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On the impact of advertising initiatives in supply chains

Wenqing Zhang [a,*], Shanling Li [b], Dan Zhang [c], Wenhua Hou [d]

[a] SolBridge International School of Business, Dong-gu, Uam-ro 128 (Samsung-dong) Daejeon, 300-814, South Korea
[b] Desautels Faculty of Management, McGill University, Canada
[c] Leeds School of Business, University of Colorado at Boulder, USA
[d] Business School, Nankai University, China

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ABSTRACT

Advertising plays an important role in affecting consumer demand. Socially responsible firms are expected to use advertising judiciously, limiting advertising of "bad" products. An example is the advertising initiative adopted by several major food manufacturers to limit the advertising of unhealthy food categories to children. Such initiatives are based on the belief that less advertising will lead to less consumption of these unhealthy food categories. However, food manufacturers usually distribute products to consumers through retailers whose advertising is not restricted by those initiative programs. In this paper, we examine the effectiveness of such advertising initiative in a leader–follower supply chain with one manufacturer and one retailer. We assume that both the manufacturer and the retailer can choose to participate in the advertising initiative by reducing their advertising levels. The problem is formulated as a Stackelberg game. We show that the effectiveness of the advertising initiative critically depends on the leader's participation in the initiative. If the leader is willing to reduce the advertising level below a threshold, the market coverage of the product can drop significantly. On the other hand, if only the follower participates in the initiative, the market coverage is likely to expand in the majority of cases. Managerial implications of this research are also discussed.

1. Introduction

Advertising plays an important role in affecting consumer demand and is a critical lever to enhance firm profitability in the marketplace. Major companies spend billions of dollars on advertising every year (Pergelova et al., 2010). On the other hand, companies are increasingly under pressure to behave responsibly in the society. They are expected to use advertising judiciously, limiting the advertising of "bad" products – products that may cause negative consequences for consumers. One category of products under increasing scrutiny is food product, reflecting the public's concerns on obesity, especially for children. Childhood obesity ranks the highest among emerging public health concerns in the United States, Canada, and globally (Daniels, 2006; Ludwig et al., 2001; Reilly and Dorosty, 1999; Reilly et al., 2003). According to CDC website, the obesity rate has nearly tripled over the last thirty years among children in North America, coupled with complaints of excessive marketing of junk food to children.

As part of their response to the public's concerns, many large food and beverage firms engage in some corporate social responsibility (CSR) activities (Carter and Jennings, 2002; Lewin et al., 2006; Ludwig and Nestle, 2008; Simon, 2006; Wilde, 2009). In 2006, the Council of Better Business Bureaus (CBBB) launched the Children's Food and Beverage Advertising Initiative (CFBAI) as a form of CSR to promote healthy dietary habits and lifestyles among children under the age of 12. CFBAI is a voluntary, self-regulatory program for food and beverage companies and is designed to shift the mix of advertising messages to children to encourage choices of healthy food. Under the terms of the CFBAI, 16 participating companies (see BBB website[1] for a complete list of the 16 companies) agreed to limit their advertising budget for traditional food and beverage products that are not considered healthy, especially under excessive consumption.

CFBAI is designed under the assumption that less advertising of unhealthy products by the large food and beverage companies will lead to less demand for these products. However, there is no evidence, empirical and otherwise, that supports such assumption. The central question that we would like to investigate is whether this assumption is valid. We consider a two-level supply chain with one manufacturer and one retailer that offers one product. We examine the impact of initiative restricting advertising on the market coverage of the product. The product under consideration is a "bad" product for which we would like to reduce the

* Corresponding author. Tel.: +82(42)630 8537.
E-mail addresses: wzhang@solbridge.ac.kr (W. Zhang), shanling.li@mcgill.ca (S. Li), dan.zhang@colorado.edu (D. Zhang), whhou@nankai.edu.cn (W. Hou).

[1] http://www.bbb.org/us/childrens-food-and-beverage-advertising-initiative/.

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market coverage. We also study the profit implications for the two supply chain partners.

Our analysis considers several different initiative programs. It is possible that either the manufacturer or the retailer participates in the program alone, or they both participate. Note that even though companies involved in CFBAI are primarily food and beverage companies, there is increasing pressure for downstream supply chain partners (e.g., Walmart) to participate as well.

We formulate the problem as a Stackelberg game in which the powerful party is considered as the leader (*he* hereafter) and the less powerful party as the follower (*she* hereafter). Either party can participate in the advertising initiative. Both analytical and numerical results show that the effectiveness of the advertising initiative critically depends on the leader–follower relationship. In general, the advertising initiative would be effective and the market coverage will be reduced if the leader participates in the initiative. If the leader is willing to reduce the advertising level below a threshold, the market coverage can show a significant drop. In contrast, if only the follower participates in the program, the market coverage would expand in the majority of cases. Interestingly, the leader's profit would not be severely affected no matter who participates in the initiative; however, the follower's profit would reduce if the leader participates in the initiative. Not surprisingly, the initiative program would be most effective if both manufacturer and retailer participate.

Our paper belongs to the emerging stream of research on CSR in supply chains. There has been growing interest in managing CSR in supply chains proactively (Li and Lee, 2012; Cho et al., 2012; Plambeck et al., 2012). Guo et al. (2013) consider the a firm's optimal sourcing decision from a mixed pool of suppliers who may or may not be socially responsible while balancing procurement cost increase and demand from socially conscious consumers. Aral and Van Wassenhove (2012) analyze optimal sourcing decisions when the level of responsibility of the supplier base is unknown and must be learned by the buyer, following a multi-armed bandit approach. These theoretical studies help understand when responsible operation is the equilibrium behavior of rational, profit-maximizing firms. However, the vast majority of the literature on CSR in supply chains is empirical and descriptive, see Carroll (1991) and Maignan et al. (2002), etc.

There is a vast literature on advertising in supply chains in both the marketing and operations literature. Since the 1970s, marketing to children and their parents has become a core part of overall marketing strategy (McNeal, 1999). In the context of supply chains, the literature focuses on two streams: (i) co-op advertising that refers to national advertising by the manufacturer and local advertising by the retailer (Davis, 1994; Jørgensen et al., 2001; Milgrom et al., 1986); (ii) non-co-op advertising that delineates the adverting effectiveness by the manufacturer and the retailer and assumes the retailer retains equal or more power than the manufacturer (Achenbaum and Mitchel, 1987; Buzzell et al., 1990; Huang and Li, 2001). While marketing power has been shifting to retailers in recent years, manufacturers traditionally hold stronger power than do retailers and act as leaders in the supply chains. In analytical framework, this leads to models where manufacturers (the leader) make decisions (advertising levels, wholesale prices, etc.) first in anticipation of retailers' responses. Very few papers deal with the effect of limiting advertising limitation of one supply chain partner on the end demand, which is a key feature of the model we analyze in this paper.

In the area of operations management, many studies can be found in examining supplier–retailer or seller–buyer power relationships (Coughlan and Wernerfelt, 1989; Choi, 1991; Dawson, 2000; Lee and Staelin, 1997). Ertek and Griffin (2002) examined price, advertising and profit decisions in both manufacturer-driven and retailer-driven decentralized supply chains. Huang et al. (2002) indicate that total demand and manufacturer's local advertising spending are higher in partnership as opposed to leader–follower structure. Similar results can be found in Esmaeili et al. (2009) and Esmaeili and Zeephongsekul (2010), where it is shown that both selling price and marketing expenditure are smaller in cooperative than in non-cooperative games, consequently demand is expected to be larger under a cooperative structure. Nonetheless, our analysis finds that the total demand can be *higher* in leader–follower structure when additional constraint is imposed. Other related research can be found in Netessine and Rudi (2004) and Lariviere and Porteus (1999).

The remainder of the paper is organized as follows. Our model is introduced in Section 2 and detailed analyzes are provided in Section 3. In Section 4, we provide some numerical experiments and discusses the managerial implications of this research and Section 5 summarizes our research findings and discusses future research directions. All proofs are given in the Appendix.

2. Model framework

We consider a decentralized food supply chain that consists of one manufacturer and one retailer. The manufacturer produces a family of traditional food products that can be aggregated into one product family, while the retailer (seller) sells the family of products in the market. We also assume the product is not healthy and the consumption of the food product might cause various diseases such as obesity and diabetes (Ebbeling et al., 2002; Reilly et al., 2003). Since the food industry has recently become a target for childhood obesity (Lobstein and Dibb, 2005), we assume either the manufacturer or the retailer might respond to the concern about childhood obesity by participating in the CFBAI-like CSR activity. In this research, we focus on the voluntarily reduced advertising level in the program, thus we use advertising pledge to replace the overall CFBAI program.

We formulate the problem as a Stackelberg game model in which the manufacturer and the retailer form a leader–follower relationship. Note that whether the manufacturer (retailer) is the leader or the follower is often determined by the relative *power* of the relevant parties, see, e.g., Cachon and Lariviere (2005) and Taylor (2002), etc. To discuss how the power is distributed between the two parties in a supply chain is beyond the scope of this paper. Therefore in our model, we assume the roles of the leader and the follower are preset.

The dynamics of the leader–follower game are as follows. There are two phases in a complete decision-making process. In the first phase, the leader decides on his advertising level; after observing the leader's decision, the follower makes her advertising decision. In the second phase, the leader set his price of the product; the follower then decides on her price after observing the price determined by the leader. Table 1 provides the notation used in our general model.

The objective of each party is to maximize his (her) profit that can be expressed as below:

$$\pi(x, w; y, \mu) = s(x, y)(1 - w - \mu)(w - c) - x, \tag{1}$$

$$\phi(y, \mu; x, w) = s(x, y)(1 - w - \mu)\mu - y, \tag{2}$$

where $\pi(x, w; y, \mu)$ and $\phi(y, \mu; x, w)$ represent the net profits made by the manufacturer and the retailer respectively resulted from the decisions of x, y, w and μ, which are explained below.

In Eqs. (1) and (2), x and y represent the advertising levels invested by the manufacturer and the retailer, respectively; c and w are unit production cost and wholesale price charged by the manufacturer; μ and p ($p = w + \mu$) are the profit margin and market price charged by the retailer; $s(x, y)$ can be considered as the *market penetration function* due to the advertising levels of x and y and

Table 1
Notation.

Notation	Meaning
β_0	Parameter for potential reserved market, $0 < \beta_0 < 1$
β_1	Consumer sensitivity parameter towards manufacturer advertising, $\beta_1 > 0$
β_2	Consumer sensitivity parameter towards retailer advertising, $\beta_2 > 0$
β_3	Advertising spillover effect parameter, $0 < \beta_3 < \beta_1\beta_2$
c	Unit production cost, $0 < c < 1$
$\pi(\cdot)$	Manufacturer's profit function
$\phi(\cdot)$	Retailer's profit function
w	Decision variable of unit whole sale price determined by the manufacturer, $c < w < 1$
x	Decision variable of manufacturer's advertising level determined by the manufacturer, $x \geqslant 0$
μ	Decision variable of unit profit margin determined by the retailer, $0 < \mu < 1$
y	Decision variable of retailer advertising level determined by the retailer, $y \geqslant 0$

measures the consumer awareness of the product. Note that we have $p < 1$ so that the expression of $1 - w - \mu = 1 - p$ captures consumer response to p. Another feature of our model is that decision-making is done in two stages. Each party makes advertising level decisions, x and y, respectively, in stage 1; and pricing decisions, w and p, respectively, in the following stage. In fact, this feature is very popular in marketing and operations management literature, see, e.g., Banerjee and Bandyopadhyay (2003) and McGahan and Ghemawat (1994). In both stages, the leader moves first and the follower moves second.

The market demand level depends on the market penetration function, $s(x,y)$, and consumer response to the market price, $(1 - w - \mu)$, as below:

$$\kappa(x,w,y,\mu) = s(x,y)(1 - w - \mu). \tag{3}$$

In the above equation, $\kappa(x,w,y,\mu)$ can be interpreted as the market coverage of the product. In our analysis later in the paper, we focus on $\kappa(x,w,y,\mu)$. The market expansion of the product corresponds to an increase in $\kappa(x,w,y,\mu)$, while a market shrinkage corresponds to a decrease in $\kappa(x,w,y,\mu)$.

We propose the following format for the market penetration function $s(x,y)$:

$$s(x,y) = 1 - \beta_0 e^{-\beta_1 x - \beta_2 y - \beta_3 xy}, \quad 0 < \beta_0 < 1, \quad \beta_1, \beta_2, \beta_3 > 0, \quad \beta_1\beta_2 > \beta_3, \tag{4}$$

where β_1 and β_2 are parameters reflecting consumer sensitivities to the advertising levels, x and y, respectively, and β_3 represents consumer sensitivity towards the advertising made by both parities. If no advertising is made at all, then $s(x,y) = s(0,0) = (1 - \beta_0)$, which can be interpreted as the reserved market coverage. We also want to highlight that as long as $\beta_3 > 0$, if one party increases his (her) advertising level, the other party would benefit from the first party's advertising and might choose to lower her (his) own advertising level. The parameter β_3 reflects this spillover effect. Similar specification of advertising function like $s(x,y)$ are very common in the marketing and operations management literature (Bergen and John, 1997; Frankenberger and Graham, 2003). Furthermore, the advertising function must meet a number of generally accepted findings about how advertising works, see Doyle and Saunders (1990) for details. Note that (4) meets all the findings. Note that in (4), we assume $\beta_1\beta_2 > \beta_3$ in order to ensure the spillover effect, β_3, is limited and would not exceed the joint effect of $\beta_1\beta_2$. This assumption also guarantees that $s(x,y)$ is submodular.

We adopt the two-dimension subscripts kq in our notation. The first subscript k indicates the leader, and the second subscript q indicates which party joins the advertising pledge. Hence we have $k \in \{r, m\}$, where r = *retailer* and m = *manufacturer*, and $q \in \{n, m, r, s\}$, where n = *none of them joins* (benchmark case), m = *manufacturer initiative*, r = *retailer initiative* and s = *simultaneous initiative*. For example, x_{rn} is the manufacturer advertising level in the benchmark case of a retailer-driven supply chain. We also use an asterisk to indicate the equilibrium value.

When the manufacturer or retailer joins the advertising pledge, the advertising level is restricted. We denote the restricted advertising level of the manufacturer (retailer) by $\bar{x}$ ($\bar{y}$). We assume either the manufacturer or the retailer, or both parties can join the advertising pledge. Depending on the parties that join the pledge, there are four cases to analyze for the manufacturer-driven supply or the retailer-driven supply chain.

1. Benchmark case: Neither party joins the advertising pledge. In equilibrium, either player can free choose any advertising level.
2. MI case: The manufacturer makes the pledge and is willing to restrict advertising level to no more than $\bar{x}$; that is, the equilibrium advertising level $x^*_{mn} \leqslant \bar{x}$ for the manufacturer-driven supply chain and the equilibrium advertising level $x^*_{rn} \leqslant \bar{x}$ for the retailer-driven supply chain.
3. RI case: The retailer makes the pledge and is willing to restrict advertising level to no more than $\bar{y}$; that is, the equilibrium advertising level $y^*_{mn} \leqslant \bar{y}$ for the manufacturer-driven supply chain and the equilibrium advertising level $y^*_{rn} \leqslant \bar{y}$ for the retailer-driven supply chain.
4. SI case: Both the manufacturer and the retailer make the pledge and is willing to restrict advertising level to no more than $\bar{x}$ and $\bar{y}$, respectively. Consequently, in equilibrium $(x^*_{ms}, y^*_{ms}) \leqslant (\bar{x}, \bar{y})$ for the manufacturer-driven supply chain and $(x^*_{rs}, y^*_{rs}) \leqslant (\bar{x}, \bar{y})$ for the retailer-driven supply chain.

To analyze all cases, we might recall that Lucchetti et al. (1987) shows a Stackelberg equilibrium exists under fairly general assumptions. Thus, the following theorem provides the theoretical foundation for our analysis:

Theorem 1. *There exists a Stackelberg equilibrium in each of the four cases of benchmark, MI, RI and SI in either a manufacturer- or retailer-driven supply chain.*

Note that Theorem 1 does not guarantee the uniqueness of Stackelberg equilibrium for our model, but we are able to explicitly solve the equilibriums that demonstrate the uniqueness of the equilibrium solutions. We will solve the four cases in a manufacturer-driven supply chain first and discuss the four cases in a retailer-driven supply chain afterwards.

3. Advertising pledge and its impact on market coverage

This section provides equilibrium analysis for various versions of the game. We consider two different supply chain structure: a manufacturer-driven supply chain and a retailer-driven supply chain. For each supply chain structure, we analyze the four cases as outlined in the previous section. Central to our analysis is the equilibrium market coverage of the product. As the purpose of advertising pledges is to reduce the market coverage, an advertising initiative is ineffective if the equilibrium market coverage is larger compared with the benchmark case. Conversely, if the equilibrium market coverage decreases, we consider the advertising initiative effective. As we will show below, the effectiveness of advertising initiatives critically depends on the supply chain structure, as the leader's pledge has quite different impact than the follower's initiative. In general, we conclude that the leader's initiative is more effective.

Section 3.1 considers the benchmark case with no initiatives in a manufacturer-driven supply chain. Section 3.2 then investigates the impact of different advertising pledges. Section 3.3 considers the effect of advertising initiatives in a retailer-driven supply chain. Much detailed analysis is provided in Appendix.

3.1. Benchmark case for a manufacturer-driven supply chain

We first examine the benchmark case assuming no party participates in the advertising pledge. In other words, both parties can freely make their decisions to maximize their net profits. For simplicity, we first omit the subscripts of m and n.

For the given format of $s(x, y)$, we may obtain the profit functions of the manufacturer and the retailer in (1) and (2) respectively as follows

$$\pi(x, w; y, \mu) = \left(1 - \beta_0 e^{-\beta_1 x - \beta_2 y - \beta_3 xy}\right)(1 - w - \mu)(w - c) - x, \tag{5}$$

$$\phi(y, \mu; x, w) = \left(1 - \beta_0 e^{-\beta_1 x - \beta_2 y - \beta_3 xy}\right)(1 - w - \mu)\mu - y. \tag{6}$$

As previously mentioned, the decisions in our Stackelberg game model are made in two stages. We adopt a backward induction approach to obtain the equilibriums in both stages.

The following proposition states equilibrium in the pricing game.

Proposition 1. *$\phi(\mu; y, w, x)$ is concave in μ and $\pi(x, w; y, \mu(w, x, y))$ is concave in w in (5) and (6). $w^* = \frac{1+c}{2}$, $\mu^* = \frac{1-c}{4}$ is the equilibrium of the pricing game.*

After solving the equilibrium shown above in the second-stage, we may write the advertising sub-game in the first-stage as:

$$\pi(x, w^*; y, \mu^*) = \frac{1}{8}(1 - c)^2\left(1 - \beta_0 e^{-\beta_1 x - \beta_2 y - \beta_3 xy}\right) - x, \tag{7}$$

$$\phi(y, \mu^*; x, w^*) = \frac{1}{16}(1 - c)^2\left(1 - \beta_0 e^{-\beta_1 x - \beta_2 y - \beta_3 xy}\right) - y.$$

Given the complete information, the manufacturer first figures out the best response function of y and incorporates it in his profit function before making his decision on the advertising level. The best response function of y in $\phi(y, \mu^*; x, w^*)$ can be written as a function of x:

$$y(x) = \begin{cases} \frac{1}{\beta_2 + \beta_3 x} f(x) & \text{if } f(x) > 0 \\ 0 & \text{if } f(x) \leqslant 0 \end{cases} \tag{8}$$

where $f(x) = \ln \frac{\beta_0(\beta_2 + \beta_3 x)(1-c)^2}{16} - \beta_1 x$. Because $y \geqslant 0$, if $f(x) \leqslant 0$, the only reasonable response of y is $y(x) = 0$. We define a $\tilde{x} \in (\infty, +\infty)$ such that $f(\tilde{x}) = 0$, which leads to $y(\tilde{x}) = 0$. In this case, only the manufacturer will do the advertising when the manufacturer's advertising levels reaches $\tilde{x}$. The corresponding manufacturer's profit function is hence

$$\pi(x, w^*; y(x), \mu^*) = \begin{cases} \frac{1}{8}(1 - c)^2 - \frac{2}{\beta_2 + \beta_3 x} - x, & \text{if } 0 \leqslant x < \tilde{x}, \\ \frac{1}{8}(1 - c)^2(1 - \beta_0 e^{-\beta_1 x}) - x, & \text{if } x \geqslant \tilde{x}. \end{cases} \tag{9}$$

We further define $x_1^* \in (\infty, +\infty)$ and $x_2^* \in (\infty, +\infty)$ as the equilibrium solutions for the first and the second profit functions in (9) with $x \in (\infty, +\infty)$, respectively.

Fig. 1 extensively presents nine possible equilibrium solutions of x for the manufacturer and illustrates the relationships among x_1^*, x_2^*, and $\tilde{x}$ in the nine cases. Note that here x_1^*, x_2^*, and $\tilde{x}$ are derived without imposing the non-negativity constraints. Some cases, such as cases 1–5, evidently generate these optimal solutions out of range. In these cases, the real optimal solution should be 0 as depicted in the figure. However the unconstrained solution can help us analyze characteristics of parameters. For more details, please refer to Appendix (d).

Based on the feasibilities of x_1^*, x_2^* and $\tilde{x}$ defined above, we further derive all feasible equilibrium solutions from the exhaustive nine cases in Fig. 1. We now replace x_1^* and x_2^* by x_{mn}^* and $y^*(x)$ by y_{mn}^* to represent advertising decisions in the manufacturer-driven supply chain and benchmark case. All feasible equilibrium solutions can be categorized in four types, shown as follows: (i) $x_{mn}^* = 0, y_{mn}^* = 0$, derived from case 1 in Fig. 1; (ii) $x_{mn}^* = x_2^* > 0, y_{mn}^* = y(x_2^*) = 0$, corresponding to cases 2, 3, 6 and 9 since in these four cases $x_2^* > \tilde{x}$ and $\pi(x = x_2^*)$ is the maximal profit; (iii) $x_{mn}^* = 0, y_{mn}^* = y(x_1^* = 0) > 0$ from cases 4 and 5 since in both cases $x_1^* < 0 < \tilde{x}$ and $\pi(x = 0 > x_1^*) > \pi(x = x_2^*)$; and (iv) $x_{mn}^* = x_1^* > 0, y_{mn}^* = y(x_1^*) > 0$, which is generated from cases 7 and 8 since in both cases $0 < x_1^* < \tilde{x}$ and $\pi(x = x_1^* > 0) > \pi(x = x_2^*)$.

Proposition 2. *In a manufacturer-driven supply chain, the equilibrium market coverage can be solved by four feasible equilibrium cases in Table 2.*

Proposition 2 states that the market coverages of the product can be measured in accordance with the four feasible equilibrium solutions. As a result of the advertising pledge, the market coverage will be inevitably affected. Therefore, it would be interesting to examine the changes in market coverage and supply chain profits when one or two parties make the advertising pledge in the manufacturer-driven supply chain against the benchmark case with no advertising pledge. The summary results are presented in Table 2. For the details of derivation, please refer to Appendix.

3.2. The effect of advertising pledges in a manufacturer-driven supply chain

If there exists advertising constraint, $x \leqslant \bar{x}$ or $y \leqslant \bar{y}$, we have to re-analyze our model and obtain new equilibrium solutions for the four cases in Table 2. The specific equilibrium solutions and corresponding profits in the four cases are presented in Tables 5(a), (b) and 6(a) as well as 6(b) in Appendix. Our findings show that the pledge would not guarantee to be effective unless the leader or both parties participates in the pledge, subject to some conditions.

In Table 2, for the benchmark case of $x_{mn}^* = 0, y_{mn}^* = 0$, the market coverages in MI, RI and SI do not change, i.e. $\kappa_{mn}^* = \kappa_{mm}^* = \kappa_{mr}^* = \kappa_{ms}^*$. This is rather obvious since the benchmark solution is $x_{mn}^* = 0, y_{mn}^* = 0$ and hence $\bar{x} = 0$ and $\bar{y} = 0$.

For the second solution pattern, $x_{mn}^* > 0$ and $y_{mn}^* = 0$ in the benchmark, only the manufacturer advertises, $\kappa_{mm}^* < \kappa_{mn}^*$ and the lower the $\bar{x}$ is, the smaller κ_{mm}^* becomes (See Appendix D.2). Our result suggests that the leader should be encouraged to participate in the advertising pledge in order to reduce the consumption of the unhealthy food product. For RI, $y_{mn}^* = 0$ results in $\bar{y} = 0$ and x_{mn}^* will not change in that the manufacturer does not make the pledge. As a result, $\kappa_{mr}^* = \kappa_{mn}^*$. For SI, since both parties make the pledge and $\bar{x} < x_{mn}^*, \bar{y} = 0 = y_{mn}^*$, the market coverage is identical to MI's market coverage.

If $x_{mn}^* = 0, y_{mn}^* > 0$, we have $\kappa_{mm}^* = \kappa_{mn}^*$ since $\bar{x} = x_{mn}^* = 0$, and the retailer keeps the optimal advertising level of y_{mn}^*. For RI

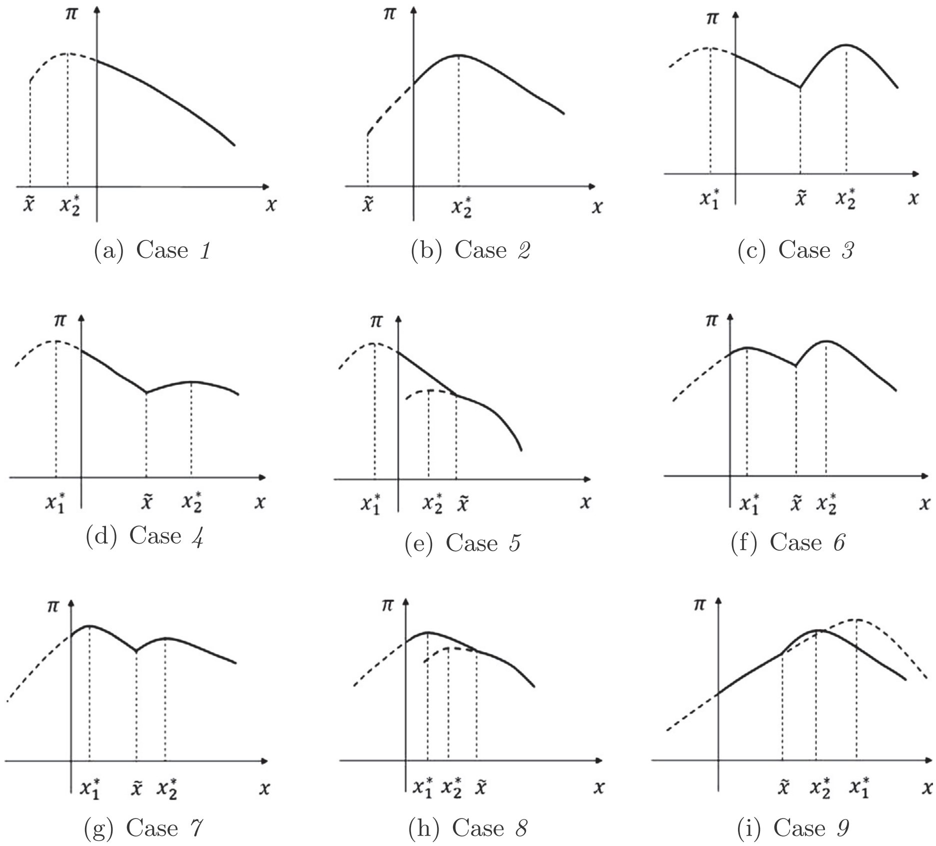


Fig. 1. Manufacturer's profit function in different parameter combinations.

Table 2
Summary of equilibrium market coverage κ, manufacturer driven supply chain.

Patterns	Benchmark	MI
$x_{mn}^*=0,\ y_{mn}^*=0$	$\frac{1-c}{4}(1-\beta_0)$	$\frac{1-c}{4}(1-\beta_0)$
$x_{mn}^*>0,\ y_{mn}^*=0$	$\frac{1-c}{4}\left(1-\frac{\beta_0\Delta}{2\beta_1}\right)$	$\frac{1-c}{4}(1-\beta_0 e^{-\beta_1\bar{x}})$
$x_{mn}^*=0,\ y_{mn}^*>0$	$\frac{1-c}{4}\left(1-\frac{\beta_0\Delta}{\beta_2}\right)$	$\frac{1-c}{4}\left(1-\frac{\beta_0\Delta}{\beta_2}\right)$
$x_{mn}^*>0,\ y_{mn}^*>0$	$\frac{1-c}{4}\left(1-\frac{\beta_0\Delta}{\sqrt{2\beta_3}}\right)$	$\frac{1-c}{4}\left(1-\frac{\beta_0\Delta}{\beta_2+\beta_3\bar{x}}\right)$
Patterns	**RI**	**SI**
$x_{mn}^*=0,\ y_{mn}^*=0$	$\frac{1-c}{4}(1-\beta_0)$	$\frac{1-c}{4}(1-\beta_0)$
$x_{mn}^*>0,\ y_{mn}^*=0$	$\frac{1-c}{4}\left(1-\frac{\beta_0\Delta}{2\beta_1}\right)$	$\frac{1-c}{4}(1-\beta_0 e^{-\beta_1\bar{x}})$
$x_{mn}^*=0,\ y_{mn}^*>0$	$\frac{1-c}{4}\left(1-\frac{\beta_0\Delta}{\beta_2+\beta_3 x_{mr}^*}\right)$	$\frac{1-c}{4}(1-\beta_0 e^{-\beta_2\bar{y}})$
$x_{mn}^*>0,\ y_{mn}^*>0$	$\frac{1-c}{4}\left(1-\frac{\beta_0\Delta}{\beta_2+\beta_3 x_{mr}^*}\right)$	$\frac{1-c}{4}(1-\beta_0 e^{-\beta_1\bar{x}-\beta_2\bar{y}-\beta_3\bar{x}\bar{y}})$

Note: $\Delta=\frac{16}{\beta_0(1-c)^2}$.

case, $\bar{y}<y_{mn}^*$ and $\kappa_{mr}^*=\frac{1-c}{4}\left(1-\frac{\beta_0\Delta}{\beta_2+\beta_3 x_{mr}^*}\right)$. If the leader (manufacturer) does not participate in the pledge, his optimal advertising level will become $x_{mr}^*(x_{mr}^*>x_{mn}^*)$ in order to protect his profit. Interestingly, the market coverage would expand if $\beta_3 x_{mr}^*>0$. In other words, if the follower takes the initiative, the market coverage may expand. This is because, when the follower (retailer) makes the pledge, the manufacturer will aggressively increase its advertising level to make up the loss in the profit due to the pledge made by the retailer. For SI, we have $y=\bar{y}$ and $\bar{x}=x_{mn}^*=0$, the market coverage is obviously smaller than that of MI and RI cases.

If $x_{mn}^*>0, y_{mn}^*>0, \kappa_{mn}^*=\frac{1-c}{4}\left(1-\frac{\beta_0\Delta}{\sqrt{2\beta_3}}\right)$ and $\kappa_{mm}^*=\frac{1-c}{4}\left(1-\frac{\beta_0\Delta}{\beta_2+\beta_3\bar{x}}\right)$. We have $\kappa_{mn}^*>\kappa_{mm}^*$. For RI, $\kappa_{mr}^*=\frac{1-c}{4}\left(1-\frac{\beta_0\Delta}{\beta_2+\beta_3 x_{mr}^*}\right)$ where x_{mr}^* is the new equilibrium solution for x. Here we have $\kappa_{mr}^*>\kappa_{mn}^*$. For SI, when both participate in the pledge, here follows $\kappa_{ms}^*=\frac{1-c}{4}s(\bar{x},\bar{y})$. Based on that, the market coverage will be smaller than that of MI at $\bar{x}$ and depends on both $\bar{x}$ and $\bar{y}$.

To summarize the result, we propose the following proposition.

Proposition 3. *In a manufacturer-driven supply chain, we have the following results:*

(i) If the manufacturer's best strategy is to invest in advertising in the benchmark case, the manufacturer's initiative will reduce the market coverage.
(ii) If the retailer's best strategy is to invest in advertising in the benchmark case, the retailer's initiative will contrarily expand the market coverage in all cases except in Case 4 when $\beta_2 \leqslant 2\beta_1$ holds.
(iii) If both the retailer's and the manufacturer's best strategies in the benchmark case are to invest in advertising, a separate initiative can reduce the market coverage.

For the detailed proof, please see mathematical analysis (D) in Appendix.

Proposition 3 states that in a manufacturer-driven supply chain, only if the leader (manufacturer) participates in the advertising pledge, the program will guarantee to be effective and the market coverage will definitely shrink. This is not true, however, when the follower (retailer) makes the pledge. With no pledge in the supply chain, the manufacturer may take advantage of his leadership by shifting part of the advertising to the follower while choosing an optimal advertising level by himself, given that he is fully aware of the response of the follower for every advertising decision he makes. Then the retailer follows up with an optimal advertising level as well in order to maximize her own profit. Therefore, in the benchmark case, both parties maximize their own profits at the equilibrium. In such a case, the supply chain is the most efficient since the leader and the follower reach a global optimal strategy-duel.

When the manufacturer decides to participate in the pledge, he has to reduce his optimal advertising level that maximizes his profit, and the retailer adjusts her optimal advertising level accordingly in order to protect her profit. Without full (optimal) advertising levels on both sides, the global efficiency is distorted and the market coverage is thus reduced. If the follower decides to participate in the pledge, the manufacturer as the first mover, knowing that the follower has to reduce her optimal advertising level, increases his optimal advertising level to prevent profit loss. As a result, the market coverage expands even more. Lastly, our results show that when both parties participate in the pledge and are willing to reduce their optimal advertising levels, the market coverage would definitely become smaller than that in the case where there is no pledge in the supply chain.

3.3. Retailer-driven supply chain

In this section, we proceed to analyze a retailer-driven supply chain where the retailer is the leader and the manufacturer is the follower. In reality, such phenomenon are very popular, such as Wal–Mart who dominates all of its suppliers. Similar to the model in the previous section, in the first stage, the retailer determines her optimal advertising level and then the manufacturer follows. In the second stage, the retailer is the first to determine the profit margin of the market price and then the manufacturer responds with his wholesale price after learning the retailer's profit margin. Similar to the previous section, a backward induction approach is used to obtain equilibriums.

In the second stage, the Stackelberg equilibrium solution provides the retailer's profit margin and manufacturer's wholesale prices as:

$$w^* = \frac{1}{4}(1+3c),\ \ \mu^* = \frac{1}{2}(1-c). \tag{10}$$

With the optimal w^* and μ^*, we have the profit functions of the leader and the follower, respectively, as follows:

$$\pi(x, w^*; y, \mu^*) = \frac{1}{16}(1-c)^2\left(1-\beta_0 e^{-\beta_1 x-\beta_2 y-\beta_3 xy}\right) - x,$$
$$\phi(y, \mu^*; x, w^*) = \frac{1}{8}(1-c)^2\left(1-\beta_0 e^{-\beta_1 x-\beta_2 y-\beta_3 xy}\right) - y.$$

The equilibrium solutions for advertising decisions in the first stage in the retailer-driven supply chain are similar to those in the manufacturer-driven supply chain except that the leader/follower roles are switched. We now present a summary table (Table 3) to demonstrate the effectiveness of advertising pledge in both manufacturer- and retailer-driven supply chains.

In Table 3, we show that when the follower makes the pledge, in general, the market coverage expands, except a special condition. The proof of the special condition is provided in Appendix D.3. Our study reveals that the critical driver for the success of the advertising pledge is the supply chain structure. That is, whether the participant is the leader or the follower in the supply chain determines the success of the advertising pledge program. If it is the leader who makes the pledge, the program will be effective. In contrast, if the follower makes the pledge, the market coverage, in general, will further expand instead. Clearly, our result provides an important guideline for the implementation of the advertising pledge program. When a company voluntarily makes an advertising pledge, the program evaluator might want to assess the power relationship between the participants and their partners in the chain. Then it would be easier to predict whether the pledge would be effective or not. In the next section, we further discuss the implication of this research by providing some numerical results related to the market coverage and profits.

4. Numerical experiments and managerial insights

We now numerically explore the dynamic changes in the market coverage and the profits when the advertising level in the pledge decreases from the optimal level when no pledge is made. For all numerical experiments, we set $c = 0.1$ and $\beta_3 = 2650$ in order to generate feasible conditions.

4.1. Market coverage and profit changes when the leader makes the pledge

As consistent with our analytical results, Fig. 2 illustrates the changes in the market coverage, profits of the manufacturer and the retailer, and total profit, respectively, when a manufacturer as the leader reduces his advertising level. We set $\beta_0 = .55, \beta_1 = 90, \beta_2 = 70$ in the figures. The horizontal axis represents the manufacturer's advertising pledge level, $\bar{x}$, that is less than x^*_{mn}, the optimal advertising level in the benchmark case and the vertical axes in Fig. 2(a–c) indicate the market coverage, the profits of the manufacturer and the retailer and total profit, respectively. Fig. 2(a) shows that the market coverage decreases almost linearly as $\bar{x}$ decreases. In Fig. 2(b), we observe that as $\bar{x}$ decreases, the manufacturer's profit is almost unchanged, however, the retailer's profit continuously decreases. We attribute the relative stability in manufacturer's profit to the leader's preemptive advantage in the Stackelberg game. In other words, the manufacturer may extend power over the less powerful one so that the follower would take over the advertising and incurs profit loss. Fig. 2(c) shows that the total supply chain profit decreases as $\bar{x}$ diminishes. This is not a surprising result since the retailer's profit keeps reducing as $\bar{x}$ gets smaller.

4.2. Market coverage and profit changes when the follower makes the pledge

Fig. 3 demonstrates the changes in market coverage and profits when the retailer makes the advertising pledge in a manufacturer-driven supply chain. In the figures, the horizontal axis represents the retailer's advertising pledge level, $\bar{y}$, which is less than y^*_{mr}, the optimal advertising level in the benchmark case and the vertical axes in Fig. 3(a–c) indicate the market coverage, the profits of the manufacturer and the retailer and total profit respectively. The parameters in the figures are $\beta_0 = .6$, $\beta_1 = 60, \beta_2 = 65$. Fig. 3(a) shows that the market coverage is a decreasing function of $\bar{y}$, which implies that the lower the advertising level, $\bar{y}$, the larger the market coverage. Although it seems counter-intuitive, we have discussed this case in the previous section. It is because the manufacturer, as the leader, makes the first move to increase his advertising level from the benchmark case in order to protect his profit. Fig. 3(a) shows that the retailer will largely benefit from her own pledge by getting higher profit at lower $\bar{y}$, while the manufacturer's profit will only be slightly hurt when $\bar{y}$ gets smaller than y^*_{mn}. Even though the retailer benefits from the profit due to participation of the pledge, the manufacturer's profit is still much higher than that of the retailer since he is the leader and possesses the preemptive advantage. In Fig. 3(c) we show that the total profit in the supply chain also

Table 3
Changes of market coverage with different initiative programs.

	Manufacturer-driven supply chain	Retailer-driven supply chain
Manufacturer initiative	Shrink	Expand/shrink[a]
Retailer initiative	Expand/shrink[a]	Shrink
Separate initiative	Shrink	Shrink

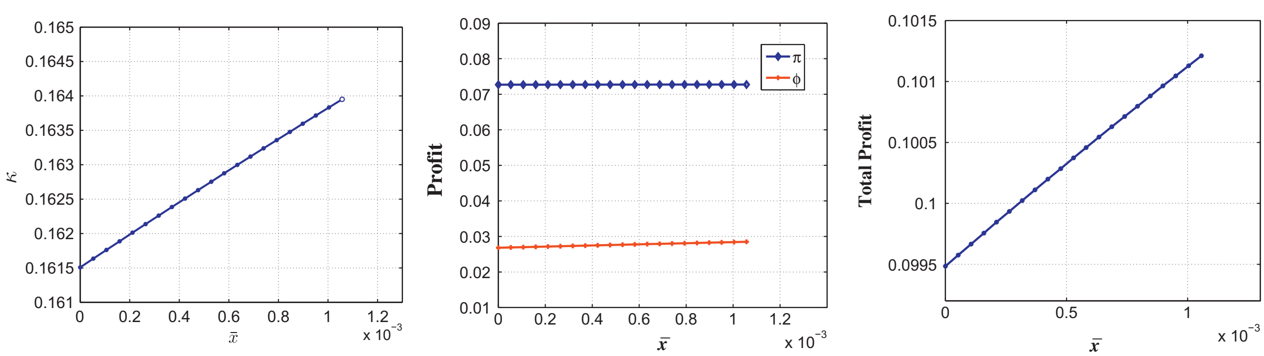
[a] Only when $\beta_2 \leqslant 2\beta_1$ in a manufacturer-driven supply chain or $\beta_1 \leqslant 2\beta_2$ in a retailer-driven supply chain for case 4, the market coverage will shrink.

improves as $\bar{y}$ decreases due to the expansion of the market coverage. The relationship study of the advertising restriction and the marketing coverage as well as the profits in our model will provide policy makers some guidelines to prevent the follower from extracting agreements from the leader to make excessive advertising investments.

4.3. A significant drop in the market coverage

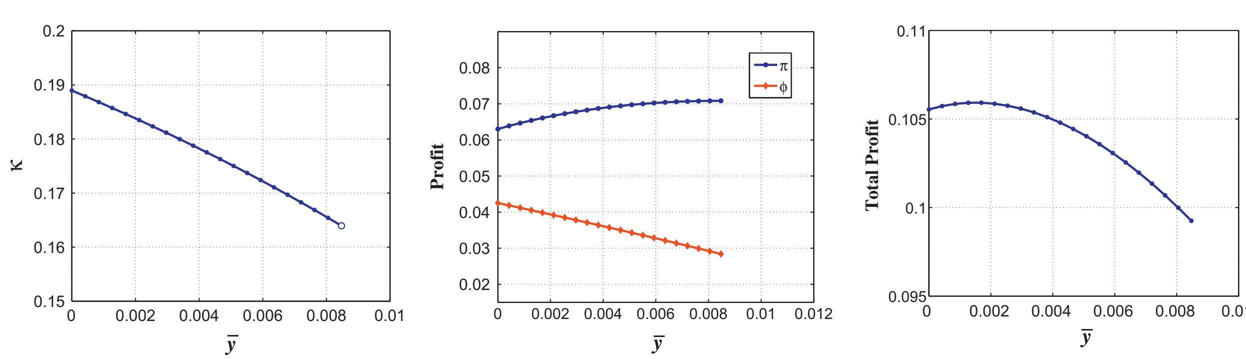
In this section, we illustrate a special case of an abrupt change in the market coverage in Fig. 4 in which we set $\beta_0 = .55, \beta_1 = 90, \beta_2 = 60$. In Fig. 4(a), we show the discontinuity in the market coverage value when the manufacturer, as the leader, participates in the pledge. This discontinuity occurs when the manufacturer decides to reduce his advertising level, $\bar{x}$, to a small value of 0.01. We call this value a threshold; one that causes the retailer to respond with a dramatic change in her advertising level (possibly, the minimal advertising level) in order to protect her own profit. Due to little advertising efforts on both parties' sides, the market coverage is affected severely and suddenly drops to a much lower value than the market coverage for $\bar{x} > 0.01$. After the threshold, the market coverage maintains the same level until $\bar{x}$ approaches 0.005. Case 6 in Fig. 1(f) illustrates what happens. Recall that there exists a $\tilde{x}$ such that the profit function can be expressed in two equations in (15). Thus, as $\bar{x}$ decreases to a specific value, say, $\hat{x}$, we find $\pi(x = \hat{x}) = \pi(x = x_1^*)$ where $\tilde{x} \leqslant \hat{x} \leqslant x_2^*$ and $x_1^* < \tilde{x}$. Thus the optimal advertising pledge for the manufacturer should be x_1^* ($x_1^* < \tilde{x}$) instead of $\bar{x}$ ($\tilde{x} < \bar{x} < \hat{x} < x_2^*$) in order to maximize his profit. Therefore in the subset of $(x_1^*, \hat{x})$, the best pledge level is x_1^* instead of $\bar{x}$, and the retailer's response action maintains the same in this subset. Therefore, we observe in Fig. 4(a) that the market share maintains the same in the range of $0.005 \leqslant \bar{x} \leqslant 0.01$,

Fig. 4(b) shows that while the manufacturer's profit is only slightly affected, the retailer's profit drops significantly at $\bar{x} = 0.01$ and maintains the same in the range of $0.005 \leqslant \bar{x} \leqslant 0.01$ so that the total profit levels out. When $\bar{x}$ decreases to less than 0.005, which means $\bar{x} < x_1^*$, while the manufacturer's profit does not change much, the retailer's profit and the total profit further decrease. We find this result rather interesting as it implies that there exists a threshold that can make the pledge very effective. If the leader is willing to reduce his (her) advertising level below the threshold, the consumption or the market coverage would have a dramatic reduction. Theoretically, to find the threshold might be difficult since it depends on many factors such as sensitivity parameters and cost. The guideline from our finding is that a participant should be encouraged to reduce his (her) advertising level as low as possible so that the reduced advertising level is likely to be below the threshold.



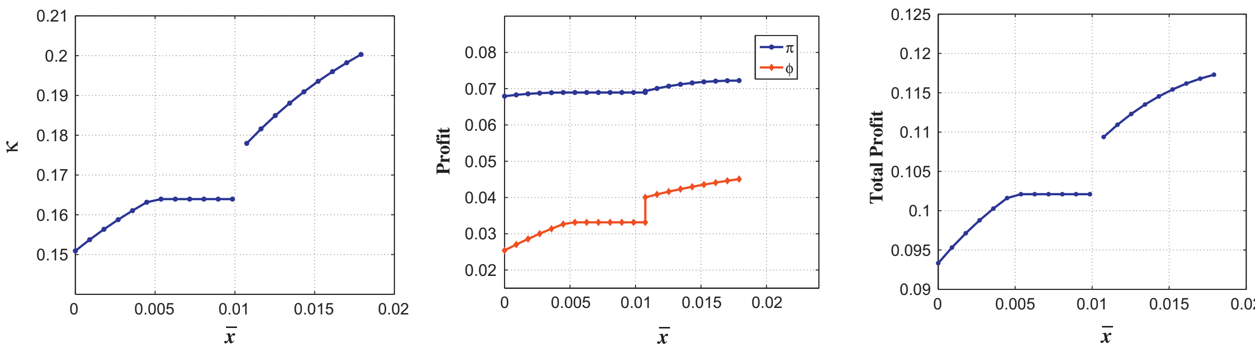
(a) Change of Market Coverage (b) Change of Profit (c) Change of Total Profit

Fig. 2. The change of κ and profits in $\bar{x}$, manufacturer-driven supply chain, a shrinkage case.



(a) Change of Market Coverage (b) Change of Profit (c) Change of Total Profit

Fig. 3. The change of κ and profits in $\bar{x}$, manufacturer-driven supply chain, an expansion case.



(a) Change of Market Coverage (b) Change of Profit (c) Change of Total Profit

Fig. 4. The change of κ and profits in $\bar{x}$, manufacturer-driven supply chain, MI, a jump case.

5. Conclusions and future research

In this paper, we examine the effectiveness of an advertising pledge as one type of CSR activity in a leader–follower supply chain. We assume that either the manufacturer or the retailer is willing to participate in the advertising pledge by reducing his (her) advertising levels in order to reduce the consumption of an unhealthy food/beverage product family. The problem is formulated as a Stackelberg game. The equilibrium solutions are obtained by a backward approach.

Our results show that the effectiveness of an advertising pledge critically depends on the leader's initiative if only one party participates in the pledge. On the other hand, if the follower participates in the program, the market coverage is likely to expand. We provide numerical examples to illustrate the changes in the market coverage and profits due to the initiative program. It is interesting to note that if the leader is willing to reduce the advertising level to a certain threshold, the market coverage will display a significant drop. We also demonstrate that the leader always has preemptive advantage so that his (her) profit will not be affected significantly whether he (she) participates in the pledge or not. In contrast, the follower may improve his (her) profits by participating in the pledge but his (her) profit can never exceed the leader's.

Our paper offers a cautionary tale of advertising programs for non-profit organizations that aim at safeguarding consumer welfare. We suggest that it may be necessary to restructure such programs depending on the supply chain context firms operate.

There exist quite a few possible future research directions. First, a dynamic game model might be developed to consider sequential competitive actions between the manufacturer and the retailer for one product case. Second, we may consider two products: one healthy and one unhealthy. Then the research problem is how to balance the advertising levels between the two products with one or two parties participating in the advertising pledge? Finally, we might examine a supply chain coordination problem by considering revenue and information sharing.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ejor.2013.10.069.

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