one detailing per month at a given physician's office, it can employ several sales representatives, having each visit the physician at a different time during the month.

3.2 News Event

The drug that suffered the bad news is Crestor. It first obtained FDA approval on August 12th, 2003, and entered the market shortly afterward. After entering the market, several severe cases of side effects occurred. Alarmed by the findings, a very influential consumer advocacy group, known as Public Citizen, submitted on March 4, 2004, a formal petition to the FDA to have the drug removed from the market. According to its petition, "three patients in the United States who were taking approved doses of rosuvastatin developed kidney failure or muscle damage. One of those patients, a 39-year-old woman, died of kidney failure and rhabdomyolysis, or muscle damage. Data obtained from the United States, the United Kingdom and Canada show seven cases of rhabdomyolysis and nine case of kidney damage or failure occurred after FDA approval." Major news network, such as CBS, immediately broadcasted the news about the petition from Public Citizen. Crestor's maker AstraZeneca wouldn't comment on the deaths or any other serious side effects, except to say that "the safety profile is totally comparable" to what pre-marketing studies had predicted.

Interestingly, this is not the first time that Public Citizen issued a petition for the removal of a statin drug. Baycol, another statin drug, withdrew from the market in the fall of 2001 following a petition by Public Citizen to the FDA. The side effects of Baycol were very similar to those of Crestor, in that they were both likely to cause kidney damage.

Not surprisingly, Public Citizen emphasized the similarity of the two drugs and noted the withdrawal of Baycol in their petition to FDA.

We argue that this case provides a unique opportunity to test predation theory. First, the news event seriously lowered Crestor's demand. It also raises questions among physicians and patients about the possibility of Crestor's withdrawal. Therefore, predation becomes possible after the news event. Second, the news event is not severe enough to cause Crestor to withdraw from the market immediately. Therefore, competitors will have to employ predation strategies if they seriously consider driving Crestor out of the market.

In addition, the news breakout is clearly not anticipated by a regular physician or a patient. Although it is possible that before the news event, physicians may have heard about the incidence of severe side effects from other sources, such as sales representative visits, medical journals and professional conferences etc, the formal petition of Public Citizen to FDA and subsequent mass media coverage still brings additional information to physicians. Moreover, it is very likely that this is the first time that a patient will receive any news about Crestor's side effect. Thus patient's reaction may influence physicians' prescription decisions as many studies have argued that patient also plays an important role in medical treatment decision. Therefore, we argue that the news event provide us a unique opportunity, ie a "natural experiment," to study the changes in advertising strategies of pharmaceutical firms after the news event.

4 The Theoretical Model

4.1 Basic Model and Results

In the theoretical part, we focus on the advertising competition between Lipitor and Crestor. Each physician is treated as a market.

Before the game starts, a bad news of Crestor is suddenly released to the public, which negatively affect its market demand. Lipitor knows the exact effect of the shock in virtue of its experience. Crestor, as a new entrant, does not know the exact effect of the shock. After the shock, Crestor remained active in the market in order to infer information about the real effect of the shock. At the same time, Lipitor may use advertising to interfere with Crestor's inference procedure. Their strategic interaction is modelled into a three-period game.

In period one, Lipitor and Crestor choose advertising level simultaneously. Each observes its realized demand (and profit), but not the other's advertising level or profit. In period two, Crestor, based on its realized market demand in period one, decides whether to exit from the market by stop advertising, or to stay and continue with advertising. If it exits, in period three Lipitor decides its advertising level as a monopolist. Otherwise the effect of the shock is revealed to Crestor, and they compete under symmetric information.

To simplify our notation, let firm 1 be Lipitor and firm 2 be Crestor. Firms 1 and 2 compete via demand-increasing advertising $A_j, j = 1, 2$. Size of market demand is assumed to be a constant and normalized to 1. The effect of the shock on firm 2's demand is chosen by nature and measured by the parameter γ, which takes only two values, γ_H or γ_L, with $\gamma_H > \gamma_L$. γ_H represents a severe shock and γ_L a mild shock. Firm 2's prior probability assessment about γ is $\rho \in (0,1)$ of $\gamma = \gamma_H$.

After the shock, firm 2's demand is given by $D^i(A_1, A_2, \alpha) \in [0,1]$, where $i = H$ when $\gamma = \gamma_H$ and $i = L$ when $\gamma = \gamma_L$, and firm 1's demand is $1 - D^i(A_1, A_2, \alpha), i = H, L$. The parameter α captures the heterogeneity across markets in preference towards firm 2, which we call it as *attachment* to firm 2. The value of α is common knowledge to each firm.

Assume $D^i(A_1, A_2, \alpha)$ is continuously differentiable, with $D^i(A_1, A_2, \alpha) \in (0,1)$ satisfying the following assumptions: [9]

A1. $D_1 < 0, D_2 > 0, D_\alpha > 0, D^H < D^L$.

A2. $D_{11} > 0, D_{22} < 0$.

A3. $D_1^L > D_1^H$.

A1 says that firm 2's demand is negatively affected by firm 1's advertising and the severity level of the shock. Meanwhile, it is strictly increasing in its own advertising and established market attachment. A2 catches the diminishing effect of advertising. A3 is the single-crossing property, which assumes that the marginal effect of firm 1's advertising is strictly strengthened by a more severe shock.

Market price is fixed[10] as p and the unit cost of advertising is $c > 0$. Since α is

[9] Here D with subscript $i = 1, 2, \alpha$ denotes the derivative of demand with respect to $A_i, i = 1, 2, \alpha$.

[10] Pharmaceutical companies compete mainly through advertising, and prices of different brands do not vary much. Besides, this assumption allows us to focus on firms' advertising strategy. Even if price is

exogenous in a given market, we write $D^L(A_1, A_2, \alpha)$ as $D^L(A_1, A_2)$ and $D^H(A_1, A_2, \alpha)$ as $D^H(A_1, A_2)$. In period three, if firm 2 stays, firms 1 and 2 compete under complete information. Firm 1's profit is

$$\pi_1^i(A_1, A_2) = p(1 - D^i(A_1, A_2)) - cA_1 - K,$$

and firm 2's is

$$\pi_2^i(A_1, A_2) = pD^i(A_1, A_2) - cA_2 - K, \quad i = H, L.$$

Here $K > 0$ is the fixed cost when a firm stays and continues advertising in the market.[11] Denote the duopoly profits as π_{jD}^i at $\gamma = \gamma_i, i = H, L$ for firm $j, j = 1, 2$. If firm 2 exits in period two, firm 1's demand is given by $1 - D^i(A_1, 0), i = H, L$.[12] Firm 1's monopoly profit is $\pi_{1M}^i, i = H, L$. Assume $\pi_{1M}^H > \pi_{1D}^H, \pi_{1M}^L > \pi_{1D}^L$. I.e., whatever the type of the shock, firm 1 prefers firm 2 to exit.

While firm 2 makes its exit decision in period two, it does not observe the real value of γ. Instead, it observes its realized demand in period one, denoted as $d(A_1, A_2, \gamma)$. An observed low demand for firm 2 can result from either a severe shock, i.e. $\gamma = \gamma_H$, or a large A_1. According to $d(A_1, A_2, \gamma)$, firm 2 forms its posterior belief $\hat{\rho} \in [0, 1]$ for $\gamma = \gamma_H$, and decides to stay or exit, where $\xi = 0$ ($\xi = 1$) denotes exit (stay).

allowed to change, our basic findings for advertising strategy should not change. As a reference, Bagwell and Ramey (1988) analyzed a signalling game with firms choosing both advertising and pricing.

[11] The fixed cost can be the fee of collecting market data, or the opportunity cost for a firm to continue its product promotion. $K > 0$ gives firm 2 incentive to exit in order to avoid a negative profit.

[12] Exiting means that firm 2 gives up the relationship building-up with the physician by stop detailing. The monopoly profit for each firm is given by $\pi_{1M}^H = p[1 - D^H(A_{1M}^H, 0)] - cA_{1M}^H$, $\pi_{1M}^L = p[1 - D^L(A_{1M}^L, 0)] - cA_{1M}^L$, with A_{1M}^H, A_{1M}^L the corresponding maximizers.

Firm 2 chooses to stay only if it expects a non-negative profit in the future. By A1, $\pi_{2D}^i, i = H, L$ strictly increases in α. If α is too large, both $\pi_{2D}^L \geq 0$ and $\pi_{2D}^H \geq 0$, and firm 2 will always stay irrespective of its posterior belief. If α is too small, both $\pi_{2D}^L < 0$ and $\pi_{2D}^H < 0$, firm 2 will exit even if it believes that the shock has only a mild effect. The interesting case is when α falls in the intermediate range such that $\pi_{2D}^L > 0 > \pi_{2D}^H$. In this case, firm 2 will exit only if the shock has a severe effect. Let such a range of α be given by $[\underline{\alpha}, \bar{\alpha}]$, where it becomes not only possible but also necessary for firm 1 to signal firm 2 its private information about the market condition.

For a given strategy pair (A_1, A_2) in period one and firm 2's exiting decision ξ in period two, firm 1 and firm 2's discounted total profits are

$$V^i(A_1, A_2, \xi) = \pi_1^i(A_1, A_2) + [\xi\pi_{1D}^i + (1 - \xi)\pi_{1M}^i]$$

$$u^i(A_1, A_2, \xi) = \pi_2^i(A_1, A_2) + \xi\pi_{2D}^i, \qquad i = H, L$$

The discount factor is assumed to be 1 for simplicity. At the beginning of period one, firm 2's expected profit is

$$U(A_1, A_2, \xi) = \rho u^H(A_1, A_2, \xi(A_1, A_2, \gamma_H)) + (1 - \rho)u^L(A_1, A_2, \xi(A_1, A_2, \gamma_L)).$$

4.2 Normal Competitive Behavior

Before we analyze the equilibrium of the game, consider an alternative scenario. Suppose there exists no exit choice of firm 2. In this case, firm 1 in stage one has no incentive to either signal firm 2 with γ, or interfere firm 2's reference of γ, and both firm 1 and firm 2 will advertise according to their one-period normal competitive level. In a one-period competition under asymmetric information, a unique profile of payoff-maximizing advertising exists, denoted as (A_1^H, A_1^L, A_2^E), with

$$A_1^H \equiv \arg\max_{A_1}[p(1 - D^H(A_1, A_2^E)) - cA_1 - K],$$

$$A_1^L \equiv \arg\max_{A_1}[p(1 - D^L(A_1, A_2^E)) - cA_1 - K],$$

$$A_2^E \equiv \arg\max_{A_2}\{p[\rho D^H(A_1^H, A_2) + (1-\rho)D^L(A_1^L, A_2)] - cA_2 - K\}.$$

Under A3, it is easy to verify that $A_1^H > A_1^L$ (Proof is in the appendix). By A1, it is true that $D^H(A_1^H, A_2^E) < D^L(A_1^L, A_2^E)$.

To have some comparative statics, let us assign $\gamma = \gamma_0$ to the demand function of firm 2 before the shock occurs, with $\gamma_H > \gamma_L > \gamma_0$ since the news is bad. Denote firm j's prior shock optimal advertising as $A_j^*, j = 1, 2$. We are mainly interested in the change of firm 1's normal competitive behavior in parameters α and γ. Firstly, when the demand function has single crossing property in (A_1, γ), it is easy to see that $A_1^i > A_1^*, i = H, L$. That is, firm 1's optimal detailing increases after the shock occurs.

Secondly,

$$\frac{dA_1^i}{d\alpha} = -\frac{D_{1\alpha}}{D_{11}}, \quad i = H, L$$

which is positive (negative) if $D_{1\alpha} < (>) 0$ is satisfied. Therefore, when the demand function has increasing (decreasing) differences in (A_1, α), firm 1's optimal detailing is also monotonic in α.

4.3 Equilibrium Concept

The equilibrium concept we employ to solve the game is Perfect Bayesian Nash equilibrium, refined by intuitive criterion in Cho and Kreps (1987). A Perfect Bayesian

Nash equilibrium is a set of strategies $\{(\hat{A}_1^i, \hat{A}_2^E)_{i=H,L}, \hat{\xi}(d(A_1, A_2, \gamma), A_2)\}$ and beliefs $\hat{\rho}(d(A_1, A_2, \gamma), A_2)$, such that the following three conditions are satisfied.

Condition 1. Optimality for firm 1. For $i = H, L$,

$$\hat{A}_1^i \in \arg\max_{A_1} V^i(A_1, \hat{A}_2^E, \hat{\xi}(d(A_1, \hat{A}_2^E, \gamma_i), \hat{A}_2^E)).$$

Condition 2. Optimality for firm 2. For $i = H, L$,

$$\hat{A}_2^E \in \arg\max_{A_2} U(\hat{A}_1^i, A_2, \hat{\xi}(d(\hat{A}_1^i, A_2, \gamma_i), A_2)),$$

and for all $d(A_1, A_2, \gamma)$, $\hat{\xi}(d(A_1, A_2, \gamma), A_2) = 1$ if and only if

$$\hat{\rho}(d(A_1, A_2, \gamma), A_2)\pi_{2D}^H + (1 - \hat{\rho}(d(A_1, A_2, \gamma), A_2))\pi_{2D}^L \geq 0.$$

Condition 3. Bayes' consistency of beliefs. If $D^H(\hat{A}_1^H, \hat{A}_2^E) \neq D^L(\hat{A}_1^L, \hat{A}_2^E)$, then $\hat{\rho}(d(\hat{A}_1^H, \hat{A}_2^E, \gamma_H), \hat{A}_2^E) = 1$ and $\hat{\rho}(d(\hat{A}_1^L, \hat{A}_2^E, \gamma_L), \hat{A}_2^E) = 0$. If $D^H(\hat{A}_1^H, \hat{A}_2^E) = D^L(\hat{A}_1^L, \hat{A}_2^E)$, then $\hat{\rho}(d(\hat{A}_1^H, \hat{A}_2^E, \gamma_H), \hat{A}_2^E) = \hat{\rho}(d(\hat{A}_1^L, \hat{A}_2^E, \gamma_L), \hat{A}_2^E) = \rho$.

If $d(A_1, A_2, \gamma) \notin \{D^H(\hat{A}_1^H, \hat{A}_2^E), D^L(\hat{A}_1^L, \hat{A}_2^E)\}$, any posterior belief is consistent.

Condition 3 requires that firm 2's posterior beliefs about γ be derived from Bayesian updating on its prior beliefs when the equilibrium advertising strategies are played. When firm 2 observes its period-one demand which does not occur under either type of the shock, any posterior belief $\hat{\rho}(d(A_1, A_2, \gamma), A_2) \in [0, 1]$ is fine. This mild condition gives rise to the multiplicity of both separating and pooling equilibria.

The "intuitive criteria" in Cho and Kreps (1987) is often invoked to refine the equilibrium set in signaling games. However, as Roberts (1986) points out, the idea is not directly applicable to a game where the recipient of the signal (firm 2) takes a simultaneous move with the sender of the signal (firm 1).[13] Following Roberts (1986), an extension of the basic intuitive criteria is applied to the present game.

To refine the equilibrium set, we require that firm 2's beliefs after observing any particular period-one demand never put positive probability on $\gamma_i, i = H, L$ under which, *given firm 2's period one advertising*, advertising of firm 1 which is necessary to generate such demand would represent deviation of firm 1 from the equilibrium strategy to a strategy dominated by the equilibrium choice. To be more explicit, fix an equilibrium at which advertising is $(\hat{A}_1^i, \hat{A}_2^E)_{i=H,L}$. The equilibrium profit of firm 2 in period one is given by $\pi_2^i(\hat{A}_1^i, \hat{A}_2^E)$. Now, consider an alternative pair $\tilde{A}_1^i, i = H, L$ such that $D^i(\tilde{A}_1^i, \hat{A}_2^E) \notin \{D^H(\hat{A}_1^H, \hat{A}_2^E), D^L(\hat{A}_1^L, \hat{A}_2^E)\}$. A deviation to $\tilde{A}_1^i$ is *equilibrium dominated* for firm 1 at γ_i if

$$V^i(\tilde{A}_1^i, \hat{A}_2^E, 0) < V^i(\hat{A}_1^i, \hat{A}_2^E, \hat{\xi}(d(\hat{A}_1^i, \hat{A}_2^E, \gamma_i), A_2^E)).$$

Thus when a deviation is equilibrium dominated at γ_i, the resulting profit of firm 1 is lower than its equilibrium profit irrespective of posterior beliefs. A sophisticated firm 1 at

[13] The game here is slightly different from the standard signaling game. In a standard signaling game, the signal sender moves first and has its action (signal) observed by the signal receiver. Instead, in our game the signal sender (firm 1) moves simultaneously with the signal receiver (firm 2) in period one. Thus firm 2 does not observe firm 1's action (advertising), instead, it observes its realized demand, which is an outcome of both firm 1's action and the effect of the shock. The simultaneity in the current game requires a tiny modification of the conventional wisdom when we refine the equilibrium set. With a little abuse of notation, in our following analysis for $\alpha \in [\underline{\alpha}, \bar{\alpha}]$, we shall still use separating equilibrium for the equilibrium where firm 2 can tell the true effect of the shock, and pooling equilibrium for the equilibrium where firm 2 can not.

either γ_H or γ_L should never choose such a deviation. Now we can define the notation of an *intuitive equilibrium*. An equilibrium strategy profile $\{(\hat{A}_1^i, \hat{A}_2^E)_{i=H,L}, \hat{\xi}(d(A_1, A_2, \gamma), A_2)\}$ and beliefs $\hat{\rho}(d(A_1, A_2, \gamma), A_2)$ is intuitive if and only if in addition to Conditions 1, 2 and 3, it satisfies

Condition 4. Elimination of equilibrium dominated strategies. That is, $\hat{\rho}(d(A_1, \hat{A}_2^E, \gamma), \hat{A}_2^E) = 0(1)$ if A_1 is equilibrium dominated for firm 1 at $\gamma = \gamma_H(\gamma_L)$ but not at $\gamma = \gamma_L(\gamma_H)$.

4.4 Equilibrium

For $\alpha < \underline{\alpha}$ or $\alpha > \bar{\alpha}$, there is no strategic element in firm 1 and firm 2's competition, and each firm advertises according to its normal competitive level, given by (A_1^H, A_1^L, A_2^E). We focus on the interesting case where $\alpha \in [\underline{\alpha}, \bar{\alpha}]$. In order to explore properties of equilibrium, we make one more assumption:

A4. $D_{12} = 0$.

Under A4, the marginal effect of firm 2's advertising is independent on firm 1's advertising level, therefore, firm 2's optimal advertising does not depend on its conjecture of firm 1's advertising level, and is pinned down at A_2^E irrespective of the effect of the shock. This assumption is somewhat restrictive. However, it makes our analysis tractable. We will use example to show that our major findings can still hold with this assumption relaxed.

If $\gamma = \gamma_H$ and both firms 1 and 2 are advertising their one-period optimal, demand realized for firm 2 is $D^H(A_1^H, A_2^E)$. Therefore, at $\gamma = \gamma_L$, if firm 1 wants to generate the same demand given that firm 2 is advertising A_2^E, firm 1 needs to advertise A_1 which solves $D^L(A_1, A_2^E) = D^H(A_1^H, A_2^E)$. Let $f(A_1, A_2^E) = (D^L)^{-1}(D^H(A_1, A_2^E), A_2^E)$ for any A_1. By A1, it is easy to see that

$$f(A_1, A_2^E) > A_1, \quad \frac{df(A_1, A_2^E)}{dA_1} = -\frac{-D_1^H}{D_1^L} > 0.$$

In order to fool firm 2 with $\gamma = \gamma_H$ when in fact $\gamma = \gamma_L$, firm 1 needs to advertise to a higher level than A_1^H. Assume

A5. $\pi_1^L(f(A_1^H, A_2^E), A_2^E) + \pi_{1M}^L > \pi_1^L(A_1^L, A_2^E) + \pi_{1D}^L$.

That is, given $A_2 = A_2^E$ and $A_1 = A_1^H$ at $\gamma = \gamma_H$, firm 1 at $\gamma = \gamma_L$ has incentive to pretend if doing so can convince firm 2 that $\gamma = \gamma_H$. Or in other words, advertising A_1^H at the severe shock by firm 1 can not induce firm 2 to set $\hat{\rho} = 1$.

In a separating equilibrium, $D^H(\hat{A}_1^H, \hat{A}_2^E) \neq D^L(\hat{A}_1^L, \hat{A}_2^E)$. Observing demand in period one allows firm 2 to infer the true value of γ, and its exit decision will be based on full information. All separating equilibria involve firm 1 advertising its best response to firm 2's advertising when the shock is mild and, when the shock is severe, firm 1 advertises at a level that results in a value of $D^H(A_1, \hat{A}_2^E)$, such that firm 1 at a mild shock is not profitable to mimic, even though mimicry would induce exit. Although there generally is a continuum of equilibria, intuitive criterion refines separating equilibria to the least-cost one, in which firm 1's advertising when the shock is severe generates $D^H(A_1, \hat{A}_2^E)$, which makes firm 1 at the mild shock to be just indifferent between mimicking to induce exit and following its equilibrium strategy. The following theorem gives the property of intuitive separating equilibrium and the condition of existence.[14]

Theorem 1 *For $\alpha \in [\underline{\alpha}, \bar{\alpha}]$, there exists at most one intuitive separating equilibrium, in which $\{\hat{A}_1^H > A_1^H, \hat{A}_1^L = A_1^L, \hat{A}_2^E = A_2^E\}$. Separating equilibrium exists if $\pi_{1M}^H - \pi_{1D}^H \geq \pi_{1M}^L - \pi_{1D}^L$.*

The most interesting property for the intuitive separating equilibrium is, when $\gamma = \gamma_H$, in order to signal firm 2 that the shock is severe, firm 1's advertising level $\hat{A}_1^H$ is higher than the normal competitive level A_1^H.

In pooling equilibrium, $D^H(\hat{A}_1^H, \hat{A}_2^E) = D^L(\hat{A}_1^L, \hat{A}_2^E)$ and firm 2 learns nothing from observing its demand in period one. The following assumption is needed for a pooling equilibrium to exist:

A6. $\rho\pi_{2D}^H + (1-\rho)\pi_{2D}^L < 0$.

A6 says that firm 2 will exit according to its prior belief. If A6 is violated, firm 2 will always stay if it gets no new information on the value of γ. However, in this case there exists at least one severity level of the shock, either γ_H or γ_L, at which firm 1 is profitable to deviate to its one-period optimal advertising. This contradicts the definition of equilibrium. The following theorem gives the property of intuitive pooling equilibria.

Theorem 2 *For $\alpha \in [\underline{\alpha}, \bar{\alpha}]$, if $\pi_{1M}^H - \pi_{1D}^H \geq \pi_{1M}^L - \pi_{1D}^L$ holds, advertising strategies in any intuitive pooling equilibrium satisfies $\{\hat{A}_1^H \in [A_1^H, A_b], \hat{A}_1^L = f(\hat{A}_1^H, \hat{A}_2^E) > A_1^L, \hat{A}_2^E = A_2^E\}$.*

[14] All proofs are in the appendix.

In pooling equilibrium, when $\gamma = \gamma_L$, firm 1 interferes firm 2's learning process, knowing that firm 2's optimal choice is to exit when no new information can be extracted. Although we have a continuum of pooling equilibria, there exists a unique Pareto-optimal one for each firm at either level of γ, given by $\{\hat{A}_1^H = A_1^H, \hat{A}_1^L = f(\hat{A}_1^H, \hat{A}_2^E) > A_1^L, \hat{A}_2^E = A_2^E\}$. At the Pareto optimal intuitive pooling equilibrium, firm 1 at $\gamma = \gamma_L$ will advertise $f(\hat{A}_1^H, \hat{A}_2^E) > A_1^L$, while firm 1 at γ_H will advertise its one-period optimal level A_1^H. For other intuitive pooling equilibria, firm 1 at both γ_H and γ_L advertises more than its pure competitive advertising.

To summarize our finding, *when α is too small or too large, firm 1 advertises according to its normal competitive level $A_1^i, i = H, L$; when α falls in the intermediate range, firm 1's predatory intention leads to a higher level of advertising compared to its pure competitive level.*

4.5 A Standard Logit Example

In our former analysis, we make the additional assumption A4 in order to have analytical solution. However, our major finding does not rely on this assumption, illustrated by the following example where we numerically solve the signaling game using the standard logit demand function.

Suppose the demand is given by the standard logit demand function, where

$$D(A_1, A_2, \gamma, \alpha) = \frac{e^{\alpha + \ln(1+A_2)}}{e^{\gamma \ln(1+A_1)} + e^{\alpha + \ln(1+A_2)}}.$$

This demand function has been used in Dube, Hitsch and Manchanda (2006) to study advertising dynamics. The rationale for using logarithmic form of advertising is to provide a well-behaved demand function. It is easily shown that the demand is strictly concave in own advertising and convex in opponent's advertising, while other specifications such as linear advertising response function can lead to increasing returns to own advertising.

It is worth mentioning that γ enters firm 1's advertising response function. Since the total demand is 1, this is equivalent to a decrease in firm 2's demand. The reason for us to take this functional form instead of letting γ enter firm 2's advertising response function, is to have the demand function satisfy the single-crossing property.[15]

Figure 3 and Figure 4 plot the optimal advertising level of firm 1 before and after the news as a function of α in a separating equilibrium when the shock is severe and mild respectively, while Figure 5 plots the optimal advertising level of firm 2 before and after the news. In addition, we plot the advertising level at the normal competitive response level after the news. First of all, when α is too low or too high, predation is either unnecessary or impossible. As such, the optimal advertising level of firm 1 and firm 2 after the news are the same as the normal competitive response advertising level. Second, when α is in the median range, firm 1 increases the advertising level more than the normal competitive response level of advertising to signal firm 2 that the shock is indeed severe. Since advertising of firm 1 and firm 2 are strategic substitute for the logit demand function, firm 2 reduces the advertising level as a response. As a response to firm 2's lower advertising level, firm 1's optimal advertising level when the shock is mild is also lower than the normal competitive advertising level. Moreover, the increase in advertising level of firm 1 when the shock is severe is much higher than the reduction in advertising of firm 1 when

[15] If γ enters firm 2's advertising response function directly, the single-crossing property is violated when firm 2's market share is less than 0.5.

the shock is mild. Thus on average, the optimal advertising level of firm 1 is higher than the normal competitive level when α is in the median range.

For the pooling equilibrium, Figure 6 and Figure 7 plot the optimal advertising level of firm 1 when the shock is severe and mild respectively, while Figure 8 plots the optimal advertising level of firm 2. Similar to the separating equilibrium case, optimal advertising level of firm 1 and firm 2 differ from the normal competitive advertising level only when α is in the median range. However, as opposed to the case of separating equilibrium, firm 1 in a pooling equilibrium increases the advertising level when the shock is mild and reduces the advertising level when the shock is severe. On average, we find that the advertising level of firm 1 is higher than the normal competitive level when α is in the median range.

The logit examples show that predation does not necessarily imply that firm 1 will increase the advertising level in all markets. However, on average predation intent does cause firm 1 to set its advertising level higher than the normal competitive response level.

It is worth mentioning that model has interesting predictions about the changes in advertising level before and after the news. When firm 1 chooses the normal competitive level of advertising, the change in advertising level of firm 1 is monotonic increasing in α for the above logit demand function, while the change in advertising of firm 1 is non-monotonic when the firm 1 uses the optimal advertising level after the news.

4.6 Discussion

4.6.1 Reentry Cost

The theoretical model shows that reentry cost alone does not necessarily prevent firms from using predatory advertising strategies. In the case of separating equilibrium, firm 2 correctly infers the nature of the shock. Realizing that its duopoly profit would be negative, firm 2 makes the right choice to exit the market when the demand shock is indeed severe. As such, firm 2 will not choose to reenter the market even if the reentry cost is zero. In the case of a pooling equilibrium, firm 2 exits the market based on the prior belief. Firm 2 will not reenter the market either unless it could obtain information later on about the true nature of the shock.

4.6.2 Other Explanation of Predation

Our theoretical model provides a possible explanation of predation which focuses on the role of asymmetric information. Advertising is used as a signaling tool. Arguably, one could find many other possible explanations of predation. We do not intent to rule out those other possible explanations. However, we do want to emphasis that the idea that predation is either impossible or unnecessary in markets with either high or low demand prior to the news event could be true in many other possible explanations of predation. As such, those models will likely to generate similar predictions as our model does. Namely, firms may increase the level of advertising to drive opponents out of the market only in those markets where demand before the news event is in the median range.

4.6.3 Implications on the Marginal Effects of Advertising.

The above analysis tells us that if there is predatory intention in firm 1's post-shock behavior, it advertises more than $A_1^i, i = H, L$. Where $A_1^i, i = H, L$ maximizes firm 1's one-period profit and satisfies the first order condition $pD_1^i(A_1, A_2^E) = c, i = H, L$, a larger than A_1^i advertising will make the marginal benefit to be less than the marginal cost, i.e. $pD_1^i(A_1, A_2^E) < c, i = H, L$. Moreover, such violation to one-period optimality happens only for $\alpha \in [\underline{\alpha}, \bar{\alpha}]$, but not for the rest possible values of α.

Therefore, if firm 1 engages in predatory advertising after the shock, there will be a downward distortion in the marginal effect of A_1 on firm 1's demand. And such predatory intention exists only for α in the intermediate range.

5 The Empirical Model and Results

We begin with a description of the data used in the empirical test. We then explain our test hypothesis and empirical strategies. Afterwards, we specify the baseline model and discuss the main results. This is followed by robustness checks of the results.

5.1 Data

The data used for the empirical analysis is from a category of prescription drug used to treat high levels of blood cholesterol; such a drug is commonly referred to as a Statin drug. The data are at the level of the physician, and are based on a panel of representative physicians from the United States. These data were obtained from a pharmaceutical consulting firm, which also provided a similar dataset to a marketing study by Narayanan and

Manchanda (2005). For each physician, we observe a sample of prescriptions written for his or her respective patients from January 1st 2004 to December 31st 2004. In addition, we also have a record of all the detailing visits made by pharmaceutical sales representatives during the same period. The dataset is unique in that we observe the detailing frequencies of all firms at the physician-level. This enables us to look at how Crestor's competitors changed their detailing strategies with respect to different physicians.

According to the convention of the industry, each sales representative can visit a physician's office only once a month, thus pharmaceutical firms usually make their advertising decision on a monthly level. Therefore we create a monthly physician panel data. For each physician we calculate the total number of sales visits and total prescription for all drugs in each month. Since the news event happens on March 4th 2004, which is the 9th week in our dataset, we decide to exclude week 9 from our study to give firms enough time to adjust to the news event. Our study focuses on changes in detailing patterns right after the news. Thus we use a short time window and exclude observations after week 13, which is five weeks after the news event. We make some adjustment in our definition of a month. We divide the time before and after the news into three periods of equal length: week 1-4(January), week 5-8 (February) and week 10-13 (March). An advantage of constructing the time period this way is that we make sure our comparisons are based on the same length of the period.

An important part of our study requires us to create measures of monthly market share. During our sample period, Crestor's share of total prescription is small at around 10%. However, some physicians in our data set have a very small number of prescriptions during each month. We are concerned that including those physicians will make our measure of market share very noisy and increase the risk of misclassifying a physician's market share level. For example, if we observe only one prescription for a physician in a given month and that prescription happens to be Crestor, we will infer that Crestor has a 100% market share for that physician. Clearly, we are not as confident to classify the physician as having high Crestor market share as another physician who prescribes 10 Crestor among 10 prescriptions. In order to have a reasonable large prescription levels to calculate market share, we restrict our sample to physicians with 10 or more prescriptions in both week 1-4 and week 5-8. This restrict our dataset to 308 physicians for whom we observe monthly detailing as well as prescription decision in all three months.

Table 2 summarizes the prescription levels and detailing intensities information of our sample physicians. The average number of total prescriptions in a month is 20.54 with a maximum of 75. Average share of Crestor's prescription is 9 percent. Lipitor has the largest market share at 43 percent, followed by Zocor at 24 percent and Pravachol at 13 percent. The average number of detailing by Lipitor, Zocor, Pravachol and Crestor are 0.83, 0.89, 0.58 and 1.29 respectively. Crestor has a much high level of detailing intensity in part due to that it just entered the market about four month ago. In addition, because of the negative news event, Crestor may increase the advertising level to counteract the news effect. Clearly there are variations in detailing intensity. For example, the maximum number of visits to a physician in a month is 11 for Crestor, while some physicians do not have any visits in a month. Table 2 also shows the distribution of market shares for each drug. For example, among physicians with at least one prescription of Crestor, the 25th quantile, median and 75th quantile are at 0.07, 0.11 and 0.20 respectively. It is worth mentioning that the distribution of Pravachol market share is the closest to that of Crestor.

We begin our study with a simple comparison of changes in advertising intensities before (February) and after (March) the news. Table 3 shows that the average number of sales visits at a physician's office increases from 3.47 to 4.39, a 26.47% increase. In addition, all firms increase the advertising level after the news. The highest increase comes from Crestor. It increases the average number of visits from 1.07 to 1.51 with an increase of 41.34%. For the three main competitors of Crestor, Lipitor increases the average number of visits from 0.79 to 0.88; Zocor increases from 0.78 to 1.01 and Pravachol increases from 0.54 to 0.88. It is possible that the increase in advertising level represents the predatory intent of Crestor's competitor. On the other hand, the changes in advertising intensity may be completely driven by competitive response.

5.2 Test Strategies

The objective of the empirical study is to test whether the changes in the detailing strategies of Crestor's competitors following the news event are consistent with the predatory advertising prediction. We focus on the changes in detailing strategy rather than price and other competition practice, such as direct to consumer advertising. Firms could change their pricing and direct to consumer advertising strategy in response to the news. However, since we focus on the response of firms immediately after the news event[16], we argue that changes in pricing and direct to consumer advertising are likely to take longer time to occur. In addition, our test looks at how the changes in detailing strategies differ across different type of physicians. Only detailing activity vary across physicians and price and

[16]We expect the effect of the bad news to be the strongest in the period immediately after the news event, together with the incentives for Crestor's competitors to use predatory strategies.

direct to consumer advertising will not vary across physicians.

The theoretical model shows that predatory intent only exists to those physicians where the prescription level for Crestor was at the median range prior to the news event. For these physicians, Crestor's opponents may increase their respective advertising level in order to induce Crestor to exit. An important factor that we need to take into account is the normal competitive response of Crestor's competitors. The theoretical model argues that, in the normal competitive response, the changes in Crestor's competitors' detailing level should be monotonic with respect to Crestor's past prescription levels. The detection of predatory intent can thus be carried out by checking whether changes in the detailing levels are non-monotonic with respect to past prescription levels. If there is predatory intent, we should observe a large increase in the advertising level with respect to those physicians whose Crestor prescription level falls in the median range.

As Lipitor is the dominant brand in the market, we expect that the incentive to predate is highest for Lipitor. Thus our main test hypothesis is that after the news event, there is non-monotonicity in the change of Lipitor's advertising with respect to Crestor's market share. The increase in advertising intensity should be highest to physicians with median Crestor market share.

In addition to our main test hypothesis, we have two additional tests as a robustness check. First of all, since the news only affects Crestor but not other drugs in the market, we expect that the non-monotonic change in detailing only happens to physicians with median Crestor market share but not to physicians with median market share for other drugs. Secondly, for the two smaller competitors in the market, Zocor and Pravachol, we expect their incentive to engage in predation (if existing at all) to be much weaker than that for Lipitor. Correspondingly, evidence of advertising distortion should be weaker for Zocor and Pravachol.

We use three different empirical approaches in this paper. Our first econometric model is a “Difference-in-Difference" estimator where we compare the difference in detailing intensity between comparison group and control group before and after the news event. Our second econometric model is a regression based estimator which allows us to control for additional covariates. Both estimators will require a specification of market share range of Crestor where predatory intent is the strongest, i.e., Crestor's prescription level is in the “median range." We are concerned about the potential misclassification problem. Thus, our third approach uses a non-parametric regression method to estimate the changes in relationship between the detailing levels of Crestor's competitors and Crestor's market share before and after the news event.

5.3 Discussion of Test Strategies

It is worth mentioning that our test of predation is quite conservative. We can not conclude that advertising is not predatory even if we find that the changes in advertising is actually monotonic in Crestor market share. If the effect of competitive response is very strong, it may dominate the effect from predatory advertising. As a result, the changes in advertising is still monotonic in Crestor market share.

In addition, our test relies on the assumption that the negative news effect has to be “right" in magnitude. Namely, the news effect will only generate predatory intent to physicians with median Crestor market share. If the news effect is too strong, Crestor's opponent may also have incentives to predate on physicians with high Crestor market share. On the other hand, if the news is trivial, Crestor's opponent will have no incentives to predate either.

As discussed at the end of our theoretical model, our theoretical model provides a possible explanation of predation. We do not rule out other possible explanations of predation. However, the idea that predation is either unnecessary or impossible in markets where the demand for Crestor is too low or too high is likely to be true for many other models of predation. Thus, the non-monotonic change in advertising could still be true. Therefore, our empirical tests are not just tests of our theoretical model but tests of more general predation models.

Finally, we want to emphasis that we tried to test whether firms have attempted to use predation strategies after the news event rather than the actual outcome of predation strategies. The main reason that we do not study the actual outcome of predation is that it is very difficult to know how long it takes predation strategies to have any effects. In addition, in a real market, the information flow is constant. Thus after the bad news event, there might be other additional information released in the market. For example, the FDA changes the warning on the label of Crestor 3 month after Public Citizen's petition. We are not able to control for the effects of these additional information on the outcome of predation strategies. As such, we focus on the short time window around the news event and test whether firms have tried predation strategies. The advantage of this approach is that we only need to observe the changes in advertising levels. In addition, by looking at a short time window around the event, the results are mostly driven by the news event rather than other additional information released in the market.

5.4 A Difference in Differences Study of Changes in Detailing Patterns

Our first econometric model is a Dif-in-Dif (Difference in Difference) estimator. The main idea of a Dif-in-Dif estimator is to compare the changes in the outcome variable of the comparison group with that of the control group.

In our baseline Dif-in-Dif estimation, the outcome variable is the number of detailing by Crestor's main competitor Lipitor in a physician's office during a period before and after the news event. Ideally, we would like to look at the changes in number of detailing during a short time window around the event date on March 4th 2004. However, we also need a large data set to provide a test with appropriate power. In addition, according to the convention of the industry, each sales representative can visit a physician's office only once a month. It is likely that the detailing decisions are determined on a monthly basis. Therefore, we will compare the changes in monthly level of detailing activities. As the news happen on March 4th (week 9), we will compare the average number of detailing to physicians in February with that in March. However, since February and March have different number of days and news event happens at the beginning of March, a direct comparison of February and March detailing level may not be appropriate. As a result, we will use data in the four weeks before the news event (week 5-8) as February, four weeks after the news event (week 10-11) as March and the first four weeks of the year (week 1-4) as January. By defining the time period this way, we guarantee the comparisons are done over the exact same number of periods.

In our baseline Dif-in-Dif estimation, the comparison group includes physicians' whose prescription level of Crestor falls in the median range. For the control group, we use two different specifications: physicians with low Crestor prescription level and physicians with high Crestor prescription level. By using these control groups, we control for the expected differences in detailing due to other factors that are not associated with the news event, such as the seasonal effect. It is worth mentioning that our test objectives are different from the standard Dif-in-Dif estimation. We are not trying to estimate the causal effect of news event on detailing level. Instead, we are interested to test if the detailing level of Lipitor increases more in the comparison group than in BOTH control groups, as the theoretical model predicts that predatory intent only exists among physicians with median Crestor market share and the changes in detailing should be non-monotonic with respect to market share.

We will use the market shares in the last month to categorize a physician. For example, for physicians we observe in February (week 5-8), we use their Crestor's market share in January (week 1-4) to determine physician's type. Unfortunately, the model can not give us guidelines about the range of market share where predatory intent exists. We decide to use the quantile of Crestor's market share distribution to determine the ranges. Based on the first 3 month prescription data, the 25th percentile of Crestor market share is at 0.07, the median is at 0.11, and the 75th percentile is at 0.2. We choose to categorize a physician as Low, Median, and High if the market share of Crestor is between [0-0.07], (0.07-0.2], and (0.2, 1] respectively. We try to categorize more physicians in the median range and avoid the potential problems of misclassifying a median market share physicians into either low or high market share groups. The downside of having a large median market share group is that we may include low or high market share physicians as median physicians, which in turn may weaken our test results. Clearly, one potential problem is the misclassification of market share range. We check the robustness of the results using alternative definition of market share range. Most of the results will hold if we use alternative but similar categorization of market share range. As an additional robustness check, in our third empirical specification, we will use nonparametric estimation method to estimate the changes in Crestor's competitors' strategy without defining the market share range arbitrarily.

The baseline difference in difference results are reported in the top panel of Table 4. During the four weeks before the news event (week 5-8), the average number of Lipitor detailing to physicians with median Crestor market share (Median Type) is 0.86, while the number of detailing towards low (Low Type) and high (High Type) Crestor market share physicians are 0.76 and 0.80 respectively. After the news event, the average number of Lipitor detailing during week 10-13 increases to 0.99 among Median Type physicians. For the Low Type physicians, Lipitor's average detailing numbers increase to 0.85; and for High Type physicians, the average number of detailing actually decreases to 0.76. Based on the first difference results, the increase in detailing numbers for the Median Type physicians is 0.135, while the increase for Low and High Type physicians are 0.09 and -0.04 respectively. The Dif-in-Dif estimates (0.05 and 0.18) suggest that Lipitor detailing activity increases the most for Median Type physicians. However, due to the large standard error (0.21 and 0.3), we can not conclude that the difference is statistically significant.

As a check of our estimates, we report in table 4 using Pravachol's market share to decide comparison group and control group while still using Liptior's detailing as the outcome variable. Namely, the comparison group includes physicians' whose prescription level of Pravachol falls in the median range. For the control group, we use physicians with low Pravachol prescription level and physicians with high Pravachol prescription level. We choose Pravachol because it has similar market share as Crestor. Since the news only impact the Crestor, we expect that Lipitor will have no predation incentive towards Pravachol. As a result, we expect that the changes in detailing should not be distorted for Median Type physicians when we use alternative specification of comparison group and control group.

The bottom panel of Table 4 reports the Dif-in-Dif estimates using Pravachol's market share to create comparison and control groups. After the news event, average Lipitor detailing numbers to physicians with median Pravachol market share decreases from 0.91 to 0.88; while the number of detailing increases from 0.74 to 0.92 for physicians with low Pravachol market share and from 0.68 to 0.78 for physicians with high Pravachol market share. Thus the Lipitor detailing intensity actually decreases for physicians with median Pravachol market share, while increases for physicians with high or low Pravachol market share. Both Dif-in-Dif estimates (-0.22 and -0.13) are negative. Clearly the changes in Lipitor detailing strategies towards Crestor and Pravachol are different. This finding provide evidence that the upward increase in Lipitor detailing level to physicians with median Crestor market share is a unique result of the news event.

Our baseline difference-in-difference estimators use the detailing level of Lipitor as the outcome variable. Since Lipitor is the dominant brand in the market, the gain from predation is higher for Lipitor. Thus, we expect Lipitor's predatory incentives are the strongest among Crestor's competitors. For the two other smaller competitors of Crestor, Zocor and Pravachol, the predatory intent should be small if it exists at all. Therefore, we run two additional Dif-in-Dif estimations by replacing the outcome variable in the baseline Dif-in-Dif estimator with the detailing levels of Zocor and Pravachol respectively. The results are included in Table 5. The mean number of Zocor detailing for physicians with median, low and high Crestor shares are 0.8, 0.8, and 0.67 before the news event; the mean detailing intensity increases to 0.9, 1.02 and 1.19 after the news event. However the increases in detailing are higher among physicians with low and high Crestor market share (0.23 and 0.52). The Dif-in-Dif results are both negative (-0.13 and -0.42) for Zocor. Changes in Pravachol detailing pattern differ from that of Lipitor as well. There is almost no increase in detailing intensity to low Crestor market share physicians, while the increases are 0.13 and 0.2 respectively for median and high Crestor share physicians. The Dif-in-Dif estimates are 0.13 and -0.08 respectively, indicating that changes in Pravochol's detailing pattern is monotonic in Crestor market share.

To summarize, the Dif-in-Dif estimation results show that Lipitor increases the advertising intensity the most to physicians with median Crestor market share after the news event. This pattern is not found for two smaller competitors, Zocor and Pravachol. In addition, Lipitor does not exhibit the same changes of strategies towards physicians with median Pravachol market share.

5.5 Regression model

Our second econometric model use a regression based model to measure the impact of bad news about Crestor on changes in the detailing patterns of Crestor's competitors. An advantage of a regression based model is that we can control for additional market characteristics. In addition, as we have a panel data of physicians, regression based model allows us to control for physician specific effect through random effect model and fixed effect model.

We begin with changes in Lipitor's detailing pattern both before and after the bad news event. The basic specification is as follows:

$$\begin{aligned} y_{it} &= \exp(\beta_0 + \beta_1 CM + \beta_2 CH + \\ &\quad (\gamma_0 + \gamma_1 CM + \gamma_2 CH) * Postevent + \delta X_{it} + \alpha_i) \end{aligned}$$

where y_{it} is the number of visits by Lipitor's sales representatives to physician i before (t=1) and after (t=2) the news event. It is a non-negative integer. Similar to the above Dif-in-Dif estimation, we use four weeks of window before and after the event. Thus t=1 if the week is between five and eight, and t=2 if the week is between ten and thirteen. CM and CH are dummy variables indicative of Crestor's market share in the median range and high range respectively during the previous four weeks. Namely, we use week 1-4 to create past market share for t=1 and week 5-8 to create past market share for t=2. In the baseline model, Crestor's medium market share is defined to be (0.0625-0.2), while high market share is defined to be (0.2-1). Postevent is a dummy variable equal to 1 for t=2. X_{it} are other factors that may affect the detailing decisions. In the baseline model, we don't include X_{it} in the regression. Instead, we include X_{it} in the robustness check section. We present the outcomes using a pooling regression, a random effect model and a fixed effect model. α_i is the physician specific effect in the random effect model and fixed effect model. In all the regressions, we weighted observations using the number of prescriptions of Statin drugs issued by the physician in weeks 1-8, in order that larger markets should have a greater impact on Lipitor's detailing response than smaller ones.

Table 6 gives the results from the baseline specification using pooling regression, random effect regression and fixed effect regression. The pooling regression estimates of γ_0, γ_1, and γ_2 are 0.06, 0.07 and -0.13 respectively. However, the coefficients are not significant. The estimated coefficients of γ_0, γ_1, and γ_2 from the random effect models are 0.06, 0.07 and -0.13 respectively. All coefficient estimates are significant. The coefficients from the fixed effect model are 0.05, 0.05 and -0.11 respectively and only the estimates of γ_0 and γ_2 are significant. First, the estimates from three different specifications are reasonably similar. All suggests that γ_0 and γ_1 are positive and γ_2 is negative. Namely, after the news event, advertising level for physicians with low and median market share increases; while decreases for physicians with high Crestor share. In addition, the magnitude of increase the detailing intensity is highest to those physicians for whom Crestor prescription levels fall in the medium range.

Our second specification of regression model looks at the changes in Zocor and Provacor detailing. We replace the dependent variable with the respective numbers of visits by Zocor and Pravacor sales representatives to physicians. Table 7 gives the results using the random effect and fixed effect model. According to the random effect models, the estimated coefficients of γ_0, γ_1, and γ_2 for Zocor are 0.23, -0.15 and 0.05 respectively, while those for Pravachol are 0.07, 0.02, 0.36 respectively. In neither case do we find evidence of an upward distortion in advertising in the median market. Zocor increases the advertising level the most to physicians with high and low Crestor market share; while Pravachol increase advertising intensity the most to physicians with high Crestor market share.

Table 8 reports the results when additional market characteristics are among the control variables. These market characteristics include the market size, the share of new patients, the share of older patients (age 65+), the share of Asian patients, the share of female patients, and the share of severe symptom patients. These additional variables help to control for other factors that might influence the demand for Crestor. All are based on the lagged four weeks of data. We find that the changes in the Lipitor detailing pattern still hold after controlling for these additional variables. The estimate of γ_0 is 0.03 in pooling regression model, 0.05 in random effect model and 0.07 in fixed effect model. Estimates of γ_1 are 0.12, 0.08 and 0.7 respectively for pooling, random effect and fixed effect model; while the estimate of γ_2 are -0.06, -0.05 and -0.12. The estimates from three different specifications are similar. They all shows that advertising level increases the most to physicians with median Crestor market share. This suggests that our findings are robust to additional control variables.

5.6 A Nonparametric Estimation

A potential concern of the Dif-in-Dif estimation and regression model is the misclassification of median market. We define a physician to be median Crestor market if Crestor's market share is between the 25th and 75th quantile. If the median market is incorrectly specified, we may not make the correct comparison. In order to check if the definition of the median market affects our findings, we non-parametrically estimate the detailing level of Crestor's major competitors during the four weeks prior to and after the news event as a function of the quantile of market share. More specifically, the Nadaraya Watson kernel regression estimator is:

$$\begin{aligned} m(x) &= \sum_{i=1}^{n} w_{ni}(x) y_i \\ w_{ni}(x) &= K(\frac{x_i - x}{h})/(\sum_{i=1}^{n} K(\frac{x_i - x}{h})) \end{aligned}$$

where y_i is the observed number of detailings, x_i is the observed quantile of market share, and x is the value of quantile of market share where we calculate the expected number of detailings.

Figure 1a plots the nonparametric estimates of detailing by Lipitor with the dependent variable being the quantile of Crestor market share. The result shows that when Crestor's market share is between the 40th and 70th qunatile, Lipitor increases the detailing level after the news event. For physician's whose Crestor's market share is below 40th quantile, Lipitor's advertising level decreases after the news event, while for physicians above 70th quantile, Lipitor's advertising level are similar before and after the news.

Figure 1b plots the nonparametric estimates of Lipitor detailing with dependent variable being the quantile of Pravachol market share. Liptior actually decreases its detailing intensity to physicians with median Pravachol market share. For physicians with low Pravachol market share, Lipitor advertising level increases after the news.

Figure 2a and Figure 2b present the result of nonparametric estimates of Zocor and Pravachol detailing level. Zocor clearly has different changes in detailing patterns after the news event. The most significant increase in Zocor detailing happens to physicians with high Crestor market share. Interestingly, Pravachol's changes in the detailing pattern are similar to that of Lipitor, as both increases the detailing level the most to physicians who are in the middle of the quantile of Crestor market share. However, the increase of

Liptior advertising is much stronger in the median range compared to that of Pravachol.

To summarize, we find strong evidence of predatory intent in the detailing strategies of Crestor's main competitor Lipitor. The results show that Lipitor increases its advertising intensity the most with physicians for whom the Crestor prescription level falls in the median range. This pattern is unique to Lipitor, and is not found with respect to other drugs in the market.

6 Conclusion

We study the responses of Crestor's competitors to bad news event of Crestor, and are particularly interested in detecting predatory behavior from normal competitive responses. We focus on the strategic interaction of Crestor and its main competitor Lipitor. A game with asymmetric information shows that, in both separating equilibria and pooling equilibria, Lipitor upward distorts its advertising with the intention to induce the exit of Crestor. In addition, Lipitor has predatory intent only to those physicians whose preference towards Crestor is in the median range, as predation is either unnecessary or impossible for the other physicians.

We test the theoretical prediction by looking at changes in Crestor's competitors' detailing patterns before and after the news event. We find that, Lipitor significantly increased its advertising intensity to physicians with whom Crestor has taken a median share in total prescription. Such pattern is not found for the two smaller competitors of Crestor, Zocor and Pravacor. This finding suggests that predatory intent may only exist with the dominant firm in the market.

Many interesting questions are worth further exploration. The theoretical model shows that there exit different incentives for Lipitor to engage in predation: In pooling equilibrium, Lipitor is trying to fool Crestor when the actual shock is mild; whereas in a separating equilibrium, Lipitor is trying to reveal Crestor a severe shock. Although our empirical test supports the existence of predation, we can not tell which kind of equilibrium were actually played after the bad news event. Future work would possibly identify more properties of predation therefore tell us which kind of equilibrium is played out in reality.

In our work, advertising is the only strategic element. However, in many other cases, more than one strategy could be utilized for predation, for example, both price and advertising. It would be interesting to extend the model to study predations with more than one strategic instrument. Moreover, the method in the current work can possibly be generalized to identify other strategic considerations (strategic entry deterrence would be an example) in industrial competition.

Appendix

1. Proof to Theorem 1.

Proof: Step I. We show that $A_1^H > A_1^L$ is true. By the definition of A_1^H and A_1^L,

$$p[1 - D^H(A_1^H, A_2^E)] - cA_1^H > p[1 - D^H(A_1^L, A_2^E)] - cA_1^L \tag{1}$$

$$p[1 - D^L(A_1^L, A_2^E)] - cA_1^L > p[1 - D^L(A_1^H, A_2^E)] - cA_1^H \tag{2}$$

(1)+(2) gives

$$D^H(A_1^H, A_2^E) + D^L(A_1^L, A_2^E) < D^H(A_1^L, A_2^E) + D^L(A_1^H, A_2^E)$$

$$\Rightarrow D^L(A_1^H, A_2^E) - D^H(A_1^H, A_2^E) > D^L(A_1^L, A_2^E) - D^H(A_1^L, A_2^E).$$

By A3, $(D^L(A_1, A_2^E) - D^H(A_1, A_2^E))$ is strictly increasing in A_1. Thus $A_1^H > A_1^L$.

Step II. Under A4, firm 2's equilibrium advertising does not depend on firm 1's advertising, thus is fixed at A_1^E. In the separating equilibrium, since firm 2 can tell $\gamma = \gamma_H$ or $\gamma = \gamma_L$ after observing its realized demand, firm 1 will advertise its one-period optimal level at $\gamma = \gamma_L$. Thus in the three-period game, we have

$$\hat{A}_1^L = A_1^L, \hat{A}_2^E = A_2^E$$

for separating equilibrium. We exploit the arbitrariness of off-equilibrium-path beliefs by setting $\hat{\rho} = 1$ if $D^i(A_1, A_2) \leq D^H(\hat{A}_1^H, A_2^E), i = H, L$, and $\hat{\rho} = 0$ otherwise. To find $\hat{A}_1^H$, consider two incentive compatibility conditions.

Firstly, if $\gamma = \gamma_L$, it should not be in firm 1's interests to mimic so that firm 2's updated belief is $\hat{\rho} = 1$. Given that the advertising pair at $\gamma = \gamma_H$ is $(\hat{A}_1^H, A_2^E)$, in order to fool firm 2, firm 1 advertises $f(\hat{A}_1^H, A_2^E)$ so that $D^L(f(\hat{A}_1^H, A_2^E), A_2^E) = D^H(\hat{A}_1^H, A_2^E)$. In a separating equilibrium, it will be too costly for firm 1 to mimic, implying

$$\pi_1^L(A_1^L, A_2^E) + \pi_{1D}^L \geq \pi_1^L(f(\hat{A}_1^H, A_2^E), A_2^E) + \pi_{1M}^L, \qquad (I)$$

reorganized as

$$\pi_1^L(A_1^L, A_2^E) - \pi_1^L(f(\hat{A}_1^H, A_2^E), A_2^E) \geq \pi_{1M}^L - \pi_{1D}^L.$$

The right-hand-side is a positive constant. Since $\pi_1^L(A_1, A_2^E)$ is strictly concave in A_1 and maximized at $A_1 = A_1^L$, the left-hand-side is strictly convex and minimized to be zero at $f(\hat{A}_1^H, A_2^E) = A_1^L$. There exist two values a, b, with $a < A_1^L < b$, such that (I) holds with either $f(A_1, A_2^E) \leq a$ or $f(A_1, A_2^E) \geq b$. Since $f(A_1, A_2^E) > A_1, f_1 > 0$, there exist two values A_a, A_b with $A_a < A_b$, such that (I) holds with either $\hat{A}_1^H \leq A_a$ or $\hat{A}_1^H \geq A_b$. Here A_b satisfies

$$\pi_1^L(A_1^L, A_2^E) - \pi_1^L(f(A_b, A_2^E), A_2^E) = \pi_{1M}^L - \pi_{1D}^L. \tag{1}$$

If $\hat{A}_1^H \leq A_a$, we have $f(\hat{A}_1^H, A_2^E) < a < A_1^L < A_1^H$, thus $\hat{A}_1^H < A_1^H$, implying $D^H(\hat{A}_1^H, A_2^E) > D^H(A_1^H, A_2^E)$. According to Condition 3, at $A_1 = A_1^H$, firm 2's posterior belief is $\hat{\rho} = 1$ and it will exit. In this case, firm 1 is better off deviating from $\hat{A}_1^H$ to A_1^H, since both induce exit but A_1^H generates a higher profit in period one for firm 1, a contradiction. Thus $\hat{A}_1^H \geq A_b$ must hold. By A5, (I) is violated at $\hat{A}_1^H = A_1^H$, implying that $A_1^H \in (A_a, A_b)$, hence $\hat{A}_1^H > A_1^H$.

Secondly, if $\gamma = \gamma_H$, equilibrium requires that it must be in firm 1's interests to signal firm 2 the true effect of the shock in order to have firm 2 exit, although part of firm 1's current profit is sacrificed by doing so. That is,

$$\pi_1^H(\hat{A}_1^H, A_2^E) + \pi_{1M}^H \geq \pi_1^H(A_1^H, A_2^E) + \pi_{1D}^H, \tag{II}$$

reorganized as

$$\pi_1^H(A_1^H, A_2^E) - \pi_1^H(\hat{A}_1^H, A_2^E) \leq \pi_{1M}^H - \pi_{1D}^H.$$

The right-hand-side is a positive constant. The left-hand-side is strictly convex and minimized to be zero at $\hat{A}_1^H = A_1^H$. There exists A_c, A_d, with $A_c < A_1^H < A_d$ such that solution to the inequality is $\hat{A}_1^H \in [A_c, A_d]$, with A_d satisfying

$$\pi_1^H(A_1^H, A_2^E) - \pi_1^H(A_d, A_2^E) = \pi_{1M}^H - \pi_{1D}^H. \tag{2}$$

If separating equilibrium exists, the set of advertising strategy given by $\{\hat{A}_1^H \in [A_b, A_d], \hat{A}_1^L = A_1^L, \hat{A}_2^E = A_2^E\}$, together with the specified beliefs and exit rule of firm 2 constitute a continuum of separating equilibria. Employing Intuitive Criterion reduces the set of separating equilibria to a unique one, with $\{\hat{A}_1^H = A_b, \hat{A}_1^L = A_1^L, \hat{A}_2^E = A_2^E\}$. To see this, suppose $\hat{A}_1^H > A_b$. To support such an equilibrium, it must be $\hat{\rho} = 0$ if firm 2 observes demand lying in $(D^H(\hat{A}_1^H, A_2^E), D^H(A_b, A_2^E))$ (otherwise firm 1 would deviate to $\hat{A}_1^H = A_b$ to maximize its profit). However, such strategy is equilibrium dominated for firm 1 at $\gamma = \gamma_L$ but not for $\gamma = \gamma_H$, a contradiction to Intuitive Criterion.

Step III. To prove the sufficient condition for the existence of separating equilibrium, it is sufficient to show that $A_b < A_d$. Since

$$\begin{aligned}
&\pi_1^H(A_1, A_2^E) - \pi_1^L(A_1, A_2^E) \\
&= p[1 - D^H(A_1, A_2^E)] - p[1 - D^L(A_1, A_2^E)] \\
&= p[D^L(A_1, A_2^E) - D^H(A_1, A_2^E)],
\end{aligned}$$

$$\frac{d[\pi_1^H(A_1, A_2^E) - \pi_1^L(A_1, A_2^E)]}{dA_1} = p[D_1^L(A_1, A_2^E) - D_1^H(A_1, A_2^E)] > 0$$

due to A3. By (1) and (2),

$$\begin{aligned}
&\pi_{1M}^H - \pi_{1D}^H \geq \pi_{1M}^L - \pi_{1D}^L \\
&\Rightarrow \pi_1^H(A_1^H) - \pi_1^H(A_d) \geq \pi_1^L(A_1^L) - \pi_1^L(f(A_b, A_2^E)) \\
&\Rightarrow \pi_1^H(A_1^H) - \pi_1^L(A_1^L) \geq \pi_1^H(A_d) - \pi_1^L(f(A_b, A_2^E)) \\
&\Rightarrow \pi_1^H(A_1^H) - \pi_1^L(A_1^H) \geq \pi_1^H(A_d) - \pi_1^L(f(A_b, A_2^E))
\end{aligned}$$

Since $A_d > A_1^H$, we have

$$\begin{aligned}
&\pi_1^H(A_d) - \pi_1^L(A_d) \geq \pi_1^H(A_d) - \pi_1^L(f(A_b, A_2^E)) \\
&\Rightarrow \pi_1^L(f(A_b, A_2^E)) - \pi_1^L(A_d) \geq 0 \\
&\Rightarrow f(A_b, A_2^E) \leq A_d.
\end{aligned}$$

The last inequality comes from A2 and the fact that $f(A_b, A_2^E) > A_1^L$ and $A_d > A_1^L$. Hence $A_b < A_d$ and the existence of intuitive separating equilibrium is guaranteed. ∎

2. Proof to Theorem 2.

Proof: Step I. We show that the strategy stated in the theorem constitute intuitive pooling equilibrium. Due to A4, $\hat{A}_2^E = A_2^E$ in pooling equilibrium. Let us set $\hat{\rho}(D^i(A_1, A_2)) = 1$ for all $D^i(A_1, A_2) < D^H(\hat{A}_1^H, A_2^E)$, and $\hat{\rho}(D^i(A_1, A_2)) = 0$ for $D^i(A_1, A_2) > D^H(\hat{A}_1^H, A_2^E)$. Given $A_1 = \hat{A}_1^H$ at $\gamma = \gamma_H$, when $\gamma = \gamma_L$ firm 1 must have incentive to generate $D^L(A_1, A_2^E) = D^H(\hat{A}_1^H, A_2^E)$, so that the true value of γ can not be inferred by firm 2. If so, firm 1 will advertise $A_1 = f(\hat{A}_1^H, A_2^E) > \hat{A}_1^H$. Thus $\{\hat{A}_1^H, \hat{A}_1^L, \hat{A}_2^E\}$ being in pooling equilibrium requires the following condition,

$$\pi_1^L(f(\hat{A}_1^H, A_2^E), A_2^E) + \pi_{1M}^L \geq \pi_1^L(A_1^L, A_2^E) + \pi_{1D}^L. \qquad (III)$$

This is equivalent to requiring $\hat{A}_1^H \in [A_a, A_b]$. Notice that $A_b > A_1^H > A_1^L$.

Since $A_d > A_b$ under $\pi_{1M}^H - \pi_{1D}^H \geq \pi_{1M}^L - \pi_{1D}^L$, by (II), firm 1 at $\gamma = \gamma_H$ is willing to advertise some level within $[A_1^H, A_b]$, if only by advertising at least that much it can have firm 2 exit. Thus the strategy set together with firm 2's beliefs stated above constitute a pooling equilibrium, which is not equilibrium dominated at either $\gamma = \gamma_H$ or $\gamma = \gamma_L$.

Step II. We show that no other advertising strategy can be in pooling equilibrium. It is easy to rule out the case $\hat{A}_1^H < A_1^H$ or $\hat{A}_1^H > A_d$, for then firm 1 should deviate to its one-period optimal level at $\gamma = \gamma_H$. Suppose $\hat{A}_1^H \in (A_b, A_d]$. Consider a deviation to $\tilde{A}_1 \in (A_b, \hat{A}_1^H)$ by firm 1. Such a deviation is equilibrium dominated for firm 1 at $\gamma = \gamma_L$ but not at $\gamma = \gamma_H$. Therefore, when firm 2 observes $D^H(\tilde{A}_1)$ or $D^L(f(\tilde{A}_1))$, it should be able to tell that $\gamma = \gamma_H$ and then will exit. Thus firm 1 at γ_H has a profitable deviation to $\tilde{A}_1$, a contradiction. ∎

References

Albk, S., Overgaard, P., 1992. “Upstream Pricing and Advertising Signal Downstream Demand." *Journal of Economics and Management Strategy,* 1, 677-698.

Bagwell, K., Ramey, G., 1992. “Advertising and Limit Pricing." *The Rand Journal of Economics,* 19, 59-71.

Berry, S., 1992. “Estimation of a Model of Entry in the Airline Industry." *Econometrica,* 60, 889-917.

Bresnahan, T., Reiss, P., 1988. “Entry and Competition in Concentrated Markets," *Journal of Political Economy,* 99, 977-1009.

Cho, I., Kreps, D., 1987. “Signalling Games and Stable Equilibria." *Quarterly Journal of Economics,* 102, 179-221.

Ellison, G., Ellison, S., 2000. “Strategic Entry Deterrence and the Behavior of Pharmaceutical Incumbents Prior to Patent Expiration." *working paper*.

Friedman, J., 1983. “Advertising and Oligopolistic Equilibrium." *The Bell Journal of Economics,* 14, 464-473.

Fudenberg, D., Tirole, J., 1986. “A “Signal-Jamming" Theory of Predation." *The Rand Journal of Economics,* 17, 366-376.

Genesove, D., Mullin, W., 2006. “Predation and Its Rate of Return: The Sugar Industry, 1887-1914." *The Rand Journal of Economics,* 1, 47-69.

Goolsbee, A., Syverson, C., 2004. “How Do Incumbents Respond to the Threat of Entry? Evidence from the Major Airlines." *working paper.*

Hellerstein, J., 1998. “The Importance of the Physician in the Generic versus Trade-Name Prescription Decision." *the Rand Journal of Economics,* 29, 108-136.

Kreps, D., Wilson, R., 1982. “Reputation and Imperfect Information." *Journal of Economic Theory,* 27, 253-279.

McGee, J., 1958. “Predatory Price Cutting: The Standard Oil (N.J.) Case." *Journal of Law and Economics,* 1, 137-169.

——, 1980. “Predatory Pricing Revisited." *Journal of Law and Economics,* 23, 443-459.

Milgrom, P., Roberts, J., 1982. “Predation, Reputation, and Entry Deterrence." *Journal of Economic Theory,* 27, 280-312.

Morton, F., 2000. “Barriers to Entry, Brand Advertising, and Generic Entry in the US Pharmaceutical Industry." *International Journal of Industrial Organization,* 18, 1085-1104.

——, 1997. “Entry and Predation: British Shipping Cartels: 1879-1929." *Journal of Economics & Management Strategies,679-724.*

Narayanan, S. and Manchanda, P., 2005. “Heterogeneous Learning and the Targeting of Marketing Communication for New Products." *Working Paper*.

Orzach, R., Overgaard, P., and Tauman, R., 2002. “Modest Advertising Signals Strength." *The Rand Journal of Economics,* 33, 340-358.

Roberts, J., 1986. “A Signaling Model of Predatory Pricing." *Oxford Economic Papers,* 38, 75-93.

Saloner, G., 1987. “Predation, Mergers, and Incomplete Information." *The RAND Journal of Economics,* 18, 165-186.

Table 1. Major Brand of Statin Drugs

Brand	Content	Method	Type	Generic Available	Maker	Market Share [1]
Advicor	niacin/lovastatin	Fermentation	Branded	No	Kos	1.6
Altocor	lovastatin	Fermentation	Branded	Yes	Andrx	0.79
Crestor	rosuvastatin	Synthetic	Branded	No	Astra Zeneca	10.89
Lescol/XL	fluvastatin	Synthetic	Branded	No	Reliant	4.38
Lipitor	atorvastatin	Synthetic	Branded	No	Pfizer	43.15
Lovastatin	lovastatin	Fermentation	Generic			2.7
Mevacor	lovastatin	Fermentation	Branded	Yes	Merck	1.12
Pravachol	pravastatin	Fermentation	Branded	No	Bristol-Myers Squibb	11.44
Zocor	simvastatin	Fermentation	Branded	No	Merck	23.42

[1] Market Share=prescription/(total number of prescription in 2004)

Table 2. Summary Statistics of Prescription and Detailing for Each Drug Brand

	Sample Size	Mean	Sd	Min	Max	25th quantile	median	75th quantile
Total Prescription	616	20.54	10.39	10	75			
Crestor Market Share	616	0.09	0.13	0	0.94	0.07	0.11	0.20
Lipitor Market Share	616	0.43	0.20	0	1.00	0.29	0.42	0.58
Zocor Market Share	616	0.24	0.16	0	0.91	0.14	0.24	0.36
Pravachol Market Share	616	0.13	0.13	0	0.73	0.08	0.14	0.22
Number of Crestor Detailing	616	1.29	1.48	0	11			
Number of Lipitor Detailing	616	0.83	1.12	0	6			
Number of Zocor Detailing	616	0.89	1.15	0	5			
Number of Pravachol Detailing	616	0.58	0.95	0	6			

[1] Market Share=prescription/(total number of prescription in February and March)

Table 3. Summary Statistics of Detailing Change for Each Drug Brand

	February	March	percentage of increase
Lipitor	0.79	0.88	11.98%
Pravachol	0.54	0.62	14.46%
Crestor	1.07	1.51	41.34%
Zocor	0.78	1.01	29.17%
Other	1.08	1.38	28.31%
Total	3.47	4.39	26.47%

Table 4. Difference in Differences Estimates, Changes in Lipitor Detailing After the News Event

								First Dif		Dif-in-Dif	
	[1]	[2]	[3]	[4]	[5]	[6]	[7]=	[8]=	[9]=		
	Before	After	Before	After	Before	After	[2]-[1]	[4]-[3]	[6]-[5]	[7]-[8]	[7]-[9]
Panel 1:	Median Crestor share		Low Crestor share		High Crestor share						
Mean	0.86	0.99	0.76	0.85	0.80	0.76	0.13	0.09	-0.04	0.04	0.18
sd	0.96	1.26	1.06	1.15	0.98	1.23	1.42	1.64	0.94	0.21	0.30
N	69	97	193	169	46	42					
Panel 2:	Median Pravachol share		Low Pravachol share		High Pravachol share						
Mean	0.91	0.88	0.74	0.92	0.68	0.78	-0.03	0.18	0.10	-0.22	-0.13
sd	0.99	1.15	1.05	1.27	1.03	1.12	1.11	1.40	1.41	0.18	0.21
N	107	112	141	141	60	55					

[1] LOW: Low Crestor market share (0-0.07], MEDIAN: median Crestor market share (0.07-0.2), HIGH: high Crestor market share [0.2+). Market share is based on prescriptions in the last 4 weeks.

[2] Before represents week 5-8, the period before the bad news.

[3] After represents week 10-13, the period after the bad news.

Table 5. Difference in Differences Estimates, Changes in Zocor and Pravachol Detailing After the News Event

								First Dif		Dif-in-Dif	
	[1]	[2]	[3]	[4]	[5]	[6]	[7]=	[8]=	[9]=		
	Before	After	Before	After	Before	After	[2]-[1]	[4]-[3]	[6]-[5]	[7]-[8]	[7]-[9]
Panel 1: Outcome variable is the number of Zocor detailings											
	Median Crestor share		Low Crestor share		High Crestor share						
Mean	0.80	0.90	0.80	1.02	0.67	1.19	0.10	0.23	0.52	-0.13	-0.42
sd	1.04	1.01	1.13	1.29	0.82	1.40	1.42	1.64	0.94	0.21	0.30
N	69	97	193	169	46	42					
Panel 2: Outcome variable is the number of Pravachol detailings											
	Median Crestor share		Low Crestor share		High Crestor share						
Mean	0.64	0.76	0.54	0.54	0.39	0.60	0.13	0.00	0.20	0.13	-0.08
sd	1.11	1.19	0.85	0.91	0.68	0.89	1.11	1.40	1.41	0.18	0.21
N	69	97	193	169	46	42					

[1] LOW: Low Crestor market share (0-0.07], MEDIAN: median Crestor market share (0.07-0.2), HIGH: high Crestor market share [0.2+). Market share is based on prescriptions in the last 4 weeks.

[2] Before represents week 5-8, the period before the bad news.

[3] After represents week 10-13, the period after the bad news.

Table 6. Baseline Results for LIPITOR

	Pooling Regression		RANDOM EFFECT		FIXED EFFECT	
	Coef	sd	Coef	sd	Coef	sd
CM	0.08	0.17	0.12	0.03	0.31	0.04
CH	-0.05	0.22	0.02	0.04	0.40	0.05
CM*Postevent	0.07	0.24	0.07	0.03	0.05	0.04
CH*Postevent	-0.13	0.25	-0.13	0.05	-0.11	0.05
Postevent	0.06	0.11	0.06	0.02	0.05	0.02
CONSTANT	-0.20	0.11	-0.22	0.02		
N	616		616		408	

1. CM: median Crestor market share (0.07-0.2), CH: high Crestor market share [0.2+). Market share is based on prescriptions in the last 4 weeks.

Table 7. Results for PROVACHOL and ZOCOR

	Zocor				Pravachol			
	RANDOM EFFECT		FIXED EFFECT		RANDOM EFFECT		FIXED EFFECT	
	Coef	sd	Coef	sd	Coef	sd	Coef	sd
CM	-0.055	0.028	-0.216	0.035	0.310	0.032	0.370	0.041
CH	-0.123	0.037	-0.256	0.053	-0.299	0.045	-0.315	0.064
CM*Postevent	-0.145	0.034	-0.139	0.038	0.016	0.039	-0.089	0.043
CH*Postevent	0.052	0.043	-0.085	0.045	0.359	0.054	0.410	0.057
Postevent	0.231	0.017	0.265	0.017	0.067	0.021	0.087	0.021
CONSTANT	-0.091	0.015			-0.502	0.018		
N	616		400		616		322	

1. CM: median Crestor market share (0.07-0.2), CH: high Crestor market share [0.2+). Market share is based on prescriptions in the last 4 weeks.

Table 8. Results of Lipitor Controlling for Market Characteristics

	Pooling		RANDOM EFFECT		FIXED EFFECT	
	Estimate	SD	Estimate	SD	Estimate	SD
CM	0.03	0.18	0.09	0.03	0.29	0.04
CH	-0.17	0.21	-0.11	0.04	0.48	0.06
CM*Postevent	0.12	0.24	0.08	0.04	0.07	0.04
CH*Postevent	-0.06	0.26	-0.05	0.05	-0.12	0.05
Postevent	0.03	0.11	0.05	0.02	0.07	0.02
MSIZE	0.01	0.01	0.00	0.00	-0.01	0.00
NEWSHARE	1.25	0.54	1.01	0.09	-1.08	0.17
OLDSHARE	-0.11	0.34	-0.09	0.05	-0.01	0.10
ASIANSHARE	0.35	0.98	0.67	0.15	2.19	0.37
FEMALESHARE	0.21	0.36	0.08	0.07	-0.60	0.10
SEVERESHARE	0.55	0.51	0.71	0.10	1.57	0.22
CONSTANT	-0.55	0.29	-0.47	0.04		
Sample size	616		616		408	

1. CM: median Crestor market share (0.07-0.2), CH: high Crestor market share [0.2+). Market share is based on prescriptions in the last 4 weeks.

Figure 1a: Nonparametric estimation of Lipitor detailing level

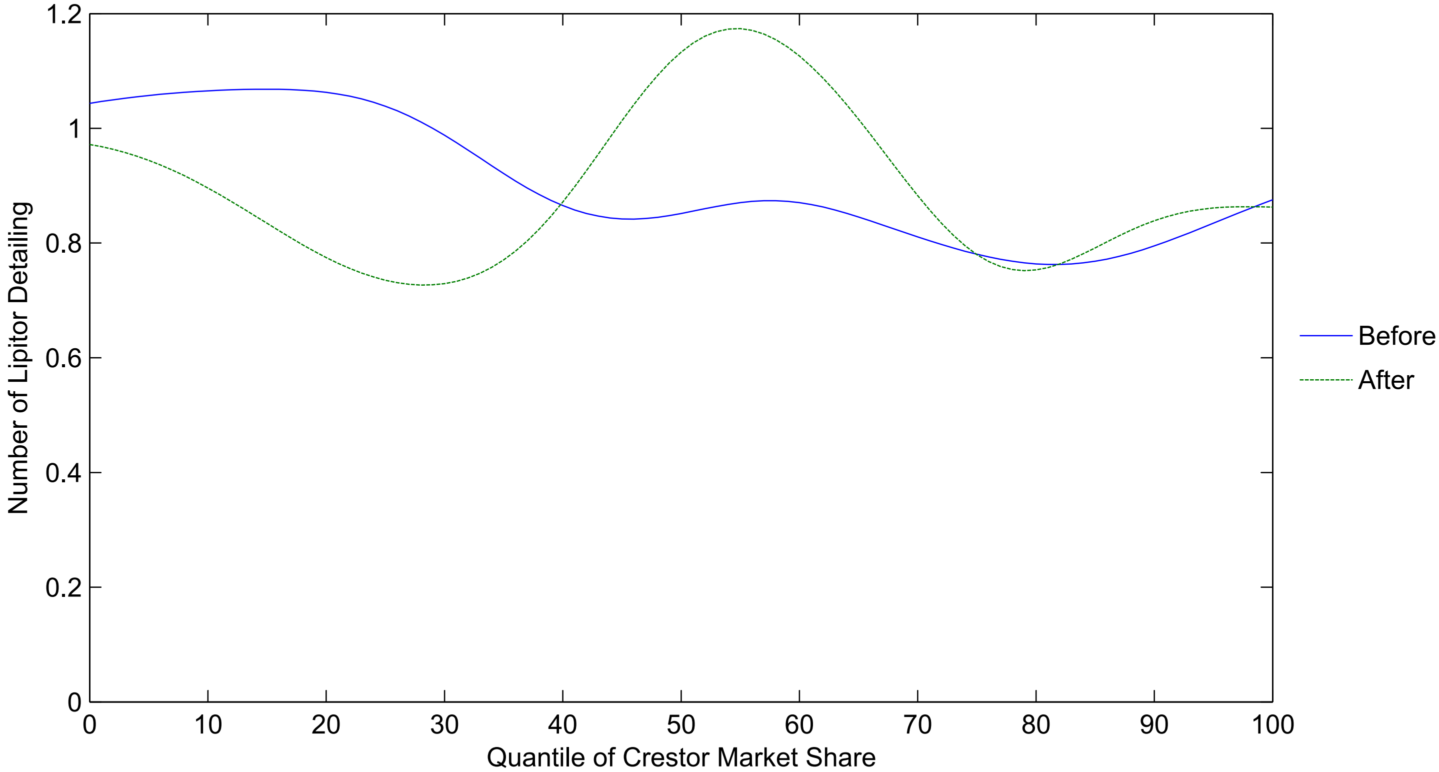

Figure 1b: Nonparametric estimation of Lipitor detailing level

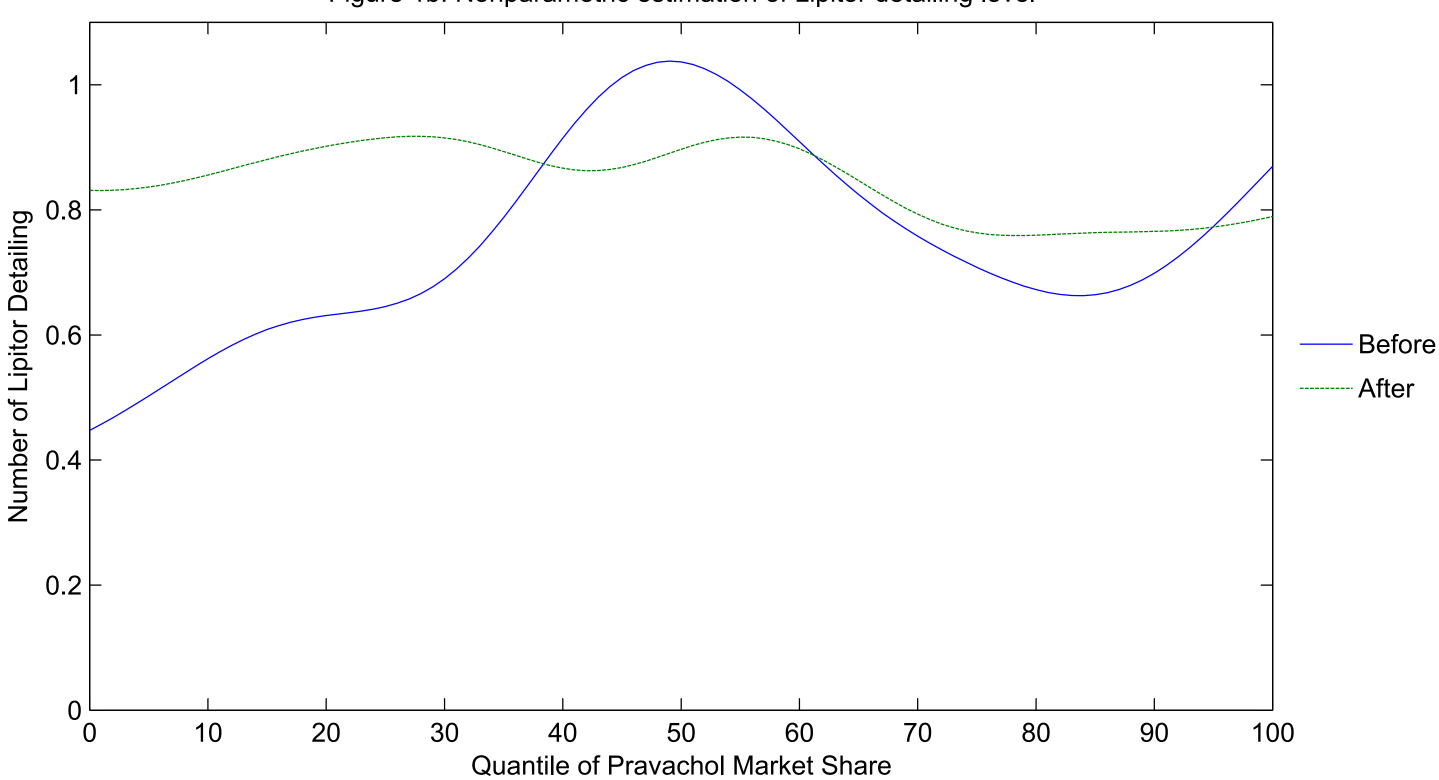

Figure 2a: Nonparametric estimation of Zocor detailing level

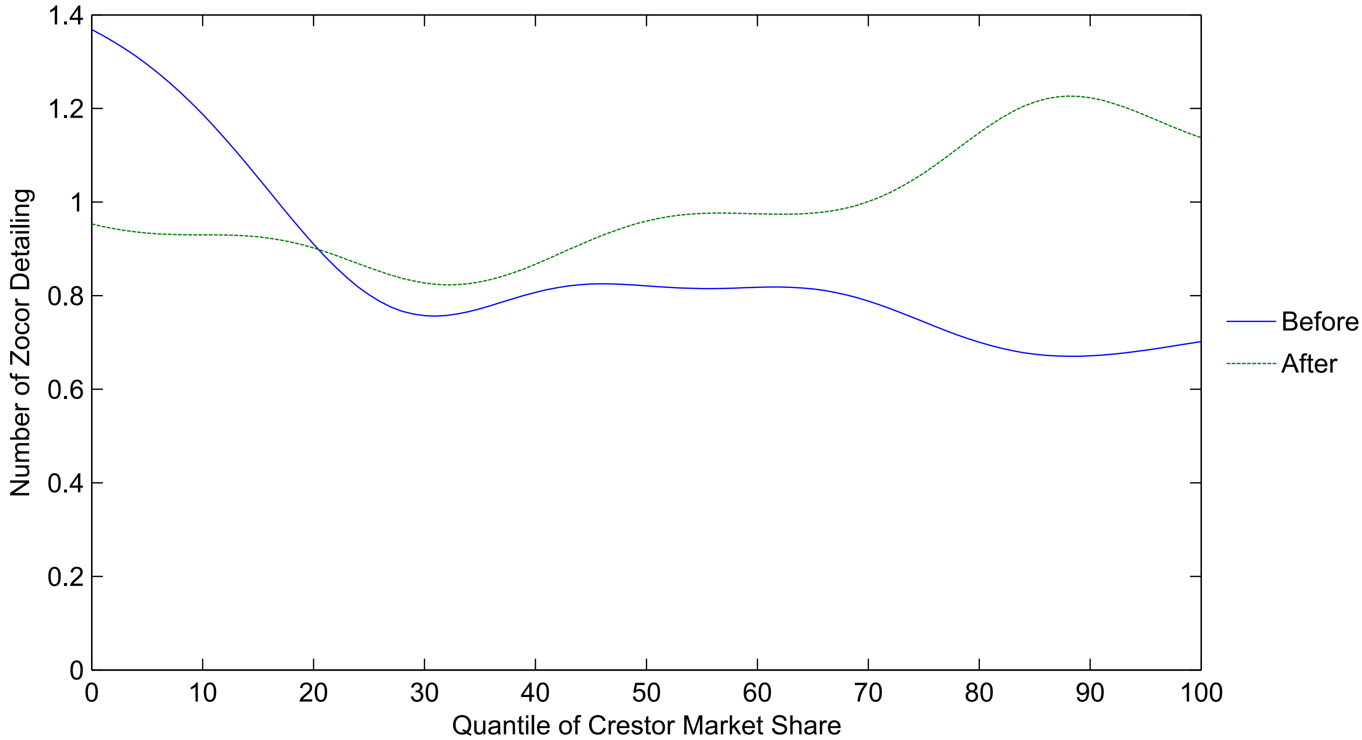

Figure 2b: Nonparametric estimation of Pravachol detailing

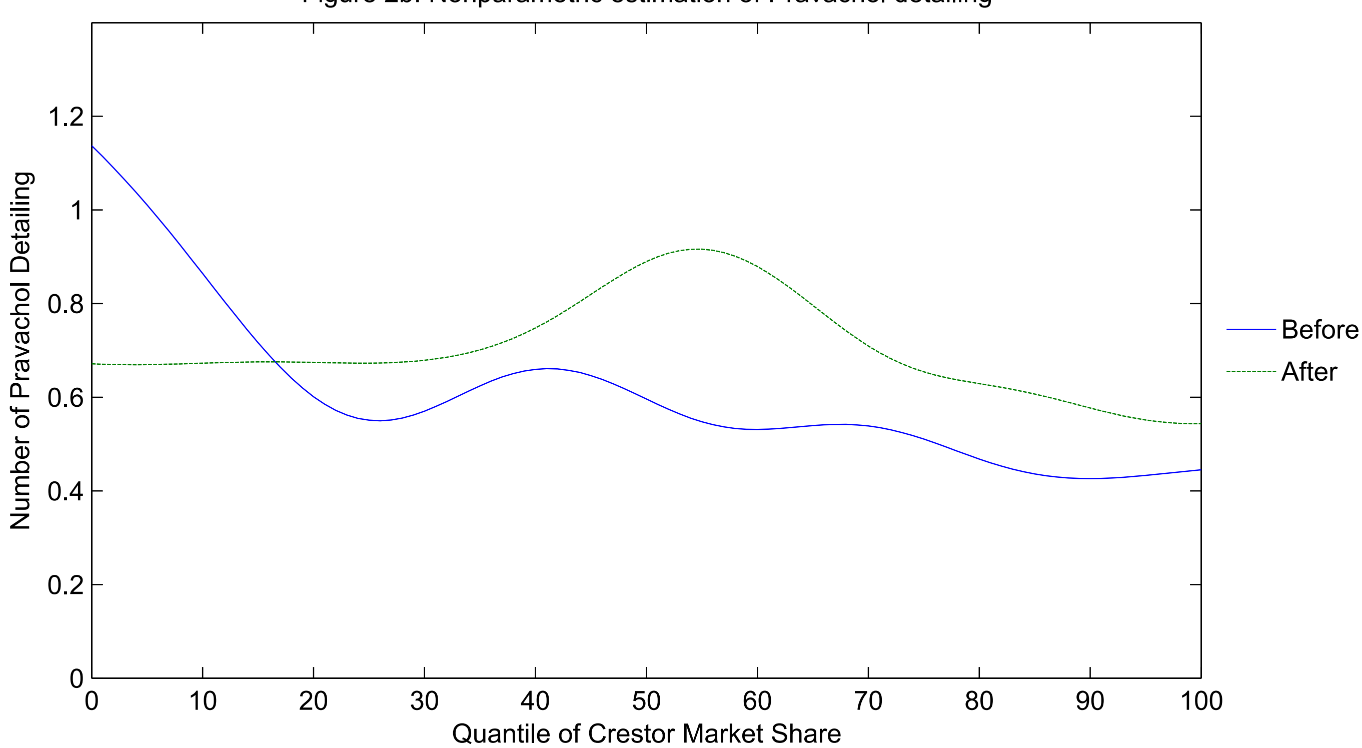

Figure 3: Optimal Advertising Level of Firm 1 in a Separating Equilibrium when the Shock is Severe

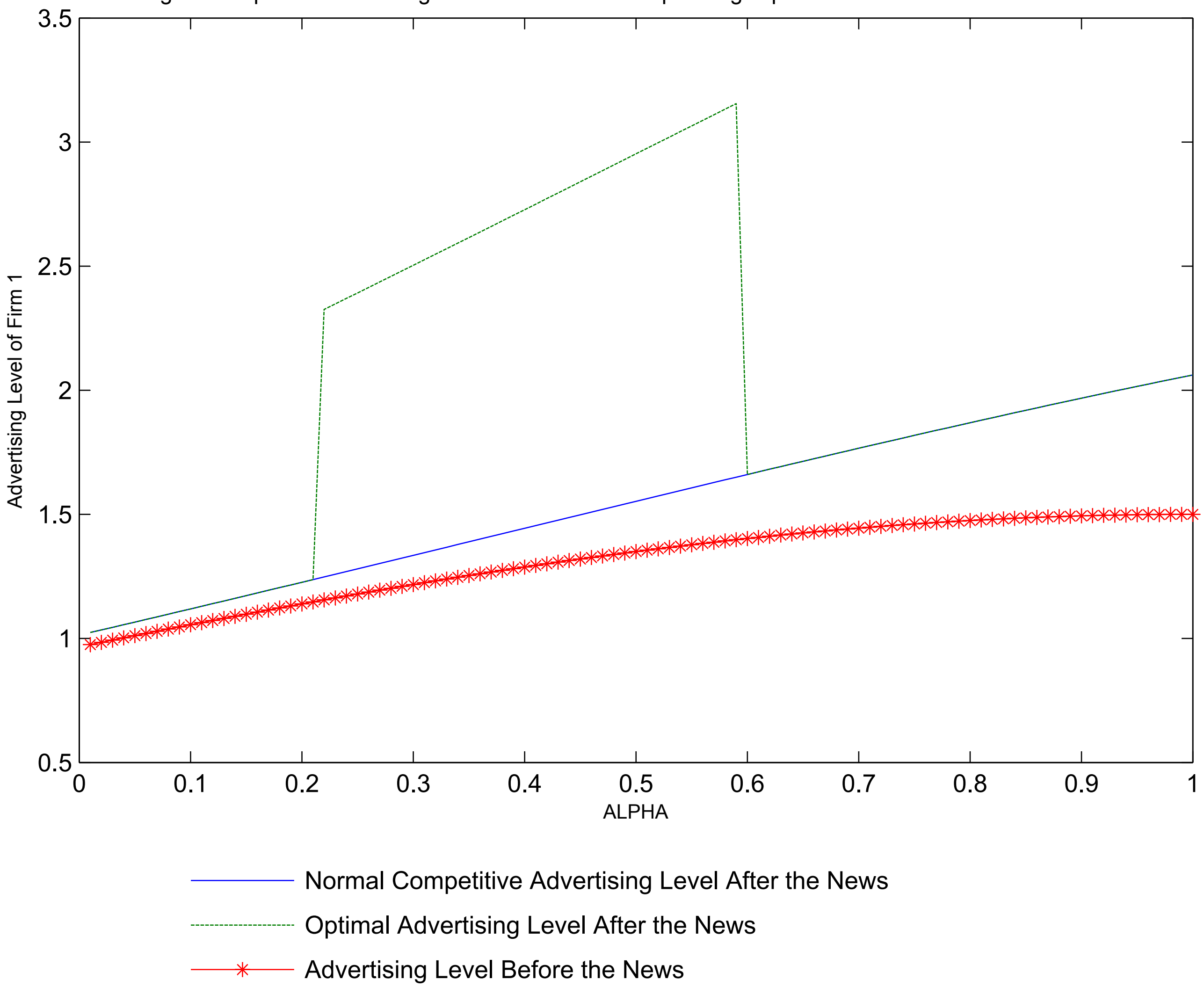

Figure 4: Opitmal Advertising Level of Firm 1 in a Separating Equilibrium when the Shock is Mild

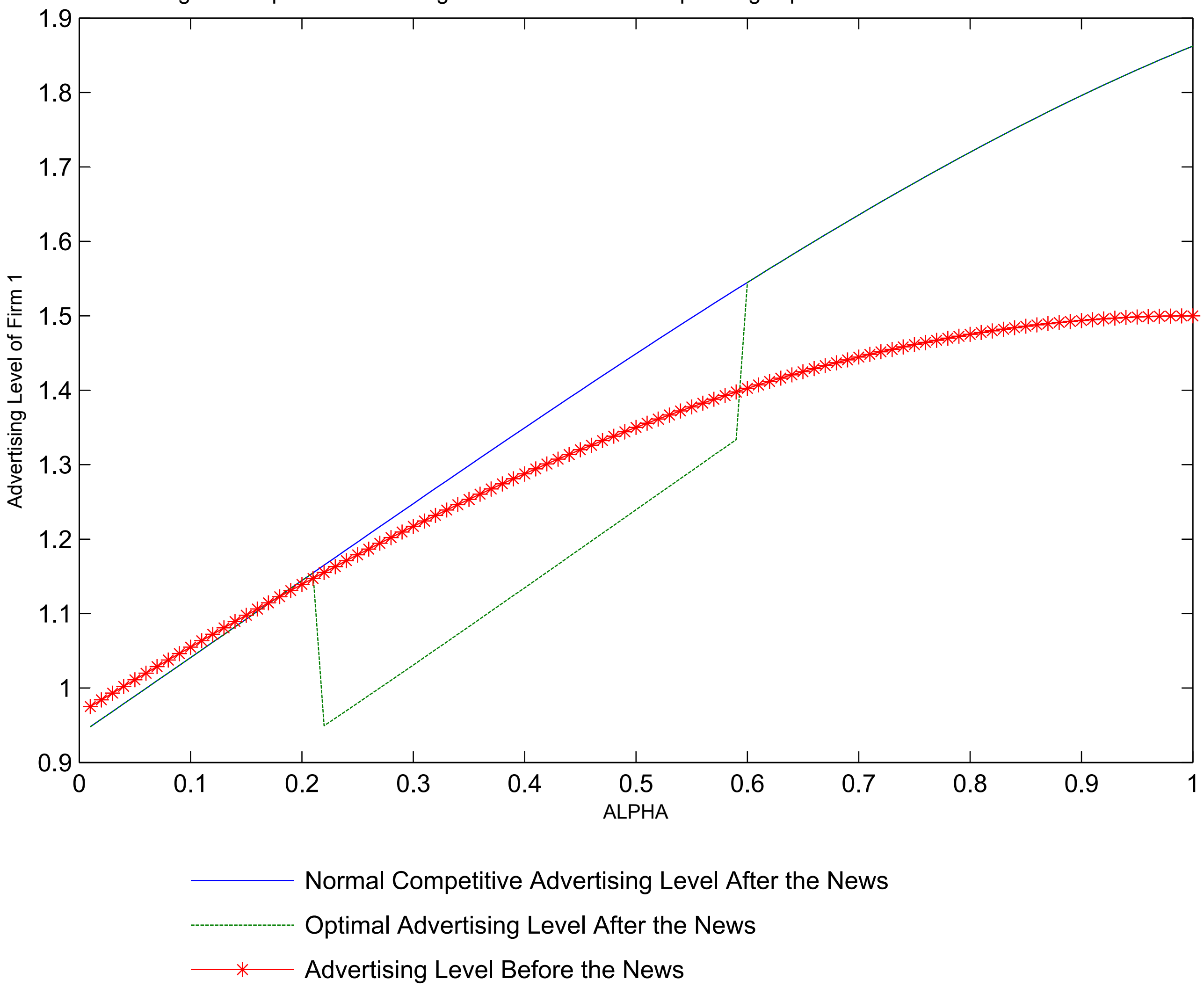

Figure 5: Optimal Advertising of Firm 2 in a Seperating Equilibrium

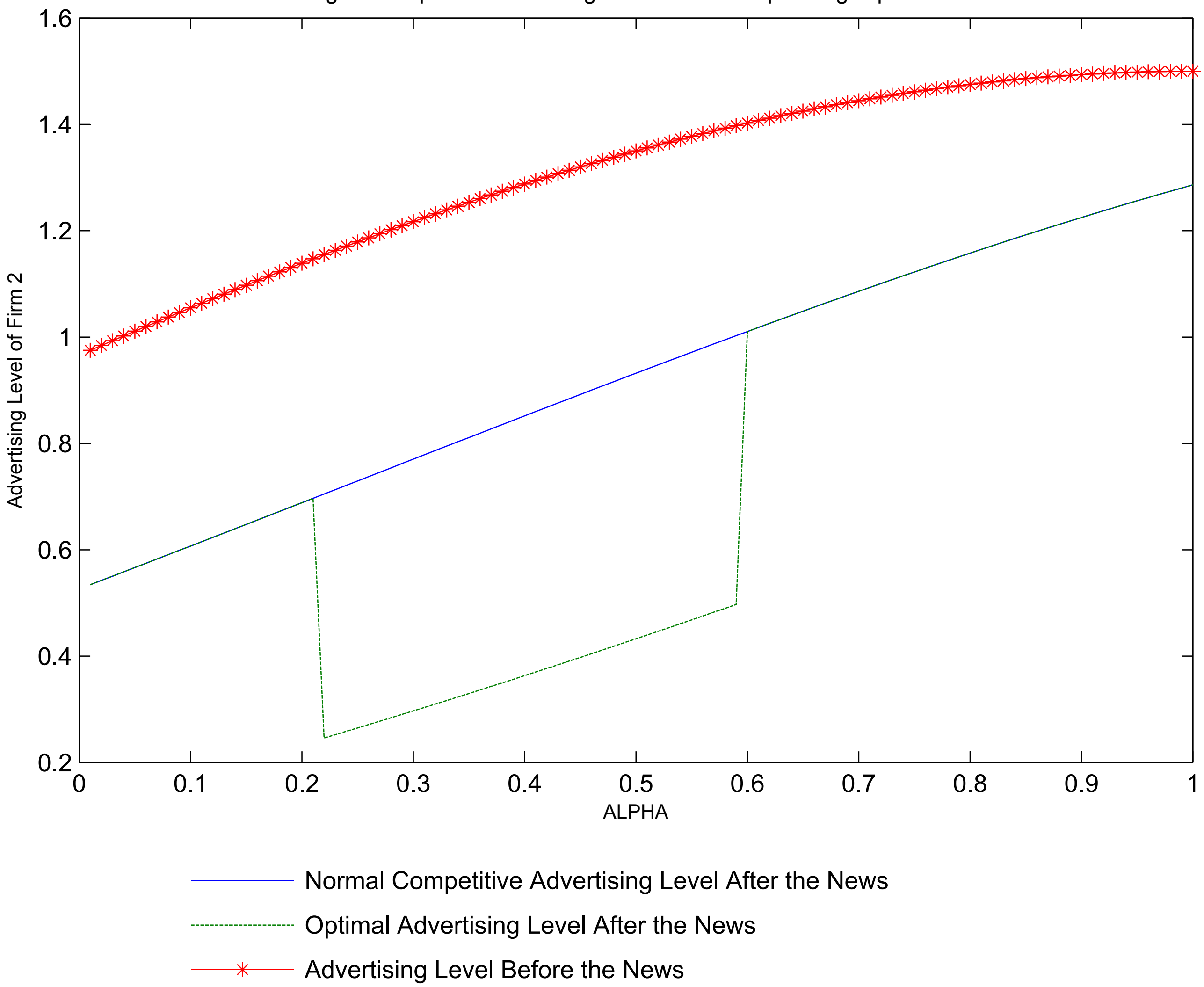

Figure 6: Optimal Advertising Level of Firm 1 in a Pooling Equilibrium when the Shock is Severe

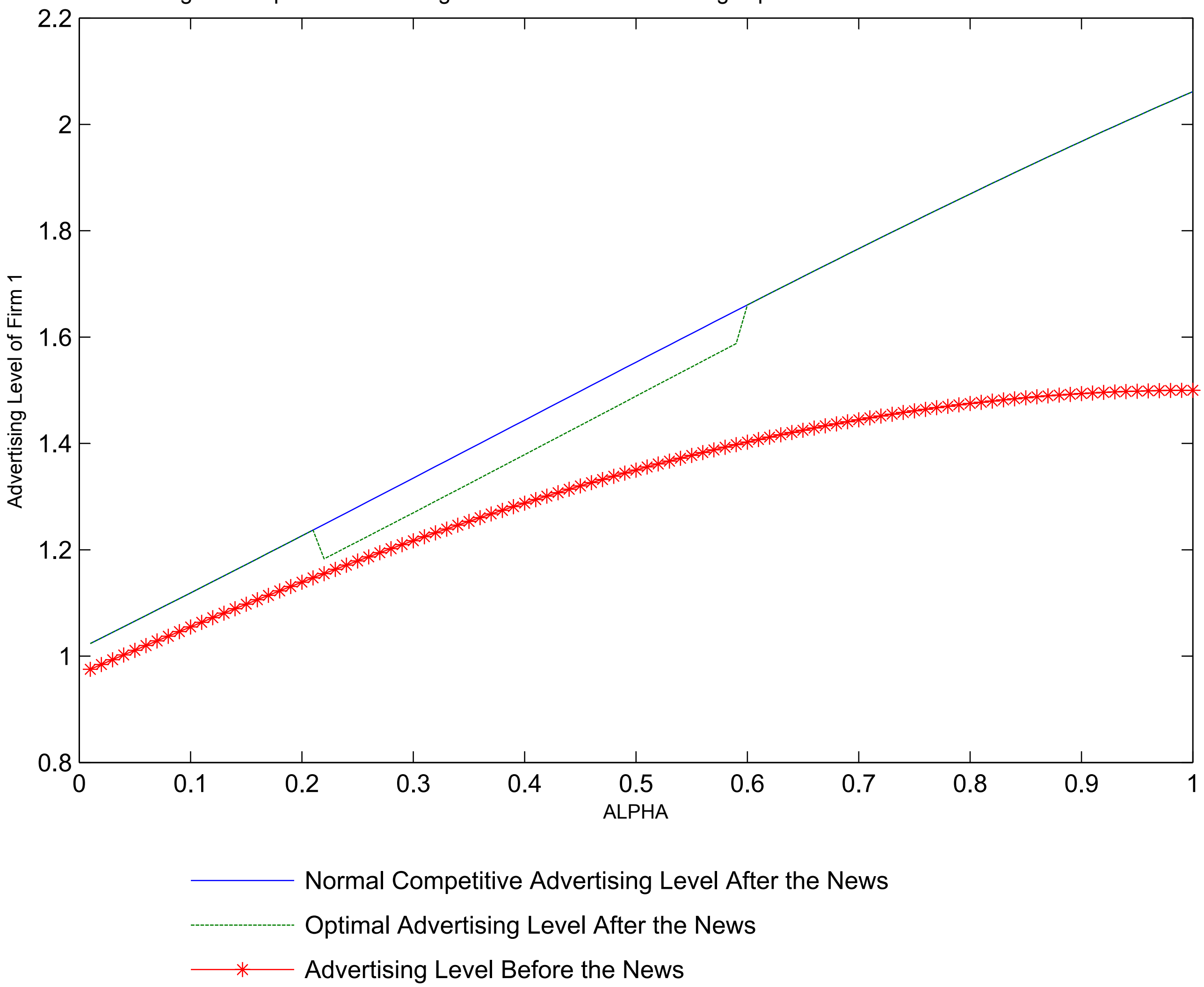

Figure 7: Optimal Advertising Level of Firm 1 in a Pooling Equilibrium when the Shock is Mild

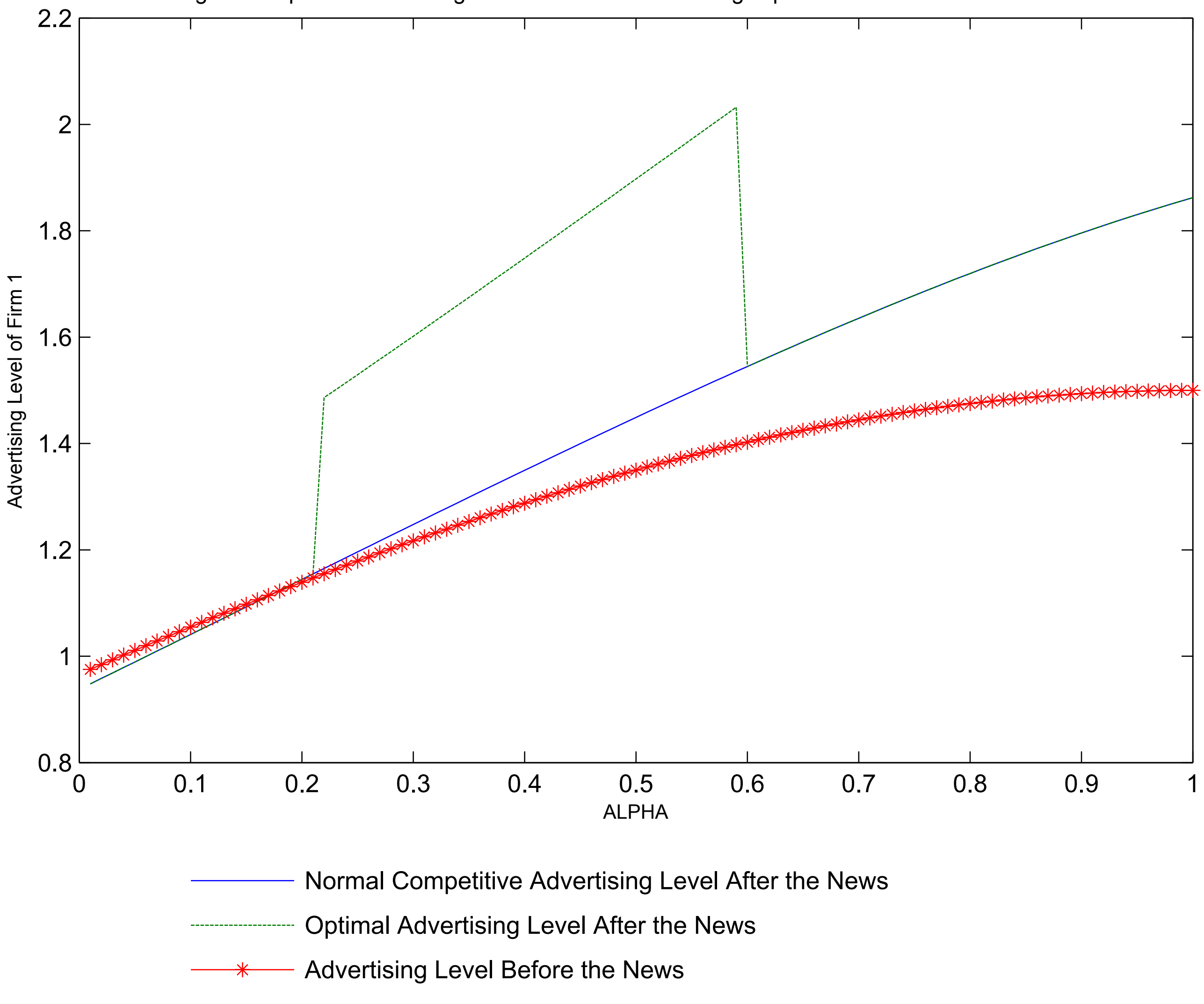

Figure 8: Optimal Advertising Level of Firm 2 in a Pooling Equilibrium