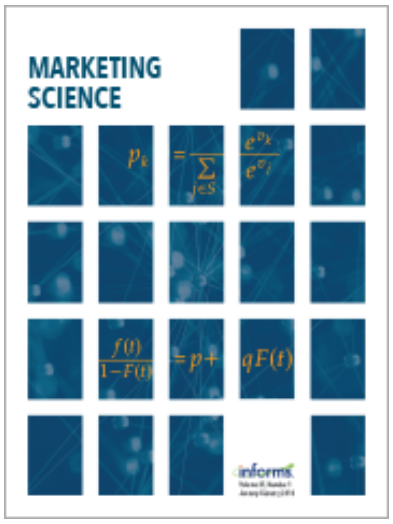

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Pharmaceutical Product Recalls: Category Effects and Competitor Response

Ram Bala,[a] **Pradeep Bhardwaj,**[b] **Pradeep K. Chintagunta**[c]

[a] Leavey School of Business, Santa Clara University, Santa Clara, California 95053; [b] College of Business Administration, University of Central Florida, Orlando, Florida 32816; [c] Booth School of Business, University of Chicago, Chicago, Illinois 60637

Contact: rbala@scu.edu, http://orcid.org/0000-0002-4085-2860 (RB); pradeep.bhardwaj@ucf.edu, http://orcid.org/0000-0002-7253-4912 (PB); pradeep.chintagunta@chicagobooth.edu (PKC)

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Abstract. In the pharmaceutical industry, a product recall financially impacts not only the firm undertaking the recall but also other competitors in the category since it affects physician and consumer perception of the category as a whole. Often, such competitors have to engage in defensive marketing at the category level without complete certainty about whether a recall will occur or not. Such defensive effort could then lead to a change in postrecall sales effort directed at capturing market share in that category. This decision is affected by the probability of the recall and the size of the loyal segment in the category facing the recall, i.e., physicians who will continue to prescribe the category even without marketing effort. We focus on competitor reaction to product recalls where the competitor participates in multiple product categories that exhibit (dis)economies of scope in sales effort across them. Equilibrium analysis of our game-theoretic model uncovers several managerial insights that illustrate the importance of scale (dis)economies on the competitor's promotional strategy in the wake of a recall. First, economies of scope across the two products leads to either an increase or decrease in postrecall sales effort for both products simultaneously depending on the loyal market size for the category. Second, diseconomies of scope can lead to a complete withdrawal of postrecall sales effort from one of the two products depending on the size of the loyal market, the cross-category price, and the recall probability. Third, as the recall probability increases, category-defense effort and postrecall sales effort are unequivocally complementary given economies of scope across the two products but may be substitutes given diseconomies of scope.

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1. Introduction

The recall of prescription drugs from the U.S. market is a relatively frequent phenomenon. More than 75 drugs have been recalled since 1969 (Wysowski and Swartz 2005). The financial impact of a recalled drug can be huge. For example, Appleby and Krantz (2004) estimate that Merck lost nearly $2.5 billion because of the recall of Vioxx. However, the recall of Vioxx had a negative impact that extended beyond Merck. It affected both the physician and the consumer perception of the COX-2 category as a treatment for arthritis because of the potential for adverse cardiovascular effects. Whenever a product recall affects the entire category, the study of competitor reaction with respect to sales effort is particularly important in this industry. Often, such competitors have to engage in defensive marketing at the category level without complete certainty about whether a recall will occur or not. This could then lead to a change in postrecall sales effort directed at capturing market share. This investment in postrecall sales effort is affected by the fact that the competitor may participate in multiple product categories that exhibit (dis)economies of scope in sales effort across them. This (dis)economies of scope arises because primary care physicians (PCPs) routinely prescribe drugs across multiple categories and hence a sales rep could talk about multiple categories with the same physician. The goal of our paper is to highlight the impact of such (dis)economies of scope on the competitor's category-defense and postrecall sales effort. In particular, we pose and answer the following research questions: What are the fundamental drivers of the competitor's postrecall sales effort? What is the relationship between category-defense effort and postrecall sales effort? Are they substitutes or complements? How does (dis)economies of scope affect the competitor's promotional strategy (both category-defense and postrecall effort) in the wake of the recall?

As a starting point, we examined historical data on competitor reaction to recalls and the current state of

sales and marketing in the pharmaceutical industry. This led us to several observations:

• We used the *New Product Spectra* database version 5.1 from *IMS Health* and articles from the pharmaceutical trade publication *The Pink Sheet* to examine competitor reaction to recalls and discovered that competitors have typically increased postrecall sales effort. A detailed description of our approach is described in the online appendix.

• The historical approach of increasing postrecall sales effort is under increasing pressure from current market conditions in the pharmaceutical industry. In recent times, there appears to be an increased emphasis on cost reduction through sales force efficiency (Rockoff 2013). Such an emphasis on sales force efficiency implies that firms have to do a better job of managing the use of their sales resource over their entire product portfolio. Our conversations with managers at prominent pharmaceutical sales and marketing firms such as ZS Associates, IMS Health, and Merkle reveal that pharmaceutical firms are being forced to reexamine their recall-related marketing strategy given the competing resource demands of multiple categories.

• Pharmaceutical firms have newer tools at their disposal to differentiate their own brand from a recalled drug within the same category. They can not only approach physicians via detailing to defend the category but also reach out to end consumers through direct-to-consumer advertising to alleviate any concerns they might have. In fact, Pfizer adopted this multipronged approach in their marketing strategy for Celebrex in the context of the Vioxx recall.[1] This introduces new challenges to the sales effort decision.

We incorporate these facts in a formal analysis of the strategic interactions of rival firms in their choice of sales and category-defense effort. A game-theoretic approach is a necessary path toward understanding such strategic interaction. We analyze the equilibrium outcome of a game-theoretic model involving three firms: a focal firm that has to respond to another firm's product recall while competing with a third firm in another product category. In the online appendix, we study a market with two homogeneous firms competing in two categories and one of the products is recalled. Our primary results remain unchanged as a consequence of this change. In our main model, we allow for the focal firm to invest in a category-defense marketing effort prior to the recall but after a "black box" warning has been issued by the Food & Drug Administration (FDA). Anticipation of product recall is common in the pharmaceutical industry because of the frequent issue of "black box warnings" by the FDA for drugs under scrutiny. A majority of the drugs that were recalled were subject to a black box warning prior to the recall.[2] This public revelation of information about a competing drug's risks results in an anticipated recall probability by the focal firm for the drug under scrutiny. Thus, the firm has to make the category-defense marketing decision with uncertainty about the actual occurrence of the recall. We incorporate the focal firm's anticipation of the recall in the form of a probability parameter that then affects the effort decision before and after the recall.

Equilibrium analysis of our game-theoretic model uncovers several managerial insights that illustrate the importance of scale (dis)economies on the competitor's promotional strategy in the wake of a recall. First, economies of scope across the two products leads to either an increase or decrease in postrecall sales effort for both products simultaneously depending on the loyal market size for the category. Second, diseconomies of scope can lead to a complete withdrawal of postrecall sales effort from one of the two products depending on the size of the loyal market, the cross-category price and the recall probability. Third, as the recall probability increases, category-defense effort and postrecall sales effort are unequivocally complementary given the economies of scope across the two products but may be substitutes given diseconomies of scope.

The rest of the paper is structured as follows. Section 2 discusses the related literature. Section 3 sets up the two-stage game-theoretic model and computes the unique subgame perfect equilibrium. Section 4 elaborates on the key results of the equilibrium and uncovers managerial insights. Proofs of all propositions are in the appendix. Finally, Section 5 concludes with a discussion of the main themes of the paper and provides directions for future research.

2. Related Literature

Several streams of literature are important to our work. Product recalls are common in many industries such as food, cosmetics, medical devices, and pharmaceuticals. Past research has evaluated the impact of such recalls both on the firm that recalls the product as well as the overall product category. Several papers examine the impact of product recalls on financial valuation: Hartman (1987), Davidson and Worrell (1992), Chen et al. (2009b), and Thirumalai and Sinha (2011). Kalaignanam et al. (2013) evaluate the impact of product recalls on learning and the consequent impact on future product failures. In this paper, we focus on the category level sales impact of product recalls. Marsh et al. (2004) find that meat product recalls affect not only the firms producing the specific meat type but also result in a shift out of meat to nonmeat products. Cleeren et al. (2013) analyze 60 fast-moving consumer good product recalls and find spillover effects to nonaffected competitors in the category when they are perceived to be guilty by association. Furthermore, they find that, for competitors, increasing their advertising might be a double-edged sword because consumers

may view such a strategy of "chasing ambulances" as being overly opportunistic. Freedman et al. (2012) investigate recalls in the toy industry and find large industrywide spillovers in the form of sales losses to manufacturers that did not experience any recalls. Roehm and Tybout (2006) conduct three experiments that identify conditions under which a brand scandal spills over and negatively affects attitudes and beliefs about the product category. They find that if a scandal pertains to a typical brand in a category, the entire category is affected. Furthermore, direct competitors are often affected because of the frequent juxtaposition of brands during the purchase process. However, they find that if consumers are primed to think about differentiation among brands, the category level spillover can be minimized. This study has several implications for the prescription pharmaceutical industry context. Often, there is a strong association between a particular brand and its category such as Vioxx and the COX-2 inhibitor category. However, competitors such as Pfizer (with the competing drug Celebrex) have the opportunity to provide information about how issues with the recalled drug do not translate to the category as a whole. This information can be delivered to physicians during a detailing call as well as patients through direct-to-consumer advertising (DTCA). This allows the firm a chance to ameliorate category level loss. We incorporate the category-defense investment decision in our game-theoretic model to evaluate conditions where the competitor might increase or decrease postrecall sales effort. Pharmaceutical drug recalls have received significant attention in the literature. Wysowski and Swartz (2005) use the FDA's database on drug recalls from 1969 to 2002 and investigate these recalls from a medical and demographic perspective. Cawley and Rizzo (2008) study the recalls of seven drugs from six therapeutic classes between 1997 and 2001 and find that competing drugs in the same class enjoyed competitive benefits in the form of higher sales after recall. Collins et al. (2013) find the reverse to be true for the COX-2 inhibitor class after the recall of Vioxx. Neither of these papers addresses the issue of eventual sales being a function of competitor marketing effort response that can counteract the negative category impact, a gap we hope to fill with our work.

Our primary contribution in this paper relates to the reaction of a competitor to a possible (uncertain) product recall through investment in category-defense marketing effort and the adjustment of its postrecall sales effort. The notion that a firm anticipates a competitor's product-related event and responds by changing its marketing variables was first addressed by Hauser and Shugan (1983) in their work on "defensive marketing." They analyze incumbent response in the context of new product introduction by the competition. This topic has been further studied by Shankar (1997 and 1999). We reverse this problem by studying incumbent response to product recall by a competitor. However, we find that the directionality of results does not automatically reverse when compared with these papers. This is because we incorporate two facts not studied by the literature: the ability of the focal firm to invest in category-defense marketing effort and the fact that the focal firm may operate in multiple product categories, not all of which are affected by the product recall. This issue is of particular relevance in the pharmaceutical industry where investment in category-defense marketing and the sharing of sales resources is a common occurrence. Dong et al. (2011) show that ignoring cross-category prescription behavior may lead to incorrect inferences regarding physician segmentation. In addition, we model competition in the cross-category, i.e., the category in which there has not been a product recall, and the impact that may have on the eventual postrecall sales effort allocation. To our knowledge, we are the first to address this issue in the literature.

3. The Model

We begin with a description of the sequence of decisions in the competitive game.

3.1. Game Sequence

We study the actions of a focal firm F that participates in two drug categories (W and B). When there is no recall in either of the two categories, we assume duopoly competition in each category. Furthermore, we assume that the competitor of firm F in each category is different. Thus, there are three firms in our analysis such that one firm (firm F) is common to both markets and each market presents a case of duopolistic competition.[3] For analytical tractability without compromising on basic insights, we assume that each category has exactly one competitor. When we study the effects of a product recall, we will assume that the competitor of focal firm F in product category W will recall its product. This competitive structure fits many examples in the pharmaceutical industry. We present two examples:

- Pfizer sells Celebrex (a nonsteroidal anti-inflammatory drug, NSAID) and Lipitor (a cholesterol-reducing drug). Prior to the recall of Vioxx, its competitor in the first category was Vioxx by Merck and the primary competitor of Lipitor is Crestor by AstraZeneca.[4]
- Sanofi-Aventis markets Ambien, a sleep disorder medication, and Anzemet, an antinauseant and antiemetic agent. Its competitor in the first category was Palladone by Purdue Pharma (now recalled) and the primary competitor of Anzemet is Zofran by GlaxoSmithKline.

Anticipation of product recall is common in the pharmaceutical industry because of the frequent issue of "black box warnings" by the FDA for drugs under scrutiny. A majority of the drugs that were recalled

were subject to a black box warning prior to the recall. This public revelation of information about a competing drug's risks results in anticipated recall probability r by the focal firm for the drug under scrutiny. Admittedly, the firm whose drug is under scrutiny would have a better estimate for this probability, but in our model this does not affect any sales and marketing effort decision before the product recall occurs. The focal firm has the ability to invest in a category-defense effort that is used to provide information about how issues with the recalled drug do not translate to the category as a whole. This could be focused on either physicians (detailing) or patients (DTCA) and we model the cumulative effort involved irrespective of the promotional channel used. This effort occurs before product recall with knowledge of the probability of recall r. This investment in category-defense effort is Stage 1 of the game. Having invested in this effort, uncertainty related to product recall is resolved and all remaining firms make sales effort decisions (Stage 2 of the game). When the product is recalled, sales effort decisions have to be made with respect to three products, two of which are offered by the focal firm and the third is offered by the competitor in the category B. These sales effort decisions have to account for the new market size in category W, which is a combination of the negative category response resulting from the recall and the focal-firm's category-defense effort that stems this decline. The full sequence of decisions is captured in Figure 1.

3.2. Second Stage Variables, Parameters, and Market Share Equations

We set up the variables and parameters of the second stage of the game. The primary variables are sales effort variables for all firms in the market. In our model, this sales effort is directed toward physicians who can prescribe one of the two competing products in each category to end consumers or patients. Although other forms of sales effort can be used, this restriction is appropriate given our pharmaceutical industry motivation. These sales effort variables are described in Table 1.

In the examples discussed in Section 3.1 (focal firms: Pfizer, Sanofi-Aventis), PCPs constitute the major percentage of physicians prescribing products across both categories. This implies that a sales rep could talk about both product categories with the same physician. Our model and analysis is most suitable for such product categories where physicians overlap. Consequently, in all further analysis, we restrict attention to a sales rep promoting both categories to the same physician potentially spending a different amount of time on each category. This difference in time is captured by the primary or secondary position of the product in a detailing call as described below.

Each sales effort variable represents the number of primary sales calls with respect to a particular product. For example, α_W is the number of primary sales calls made by the "competitor in category W" for its product in this category. We label these as "primary calls" because in the case of a multiproduct sales rep, this primary call can be used to deliver information about a second product (referred to as "secondary detail" in the pharmaceutical industry). In our model, only the focal firm has two products. Thus, in each of the primary calls α_{FW} made by the focal firm F for its product in category W, a secondary detail is delivered for its product in category B. Similarly, in each of the primary calls α_{FB}, made by the focal firm F for its product in category B, a secondary detail is delivered for its product in category W. The fact that each sales rep delivers primary calls for two different products to the same

Figure 1. Product Recall Game Sequence

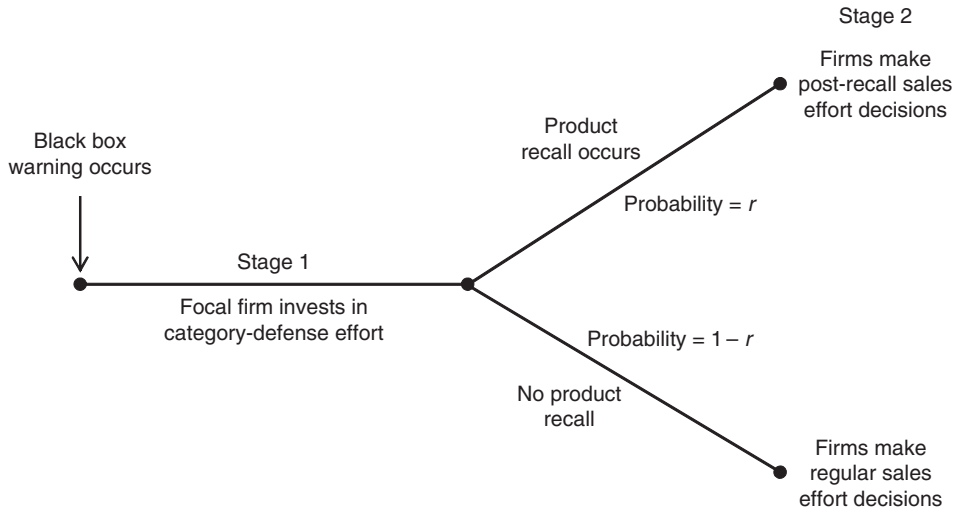

Table 1. List of Sales Effort Variables

Sales effort variable	Firm
α_W	Competitor in category W
α_B	Competitor in category B
α_{FW}	Focal firm in category W
α_{FB}	Focal firm in category B

Table 2. List of Effective Sales Effort Variables

Effective sales effort variable	Firm
α_W	Competitor in category W
α_B	Competitor in category B
$\alpha_{FW} + \rho \cdot \alpha_{FB}$	Focal firm in category W
$\alpha_{FB} + \rho \cdot \alpha_{FW}$	Focal firm in category B

physician and each primary call contains information about the other product affects outcomes in the following ways:

- For the same fixed cost incurred in arranging primary calls for a particular product, the sales rep is able to cross-sell another product that is of interest to the physician. This is an "economies of scope" effect and has a positive impact on the market share of the product in the other category that is proportional to the number of calls delivered for the primary product.
- Since the same sales rep delivers calls for both products to the same physician, the physician experiences confusion and fatigue as widely documented in the marketing and economics literature (Kuksov and Villas-Boas 2010, Kamenica 2008, Bordalo et al. 2016). A consequence of this is that the primary calls delivered for a product have a negative effect on the market share of the product in the other category.

We have listed two effects, one positive and the other negative, resulting from a sales rep promoting two products to the same physician. The net effect could be either positive (economies of scope) or negative (diseconomies of scope) and is captured by the parameter ρ, which lies in the range $(-1, 1)$. The parameter is applied symmetrically to both products (Rao and Turner 1984) such that the following expressions occur for effective sales effort for a multiproduct firm:

$$\begin{aligned}&\text{Product 1 effective sales effort}\\&\quad = \text{Product 1 actual sales effort}\\&\qquad + \rho \cdot \text{Product 2 actual sales effort},\\&\text{Product 2 effective sales effort}\\&\quad = \text{Product 2 actual sales effort}\\&\qquad + \rho \cdot \text{Product 1 actual sales effort}.\end{aligned}$$

Thus, the sales effort variables can be transformed to "effective" sales effort variables. This change materially affects only the sales effort variables of the focal firm since it is the only firm in this mix selling two products. These effective sales effort variables are described in Table 2.

We elaborate on the sales effort cost function. The cost to a firm of delivering α sales calls for a product is a convex, increasing function of α. In particular, we model this as a quadratic function. We use c as an overall scalar for the entire cost function for all firms. Thus the cost to a firm for delivering α calls in a particular category is $c \cdot \alpha^2$.

We address the issue of price in each category. In pharmaceutical markets, price setting is a result of many complex factors such as characteristics of the drug, prevalent health care policy, and managed care issues. Price competition in pharmaceutical markets usually happens when firms want their drugs to be included in the formulary of various health insurance companies. The latter want the payments for the insured patients' treatments to be minimized. Consequently, price competition in the physician's office occurs only when at least one of the competing products is a generic. In each of the product categories that we consider, we restrict our attention to competition between two patented products produced by different pharmaceutical firms but used for the same indication. Hence, we assume that the market share outcome in the physician's office is inelastic in price for all further analysis. Consequently, we represent price in each category as common to both firms and its magnitude is indicative of the nature of managed care agreements in each category. Setting different prices across the two categories allows us to determine outcomes as a function of variation in category characteristics, which then adds to managerial insight. We normalize the price in category W to 1 and denote the price in category B as p. Henceforth, we use the term *cross-category* for category B and *cross-category price* for price p. In our context, cross-category refers to the category that is not affected by the recall (category B) and this definition holds throughout the paper. The parameter p could be ⟨or⟩ 1 (the price in category W). Next, we determine the market share of each firm.

The market share of each firm is determined as follows. If firms 1 and 2 compete in a particular product category, then the market shares are given by the following:

$$\begin{aligned}&\text{Firm 1 Market Share} = \tfrac{1}{2} + \tfrac{1}{2}(\text{Firm 1 Effective sales effort}\\&\qquad - \text{Firm 2 Effective sales effort}),\\&\text{Firm 2 Market Share} = \tfrac{1}{2} + \tfrac{1}{2}(\text{Firm 2 Effective sales effort}\\&\qquad - \text{Firm 1 Effective sales effort}).\end{aligned} \tag{1}$$

If, on the other hand, a firm is a monopoly in a product category, its market share is given by the following:

$$\begin{aligned}&\text{Market Share of Monopoly Firm}\\&\quad = \tfrac{1}{2} + \text{Effective sales effort of monopoly firm}.\end{aligned} \tag{2}$$

This structure of expressions can be shown to emerge from a micromodel where patients are distributed uniformly with respect to their "fit" with respect to the two available drugs in the market. A higher sales effort increases the perceived quality of the product from the physician's viewpoint without affecting fit. The physician's objective is to maximize patient welfare. A similar setup in a pharmaceutical context is used by Bala and Bhardwaj (2010) and Bala et al. (2013) and we describe this formulation in the online appendix. The above expressions for market share do not make any assumptions about the overall size of the market. The original market size for both categories is normalized to one. A decrease in the overall market for the category as a consequence of a recall is captured by a category loss parameter described later. The expressions only capture competing firms in the same category and do not include potential substitutes outside the category. Such substitutes are accounted for by the category loss parameter.[5]

3.3. Stage 2: Sales Effort Decisions

As is usual practice, we use backward induction and analyze Stage 2 decisions under the two potential scenarios. We study the "no product recall" scenario first.

3.3.1. No Recall Scenario. Based on the setup described above, the profit functions for this scenario are

$$\pi_{WNR} = \left(\frac{1}{2} + \frac{\alpha_W - \alpha_{FW} - \rho\alpha_{FB}}{2}\right) - c\cdot\alpha_W^2, \tag{3}$$

$$\pi_{FNR} = \left(\frac{1}{2} + \frac{\alpha_{FW} + \rho\alpha_{FB} - \alpha_W}{2}\right) + p\cdot\left(\frac{1}{2} + \frac{\alpha_{FB} + \rho\alpha_{FW} - \alpha_B}{2}\right) - c\cdot\alpha_{FW}^2 - c\cdot\alpha_{FB}^2, \tag{4}$$

$$\pi_{BNR} = p\cdot\left(\frac{1}{2} + \frac{\alpha_B - \alpha_{FB} - \rho\alpha_{FW}}{2}\right) - c\cdot\alpha_B^2. \tag{5}$$

In the above equations, π_F is the profit function of the focal firm and includes products from both categories. The profit function of the competitor in category W is π_{WNR}, whereas π_{BNR} is the corresponding function for the competitor in category B. The focal firm maximizes π_{FNR} by setting α_{FW} and α_{FB}. The competitor in category W maximizes π_W by setting α_W. The competitor in category B maximizes π_B by setting α_B. As mentioned earlier, the potential market size for both categories is normalized to one. This second stage of the game has a unique equilibrium in sales effort levels as given by

$$\alpha_{FW}^* = \frac{1 + p\cdot\rho}{4c}, \tag{6}$$

$$\alpha_{FB}^* = \frac{p + \rho}{4c}, \tag{7}$$

$$\alpha_W^* = \frac{1}{4c}, \tag{8}$$

$$\alpha_B^* = \frac{p}{4c}. \tag{9}$$

As described earlier, we need to ensure that the effective sales effort levels are between 0 and 1. After deriving the equilibrium sales effort levels for the recall scenario, we will derive a common set of conditions across the two scenarios that will ensure that the sales effort levels meet the boundary conditions. We study the recall scenario next.

3.3.2. Recall Scenario. If the product recall occurs, then the competitor of the focal firm in category W does not have to exert sales effort for its product since its product has been recalled. This implies that $\alpha_W = 0$ and the resulting sales effort cost is also zero. We use $m(x) \le 1$ as the market size for category W after recall. As discussed in Section 1, a product recall affects physician and consumer perception of the category as a whole leading to a shrinkage in the market. Often, competitors have to engage in defensive marketing at the category level to stem this shrinkage prior to the actual recall without complete certainty about whether a recall will occur or not. We label this category-defense effort as x, and $m(x)$ is the effective market size as a consequence of this effort. Since x is exerted prior to the recall, $m(x)$ is a parameter in the second stage problem and will be solved for in the first stage given possible second stage outcomes. We assume that the price in category W does not change after the recall. A price change may happen in practice but would require another parameter in the second period that does not add to the insights. We omit such a parameter in the interest of analytical simplicity. We can now put together the profit function for each of the two firms in this scenario

$$\pi_{FR} = \left(\frac{1}{2} + \alpha_{FW} + \rho\alpha_{FB}\right)\cdot m(x) + p\cdot\left(\frac{1}{2} + \frac{\alpha_{FB} + \rho\alpha_{FW} - \alpha_B}{2}\right) - c\cdot\alpha_{FW}^2 - c\cdot\alpha_{FB}^2, \tag{10}$$

$$\pi_{BR} = p\cdot\left(\frac{1}{2} + \frac{\alpha_B - \alpha_{FB} - \rho\alpha_{FW}}{2}\right) - c\cdot\alpha_B^2. \tag{11}$$

The descriptions for profit functions and firm objectives are the same as described in Section 3.3.1 related to "no recall" profit functions. The primary difference is the absence of a profit function for the competing firm in category W given that its product is recalled, as well as an adjustment of this product category's market size to $m(x) \le 1$. The focal firm is now a monopolist in category W. As before, the focal firm maximizes π_F by setting α_{FW} and α_{FB}. The competitor in category B maximizes π_B by setting α_B. This second stage of the game has a unique equilibrium in sales effort levels as given by

$$\alpha_{FW}^* = \frac{2m(x) + p\cdot\rho}{4c}, \tag{12}$$

$$\alpha^*_{FB} = \frac{p+2m(x)\cdot\rho}{4c}, \tag{13}$$

$$\alpha^*_{B} = \frac{p}{4c}. \tag{14}$$

As in the recall scenario, we need to ensure that the effective sales effort levels obey boundary conditions. We find that the following condition ensures that all upper bounds are obeyed across the no recall and recall scenarios:

$$c > p+2.$$

When $\rho<0$, the possibility of sales effort levels below zero arises. We benchmark our results such that for $\rho<0$, equilibrium second stage effort levels in the no recall case are always strictly positive. This requires the following condition:

$$\rho > \max\left\{-p, -\frac{1}{p}\right\}.$$

Given this benchmark, we can then evaluate the possibility that postrecall sales effort levels might hit zero given the investment in category-defense effort prior to uncertainty resolution. We solve the Stage 1 game in Section 3.4.

3.4. Stage 1: Category-Defense Effort Decision for the Focal Firm

The new market size $m(x)$ consists of two components: a loyal set of physicians (and hence patients; denoted by ϕ) that is preserved without having to exert any sales effort and a set of switchers $1-\phi$ that could be prevented from leaving with the right amount of marketing effort. We illustrate our conceptualization of "loyal" versus "switcher" segments using an example. When Merck recalled Vioxx, Pfizer's products in the COX-2 category (Celebrex and Bextra) came under increasing scrutiny by both physicians and patients. Often, whether a particular physician would continue to prescribe Celebrex and/or Bextra would depend on their individual medical opinion of how closely Vioxx was representative of the category as whole. This individual opinion is also influenced by the composition of patients they treat and their corresponding health characteristics. For example, since the greatest risk from Vioxx was for patients with preexisting cardiovascular conditions, physicians with fewer such patients may not view the category unfavorably.[6] Such physicians would be physicians who are loyal to the category and can be captured by the postrecall sales effort by the competitor (focal firm) without having to invest in category-defense effort. On the other hand, other physicians may not be loyal to the category but may be willing to prescribe within the category if given the right kind of information by the firm on how the issues with the recalled product do not carry over to the category as a whole. Thus, these are "switchers" who would switch out of the category to a benchmark drug if not provided this information. Since category-defense effort could either take the form of detailing to physicians or DTCA to patients, the cumulative category-defense effort variable x that was introduced earlier includes both traditional detailing as well as consumer advertising and any other effort that could stem the attrition of patients from the category. We put this together to define $m(x)$ as follows:

$$m(x)=\phi+(1-\phi)\cdot x. \tag{15}$$

The second term in Equation (15) reaches its maximum value $1-\phi$ only when the firm exerts the maximum possible category-defense effort $x=1$. At that point, the overall market size m equals its maximum value 1. This effort investment occurs before uncertainty about the recall is resolved.

We substitute the second stage equilibrium sales effort levels given in Equations (6) through (9) into the profit function given in Equation (4) to obtain the equilibrium second stage profit π^*_{FNR} under the no recall scenario. Similarly, we substitute the second stage equilibrium sales effort levels given by Equations (12) through (14) into the profit function given in Equation (10) to obtain the equilibrium second stage profit π^*_{FR} under the recall scenario. We assume that the cost of category-defense effort x to be a convex, quadratic function of x. Given that the anticipated probability of recall by the focal firm is r, the expected first stage profit for the focal firm can be written as

$$E(\pi_F)=r\cdot\pi^*_{FR}+(1-r)\cdot\pi^*_{FNR}-x^2. \tag{16}$$

The focal firm maximizes $E(\pi_F)$ by setting x. The first stage game has a unique solution in x given by

$$x^*=\frac{r\cdot(1-\phi)(c+\phi+p\cdot\rho+\phi\cdot\rho^2)}{4c-r\cdot(1+\rho^2)(1-\phi)^2}. \tag{17}$$

The above expression is always between 0 and 1 as long as our original condition $c>p+2$ is obeyed. Having solved for the subgame perfect equilibrium of this two-stage game, we highlight the key managerial results that emerge in Section 4.

4. Key Results

Our focus in this paper is to analyze how the anticipation of recall affects the focal firm's postrecall decisions and the nuanced relationship between category-defense effort that occurs prior to the recall and postrecall sales effort across products in different categories. To make the analysis tractable, we make some assumptions on the primitive parameters. First, we assume that cross-category price is neither too high nor too low and is bounded as follows: $\frac{1}{2}\le p\le 2$. Second, we evaluate all results at $c=4$. We could reevaluate

the results for values other than $c=4$ and this merely changes the cutoffs at which the results hold without a change in the insights. Furthermore, all values of $c \geq 4$ when combined with our first assumption $\frac{1}{2} \leq p \leq 2$ ensure that our original condition $c > p+2$ is obeyed. For clarity of insights, we separate the key results based on whether the two products display either economies or diseconomies of scope in sales resource usage. This allows us to compare and contrast our results based on this dimension. We address the case of economies of scope ($\rho \geq 0$) first.

4.1. Economies of Scope Across Categories: $\rho \geq 0$

In many pharmaceutical industry examples, PCPs constitute the major percentage of physicians prescribing products across both categories. This implies that a sales rep could talk about both product categories with the same physician. When the prescribing physicians are distinct across categories, there are no (dis)economies of scope and ρ can be set to zero. In our analysis, this is a special case within the economies of scope, and we merely need to set $\rho=0$ in Propositions 1 and 2. Our first proposition highlights the postrecall sales effort decision for the focal firm for both categories W and B and compares them with the no recall scenario.

Proposition 1. *The focal firm increases its postrecall sales effort for both categories W and B when compared to the benchmark "no recall" scenario under the following conditions*:

Condition set 1:

$$\tfrac{1}{2} < \phi \leq 1,$$

Condition set 2:

$$\frac{\sqrt{7-\rho(2p+\rho)}}{4+\sqrt{7-\rho(2p+\rho)}} < \phi \leq \frac{1}{2},$$

$$\frac{16-32\phi}{9+2p\rho+\rho^2} < r \leq 1.$$

The above proposition serves to explain how economies of scope across the two products leads to either an increase or decrease in postrecall sales effort for both products simultaneously depending on the loyal market size for the category. First, we observe that, given economies of scope in sales resource use across categories, the focal firm either increases or decreases its postrecall sales effort for both products simultaneously. Whether it increases or decreases effort critically hinges on the loyal segment size ϕ. When ϕ is low ($< \sqrt{7-\rho(2p+\rho)}/(4+\sqrt{7-\rho(2p+\rho)})$), the focal firm invests in category-defense effort to build postrecall market size but decreases its postrecall sales effort on both products. This implies a *substitution* effect between category-defense effort and postrecall sales effort. This occurs because although building postrecall market is justified in return on investment (ROI) terms, the final market size is still too small to warrant an increase in postrecall sales effort to capture a higher market share. When ϕ is high ($> \frac{1}{2}$), the baseline market size is high to begin with and is further increased by category-defense effort ensuring a high ROI for market share increasing postrecall sales effort leading to an increase in such effort. This implies a *complementarity* effect between category-defense effort and postrecall sales effort. When ϕ is intermediate, whether the firm will increase postrecall sales effort as compared to a no recall baseline depends on the firm's anticipated recall probability r. An increase occurs only if the anticipated recall probability is high enough to justify the ROI of higher postrecall sales effort. However, the cutoff for intermediate ϕ and high enough r depends on the other parameters p and ρ. Examining the expressions $\sqrt{7-\rho(2p+\rho)}/(4+\sqrt{7-\rho(2p+\rho)})$ and $(16-32\phi)/(9+2p\rho+\rho^2)$ reveals that an increase in either price p or economies of scope ρ decreases both thresholds implying that an increase in postrecall sales effort is optimal for a larger region of the parameter space. Thus, an increase in either p or ρ supports an increase in postrecall sales effort for both products. This occurs for the following reasons. For a given $\rho>0$, an increase in p increases the value of the cross-category and improves not only the ROI of sales effort for category B but also that of category W through the use of economies of scope. Note that at $\rho=0$, price p has no impact on the thresholds and postrecall sales effort for category B is the same across the recall and no recall scenarios. Similarly, for a given p, an increase in positive ρ increases the ROI of sales effort for both categories.

We have discussed the substitutability or complementarity of category-defense effort and postrecall sales effort in comparison to a scenario where a recall is not expected ($r=0$). However, given that $r>0$, how does a change in the underlying parameters affect the two investments? Would category-defense effort and postrecall sales effort both go up (complementarity) or would there be a substitution across these two kinds of effort with a change in parameters. The next proposition examines this in the context of economies of scope across the product categories as the recall probability r increases.

Proposition 2. *With economies of scope ($\rho>0$) across the two product categories, the focal firm's category-defense effort and postrecall sales effort in category W complement each other as recall probability r increases for all values of ϕ and p.*

It is clear that the ROI for category-defense effort increases with an increase in recall probability r because the possibility of recall is the main driver of such effort. As category-defense effort builds a larger market, greater postrecall sales effort is required to capture a share of this market, and this can be achieved

without compromising the cross-category because of the economies of scope. Consequently, an increase in r increases both category-defense and postrecall sales effort. Having examined the equilibrium effort decisions in a setting with economies of scope, we shift attention to the case where we have diseconomies of scope ($\rho<0$) across the two categories.

4.2. Diseconomies of Scope Across Categories: $\rho<0$

In the context of economies of scope across categories, it is never optimal for the focal firm to shut off postrecall sales effort for either of the two products. However, with diseconomies of scope, this outcome becomes a possibility simply because the sales effort invested in one product has a negative effect on the cross-category product. The next proposition characterizes this outcome as a function of the basic parameters. This analysis for the scenario with $\rho<0$ is much more algebraically complicated than the previous scenario with $\rho>0$. Consequently, in the interest of tractability and insight, we present the results for two different values of the loyal market size: $\phi=0$ and $\phi=\frac{1}{2}$.

Proposition 3. (1) *At $\phi=0$ and $\rho<0$:*

(a) *Postrecall sales effort for product in category B is never set to zero.*

(b) *Postrecall sales effort for product in category W is set to zero when $\rho\le\rho^{*}$[7] and*

Condition set 1:

$$p>p^{*}.$$

Condition set 2:

$$p\le p^{*},\quad r\le\frac{16p^2}{8-p^2+p^4}.$$

(2) *At $\phi=\frac{1}{2}$ and $\rho<0$:*

(a) *Postrecall sales effort for product in category B is set to zero when*

$$\rho<\sqrt{\frac{1{,}024+r(p^2(-64+r)+16(16+r))}{p^2r^2}}-\frac{4(8+r)}{pr},\quad \textit{and}$$

Condition set 1:

$$p\le 1.$$

Condition set 2:

$$1<p\le\frac{\sqrt{497}}{21},\quad r>\frac{64(p^2-1)}{7+p^2}.$$

(b) *Postrecall sales effort for product in category W is never set to zero.*

The proposition illustrates how diseconomies of scope can lead to a complete withdrawal of postrecall sales effort from one of the two products depending on the size of the loyal market, the cross-category price, and the recall probability. Our first observation is the fact that the choice of which product's sales effort to set to zero depends on the loyal market size ϕ. When ϕ is low, the focal firm invests in category-defense effort to build market size in the recall-affected category but can set postrecall sales effort for the product in this category to zero if diseconomies of scope are high enough. In such a scenario, only the baseline market share of $\frac{1}{2}$ (there is no diseconomies of scope since the sales rep promotes only a single product) is obtained for the recall-affected category but over a larger market size than ϕ. When ϕ is high and category-defense effort is also used, the focal firm wants to capture as much market share as possible in the recall-affected category and ends up setting the cross-category product sales effort to zero if diseconomies of scope are large enough. However, additional conditions are required for both of these outcomes based on price p and recall probability r. For low ϕ and low enough ρ, sales effort in the recall-affected category W is set to zero only if the cross-category price p is higher than a threshold or for other values of p when recall probability r is low enough. Higher cross-category price p implies a greater ROI in cross-category B justifying a pullout in category W. At the lower price p, if recall probability r is low enough, an actual recall is a surprise outcome that is not appropriately planned for with the right level of category-defense effort. Given that loyal market size ϕ is low to begin with, any postrecall sales effort is not justified by ROI. For high ϕ and low enough ρ, sales effort in cross-category B is set to zero only if the cross-category price p is lower than the price in recall-affected category W (=1). Even if the price is higher, if recall probability r is high, the focal firm prepares for the recall better by investing in category-defense effort and having built the market using such effort, the firm finds it optimal to focus on the product in the recall-affected category at the expense of the product in the cross-category.

Next, we compare the postrecall sales effort across recall and no recall scenarios when $\rho<0$ is similar to Proposition 1 for $\rho>0$. We restrict attention to those parameter conditions where the focal firm does not shut off postrecall sales effort to products of either category. However, unlike the scenario where $\rho>0$, we find that it is optimal for the firm to decrease sales effort for the product in a category while increasing sales effort for the cross-category product. The general set of conditions for this to occur are complex and onerous to list. In the next proposition, we present a sufficient set of conditions that result in this outcome, highlighting the subtle interplay between diseconomies of scope, cross-category price, and loyal market size.

Proposition 4. (1) *The focal firm decreases postrecall sales effort as compared to the "no recall" scenario for recall-affected category W while simultaneously increasing corresponding effort for cross-category B under some conditions.*

A sufficient set of conditions where both effort levels remain positive and this outcome occurs is

$$\phi=0, \quad p>\frac{1}{\sqrt{3}}, \quad \rho>\sqrt{\frac{4p^2}{r^2}-1}-\frac{2p}{r}.$$

(2) *The focal firm increases postrecall sales effort as compared to the "no recall" scenario for recall-affected category W while simultaneously decreasing corresponding effort for cross-category B under some conditions. A sufficient set of conditions where both effort levels remain positive and this outcome occurs is*

$$\phi=\frac{1}{2}, \quad p>\frac{3}{\sqrt{7}}, \quad \rho>\sqrt{\frac{64p^2}{(8+r)^2}-1}-\frac{8p}{8+r}.$$

The two cases described in the above proposition differ primarily in the size of the loyal market segment. Both condition sets are applicable at high enough price and high enough $\rho<0$. At low ϕ, the ROI for postrecall sales effort for the recall-affected category W is low. Consequently, when cross-category price p is high enough, it is optimal for the firm to increase sales effort for the cross-category while reducing effort in the recall-affected category. Both sales effort levels remain positive as long as diseconomies of scope is not too high. On the other hand, at high ϕ, the ROI for postrecall sales effort for the recall-affected category W is high. When cross-category price p is high enough, the effective profits despite reduced sales effort on the cross-category product is high enough and provides a positive effort boost to the product in the recall-affected category given that $\rho<0$. Consequently, a similar set of conditions with respect to p and ρ tilts in favor of exploiting the loyal segment in category W given its larger size.

Finally, we examine how diseconomies of scope influences the complementarity or substitutability across category-defense and postrecall sales effort as a function of the anticipated recall probability. Once again, because of tractability issues, we evaluate this outcome only for $\phi=0$. Our goal is to show that results from the economies of scope case do not carry over directly and depend on the nuanced interaction across the parameters.

Proposition 5. *With diseconomies of scope ($\rho<0$) across the two product categories at $\phi=0$, the focal firm's category-defense effort and postrecall sales effort for product in recall-affected category W complement each other as recall probability r increases if $p<(1+\rho^2)/(-4\rho)$ and $r>-4p\rho/(1+\rho^2)$ and are substitutes otherwise.*

Propositions 2 and 5 together serve to answer the question of how (dis)economies of scope affect the complementarity or substitutability of category-defense and postrecall sales effort. They show that as the recall probability increases, category-defense effort and postrecall sales effort are unequivocally complementary given economies of scope across the two products but may be substitutes given diseconomies of scope. An increase in recall probability r increases the ROI of category-defense effort and helps build postrecall market size in category W. Given that $\rho<0$, increasing postrecall sales effort for the product in category W has a negative effect on the cross-category. When r is low, this negative effect overcomes the benefit of an increase in postrecall sales effort for category W product for any value of cross-category price p. When r exceeds a threshold, increasing postrecall sales effort is feasible if cross-category price is low enough such that any reduction in profit from category B is compensated by higher profit from category W. For other conditions, decreasing postrecall sales effort for product in category W is the optimal outcome ensuring that category-defense effort and postrecall sales effort are substitutes. This is contrary to the case with economies of scope where category-defense effort and postrecall sales effort are unequivocal complements as recall probability increases as shown in Proposition 2. We summarize our analysis and discuss managerial implications and future research possibilities in Section 5.

5. Discussion

Our paper was motivated by the challenges faced by managers in the pharmaceutical industry in terms of their reaction to product recalls by competitors. Product recalls may have a category level impact because of adverse physician and end-consumer reaction to the category as a whole. Given that most companies offer products in multiple categories and use shared sales resources across them, a common question they have to answer is whether it is feasible to reduce focus on the product category affected by the recall to sharpen focus on the other categories. The answer to this question has become particularly crucial given the current environment in the pharmaceutical industry that compels firms to efficiently manage their sales force investment across the entire product portfolio. Furthermore, given that drug recalls can often be anticipated given the nature of warnings issued by the FDA, firms can invest in category-defense effort that distances the rest of the category from the recalled product. However, such effort, which could take various forms including DTCA, has to be invested before uncertainty about the product recall is resolved. Managers in this industry have to make a prudent decision about their investment in category-defense effort and the consequent impact on postrecall sales effort while being mindful of ROI across the entire product portfolio and the inherent uncertainty of the product recall decision.

To answer these questions, we first examined historical decision making with respect to postrecall sales

effort. We unearthed a few examples where information about such decisions was available. We discovered that the modal tendency is to increase sales effort for the product in the affected category. Given the renewed focus on sales force efficiency in the current environment, we explain the rationale for such decision making in the past and also analyze its limitations by formulating a game-theoretic model where a focal firm competes in two categories, only one of which is affected by the recall.

Our model and analysis develops several normative conclusions with respect to a firm's category-defense marketing effort and postrecall sales effort. The managerial implications vary significantly depending on whether we have economies or diseconomies of scope in sales resource usage across categories. Furthermore, the results crucially hinge on the loyal market size for the recall-affected category. With economies of scope, the focal firm raises postrecall sales effort for products in both categories when compared with the no recall scenario when loyal market size is high or when it is intermediate with high enough anticipated recall probability. When the loyal market size is low, the focal firm reduces postrecall sales effort for both products. Higher cross-category price supports an increase in postrecall sales effort. These results are an outcome of the ROI for category-defense effort as reflected by the loyal market size and high recall probability, and the ability to leverage the larger market through economies of scope and cross-category price. Thus, when loyal market size is low, a comparison of the recall and no recall scenarios reflects a substitution effect across category-defense effort and postrecall sales effort. The issue of complementarity versus substitutability of the two kinds of effort is also relevant as the underlying parameters change. We find that an increase in recall probability leads to a complementary effect. Once again, this depends on the directional movement of ROI of category-defense and postrecall sales effort as a function of the parameters.

With diseconomies of scope, the nature and structure of the managerial implications change. It is now possible for the focal firm to completely shut off postrecall sales effort for either of the two products it sells. In particular, at low loyal market size, sales effort for the product in the recall-affected category may be set to zero at sufficiently high diseconomies of scope and high enough cross-category price or low recall probability. When cross-category price is high, the firm is concerned about the negative effects of promoting the recall-affected product on the cross-category product. On the other hand, a low recall probability drives this result because of insufficient investment in category-defense effort followed by the surprise recall outcome that occurs. This latter outcome reveals the role that the focal firm's inferior information (relative to the firm issuing the recall) plays in postrecall sales effort outcomes. When the market size is high, the firm may shut off promotion for the cross-category product for high diseconomies of scope if cross-category price is low (indicating lower ROI and a need to protect the recall-affected product) or high recall probability, which indicates a greater investment in category-defense investment and the need to benefit from that investment by focusing postrecall effort on the product in the recall-affected category. Finally, unlike the economies of scope case, complementarity between category-defense effort and postrecall sales effort as the underlying parameters change occurs only under a limited set of conditions: when cross-category price is low and recall probability is high. Low cross-category price drives higher sales effort for the product in the recall-affected category whereas high recall probability drives up category-defense effort. Under all other conditions with diseconomies of scope, the two kinds of effort are substitutes.

An aspect of this setting that we have not considered in the model is the change in the nature of the relationship between the firm and the other participants in the channel as a consequence of the recall. For example, a pharmaceutical firm affected by a competitor's recall may have to take into account the impact of the recall on its managed care relationships. Whether and how these changes should be implemented would be an important topic for further research.

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Appendix

Proof of Proposition 1

We substitute the equilibrium category-defense effort expression given in Equation (17) into a postrecall market size expression given by Equation (15) to obtain the equilibrium market size m^* under the recall scenario. We substitute m^* into the second stage equilibrium sales effort levels under the recall scenario given by Equations (12) through (14) to obtain the equilibrium sales effort levels as a function of the primitive parameters. Comparing these sales effort levels with the no recall second stage equilibrium sales effort levels given by Equations (6) through (9) for $\rho > 0$ gives us the required results.

Proof of Proposition 2

We substitute the equilibrium category-defense effort expression given in Equation (17) into a postrecall market size expression given by Equation (15) to obtain the equilibrium market size m^* under the recall scenario. We substitute m^* into the second stage equilibrium sales effort levels under the recall scenario given by Equations (12) through (14) to obtain the equilibrium sales effort levels as a function of the primitive parameters.

The result then follows by examining the sign of $\partial x^*/\partial r$ and $\partial \alpha^*_{FW}/\partial r$ for $\rho > 0$. We find that $\partial x^*/\partial r > 0$ and $\partial \alpha^*_{FW}/\partial r > 0$ for all values of ϕ and p.

Proof of Proposition 3

We substitute the equilibrium category-defense effort expression given in Equation (17) into a postrecall market size expression given by Equation (15) to obtain the equilibrium market size m^* under the recall scenario. We substitute m^* into the second stage equilibrium sales effort levels under the recall scenario given by Equations (12) through (14) to obtain the equilibrium sales effort levels as a function of the primitive parameters.

Examining these equilibrium sales effort levels for $\phi = 0$ and $\phi = \frac{1}{2}$ when $\rho < 0$ gives us the required results.

The expressions for ρ^* and p^* are as follows.

Consider the polynomial equation in x

$$-8r + (-16p - p \cdot r)x + p \cdot r \cdot x^3 = 0.$$

Arrange the real roots of this equation in ascending order. The second root in this sequence is ρ^*.

Consider the polynomial equation in x

$$8 - 17x^2 + x^4 = 0.$$

Arrange the real roots of this equation in ascending order. The third root in this sequence is p^*.

Proof of Proposition 4

We substitute the equilibrium category-defense effort expression given in Equation (17) into a postrecall market size expression given by Equation (15) to obtain the equilibrium market size m^* under the recall scenario. We substitute m^* into the second stage equilibrium sales effort levels under the recall scenario given by Equations (12) through (14) to obtain the equilibrium sales effort levels as a function of the primitive parameters. Comparing these sales effort levels with the no recall second stage equilibrium sales effort levels given by Equations (6) through (9) for $\rho < 0$ and at $\phi = 0$ and $\phi = \frac{1}{2}$ gives us the required results. In this case, we also impose the conditions $\alpha^*_{FW} > 0$ and $\alpha^*_{BW} > 0$.

Proof of Proposition 5

We substitute the equilibrium category-defense effort expression given in Equation (17) into a postrecall market size expression given by Equation (15) to obtain the equilibrium market size m^* under the recall scenario. We substitute m^* into the second stage equilibrium sales effort levels under the recall scenario given by Equations (12) through (14) to obtain the equilibrium sales effort levels as a function of the primitive parameters.

The result then follows by examining the sign of $\partial x^*/\partial r$ and $\partial \alpha^*_{FW}/\partial r$ for $\rho < 0$ at $\phi = 0$. We find that $\partial x^*/\partial r > 0$ and $\partial \alpha^*_{FW}/\partial r > 0$ only when $p < 1 + \rho^2/(-4\rho)$ and $r > -4p \cdot \rho/(1+\rho^2)$.

Endnotes

[1] Pfizer goes on offense with Celebrex: TV ads, study proposal stress safety. *The Pink Sheets*, October 25, 2004.

[2] http://www.fda.gov/Safety/Recalls/ArchiveRecalls/default.htm.

[3] In the online appendix, we study a market with two homogeneous firms competing in two categories and one of the products is recalled. Our primary results remain unchanged as a consequence of this change.

[4] In each of these two drug categories, the focal firm may have more than one related product. For example, at the time of the Vioxx recall, Pfizer had both Celebrex and Bextra in the COX-2 inhibitor category. In such cases, we can consider the focal firm's parameters and variables related to the category as average measures across multiple related products. The primary insights will continue to hold even with this assumption.

[5] An example of such substitutes would be over-the-counter NSAIDs that saw a surge in sales after the recall of Vioxx. However, they would be considered outside the COX-2 category and not included in the market share expressions.

[6] http://www.uphs.upenn.edu/news/news_releases/2012/05/risk/.

[7] Expressions for ρ^* and p^* in implicit form are provided in the appendix.

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