

Advertising in Specialized Markets: Example from the U.S. Pharmaceutical Industry

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Abstract

This paper studies the usefulness of advertising to both consumers and experts in specialized markets like the prescription drugs, travel and real-estate markets where the consumers' purchasing decisions are influenced by the experts (e.g., doctors, travel agents and real-estate agents). Inspired by the features of the prescription drugs market the study shows that direct-to-consumer-advertising (DTCA) does not substitute for advertising directed to physicians even when physician-advertising is only persuasive in nature. Furthermore, the paper analyzes possible advertising equilibriums in a two-firm setting and finds that it is possible to have a sub-game perfect, non-symmetric Nash Equilibrium in which only one firm advertises to the consumers and the other firm becomes a free-rider when, (i) the number of patients who are aware of treatment is very low, and (ii) there are very few patients who insist for a particular drug. Otherwise, for familiar diseases a non-advertising equilibrium is most likely. Finally, consumer advertising can have welfare improving implications depending on the disease types and patient characteristics.

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1 Introduction

In market economies, for most products a consumer himself decides *whether* and *how much* to buy of *which* brand. For some products, however, consumers are *oblivious* in the sense that they are not aware of their best consumption choice. Instead there are agents or *experts*, who decide on behalf of the consumers which product to purchase. *Oblivious* consumers either cannot or do not fully control their own consumption decisions. Some examples of such specialized markets are the real-estate market, travel-agent market, prescription drugs market and contractor market. In this paper we study advertising in such specialized markets. For example, whether advertisement should be directed to the consumers or to the experts? How should firms decide on consumer advertising? What implications might consumer advertising have for social welfare?

A patient's inability to choose his own medication has made direct-to-consumer-advertising (DTCA) of prescription drugs a highly controversial means of promotion. The U.S. is one of the only two countries that allow DTCA of prescription drugs. The rest of the world, with the exception of New Zealand, does not. This is why in this paper we specifically study the advertising in the U.S. prescription drugs market and analyze the different advertising strategies and possible advertising equilibriums.

The interesting results that are common findings of the existing empirical research (Rosenthal et al (2003), Berndt et al (1995)) state that DTCA

- significantly increases sales of an entire therapeutic class of drugs
- has no significant effect on market share within a therapeutic class

Question: If the benefits of DTCA by a brand is shared by the entire class of drugs, then why do only some brands take the burden of advertising? What can explain the within-class variation of DTCA? We provide a theoretical answer to this question in this paper.

Economic studies of advertising of prescription drugs to physicians by Bond and Lean (1977), Hurwitz and Caves (1988), Leffer (1981), and Vernon (1981) suggested that this marketing was more “persuasive” than “informative” in nature, although the distinction between the two was not unambiguous.

Our models differ from the set ups of the mentioned studies because we explicitly model some distinctive features of the U.S. pharmaceutical advertising. In brief, our models capture the following characteristics of the U.S. prescription drugs market:

- Manufacturers can advertise to *both* doctors and consumers.

- Drug companies can influence the doctors’ preferences for different brands by sending “benefits” in the form of advertisements.
- Even though patients cannot buy whatever medicine they like, patients can strongly influence a doctor’s prescribing decision by insisting for particular brands. Patients can get influenced by direct-to-consumer-advertising (DTCA) of prescription drugs.
- Some diseases or treatment-options are known to people more than others.

The theoretical models allow firms’ *participation decisions* to be qualitatively different from the decision of *how much* to advertise.¹

The paper then provides some economic intuition behind the pharmaceutical advertising strategies:

First we ask, within a class of drugs, why only some manufacturers bear the burden of advertising when others become *free riders*? We analyze the advertising equilibriums in the prescription drugs market and find that it is possible to have a sub-game perfect non-symmetric Nash-equilibrium (where both firms advertise to doctors but only one firm bears the burden of advertising to consumers and the other firm becomes a free-rider) when, (i) the number of patients who are aware of treatment is very low, and (ii) there are very few patients who insist for a particular brand of drug.² These results are quite intuitive. If the medicine is for very unfamiliar disease, then unless the patients see advertisements, they do not visit the doctor. Hence, if no firm advertises, there is no market and all firms have zero profit. This gives incentive to the advertising firm to continue advertising. On the other hand, the non-advertising firm is already sharing the market as a free-rider since DTCA has a strong *public good* feature. There are very few “stubborn” people (people who insist for particular brands after viewing an advertisement) and hence the non-advertising firm will not get any extra market share by starting DTCA. On top of that, some non-stubborn patients who already received advertisement from the other firm, will receive advertisements again which will be a waste (they would see doctor anyway). Thus for the non-advertising firm, marginal cost of advertising becomes greater than the marginal benefit of advertising. Hence, we get the free-riding equilibrium.

¹Empirical studies use sophisticated methods (e.g. two-stage models) to distinguish “whether” decisions from “how much” decisions. However, theoretical models generally assume the two to be qualitatively the same.

²Otherwise, for very familiar diseases a non-advertising equilibrium is most likely. That is, drugs belonging to classes for which treatment is commonly known, do not advertise to consumers. We also find that, all competing brands in a class are likely to advertise to consumers if number of insisting patients are very high.

The second question is, when a firm decides to advertise to consumers, does it substitute doctor advertising with DTCA? We find that in this set up once a firm decides to engage in DTCA, doctor and consumer advertisings are not substitutes. When there are few stubborn patients, then most patients rely on the doctor's choice. Even when there are many stubborn patients, doctor advertising still remains important because once a stubborn patient sees advertisement for rival brands he becomes confused and relies on doctor's judgment entirely.

From our analysis we also get some economic insights on the following two questions: First, what could be the welfare improving implications of DTCA? When DTCA is done for unfamiliar diseases, more patients visit the doctor and get proper treatment because of increased awareness about the disease. As long as there are not many stubborn patients, doctor's decisions are not distorted due to DTCA.

And second, Why might DTCA be prohibited? When DTCA is done for very familiar diseases, the only motivation for doing consumer advertising is stealing market share (when a stubborn patient views advertisement from only one brand and not from any rival). If we assume that doctor is the best judge for prescriptions, any distortion of the doctor's judgment is socially undesirable. Also, when there are many stubborn patients then a symmetric advertising equilibrium is most likely. As more firms advertise, more stubborn patients view advertisements from rival brands and depend entirely on the doctor's decision as they would do in the first place if there was no DTCA. DTCA in this case results in a waste of money without any real significance to any side.

The following section provides a brief overview of DTCA in the U.S. and summarizes the literature related to this paper. Section 3 presents the theoretical models and results. Section 4 concludes.

2 History of DTCA and Related Literature

Direct-to-consumer-advertising(DTCA) of prescription drugs is a fairly new phenomenon in the U.S.. There was no interesting story to discuss even 20 years ago. Physician advertisements in the forms of sampling, detailing and medical journal entries were the traditional ways of advertising prescription drugs. In recent years, however, the drug companies tripled their advertisement budget to acquaint American consumers with diseases like depression, erectile dysfunction, acid reflux disease and even toenail fungus. Especially after the relaxation of advertising restriction on the broadcast media by the Food and Drug Administration in August 1997, direct-to-consumer-advertising

(DTCA) expenditure has skyrocketed. DTCA spending has increased both in terms of dollar bills and as a percentage of total promotional spending. The average annual growth rate in DTCA was 33 percent between 1996 and 2000, compared to a 14 percent growth rate for total promotional spending during the same period. In 2001, spending for DTCA (\$2.7 billion) comprised 15 percent of total promotional spending, up from 8 percent (\$800 million) in 1996³. However, even though DTCA has grown disproportionately compared to other forms of drug promotions over the last decade, physicians still remain the primary focus of marketing efforts (85 percent of total promotional spending)⁴. It is a very interesting observation that DTCA is concentrated mostly among few therapeutic classes of drugs like Antidepressants, PPI's, Antihistamines, Cholesterol reducers, Nasal Sprays etc. where as physician promotion is universally accepted. Another even more striking observation is that, even in the same therapeutic class, not all the major players engage in DTCA (Table 1).

Literature on advertising is plenty, economic researchers have also studied many aspects of the expert/specialized markets. But studies of advertising in the specialized market is scarce and this paper takes a step forward to bridge this gap. Advertisers face more complex choices in the specialized markets simply because purchasing decisions are not made by purchasers. This is the age of *specialization* and the more *specialized* different markets become, the more we will see scenarios where manufacturers are left with major marketing dilemmas. Our goal is to provide some theoretical justifications and guidance for such advertising decisions. Economic studies of advertising of prescription drugs to physicians by Bond and Lean (1977), Hurwitz and Caves (1988), Leffer (1981), and Vernon (1981) suggested that this marketing was more “persuasive” than “informative” in nature, although the distinction between the two was not unambiguous. There is literature on advertising that assumes that advertising changes consumer preferences (Kaldor 1950), or advertising that informs consumers about existence and price of a product (Butters 1977), or advertising that informs consumers about product characteristics and price (Stigler 1961). Empirical papers have studied aspects of DTCA of prescription drugs using US data. Berndt et al(1995), Iizuka(2004), Wosinska(2002), Rosenthal et al(2003) are to name a few.

³A recent New York Time article (August 3, 2005: Drug Makers to Police Consumer Campaigns) reports that spending on DTCA in 2004 was 4 billion dollars

⁴*source*: Prescription Drugs Trends, a chartbook update by Kaiser Family Foundation, November 2001.

	FDA approval date	Total Physician Promotion to Sales Ratio	3-year DTC to sales ratio
Antidepressants			
CELEXA	1998	0.52	0.00
SERZONE	1994	0.35	0.01
EFFEXOR XR	1993	0.21	0.00
PAXIL	1992	0.16	0.01
ZOLOFT	1991	0.14	0.00
PROZAC	1987	0.09	0.01
PPIs			
ACIPHEX	1999	2.05	0.00
PREVACID	1995	0.15	0.00
PRILOSEC	1989	0.08	0.02
Antihistamines			
ASTELIN	1996	0.68	0.00
SEMPREX-D	1994	0.44	0.00
ALLEGRA	1996	0.26	0.11
ZYRTEC	1995	0.30	0.15
CLARITIN	1993	0.08	0.06
Cholesterol			
LESCOL	1993	0.18	0.00
PRAVACHOL	1991	0.13	0.05
LIPITOR	1996	0.12	0.01
ZOCOR	1991	0.11	0.03
MEVACOR	1991	0.02	0.00
Nasal Sprays			
NASONEX	1997	0.48	0.23
RHINOCORT	1994	0.32	0.00
NASACORT	1991	0.47	0.09
FLONASE	1994	0.20	0.12
VANCENASE	BEFORE 1982	0.40	0.00
BECONASE	BEFORE 1982	0.00	0.00

Table 1: Approval Date and Promotion to Sales Ratios for Five Therapeutic Classes, 1997-1999 (Source: Demand Effects of Recent Changes in Prescription Drug Promotion, *Rosenthal et. al*, June 2003)

3 Models Demonstrating the Existence of SPNEs:

We consider an industry composed of two firms each of which produces one brand of prescription drug for treating the same disease. The two brands of drugs are homogeneous in the sense that a doctor's precision of a drug's ability to treat the disease is same for both drugs. There are N consumers and one doctor where N is a very large number. Only the doctor is aware of the existence and effectiveness of both drugs. The firms can advertise to both doctor and consumers. Even though doctor is ex-ante indifferent between prescribing either drug, his perceived preference changes by the "rewards" or advertisements sent to him by each firm. If s_i is the number of advertisements the doctor receives from firm i , then doctor prescribes medicine i with probability, $\frac{s_i}{s_1+s_2}$, $i = 1, 2$ (Tullock 1967).

Marginal cost (MC) of advertising to doctor is C_d , the same for both firms. Each firm's consumer advertising follows the Butters'(1977) set up. Let firm i sends σ_i , $i = 1, 2$ advertisements to consumers. These are fliers randomly sent by each firm that contain information on what disease/symptoms the drug is used for and how effective the drug is for such treatment. Then with probabilities β and γ a consumer receives at least one advertisement(ad) from firm 1 and firm 2 respectively. Following Butter's advertising model, if firm 1 sends σ_1 fliers to consumers, then the probability that a consumer receives no ad from firm 1 is given by

$$(1 - 1/N)^{\sigma_1} \approx e^{-\sigma_1/N}$$

since N is assumed to be a very large number. So, we can write,

$$\beta = 1 - e^{-\sigma_1/N}$$

and

$$\gamma = 1 - e^{-\sigma_2/N}$$

There is unit demand by each consumer. MC of advertising to consumers is C_c , assumed same for both firms. There is an exogenously given probability ϕ that a consumer is "stubborn type". A stubborn person is easily impressed by an ad and insists to the doctor for prescribing that brand of drug. If a doctor encounters a stubborn person, he prescribes what the stubborn person wants. In case, a stubborn person receives ad from both firms, then he is confused and relies entirely on doctor's decision. A non-stubborn person always relies on doctor's wisdom.

There is another probability θ that a consumer already knew (even if he did

not receive any ad) about the existence of this disease and that the disease was treatable by visiting the doctor.⁵ We assume that every consumer is a potential patient if he knows about the symptoms and treatment possibility.

To distinguish between a firm's participation decision and firm's decision of how much to advertise we introduce the following simple assumption. If a firm chooses to advertise to consumers, it has to incur a small fixed cost, F which would not exist otherwise. We can think of it as a regulatory requirement. For example, the FDA requires that if a company advertises to consumers, it has to put up a website on the internet that gives information on the drug's effectiveness and major side effects. The companies who do not engage in DTCA do not have to have a website. But any firm that does consumer advertising must comply to this regulation irrespective of *how much* advertising it does.

It is widely accepted that demand is very price inelastic for brand name prescription drugs⁶ These drugs are a necessity to a patient, there are not many substitutes available and the effective price that an insured consumer has to pay is small. Prescription coverage by insurance companies has been steadily increasing shifting the burden of drug expenditures away from consumers to private and government insurance programs.⁷ We assume that demand is price inelastic between $[0, p]$ and for a price higher than p , demand drops to zero. Firms do not compete over price, instead price is given by market convention. However, price guarantees excess profit margin⁸. Initially, we do not assume that both firms charge same price, but later we modify this assumption with justification. Hence the choice variables for each firm are, "number of doctor advertisements" and "number of consumer advertisements".

Each firm's advertising decision is made in 3 stages. In *Stage I*, firm decides whether to advertise to consumers or not. In *Stage II*, amount of consumer advertisement is chosen. And then in *Stage III*, amount of doctor advertisement is decided⁹. This is a static game in the sense that no firm uses its experience from previous games to make decision this period. This is a simultaneous move

⁵In Model I, θ is assumed zero. That is, the drugs are used to treat a very unfamiliar disease and if a consumer does not receive any ad he does not visit the doctor. This assumption will be relaxed in Model II.

⁶In our entire analysis we implicitly assume that there are no over-the-counter medicines available for treating the same disease. This guaranties that once a consumer is aware of a disease, he has to visit the doctor. We also assume that there are no generic substitute drugs available for these two brand-name drugs.

⁷*Source:* Prescription Drugs Trends, a chart book update by Kaiser Family Foundation, November 2001

⁸The minimum profit margin required for consistent analysis is $p > 8C_c$

⁹We do not know if doctor and consumer advertising decisions are made jointly by firms in reality, or in what order they are made. We assume that the game is played in this order

game where firms observe each other's move at the end of every stage.

To solve the model by backward induction, first we find out profit maximizing levels of s_1 and s_2 given σ_1 and σ_2 . Then we substitute $s_1(\sigma_1, \sigma_2)$; $s_2(\sigma_1, \sigma_2)$ in the original profit functions to find the profit maximizing levels of σ_1 and σ_2 in terms of the parameters of the model. And finally, we compare four different cases(different sub-games) where either both firms advertise to consumers, or one advertises but the other does not and where no one advertises to consumers. By comparing expected profits in all these cases we are able to determine if there is any pure strategy sub-game perfect Nash equilibrium in this game.

Model I: Unfamiliar disease

General expected profit function¹⁰ for firm 1 is written as:

$$E[\pi_1] = Np_1[\phi\beta(1 - \gamma) + \frac{s_1}{s_1 + s_2}\{\phi\beta\gamma + (1 - \phi)(\beta + \gamma - \beta\gamma)\}] - \sigma_1 C_c - s_1 C_d - F$$

This implies,

$$E[\pi_1(\sigma_1, s_1)] = Np_1[\phi(1 - e^{-\sigma_1/N})e^{-\sigma_2/N} + \frac{s_1}{s_1 + s_2}(1 - e^{-\sigma_1/N}e^{-\sigma_2/N} + 2\phi e^{-\sigma_1/N}e^{-\sigma_2/N} - \phi e^{-\sigma_1/N} - \phi e^{-\sigma_2/N})] - \sigma_1 C_c - s_1 C_d - F$$

Similarly for firm 2 the general profit function can be written as:

$$E[\pi_2] = Np_2[\phi(1 - \beta)\gamma + \frac{s_2}{s_1 + s_2}\{\phi\beta\gamma + (1 - \phi)(\beta + \gamma - \beta\gamma)\}] - \sigma_2 C_c - s_2 C_d - F$$

Thus,

$$E[\pi_2(\sigma_2, s_2)] = Np_2[\phi e^{-\sigma_1/N}(1 - e^{-\sigma_2/N}) + \frac{s_2}{s_1 + s_2}(1 - e^{-\sigma_1/N}e^{-\sigma_2/N} + 2\phi e^{-\sigma_1/N}e^{-\sigma_2/N} - \phi e^{-\sigma_1/N} - \phi e^{-\sigma_2/N})] - \sigma_2 C_c - s_2 C_d - F$$

¹⁰when firm advertises to consumers

3.1 Case I : $\sigma_1 = 0, \sigma_2 = 0$

Since in model I we have assumed that no consumer visits the doctor unless he receives an ad, for Case I, expected profit of both firms is going to be zero. That is,

$$E[\pi_1(\sigma_1, s_1)] = 0$$

$$E[\pi_2(\sigma_2, s_2)] = 0$$

3.2 Case II : $\sigma_1 = 0, \sigma_2 \neq 0$

Here we see the “market expansion effect” of consumer-advertisement in an emphasized manner. Market changes from zero to a significant positive number even when only one firm chooses to advertise to the consumers. This effect is emphasized due to the assumption that *no* consumer visits the doctor unless he receives at least one advertisement. Solving the first order conditions of profit maximizations for both firms with respect to s_1 and s_2 gives (calculations for Model I are presented in Appendix 1),

$$\frac{s_1}{s_1 + s_2} = \frac{p_1}{p_1 + p_2}$$

and

$$\frac{s_2}{s_1 + s_2} = \frac{p_2}{p_1 + p_2}$$

And also,

$$s_i = \frac{p_i^2 p_j}{(p_i + p_j)^2} \frac{N}{C_d} (1 - \phi)(1 - e^{-\sigma_2/N}), \quad i, j = 1, 2; \quad i \neq j$$

3.2.1 Discussion on Price:

Even though price is a parameter in this model, it is evident from the above analysis that the higher the relative price of a firm the higher will be its market share. This is apparently a strange result that comes from the assumption of price-inelasticity of demand in a given range (above which demand vanishes). Given this is true, it is now reasonable to assume that both firms charge the highest parametric price p for which demand is positive.

Rosenthal et al (2003) estimated how relative price affects relative market share of prescription drugs. They found that IV estimates of the coefficient on the price variable were positive and significant. Their inference was that perhaps their price variable was measured with error. The above analysis complements

their empirical findings and gives one possible explanation for the unexpected sign on the price coefficient. Hence later in the paper we will assume for simplicity that both firms charge the same exogenous price p .

Lemma 1: *Higher the relative price of a firm, higher is its relative market share.*

Expected profits of both firms are solved in terms of the parameters of the model:

$$E[\pi_1] = N \frac{p_1^3}{(p_1 + p_2)^2} (1 - \phi) \left(1 - \frac{C_c(p_1 + p_2)^2}{p_2(\phi p_1^2 + 2\phi p_1 p_2 + p_2^2)} \right)$$

And,

$$E[\pi_2] = \frac{N p_2 (\phi p_1^2 + 2\phi p_1 p_2 + p_2^2)}{(p_1 + p_2)^2} - N C_c [1 + \log p_2 + \log(\phi p_1^2 + 2\phi p_1 p_2 + p_2^2) - \log C_c - 2 \log(p_1 + p_2)] - F$$

3.3 Case III : $\sigma_1 \neq 0, \sigma_2 = 0$

We follow the same procedure to find profits of both firms in terms of the parameters of the model:

$$E[\pi_1] = \frac{N p_1 (\phi p_2^2 + 2\phi p_1 p_2 + p_1^2)}{(p_1 + p_2)^2} - N C_c [1 + \log p_1 + \log(\phi p_2^2 + 2\phi p_1 p_2 + p_1^2) - \log C_c - 2 \log(p_1 + p_2)] - F$$

and

$$E[\pi_2] = \frac{N p_2^3}{(p_1 + p_2)^2} (1 - \phi) \left(1 - \frac{C_c(p_1 + p_2)^2}{p_1(\phi p_2^2 + 2\phi p_1 p_2 + p_1^2)} \right)$$

3.4 Case IV : $\sigma_1 \neq 0, \sigma_2 \neq 0$

Following the same steps as the previous cases and imposing $p_1 = p_2$ we get,

$$E[\pi_1] = \frac{N(p - 4C_c)\sqrt{\phi^2 + \frac{16C_c(1+2\phi)}{p}} + \phi(p + 20C_c)}{4\sqrt{\phi^2 + \frac{16C_c(1+2\phi)}{p}} + \phi} -$$

$$NC_c[\log p + \log(\sqrt{\phi^2 + \frac{16C_c}{p}(1 + 2\phi)} + \phi) - \log 8 - \log C_c] - F$$

and

$$E[\pi_2] = \frac{N(p - 4C_c)\sqrt{\phi^2 + \frac{16C_c(1+2\phi)}{p}} + \phi(p + 20C_c)}{4\sqrt{\phi^2 + \frac{16C_c(1+2\phi)}{p}} + \phi} -$$

$$NC_c[\log 2 + \log(1 + 2\phi) - \log(\sqrt{\phi^2 + \frac{16C_c(1 + 2\phi)}{p}} - \phi)] - F$$

3.5 Analysis of Nash Equilibrium

Now that we have calculated expected profit for each firm (in terms of the parameters of the model) in different sub-games, it is possible to compare the profits under the different consumer advertising strategies a firm might choose. Due to our simplifying assumption in Model I that no consumer knows about a possible treatment until he receives an ad, we can rule out the possibility of $(\sigma_1 = 0, \sigma_2 = 0)$ being a SPNE. It also makes our job easier to analyze the other possibilities. For example, we now want to check if $(\sigma_1 = 0, \sigma_2 \neq 0)$ can be a Nash equilibrium of this game. We need to check only one condition for this, whether

$$E\pi_1|_{(\sigma_1 = 0; \sigma_2 \neq 0)} > E\pi_1|_{(\sigma_1 \neq 0; \sigma_2 \neq 0)}$$

That is, we need to verify if,

$$\frac{p}{4}(1 - \phi)\left[1 - \frac{4C_c}{p(1 + 3\phi)}\right] > \frac{1}{4} \frac{(p - 4C_c)\sqrt{\phi^2 + \frac{16C_c(1+2\phi)}{p}} + \phi(p + 20C_c)}{\sqrt{\phi^2 + \frac{16C_c(1+2\phi)}{p}} + \phi}$$

$$- C_c[\log p + \log(\sqrt{\phi^2 + \frac{16C_c}{p}(1 + 2\phi)} + \phi) - \log 8 - \log C_c] - F$$

Analytically, we can surely say that L.H.S of the above inequality is greater than R.H.S., if $\phi = 0$. The difference exactly equals the value $C_c[\frac{1}{2} \log p -$

$\frac{1}{2} \log C_c - \log 2] + F/N$. This value has to be positive as this represents the ratio of the number of consumer advertisements sent by firm 1 in equilibrium (when both firms advertise to consumers) to the number of patients plus the fixed cost of advertising as a fraction of N . Hence, at $\phi = 0$ it is possible to have a sub-game perfect, non-symmetric¹¹ Nash equilibrium in which one firm bears the burden of advertising and the other firm becomes a *free-rider*. Also, if we compare $\pi_1|(\sigma_1 = 0, \sigma_2 \neq 0)$ and $\pi_2|(\sigma_1 = 0, \sigma_2 \neq 0)$, we find that in a non-symmetric equilibrium the free-riding firm earns more profit (when $\phi = 0$). As ϕ increases to 1, it is impossible to have a non-symmetric equilibrium given a high profit margin. In that case, for $\phi \approx 1$, the symmetric-advertising equilibrium is most likely.

In general, for very low values of ϕ it is possible to have a non-symmetric equilibrium.

Proposition 1: *For unfamiliar diseases ($\theta = 0$) a non-symmetric sub-game perfect Nash equilibrium (when one firm bears the burden of advertising to consumers and the other firm becomes a free-rider) can exist only when $\phi \approx 0$. Otherwise, a symmetric advertising equilibrium is most likely.*

Model II: Introducing θ

In Model I, firms had two channels of gaining from doing DTCA. First was through ϕ which directly affected a firm's market share, and the second was simply through the "market expansion effect" of DTCA. Now we want to be able to neutralize the market expansion effect by introducing a parameter θ - probability that a consumer already knows about the disease or treatment possibility. In other words, now patients visit the doctor even without viewing any ad with probability θ . We can make $\theta \approx 1$ to analyze the case when DTCA impacts a firm's profit only through ϕ . The general profit functions now look like the following (after writing s_1 and s_2 as functions of σ_1 and σ_2):

$$E[\pi_1(\sigma_1)] = Np\phi(1 - e^{-\sigma_1/N})e^{-\sigma_2/N} + \frac{Np}{4}[(1 - \phi - \theta)(2 - e^{-\sigma_1/N} - e^{-\sigma_2/N}) - (1 - e^{-\sigma_1/N})(1 - e^{-\sigma_2/N})(1 - 2\phi - \theta) + \theta] - \sigma_1 C_c - F$$

¹¹non-symmetric in terms of firms' decisions to advertise to consumers

$$E[\pi_2(\sigma_2)] = Np\phi(1 - e^{-\sigma_2/N})e^{-\sigma_1/N} + \frac{Np}{4}[(1 - \phi - \theta)(2 - e^{-\sigma_1/N} - e^{-\sigma_2/N}) - (1 - e^{-\sigma_1/N})(1 - e^{-\sigma_2/N})(1 - 2\phi - \theta) + \theta] - \sigma_2 C_c - F$$

As in Model I, we again find expected profits of firms in four different cases in terms of the parameters which enable us to analyze the existence of SPNEs of this game (calculations presented in Appendix 2).

3.6 Analysis of Nash Equilibrium: $\theta \neq 0$

Now the goal is to find out possible conditions under which particular advertising strategies can be SPNEs. Again, let us focus on the non-symmetric strategy payoffs when firm 1 does not advertise to consumers, but firm 2 chooses to do consumer-advertising. To see whether this particular strategy-combination is a SPNE, we need to satisfy 2 conditions :

Condition 1

$$\pi_1|_{\sigma_1=0, \sigma_2 \neq 0} > \pi_1|_{\sigma_1 \neq 0, \sigma_2 \neq 0}$$

and

Condition 2

$$\pi_2|_{\sigma_1=0, \sigma_2 \neq 0} > \pi_2|_{\sigma_1=0, \sigma_2=0}$$

Condition 1 requires that,

$$\frac{N}{4} \left[p(1 - \phi) - \frac{4C_c(1 - \theta - \phi)}{1 + 3\phi - \theta} \right] > \frac{Np}{4} + \frac{6NC_c\phi}{\sqrt{\phi^2 + \frac{16C_c}{p}(1 + 2\phi - \theta) + \phi}} - NC_c \left[1 + \log p + \log \left(\sqrt{\phi^2 + \frac{16C_c}{p}(1 + 2\phi - \theta) + \phi} \right) - \log 8 - \log C_c \right] - F$$

and *Condition 2* requires that,

$$\frac{N}{4} [p(1 + 3\phi) - 4C_c] - NC_c [\log p + \log(1 + 3\phi - \theta) - \log 4 - \log C_c] - F > Np \frac{\theta}{4}$$

The conditions are computationally too complicated to derive any general conclusions. So, for our purpose we study them under different extreme values of θ and ϕ . Hence, we can make analysis of few different cases that will shed light on likelihoods of different symmetric and non-symmetric sub-game perfect Nash Equilibriums for different parameter values.

3.6.1 Case i: $\phi = 0, \theta = 1$

In this case, *Condition 1* always holds¹² but *Condition 2* is never satisfied¹³. So, in this case a non-symmetric equilibrium is never possible. If so, then which symmetric equilibrium is likely? Analysis of the profit functions show that a symmetric non-advertising equilibrium is the only possibility in this case. This result is very intuitive. If everyone knows about existence of a treatment, then consumer-advertising loses its “informative” quality. So, on top of that if there are no stubborn patients, no firm has any incentive to engage in DTCA.

Proposition 2: *No firm advertises to consumers in equilibrium ($\sigma_1 = 0, \sigma_2 = 0$) if there are no stubborn patients ($\phi = 0$) and if patients are fully aware of the symptoms and treatment possibility ($\theta = 1$).*

3.6.2 Case ii: $\phi = 1, \theta = 1$

In this case, *Condition 1* and *Condition 2* cannot hold simultaneously. Hence, a non-symmetric equilibrium can be ruled out with certainty. Under our assumption of very high profit margin, there should be a symmetric advertising

¹²

$$\frac{F}{N} + C_c[1 + \log p - \log 8 - \log C_c] > 0$$

This analysis assumes that profit margin is at least as large to allow $p > 8C_c$

¹³

$$\frac{F}{N} + C_c[1 + \log p + \log 4 - \log C_c] \not> 0$$

equilibrium ¹⁴. This result is intuitive too: If every patient is stubborn, DTCA acts as a major source of increasing market share. Firms advertise because, any patient who receives ad from only one firm contributes to that firm's market share. Also, any patient who received ad from the other firm gets nullified (depends on doctor's decision only) as soon as they receive an ad from this firm too. In Model I we saw that when $\theta = 0$ but $\phi = 1$, then too the symmetric advertising equilibrium was expected. There the same intuition worked, also DTCA maintained its informative value since the disease was very unfamiliar. However, if profit margin is not so high, a symmetric non-advertising equilibrium cannot be ruled out.

We can summarize all the intuition from our analysis of advertising equilibriums in Table 2. Similar analysis can be done to show that when $\phi = 0$ but $\theta > 0$, non-symmetric equilibrium is likely for low values of θ . But as value of θ increases, a symmetric-nonadvertising equilibrium becomes most likely. In short,

- For $\phi \approx 0$, $\theta \approx 0$ the only advertising equilibrium is a *non-symmetric* equilibrium.
- When $\phi \approx 0$, but θ is very high, a *symmetric non-advertising* equilibrium is likely.
- As value of ϕ becomes high, $\forall \theta$, a *symmetric advertising* equilibrium becomes most likely.

	$\theta = 0$	$\theta = 1$
$\phi = 0$	Non-Symmetric	Symmetric Non-Advertising
$\phi = 1$	Symmetric Advertising	Symmetric Advertising

Table 2: Likelihood of different advertising SPNEs for different parameter values

As we have already mentioned, surveys done in the US find that the value of ϕ is very small. Hence we can claim that in this country, **diseases for which θ is high should see much less DTCA.**

¹⁴This requires,

$$4/3C_c + F/N + C_c[\log p + \log(\sqrt{1 + \frac{32C_c}{p}} + 1) - \log 8 - \log C_c] < P/4 + \frac{6C_c}{\sqrt{1 + \frac{32C_c}{p}} + 1}$$

3.7 Correlation Between Doctor and Consumer Advertisements

So far, we have seen under what conditions firms might choose to engage in DTCA. The question that automatically follows is whether a firm that decides to do consumer advertising reduces number of advertisements sent to the doctor. Are doctor and consumer advertisements negatively correlated? Especially if number of stubborn patients are very high, it might make sense to not advertise to doctors as much, instead increase DTCA so that patients make the doctor prescribe whatever they want.

However, we find that in these models DTCA always complements doctor advertisements. Even in the case where $\phi = 1$, we find that DTCA and doctor-advertising are positively correlated¹⁵. This result is not surprising intuitively if we think carefully. Doctor advertising is always very important for firms because we assume that even a stubborn person relies on the doctor's prescribing decision if he receives ad from more than one firm. Hence, when ϕ is very high a firm advertises to consumers because (i)it hopes to reach some stubborn patients to whom the other firm's ad did not reach and (ii)the firm wants its own ad to reach all those patients who have received the other firm's ad. Doctor advertisement is always important because the doctor makes decision on behalf of non-stubborn patients and also those stubborn patients who received ad from both firms.

Proposition 3: *Advertising to consumers does not substitute for advertising directed to physicians ($\frac{\delta s_i}{\delta \sigma_i} \not\leq 0$)*

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$$\begin{aligned}
 s_{i|i=1,2} &= \frac{NP}{4C_d} [1 - (1 - 2\phi)e^{-\sigma_1/N}e^{-\sigma_2/N} - \phi(e^{-\sigma_1/N} + e^{-\sigma_2/N})] \\
 \frac{\delta s_1}{\delta \sigma_1} &= \frac{NP}{4C_d} \left[\frac{1 - 2\phi}{N} e^{-\sigma_1/N} e^{-\sigma_2/N} + \frac{\phi}{N} e^{-\sigma_1/N} \right] \\
 &\Rightarrow \frac{\delta s_1}{\delta \sigma_1} = \frac{P}{4C_d} [e^{-\sigma_1/N} \{ \phi + (1 - 2\phi)e^{-\sigma_2/N} \}] \\
 \text{Hence, } \frac{\delta s_1}{\delta \sigma_1} &< 0 \Leftrightarrow \phi + (1 - 2\phi)e^{-\sigma_2/N} < 0 \\
 &\Leftrightarrow \phi < (2\phi - 1)e^{-\sigma_2/N}
 \end{aligned}$$

But this does not hold for any ϕ . Even with both ϕ and θ in the model, the same conclusion holds

4 Conclusion

Our goal was to find out which advertising strategies are likely to be employed and under what circumstances when it comes to promoting a product in a specialized market set up. Focusing specifically on the pharmaceutical industry we find that engaging in DTCA is indeed the logical thing to do for companies if,

1. many consumers are willing to contribute to their own prescription decisions, and
2. the prescription medication is used to treat unfamiliar diseases

Our analysis is based on the assumption that the companies must have a very high profit margin. Indeed, pharmaceuticals more often than not rank as the most profitable sector in the United States¹⁶. The observed trend¹⁷ in advertising by the U.S. pharmaceutical companies can be well-explained by our model. Our theoretical conclusion complements the empirical finding by Iizuka (2004) that DTCA is mostly done for under-treated diseases. That is, we see DTCA for disease categories that have very low values of θ in general. Also, according to surveys¹⁸ conducted by several pharmaceutical research groups only very small percent of patients can be called *stubborn* consumers. Less than 30% patients talk to their doctors after viewing an ad about a particular drug, and only few of them effectively succeed to make their doctors prescribe what they wanted. So, this suggests that ϕ is not very large for U.S. patients and these can well explain why we find only some companies bearing the burden of advertising to consumers while others selling competing brands become free-riders on them. As we have already mentioned, in reality we find significant within-class variation in DTCA and our models suggest that such non-symmetric advertising is likely for unfamiliar diseases and when patients are not stubborn in general. Also, it is easy to see that for unfamiliar diseases DTCA increases awareness and hence market size, but the only channel through which DTCA could affect market share is through stubborn patients. If there are not many stubborn patients, DTCA has no significant effect on market share. Thus, our theoretical result supports the facts and empirical findings.

Even without an explicit theoretical analysis on welfare effect of DTCA, intuitively we can say that if DTCA is done for low θ (unfamiliar-disease), then it has a welfare improving effect. Patients who would not otherwise be treated

¹⁶Source: annual Fortune 500 ranking of America's top industries

¹⁷DTCA is concentrated among very few classes of drugs.

¹⁸For example, 1997 Prevention magazine survey.

now consult a physician and get treatment as a result of DTCA¹⁹. However, if DTCA is done for high ϕ (more consumers are stubborn type) it is likely to have a welfare-reducing effect if we assume that insisting patients distort doctor's *expert* decision, or arguing with patients result in the waste of valuable time (many doctor surveys suggest this). But whether the overall effect of DTCA on welfare is positive or negative will depend on the relative values of θ and ϕ for each particular disease category and market. Another point to notice here is that, we show that doctor advertising is important even if it does not inform quality or existence. Normally people believe that all drug companies advertise to doctors because doctors need to know about the product and its quality. But we show that even if doctor knows about the product and its quality, firms still have incentives to heavily advertise to doctors as long as doctors can be influenced.

Even though the analysis in the paper is presented in the context of the pharmaceutical industry rather than in a general framework of manufacturers, experts and consumers, very similar intuition should hold in any specialized markets where consumers choose to rely on expert-opinion. Analysis in terms of pharmaceutical companies, doctors and patients certainly have intuitive appeal. Introduction of so called "stubborn patients" makes the paper more relevant to other specialized markets where the consumers can have strong influence on the experts.

This paper is only the first step in studying advertising prospects and challenges in a specialized market setting. We believe there are many opportunities for research in this area that can generate useful economic insights. Empirical tests for the theoretical propositions derived in this paper are difficult due to unavailability of data. We are working on finding acceptable proxy variables. Future research agenda includes extending the model to multi-firm and multi-period settings.

¹⁹Again, our crucial assumption here is that there are no OTC medicines for these prescription drugs. Otherwise, even when patients do not see a doctor, they can treat themselves using over-the-counter drugs

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A Appendix 1: Solution to Model I

A.1 Case I : $\sigma_1 = 0, \sigma_2 = 0$

$$E[\pi_1(\sigma_1, s_1)] = 0$$

$$E[\pi_2(\sigma_2, s_2)] = 0$$

A.2 Case II : $\sigma_1 = 0, \sigma_2 \neq 0$

We have

$$E[\pi_1(0, s_1)] = Np_1 \frac{s_1}{s_1 + s_2} (1 - \phi)(1 - e^{-\sigma_2/N}) - s_1 C_d$$

$$\text{Therefore, } \frac{\partial E[\pi_1(0, s_1)]}{\partial s_1} = Np_1 \frac{s_2}{(s_1 + s_2)^2} (1 - \phi)(1 - e^{-\sigma_2/N}) - C_d = 0$$

We also have

$$E[\pi_2(\sigma_2, s_2)] = Np_2 \phi(1 - e^{-\sigma_2/N}) + Np_2 \frac{s_2}{s_1 + s_2} (1 - \phi)(1 - e^{-\sigma_2/N}) - \sigma_1 C_c - s_1 C_d - F$$

$$\text{So, } \frac{\partial E[\pi_2(\sigma_2, s_2)]}{\partial s_2} = Np_2 \frac{s_1}{(s_1 + s_2)^2} (1 - \phi)(1 - e^{-\sigma_2/N}) - C_d = 0$$

Solving for s_1 and s_2 ,

$$\frac{s_1}{s_1 + s_2} = \frac{p_1}{p_1 + p_2}$$

and

$$\frac{s_2}{s_1 + s_2} = \frac{p_2}{p_1 + p_2}$$

And also,

$$s_1 = \frac{(p_1)^2 p_2}{(p_1 + p_2)^2} \frac{N}{C_d} (1 - \phi)(1 - e^{-\sigma_2/N})$$

$$s_2 = \frac{p_1 (p_2)^2}{(p_1 + p_2)^2} \frac{N}{C_d} (1 - \phi)(1 - e^{-\sigma_2/N})$$

Putting these values back in the original profit functions,

$$E[\pi_2(\sigma_2)] = N p_2 \phi (1 - e^{-\sigma_2/N}) + N(1 - \phi) \frac{(p_2)^3}{(p_1 + p_2)^2} (1 - e^{-\sigma_2/N}) - \sigma_2 C_c - F$$

$$\text{So, } \frac{\partial E[\pi_2(\sigma_2)]}{\partial \sigma_2} = p_2 \phi e^{-\sigma_2/N} + (1 - \phi) \frac{(p_2)^3}{(p_1 + p_2)^2} e^{-\sigma_2/N} - C_c = 0$$

$$\implies e^{-\sigma_2/N} = \frac{C_c}{p_2} \frac{(p_1 + p_2)^2}{\phi p^2 + 2\phi p_1 p_2 + p^2}$$

Taking logarithms of both sides,

$$\frac{\sigma_2}{N} = \log p_2 + \log(\phi p_1^2 + 2\phi p_1 p_2 + p_2^2) - \log C_c - 2 \log(p_1 + p_2)$$

Also,

$$\frac{\partial^2 E[\pi_2(\sigma_2)]}{\partial \sigma_2^2} = -\frac{p_2}{N} e^{-\sigma_2/N} \frac{\phi p_1^2 + 2\phi p_1 p_2 + p_2^2}{(p_1 + p_2)^2} < 0$$

Using these results one can now write,

$$E\pi_1 = N \frac{p_1^3}{(p_1 + p_2)^2} (1 - \phi) \left(1 - \frac{C_c (p_1 + p_2)^2}{p_2 (\phi p_1^2 + 2\phi p_1 p_2 + p_2^2)}\right)$$

Similarly, one can derive that

$$E\pi_2 = \frac{N p_2 (\phi p_1^2 + 2\phi p_1 p_2 + p_2^2)}{(p_1 + p_2)^2} - N C_c [1 + \log p_2 + \log(\phi p_1^2 + 2\phi p_1 p_2 + p_2^2) - \log C_c - 2 \log(p_1 + p_2)] - F$$

A.3 Case III : $\sigma_1 \neq 0, \sigma_2 = 0$

We follow the same procedure:

$$E[\pi_1(\sigma_1, s_1)] = N p_1 \phi (1 - e^{-\sigma_1/N}) + N p_1 \frac{s_1}{s_1 + s_2} (1 - \phi) (1 - e^{-\sigma_1/N}) - \sigma_1 C - c - s_1 C_d - F$$

$$\implies \frac{\partial [\pi_1(\sigma_1, s_1)]}{\partial s_1} = N p_1 \frac{s_2}{(s_1 + s_2)^2} (1 - \phi) (1 - e^{-\sigma_1/N}) - C_d = 0$$

and

$$E[\pi_2(0, s_2)] = Np_2 \frac{s_2}{s_1 + s_2} (1 - \phi)(1 - e^{-\sigma_1/N}) - s_2 C_d$$

$$\implies \frac{\partial E[\pi_2(0, s_2)]}{\partial s_2} = Np_2 \frac{s_1}{(s_1 + s_2)^2} (1 - \phi)(1 - e^{-\sigma_1/N}) - C_d = 0$$

Using similar calculations as Case II, one gets

$$\frac{s_1}{s_1 + s_2} = \frac{p_1}{p_1 + p_2}$$

and

$$\frac{s_2}{s_1 + s_2} = \frac{p_2}{p_1 + p_2}$$

. Also,

$$s_i = \frac{p_i^2 p_j}{(p_i + p_j)^2} \frac{N}{C_d} (1 - \phi)(1 - e^{-\sigma_1/N}), \quad i, j = 1, 2; \quad i \neq j$$

Now putting these values in original profit function of firm 1 and taking first order condition with respect to σ_1 one gets,

$$\frac{\partial E[\pi_1(\sigma_1)]}{\partial \sigma_1} = e^{-\sigma_1/N} \frac{p_1(\phi p_2^2 + 2\phi p_1 p_2 + p_1^2)}{(p_1 + p_2)^2} - C_c = 0$$

$$\implies e^{-\sigma_1/N} = \frac{C_c (p_1 + p_2)^2}{p_1(\phi p_2^2 + 2\phi p_1 p_2 + p_1^2)}$$

Taking logarithms on both sides of the last equation, we get

$$\frac{\sigma_1}{N} = \log p + \log(\phi p_2^2 + 2\phi p_1 p_2 + p_1^2) - \log C_c - 2 \log(p_1 + p_2)$$

Writing the expected profit functions in terms of the parameters,

$$E[\pi_1] = \frac{Np_1(\phi p_2^2 + 2\phi p_1 p_2 + p_1^2)}{(p_1 + p_2)^2} - NC_c[1 + \log p_1 + \log(\phi p_2^2 + 2\phi p_1 p_2 + p_1^2) - \log C_c - 2 \log(p_1 + p_2)] - F$$

and

$$E[\pi_2] = \frac{Np_2^3}{(p_1 + p_2)^2} (1 - \phi) \left(1 - \frac{C_c (p_1 + p_2)^2}{p_1(\phi p_2^2 + 2\phi p_1 p_2 + p_1^2)} \right)$$

A.4 Case IV : $\sigma_1 \neq 0, \sigma_2 \neq 0$

We now impose $p_1 = p_2$:

$$E[\pi_1(\sigma_1, s_1)] = Np[\phi(1 - e^{-\sigma_1/N})e^{-\sigma_2/N} + \frac{s_1}{s_1 + s_2}(1 - e^{-\sigma_1/N}e^{-\sigma_2/N} + 2\phi e^{-\sigma_1/N}e^{-\sigma_2/N} - \phi e^{-\sigma_1/N} - \phi e^{-\sigma_2/N})] - \sigma_1 C_c - s_1 C_d - F$$

and

$$E[\pi_2(\sigma_2, s_2)] = Np[\phi(1 - e^{-\sigma_2/N})e^{-\sigma_1/N} + \frac{s_2}{s_1 + s_2}(1 - e^{-\sigma_1/N}e^{-\sigma_2/N} + 2\phi e^{-\sigma_1/N}e^{-\sigma_2/N} - \phi e^{-\sigma_1/N} - \phi e^{-\sigma_2/N})] - \sigma_2 C_c - s_2 C_d - F$$

Taking first order conditions with respect to s_1 and s_2 and then solving,

$$\frac{s_1}{s_1 + s_2} = \frac{s_2}{s_1 + s_2} = \frac{1}{2}$$

and also,

$$s_1 = s_2 = \frac{Np}{4C_d}[1 - e^{-\sigma_1/N}e^{-\sigma_2/N} + 2\phi e^{-\sigma_1/N}e^{-\sigma_2/N} - \phi e^{-\sigma_1/N} - \phi e^{-\sigma_2/N}]$$

These values are put back in the profit functions, and then first order conditions are enforced with respect to σ_1 and σ_2 for π_1 and π_2 respectively. And finally, these first order conditions are solved to get values of σ_1 and σ_2 in terms of the parameters of the model.

$$E[\pi_1(\sigma_1)] = Np\phi(1 - e^{-\sigma_1/N})e^{-\sigma_2/N} + \frac{Np}{4}(1 - e^{-\sigma_1/N}e^{-\sigma_2/N} + 2\phi e^{-\sigma_1/N}e^{-\sigma_2/N} - \phi e^{-\sigma_1/N} - \phi e^{-\sigma_2/N}) - \sigma_1 C_c - F$$

$$E[\pi_2(\sigma_2)] = Np\phi(1 - e^{-\sigma_2/N})e^{-\sigma_1/N} + \frac{Np}{4}(1 - e^{-\sigma_1/N}e^{-\sigma_2/N} + 2\phi e^{-\sigma_1/N}e^{-\sigma_2/N} - \phi e^{-\sigma_1/N} - \phi e^{-\sigma_2/N}) - \sigma_2 C_c - F$$

$$\implies \frac{\partial E[\pi_1(\sigma_1)]}{\partial \sigma_1} = \frac{pe^{-\sigma_1/N}}{4}(e^{-\sigma_2/N}(1 + 2\phi) + \phi) - C_c = 0$$

$$\frac{\partial E[\pi_2(\sigma_2)]}{\partial \sigma_2} = \frac{p}{4}e^{-\sigma_1/N}e^{-\sigma_2/N}(1 + 2\phi) + \frac{p\phi}{4}e^{-\sigma_2/N} - C_c = 0$$

$$\text{and } \frac{\partial^2 E[\pi_i(\sigma_i)]}{\partial \sigma_i^2} = -\frac{pe^{-\sigma_i/N}}{4N}(e^{-\sigma_j/N}(1 + 2\phi) + \phi) < 0, \text{ where } i, j \in \{1, 2\}, i \neq j.$$

Solving, we get,

$$e^{-\sigma_2/N} = \frac{\sqrt{\phi^2 + \frac{16C_c}{p}(1+2\phi)} - \phi}{2(1+2\phi)}$$

$$e^{-\sigma_1/N} = \frac{8C_c}{p(\sqrt{\phi^2 + \frac{16C_c}{p}(1+2\phi)} + \phi)}$$

and so,

$$\frac{\sigma_2}{N} = \log 2 + \log(1+2\phi) - \log\left(\sqrt{\phi^2 + \frac{16C_c}{p}(1+2\phi)} - \phi\right)$$

$$\frac{\sigma_1}{N} = \log p + \log\left(\sqrt{\phi^2 + \frac{16C_c}{p}(1+2\phi)} + \phi\right) - \log 8 - \log C_c$$

Now these values are inserted in the profit functions to get expected profits in terms of the parameters of the model. After simplifications we get,

$$E[\pi_1] = \frac{N(p-4C_c)\sqrt{\phi^2 + \frac{16C_c(1+2\phi)}{p}} + \phi(p+20C_c)}{4\sqrt{\phi^2 + \frac{16C_c(1+2\phi)}{p}} + \phi} -$$

$$NC_c[\log p + \log\left(\sqrt{\phi^2 + \frac{16C_c}{p}(1+2\phi)} + \phi\right) - \log 8 - \log C_c] - F$$

and

$$E[\pi_2] = \frac{N(p-4C_c)\sqrt{\phi^2 + \frac{16C_c(1+2\phi)}{p}} + \phi(p+20C_c)}{4\sqrt{\phi^2 + \frac{16C_c(1+2\phi)}{p}} + \phi} -$$

$$NC_c[\log 2 + \log(1+2\phi) - \log\left(\sqrt{\phi^2 + \frac{16C_c(1+2\phi)}{p}} - \phi\right)] - F$$

B Appendix 2: Solution to Model II

We follow the same solution procedure as in case of Model I. Here we just report the expected profits of firms in four separate cases in terms of the parameters of the model.

B.1 Case I : $\sigma_1 = 0, \sigma_2 = 0$

$$E[\pi_1] = Np\frac{\theta}{4}$$

and

$$E[\pi_2] = Np\frac{\theta}{4}$$

B.2 Case II : $\sigma_1 = 0, \sigma_2 \neq 0$

$$E[\pi_2] = \frac{N}{4}[p(1 + 3\phi) - 4C_c] - NC_c[\log p + \log(1 + 3\phi - \theta) - \log 4 - \log C_c] - F$$

$$E[\pi_1] = \frac{N}{4}[p(1 - \phi) - \frac{4C_c(1 - \theta - \phi)}{1 + 3\phi - \theta}]$$

B.3 Case III : $\sigma_1 \neq 0, \sigma_2 = 0$

$$E[\pi_1] = \frac{N}{4}[p(1 + 3\phi) - 4C_c] - NC_c[\log p + \log(1 + 3\phi - \theta) - \log 4 - \log C_c] - F$$

$$E[\pi_2] = \frac{N}{4}[p(1 - \phi) - \frac{4C_c(1 - \phi - \theta)}{1 + 3\phi - \theta}]$$

B.4 Case IV : $\sigma_1 \neq 0, \sigma_2 \neq 0$

$$E[\pi_1] = \frac{Np}{4} + \frac{6NC_c\phi}{\sqrt{\phi^2 + \frac{16C_c}{p}(1 + 2\phi - \theta) + \phi}} -$$

$$NC_c[1 + \log p + \log(\sqrt{\phi^2 + \frac{16C_c}{p}(1 + 2\phi - \theta) + \phi}) - \log 8 - \log C_c] - F$$

and

$$E[\pi_2] = \frac{Np}{4} + \frac{6NC_c\phi}{\sqrt{\phi^2 + \frac{16C_c}{p}(1 + 2\phi - \theta) + \phi}} -$$

$$NC_c[1 + \log 2 + \log(1 + 2\phi - \theta) - \log(\sqrt{\phi^2 + \frac{16C_c}{p}(1 + 2\phi - \theta) - \phi})] - F$$