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Does Competition Increase Advertising?

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Abstract

In Milgrom-Roberts (1986)'s model, introducing the possibility to die before customers' repurchase alters the firm's advertising incentive to signal hidden product quality. Two opposing forces result, one mechanical and the other strategic. Depending on their relative strengths, the equilibrium advertising can either rise or fall. To the extent that competition threatens firms' survival, our result explains the mixed findings on the causal effects of competition on advertising. Introducing firm deaths in their model offers a new test of whether advertising signals quality, still an unsettled empirical question since Nelson (1974) first articulates advertising as a signal.

Keywords: Advertising; Signaling; Competition; Product Quality; Introductory pricing.

1. Introduction

Milgrom and Roberts (1986) formalize Nelson (1974)'s insight that seemingly uninformative and conspicuous spending can signal a firm's hidden product quality. We extend the two period version of their canonical model by making it possible for the firm to die before satisfied customers come back to buy its product again.

Advertising can indirectly inform customers when it is only profitable for the firm with a high quality product to spend on it. Customers come back for the product in period 2 if the product they bought at period 1 is satisfying. As high quality products more likely satisfy customers than do low quality products, advertising yields a higher return for the firm with a high quality product. If advertising spending reaches a high enough level, the firm with a low quality product will find it unprofitable to mimic through advertising. Under such a separating equilibrium, rather than being wasteful seemingly uninformative advertising becomes valuable; it indirectly informs customers of the hidden product quality.

The possibility to die alters the firm's advertising incentives to signal hidden product quality. Specifically, dying before reaching period 2 prohibits the firm from reaping the return of its advertising because satisfied customers cannot come back to buy its products again. It thus appears that the possibility to die mechanically discourages the firm from advertising. However, there exists another mechanical force that works in an opposite direction. Specifically, the possibility to die enlarges the profit difference between the firm of a low quality product to be perceived by customers as carrying a high quality product. Everything else being equal, such a larger profit difference incentivizes the firm to use advertising to mimic the firm with a high quality product. The firm with a high quality product may respond strategically by increasing advertising to render such mimicry unprofitable. On the other hand, the higher death rates also encourage the firm with a high quality product to strategically increase advertising in order to deter mimicking by a firm with a low quality product. Whether the possibility to die decreases or increases advertising depends on the relative strengths of these forces.

We set up the two-period model in section 2. Focusing on the separating equilibrium with positive advertising spending, we derive the equilibrium price and advertising as functions of the firm's death rates in section 3. In section 4.1, we examine the effects of increasing the firm's death rates on the equilibrium advertising spending. We first show that the equilibrium advertising spending can either increase or decrease with the firm's death rates depending on the parameters. We then show that if the death rate of the firm with a low quality product increases by more than that of the firm with a high quality product, then the more rapidly the production cost rises with product quality, the more likely the equilibrium advertising spending increases with the firm's death rates. Some numerical examples in section 4.3 illustrate these theoretical results.

These theoretical results shed light on the question of whether competition increases advertising, as we argue in section 5. The studies that address this question yield mixed empirical findings. We survey the empirical studies in section 5.1. In section 5.2, we argue that to the extent that competition threatens firm survival, the ambiguous effect of increasing firm's death rates on equilibrium advertising spending in our results gives a theoretical justification of the mixed empirical findings. Section 5.3 describes a new empirical test of the signaling role of advertising suggested by our results. We relate our results to those found in the theoretical literature in section 6.

2. Model

It helps to recall the Nelson-Milgrom-Roberts's framework. Customers are interested in buying an experience good (as opposed to a search good) with unknown quality. Those who have tried and are satisfied with the product will make a repurchase. A firm that offers a high quality product can recover its advertising spending when their satisfied customers repurchase. By contrast, a firm of low quality good cannot recover its advertising spending because fewer customers are satisfied with its product resulting in fewer repurchases. Rational buyers see this difference between the types of the firm and can thus infer that advertised products are of high quality, for which they are willing to pay more.

We augment this model of Milgrom and Roberts (1986) with possible firm deaths. A two-period sequential-move game involves a firm and customers of a total mass 1.

The firm's products can be of high quality (H) or low quality (L). The firm is referred to as type-H if its product is of high quality, and as type-L if its product is of low quality. The customers are characterized by their valuations of the product, denoted by r, which are uniformly distributed over $[0, 1]$. Each customer demands at most one unit of the product per period. The marginal cost of production is C_s when quality is $s = \{L, H\}$. We assume that $C_s < 1$, i.e., the marginal cost is below the maximum valuation of the customers. To ensure a unique separating equilibrium, we assume $C_H > C_L$ but "C_H does not exceed C_L by too great an amount," a phrase use in Milgrom and Roberts (1986).[1]

The firm knows its product quality; but the customers observe the product quality only after consumption (i.e., the product is an "experience good" as in Nelson 1974). Specifically, product quality is defined as the probability that a randomly-selected customer, independent of her valuation, will be satisfied with the product.[2] Assume $0 < L < H = 1$, meaning that all customers will be satisfied with the high quality product but only some of them will be satisfied with the low quality product.

2.1 Timing of the game

Figure 1 summarizes the timing of the game. In period 1, Nature randomly determines the firm's products as high quality with probability β and low quality with probability $1 - \beta$, where $0 < \beta < 1$.[3] The firm then chooses the price of the product, P_1, and the advertising spending, A. Upon observing (P_1, A), the customers assign a probability $\rho(P_1, A) \in [0, 1]$ that the product quality is H and make the purchasing decisions.

In period 2, the firm dies with a probability that is *independent of* the firm's pricing and advertising.[4] Let the firm's death rates increase in a parameter θ that summarizes the factors

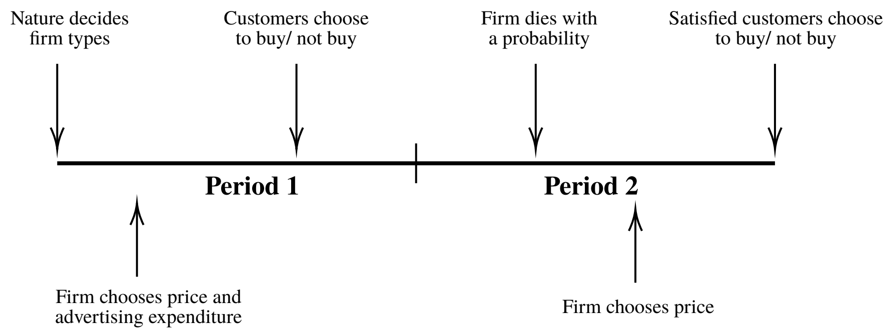
[1]In another classic signaling model of advertising, Schmalensee (1978) does assume higher quality goods are more expensive to produce.

[2]This "taste-fitting" quality follows Milgrom and Roberts (1986). It is one of the several ways to model product quality. Analogously, Hsu, Lu, and Ng (2014) model quality as the degree of personalized/customized of an product to fit a user. Quality can also be based on not just product characteristics but also the number of other users, as in Lai and Ng (2022)'s crowding out effect that reduces product quality when more users are using it.

[3]The setting rules out the possibility that a firm can vary its product quality across periods of time. One justification is the organizational mode, which takes a long time to adjust due to various contracting issues (such as hold-up), dictates the product quality (Lu, Ng, and Tao, 2012; Ng, 2014).

[4]Milgrom and Roberts (1986) also implicitly imply this independence. In their model, both types of firms survive after the initial advertising period with probability one.

Figure 1: Timing of the game



affecting firm survival (such as competition). In turn, the death rate determines how a firm of type-s (where $s =\in \{L, H\}$) discounts its period 2 payoff as follows:

$$\text{Augmented discount factor}_s = \text{Usual discount factor} \times (1 - \text{Death rate}_s). \tag{1}$$

We denote the augmented discount factor in (1) of a type-s firm by $\delta_s(\theta) \in (0, 1)$. For brevity, in the analysis below, we simply write δ_H and δ_L instead. They are not constants but depend on the firm's death rates that are ultimately linked to parameter θ.

Conditional on survival in period 2, the firm also chooses product price P_2. If a customer buys the product in period 1, she will learn whether the product is satisfactory or not. We assume that only those who have bought a product in period 1 and are satisfied ("satisfied period 1 buyers") will make the repurchase decision in period 2. Thus, further advertising by the firm will not be useful.

2.2 Payoff functions

In any period $t = \{1, 2\}$, given the product price P_t, the utility of a customer with a valuation r is:

$$U = \begin{cases} r - P_t & \text{if she buys the product and is satisfied,} \\ -P_t & \text{if she buys the product but is not satisfied,} \\ 0 & \text{if she does not buy the product.} \end{cases} \tag{2}$$

In period 1, since customers do not observe the product quality, they form an expectation ($\overline{s}$) based on the product price and the advertising spending, where $\overline{s} = \rho H + (1-\rho)L = \rho + (1-\rho)L$. The marginal customer (having a valuation r^*) is indifferent between buying and not buying, i.e., $\overline{s}(r^* - P) + (1-\overline{s})(-P) = 0$. Therefore, the valuation of the marginal customer is:

$$r^* = \frac{P}{\overline{s}}. \tag{3}$$

Customers with valuations above r^* will buy and those with valuations below r^* will not buy in the first period. The derived demand in the first period is:

$$D_1 = 1 - r^* = 1 - \frac{P}{\overline{s}}. \tag{4}$$

Advertising thus affects the demand indirectly through changing the customers' perception of the product quality.

The realized product quality in period 2 must be s; it is also the fraction of satisfied period 1 buyers. Let P_2 be the price chosen by the firm in period 2. If $P_2 \leq r^*$, then all satisfied period 1 buyers obtain non-negative utility and will buy again. If $P_2 > r^*$, only those with valuations above P_2 will get a positive utility and will buy again. Therefore, the demand in period 2 is:

$$D_2 = \begin{cases} s(1-P_2) & \text{if } P_2 > r^*, \\ s(1-r^*) & \text{if } P_2 \leq r^*. \end{cases} \tag{5}$$

The firm's problem is to choose P_2 to maximize $(P_2 - C_s)D_2$, which yields $P_2 = \max\left\{r^*, \frac{1+C_s}{2}\right\}$, or:[5]

$$P_2 = \max\left\{\frac{P_1}{\overline{s}}, \frac{1+C_s}{2}\right\}. \tag{6}$$

Let $\Pi(P, s, \rho)$ be the expected gross profit (i.e., before deducting the advertising spending)

[5]As is pointed out by Milgrom and Roberts (1986), the introductory price, P_1, must be lower than P_2 as long as $\overline{s} \neq 0$.

of a type-s firm which charges $P_1 = P$ in period 1 and is regarded as type-H with probability ρ. Accounting for the augmented discounting factor yields the following profit function:

$$\Pi(P, s, \rho) = \underbrace{\left(1 - \frac{P}{\overline{s}}\right)(P - C_s)}_{\text{First period gross profit}} + \underbrace{\delta_s s \left(1 - \max\left\{\frac{P}{\overline{s}}, \frac{1 + C_s}{2}\right\}\right)\left(\max\left\{\frac{P}{\overline{s}}, \frac{1 + C_s}{2}\right\} - C_s\right)}_{\text{Second period gross profit}}. \tag{7}$$

The firm's expected profit net of advertising is thus $\Pi(P, s, \rho) - A$.

3. Equilibrium analysis

The solution concept is a form of sequential equilibrium with elimination of dominated strategies. As we aim at identifying the effects of increasing the firm's death rates on advertising when advertising plays a signaling role, we only focus on separating equilibria in which a type-H firm advertises ($A > 0$) while a type-L firm does not ($A = 0$).

Before analyzing the equilibrium, it is convenient to write down the profit functions when the firm is perceived by the customers as a certain type and the corresponding profit-maximizing prices. Let $\pi(P, s, s')$ be the gross profit of a type-s firm perceived by the customers as type-s', which chooses a price P. Let $P^s_{s'}$ be the maximizer of $\pi(P, s, s')$:

$$P^s_{s'} = \arg\max_P \pi(P, s, s'). \tag{8}$$

When the firm is known to be of type s, the optimal price P^s_s and $\pi(P, s, s)$ are called the "full-information" price and profit, respectively. Using (7) and solving the firm profit maximization problem, we can explicitly derive $\pi(P, s, s')$ and $P^s_{s'}$. Lemma 1 characterizes them; the proof of which is given in Appendix A.

Lemma 1 *$\pi(P, s, s')$ and $P^s_{s'}$ are given by:*

$$\pi(P, s, s') = \left(1 - \frac{P}{s'}\right)\left[(P - C_s) + \delta_s s\left(\frac{P}{s'} - C_s\right)\right]. \tag{9}$$

$$P^s_{s'} = \left[\frac{1}{2} + \frac{(1 + \delta_s s)C_s}{2(s' + \delta_s s)}\right] s'. \tag{10}$$

In any separating equilibrium, customers believe that the product quality is H upon observing positive advertising spending and that the product quality is L upon observing zero advertising spending. Given this belief, in equilibrium a type-H firm cannot do better by mimicking a type-L firm, and vice versa.

Specifically, a type-H firm would obtain $\pi(P, H, H) - A$ if it is perceived as type-H and advertises. On the other hand, if it is perceived as type-L, it would optimally choose $(P^H_L, 0)$ and obtain $\pi(P^H_L, H, L)$. The equilibrium must satisfy:

$$\pi(P, H, H) - A \geq \pi(P^H_L, H, L). \tag{11}$$

Similarly, if a type-L firm is perceived as type-L, it would optimally choose $(P^L_L, 0)$ and obtain $\pi(P^L_L, L, L)$. If it is perceived as type-H, it would obtain $\pi(P, L, H) - A$. The equilibrium must satisfy:

$$\pi(P^L_L, L, L) \geq \pi(P, L, H) - A. \tag{12}$$

According to Proposition 1 of Milgrom and Roberts (1986), there exists a separating equilibrium if and only if for some $(P, A) \geq 0$ the two inequalities in (11) and (12) are satisfied. At any separating equilibrium, the type-H firm chooses (P, A) that satisfy (11) and (12) and the type-L firm chooses $(P^L_L, 0)$. Customers assign $\rho(P, A) = 1$ and $\rho(P^L_L, 0) = 0$; for all other combinations of (P', A'), customers assign $\rho(P', A') = 0$ (or sufficiently small) so that neither the type-H firm nor the type-L firm has the incentive to deviate.

In our analysis, we only consider cases in which positive advertising spending indeed can be explained by signaling.[6] Among all possible separating equilibria, a type-H firm will

[6]Technically, this means the interior solutions exist in the game. In mathematics, it translates to conditions

choose (P, A) to maximize the profit, subject to the constraints in (11) and (12). Since we only consider cases of positive advertising in equilibrium, according to Proposition 2 of Milgrom and Roberts (1986), the optimal choice of a type-H firm, (P^*, A^*), must be a solution to:

$$\max_{P,A} \ \pi(P, H, H) - A \quad \text{subject to } \pi(P, L, H) - A \leq \pi(P_L^L, L, L), \tag{13}$$

where P^* solves:

$$\max_{P} \ \pi(P, H, H) - \pi(P, L, H) \quad \text{subject to } \pi(P, L, H) - \pi(P_L^L, L, L) > 0. \tag{14}$$

To derive the separating equilibrium price and the advertising in the introductory period explicitly, we first consider the graphical representation of the optimization problem of a type-H firm in the separating equilibrium shown in Figure 2. In both Figure 2(a) and 2(b), the constraint in (13) (i.e., $\pi(P, L, H) - A \leq \pi(P_L^L, L, L)$) is represented by the area above $\pi(P, L, H) - A = \pi(P_L^L, L, L)$. The objective function in (13) (i.e., $\pi(P, H, H) - A$)) can be represented by the isoprofit curves in which lower isoprofit curves indicate *higher* profits for the firm. Therefore, the firm optimizes by choosing (P^*, A^*) such that the isoprofit curve is tangent to $\pi(P, L, H) - A = \pi(P_L^L, L, L)$. The maximizers of $\pi(P, H, H)$ and $\pi(P, L, H)$ are by definition P_H^H and P_H^L, respectively. Figure 2(a) shows an example of a separating equilibrium when $P^* < P_H^H$, whereas Figure 2(b) shows an example of a separating equilibrium when $P^* > P_H^H$.

We can derive (P^*, A^*) as follows. We first note from (9) and (10) that:

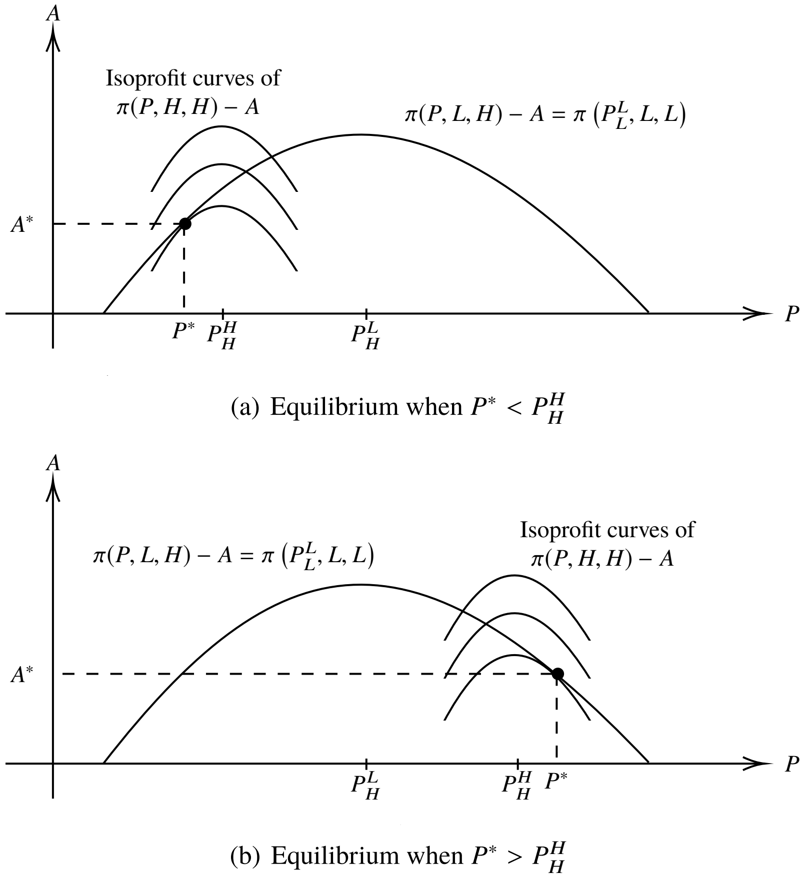
$$\pi(P, H, H) = (1 + \delta_H)(1 - P)(P - C_H), \tag{15}$$

$$\pi(P, L, H) = (1 + \delta_L L)(1 - P)(P - C_L), \tag{16}$$

$$\begin{aligned}\pi(P_L^L, L, L) &= \left[1 - \left(\frac{1}{2} + \frac{C_L}{2L}\frac{1 + \delta_L L}{1 + \delta_L}\right)\right]\left[(1 + \delta_L)\left(\frac{1}{2} + \frac{C_L}{2L}\frac{1 + \delta_L L}{1 + \delta_L}\right)L - (1 + \delta_L L)C_L\right] \\ &= \frac{[(L - C_L) + \delta_L L(1 - C_L)]^2}{4L(1 + \delta_L)}.\end{aligned} \tag{17}$$

(4), (5), and (6) in Milgrom and Roberts (1986) holding in our modified model. It will be proven to be so in Appendix B. The required technical assumption in words is that the low quality product is slightly cheaper (but not way cheaper) to produce. Milgrom and Roberts (1986) also discuss other possibilities such as corner solutions. In Appendix C, we examine whether and under what conditions pooling equilibria exist.

Figure 2: The optimization problem of a type-H firm in the separating equilibrium



Note: Panel (a) shows an example of a separating equilibrium when $P^* < P^H_H$; panel (b) shows an example of a separating equilibrium when $P^* > P^H_H$. In each case, (P^*, A^*) is the equilibrium, and P^H_H and P^L_H are the maximizers of $\pi(P, H, H)$ and $\pi(P, L, H)$ respectively.

We can thus express the isoprofit curve for a particular profit level Π as:

$$A = (1 + \delta_H)(1 - P)(P - C_H) - \Pi. \tag{18}$$

On the other hand, the constraint can be written as:

$$A \geq (1 + \delta_L L)(1 - P)(P - C_L) - \frac{[(L - C_L) + \delta_L L(1 - C_L)]^2}{4L(1 + \delta_L)}. \tag{19}$$

At any interior solution (P^*, A^*), the isoprofit curve must be tangent to the constraint.

Therefore, P^* satisfies the following tangency condition:

$$\underbrace{(1+\delta_H)(1+C_H-2P^*)}_{\text{Slope of the isoprofit curve}} = \underbrace{(1+\delta_L L)(1+C_L-2P^*)}_{\text{Slope of the constraint}}. \tag{20}$$

Rearranging, we have:

$$P^* = \frac{1}{2} + \frac{(C_H - C_L) + (\delta_H C_H - \delta_L L C_L)}{2(\delta_H - \delta_L L)}. \tag{21}$$

The optimal advertising spending is therefore $A^* = \pi(P^*, L, H) - \pi(P^L_L, L, L)$ where $\pi(P^*, L, H)$ is given by (16) and $\pi(P^L_L, L, L)$ is given by (17). These results are summarized in Lemma 2.

Lemma 2 *In the separating equilibrium, (P^*, A^*) is given by:*

$$P^* = \frac{1}{2} + \frac{(C_H - C_L) + (\delta_H C_H - \delta_L L C_L)}{2(\delta_H - \delta_L L)}, \tag{22}$$

$$A^* = \pi(P^*, L, H) - \pi(P^L_L, L, L), \tag{23}$$

where $\pi(P^*, L, H) = (1+\delta_L L)(1-P^*)(P^* - C_L)$ and $\pi(P^L_L, L, L) = \frac{[(L-C_L)+\delta_L L(1-C_L)]^2}{4L(1+\delta_L)}$.

Equation (23) says that at the separating equilibrium, the advertising spending of a type-H firm is the difference between two terms. The first term, $\pi(P^*, L, H)$, is the gross profit for a type-L firm perceived as offering high quality products. The second term, $\pi(P^L_L, L, L)$, is the full-information payoff in which a type-L firm is perceived by the customers as type-L. The intuition is that A^* is the minimum advertising spending just enough to deter a type-L firm from mimicking a type-H firm. At this level of spending, a type-L firm would not find it profitable to do so. Customers' beliefs are such that $\rho(P^*, A^*) = 1$ and $\rho(P^L_L, 0) = 0$; and for all other combinations of (P', A') that are off-the-equilibrium path, customers assign $\rho(P', A') = 0$.

4. Comparative statics

4.1 The effects of increasing the firm's death rates on advertising

Recall that the firm's death rates increase in parameter θ. Thus, because of (1), the augmented discount factors *decreases* in parameter θ. The effects of increasing the firm's death rates on advertising can be expressed as the sign of the derivative of the equilibrium advertising spending, A^*, with respect to θ. According to Lemma 2, it is given by:

$$\frac{\partial A^*}{\partial \theta} = \frac{\partial \pi(P^*, L, H)}{\partial \theta} - \frac{\partial \pi(P_L^L, L, L)}{\partial \theta}. \tag{24}$$

To simplify notations, below we use δ'_s to denote the derivative of δ_s with respect to θ for $s = \{L, H\}$.

The first term on the right hand side of (24) concerns the impact of increasing θ on the gross profit for a type-L firm perceived as offering high quality products:

$$\begin{aligned}\frac{\partial \pi(P^*, L, H)}{\partial \theta} &= \frac{\partial}{\partial \theta}(1+\delta_L L)(1-P^*)(P^*-C_L) \\ &= \delta'_L L(1-P^*)(P^*-C_L) + (1+\delta_L L)(1+C_L-2P^*)\frac{\partial P^*}{\partial \theta}.\end{aligned} \tag{25}$$

To find $\frac{\partial P^*}{\partial \theta}$, we can totally differentiate (20) and rearrange to obtain:

$$\frac{\partial P^*}{\partial \theta} = \frac{(1+\delta_L L)(1+C_L-2P^*)}{2(\delta_H - \delta_L L)}\left(\frac{\delta'_H}{1+\delta_H} - \frac{\delta'_L L}{1+\delta_L L}\right). \tag{26}$$

Let $\Delta \equiv \frac{\delta'_H}{1+\delta_H} - \frac{\delta'_L L}{1+\delta_L L}$. Then:

$$\frac{\partial \pi(P^*, L, H)}{\partial \theta} = \left\{\underbrace{\delta'_L L}_{<0}\underbrace{(1-P^*)}_{>0}\underbrace{(P^*-C_L)}_{>0}\right\} + \left\{\underbrace{\frac{[(1+\delta_L L)(1+C_L-2P^*)]^2}{2(\delta_H-\delta_L L)}}_{>0}\underbrace{\Delta}_{?}\right\}. \tag{27}$$

The signs of the various terms in (27) are determined as follows: First, we note that both $1 - P^*$

and $P^* - C_L$ are positive because in a separating equilibrium in which $P^* > 0$ and $A^* > 0$, firm profit must be non-zero so that $\pi(P^*, L, H) \geq A^* > 0$. Therefore, the terms within the first curly bracket are negative. Second, since $L < 1$ by assumption, we have $1 > \delta_H > \delta_L L$. Therefore, the first term within the second curly bracket is positive. Finally, the sign of Δ depends on the values of L, δ_L, δ_H, δ'_L, and δ'_H. Suppose $\delta_H \geq \delta_L$ and $0 > \delta'_H > \delta'_L$, both $\frac{\delta'_H}{1+\delta_H}$ and $\frac{\delta'_L L}{1+\delta_L L}$ are negative so that $\Delta \gtreqless 0$. On the other hand, when $\delta_H = \delta_L$ and $0 > \delta'_H = \delta'_L$, $\Delta = \frac{\delta'_L(1-L)}{(1+\delta_L)(1+\delta_L L)} < 0$. Either way, the second curly bracket can be either positive or negative. Overall, without imposing additional restrictions on the changes of the augmented discount factors, we cannot sign $\frac{\partial \pi(P^*,L,H)}{\partial \theta}$.

The second term on the right hand side of (24) concerns the impact of increasing θ on the full-information payoff in which a type-L firm is perceived by the customers as type-L, $\pi(P_L^L, L, L)$:

$$\begin{aligned}\frac{\partial \pi(P_L^L, L, L)}{\partial \theta} &= \frac{\partial}{\partial \theta}\frac{[(L-C_L)+\delta_L L(1-C_L)]^2}{4L(1+\delta_L)} \\ &= \frac{(1+\delta_L)\{2[(L-C_L)+\delta_L L(1-C_L)]\delta'_L L(1-C_L)\} - [(L-C_L)+\delta_L L(1-C_L)]^2\delta'_L}{4L(1+\delta_L)^2} \\ &= \frac{\overbrace{[(L-C_L)+\delta_L L(1-C_L)]}^{>0}\ \overbrace{\delta'_L}^{<0}}{4L(1+\delta_L)^2}\underbrace{[L(1+\delta_L)(1-C_L)+c_L(1-L)]}_{>0} < 0.\end{aligned} \tag{28}$$

Since a random customer of any valuation r will only be satisfied with a low quality product with probability $L < 1$. Anytime when it is sold at P, only those with valuation $r \geq P/L$ will buy, and those with $r < P/L$ will not. For a low quality product to exist, it must have some positive demand, meaning that if it is priced at its marginal cost C_L, the marginal customer has a valuation below 1, which means $1 > C_L/L$ or $L > C_L$. Therefore, we have $(L - C_L) + \delta_L L(1 - C_L) > 0$. Besides, since $1 > L$, we also have $L(1 + \delta_L)(1 - C_L) + c_L(1 - L) > 0$. Thus, $\frac{\partial \pi(P_L^L,L,L)}{\partial \theta} < 0$; this is true even when $\delta_H = \delta_L$ and $0 > \delta'_H = \delta'_L$ as this derivative only involves δ_L and δ'_L.

The above derivations suggest that the impact of increasing the firm's death rates (thus, decreasing the augmented discounted factors) on $\pi(P_L^L, L, L)$ is negative, but the effect on

$\pi(P^{*}, L, H)$ can be ambiguous. Increasing the firm's death rates thus has an ambiguous effect on the equilibrium advertising spending.

Proposition 1 *Suppose increasing the firm's death rates reduces the augmented discounted factors such that $0 > \delta'_H \geq \delta'_L$. Under $\delta_H \geq \delta_L$, increasing the firm's death rates decreases the full-information payoff in which a type-L firm is perceived by the customers as type-L, $\pi(P^L_L, L, L)$, but has an ambiguous impact on the gross profit for a type-L firm perceived as type-H, $\pi(P^{*}, L, H)$. Overall, the impact of increasing the firm's death rates on advertising spending is ambiguous.*

We now discuss the intuition behind the math. Two forces are in play.

- **The "mechanical" force:** First, increasing the death rates of both types of firms mechanically reduces the return on advertising as fewer repurchases will result. It reduces the gross profit for a type-L firm perceived as a type-H firm ($\pi(P^{*}, L, H)$), resulting in a negative force on advertising. On the other hand, increasing the death rates of both types of firms directly reduces the full-information payoff in which a type-L firm is perceived by the customers as type-L ($\pi(P^L_L, L, L)$), which provides more incentive for a type-L firm to mimic a type-H firm. Thus, a higher advertising spending is required to deter a type-L firm from doing so.
- **The "strategic" force:** Second, increasing the death rates of both types of firms affects the gross profit for a type-L firm perceived as a type-H firm ($\pi(P^{*}, L, H)$). It is a type-H firm's strategic response to increase its advertising spending in order to deter a type-L firm from mimicking it. Whether the change is positive or negative depends on the likelihoods of repeated repurchases for the two types of firms.

Overall the impact of increasing the firm's death rates on advertising spending depends on the relative magnitudes of these forces.

4.2 When will higher death rates more likely increase advertising?

To understand when higher death rates will more likely increase advertising, we can further examine (27) and (28).

The first intuitive factor is a relatively mild increase in the death rate of a type-H firm as θ increases. By (1), a relatively mild increase means that δ'_H is sufficiently small in magnitude. Everything else equal, a smaller reduction of δ'_H leads to a smaller drop in the profit of a type-H firm. It is thus more likely for a type-H firm to continue to be willing to increase advertising to render a type-L firm's mimicry unprofitable after its death rate increases. On the other hand, a type-L firm's incentive to mimic a type-H firm by advertising is likely stronger, which pushes a type-H firm to strategically increase advertising. The math is indeed consistent with this intuition. We first note that (28) does not depend on δ'_H. Therefore, if δ'_H becomes smaller in magnitude, $\frac{\partial \pi(P_L^L, L, L)}{\partial \theta}$ remains at the same negative level. Besides, (27) does depend on δ'_H. Specifically, when δ'_H becomes smaller in magnitude, all the other parts remain unchanged except that Δ becomes more likely positive.

Another relevant factor is C_H, the production cost of the high quality product which can intuitively be interpreted as how rapidly the production cost rises with quality. This is an important parameter that differentiates two classic papers on formalizing the notion of advertising as a signal of hidden product quality. Before Milgrom and Roberts (1986), Kihlstrom and Riordan (1984) also formalize the insight of Nelson (1970, 1974). In their model, advertising can signal hidden quality if producing high quality goods is sufficiently less costly. In other words, production cost must negatively correlate with product quality. Although there are cases where production cost is indeed cheaper for higher quality product, they are more of exceptions than the usual.[7] On the other hand, the model of Milgrom and Roberts (1986) takes the case that $C_H > C_L$ but "C_H does not exceed C_L by too great an amount." Intuitively, it means that it is not cheaper to produce a higher quality product but it is also not terribly more expensive. There are also products, such as machinery for iron foundry or those used in the health equipment manufacturing for human implants, that are exponentially more expensive to produce only with a small precision improvement. This case must therefore exclude these types of products.

Mathematically, we can see from (28) that $\frac{\partial \pi(P_L^L, L, L)}{\partial \theta}$ depends on neither C_H nor P^*. We

[7] As an example, software developers usually develop the full-version first before spending extra efforts in removing certain functionality so as to come up with a student-version, making $C_H < C_L$.

can thus focus on $\frac{\partial \pi(P^*,L,H)}{\partial \theta}$:

$$\begin{aligned}\frac{\partial^2 \pi(P^*, L, H)}{\partial C_H \partial \theta} &= \delta'_L L(1 + C_L - 2P^*)\frac{\partial P^*}{\partial C_H} + \frac{(1+\delta_L L)^2}{2(\delta_H - \delta_L L)}\Delta \times (-4)(1 + C_L - 2P^*)\frac{\partial P^*}{\partial C_H} \\ &= \underbrace{(1 + C_L - 2P^*)}_{<0 \text{ when } C_H > C_L} \underbrace{\frac{\partial P^*}{\partial C_H}}_{>0} \left[\delta'_L L - \frac{2(1+\delta_L L)^2}{\delta_H - \delta_L L}\Delta\right], \end{aligned} \tag{29}$$

where, as before, $\Delta \equiv \frac{\delta'_H}{1+\delta_H} - \frac{\delta'_L L}{1+\delta_L L}$.

Recall that when $C_H > C_L$, $1 + C_L - 2P^* < 0$. Besides, $\frac{\partial P^*}{\partial C_H} = \frac{1+\delta_H}{2(\delta_H - \delta_L L)} > 0$. Therefore, the signs of (29) depends on the sign of the terms in the square bracket. Suppose $\delta_H \geq \delta_L$ and $0 > \delta'_H > \delta'_L$. If δ'_H is sufficiently small in magnitude, then $\Delta > 0$ and the terms in the square bracket will be negative, so that $\frac{\partial^2 \pi(P^*,L,H)}{\partial C_H \partial \theta} > 0$.

Proposition 2 *Suppose increasing the firm's death rates reduces the augmented discounted factors such that* $0 > \delta'_H > \delta'_L$*. Under* $\delta_H \geq \delta_L$*, increasing* C_H *makes increasing the firm's death rates more likely to increase advertising when* δ'_H *is sufficiently small in magnitude.*

In Proposition 2, increasing the firm's death rates reduces the augmented discounted factors such that $0 > \delta'_H > \delta'_L$. Such reductions of the augmented discounted factors are a little more restrictive than those in Proposition 1 where $0 > \delta'_H \geq \delta'_L$. In words, $0 > \delta'_H > \delta'_L$ means increasing the death rates discounts period 2's payoff by more for the type-L firm than the type-H firm. To see why we need this differential impact of parameter θ on the augmented discounted factors, suppose $\delta_H = \delta_L$ and $0 > \delta'_H = \delta'_L$. The terms in the square bracket in (29) become $\delta'_L L - \frac{2(1+\delta_L L)^2}{\delta_L(1-L)} \frac{\delta'_L(1-L)}{(1+\delta_L)(1+\delta_L L)} = \delta'_L \left[L - \frac{2(1+\delta_L L)}{\delta_L(1+\delta_L)}\right] = \delta'_L \left[\frac{\delta_L L + \delta_L^2 L - 2 - 2\delta_L L}{\delta_L(1+\delta_L)}\right] = \delta'_L \left[\frac{\delta_L L(\delta_L - 1) - 2}{\delta_L(1+\delta_L)}\right] > 0$, so that $\frac{\partial^2 \pi(P^*,L,H)}{\partial C_H \partial \theta} < 0$. In other words, higher θ could more likely decrease advertising without the differential impact of parameter θ.

4.3 Numerical examples

Table 1 presents some numerical examples with specific values to illustrate the theoretical findings.

In Example 1, we fix $L = 0.40$ and $C_L = 0.50$, and we consider different values of C_H $(= \{0.52, 0.54, \ldots, 0.70\})$. We assume that before the firm's death rates increase, $\delta_L = 0.40$

and $\delta_H = 0.80$. Columns (4) and (5) show the corresponding equilibrium prices and advertising spending.[8]

We consider two cases of increasing the firm's death rates: (a) $\delta_L = 0.30$ and $\delta_H = 0.75$, representing a relatively large drop in δ_H (from 0.80 to 0.75), and (b) $\delta_L = 0.3$ and $\delta_H = 0.79$, representing a relatively mild drop in δ_H (from 0.80 to 0.79). Columns (6) and (7) show the corresponding equilibrium prices and advertising spending in the former case while Columns (6) and (7) show the corresponding equilibrium prices and advertising spending in the latter case.

Columns (8) and (11) show the changes in equilibrium advertising spending in these two cases. In Example 2, we increase L from 0.40 to 0.60 and compute the same numbers accordingly.

Note that in the table, certain values of A^* are computed to be negative; these cases are to be ignored since we only consider equilibria with positive advertising.

Table 1: Impact of increasing firm's death rates on advertising: Numerical examples

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
			Low θ [$\delta_L = 0.40, \delta_H = 0.80$]		High θ [$\delta_L = 0.30, \delta_H = 0.75$]		ΔA^*	High θ [$\delta_L = 0.30, \delta_H = 0.79$]		ΔA^*
L	C_L	C_H	P^*	A^*	P^*	A^*	[= (7) − (5)]	P^*	A^*	[= (10) − (5)]
Example 1										
0.40	0.50	0.52	778.13	71.40	777.78	68.37	−3.04	776.72	68.43	−2.97
0.40	0.50	0.54	806.25	68.65	805.56	65.77	−2.88	803.43	66.03	−2.62
0.40	0.50	0.56	834.38	64.06	833.33	61.45	−2.61	830.15	62.04	−2.03
0.40	0.50	0.58	862.50	57.64	861.11	55.40	−2.24	856.87	56.44	−1.20
0.40	0.50	0.60	890.63	49.38	888.89	47.63	−1.76	883.58	49.25	−0.14
0.40	0.50	0.62	918.75	39.29	916.67	38.12	−1.17	910.30	40.45	1.16
0.40	0.50	0.64	946.88	27.36	944.44	26.89	−0.48	937.01	30.06	2.70
0.40	0.50	0.66	975.00	13.60	972.22	13.92	0.33	963.73	18.07	4.47
0.40	0.50	0.68	1003.13	−2.00	1000.00	−0.77	1.23	990.45	4.48	6.48
0.40	0.50	0.70	1031.25	−19.44	1027.78	−17.19	2.25	1017.16	−10.71	8.73
Example 2										
0.60	0.50	0.52	782.14	61.81	780.70	61.07	−0.75	779.34	61.16	−0.65
0.60	0.50	0.54	814.29	57.97	811.40	57.73	−0.24	808.69	58.12	0.14
0.60	0.50	0.56	846.43	51.57	842.11	52.17	0.60	838.03	53.03	1.47
0.60	0.50	0.58	878.57	42.60	872.81	44.38	1.79	867.38	45.92	3.32
0.60	0.50	0.60	910.71	31.07	903.51	34.37	3.31	896.72	36.78	5.71
0.60	0.50	0.62	942.86	16.97	934.21	22.14	5.16	926.07	25.60	8.63
0.60	0.50	0.64	975.00	0.32	964.91	7.68	7.36	955.41	12.39	12.07
0.60	0.50	0.66	1007.14	−18.90	995.61	−9.01	9.89	984.75	−2.85	16.05
0.60	0.50	0.68	1039.29	−40.68	1026.32	−27.91	12.76	1014.10	−20.12	20.55
0.60	0.50	0.70	1071.43	−65.02	1057.02	−49.05	15.97	1043.44	−39.43	25.59

Note: The equilibrium price and advertising are computed using Lemma 2. In this table, the values of both P^* and A^* are multiplied by 1000. Cases when $A^* < 0$ are to be ignored since we only consider equilibria with positive advertising.

[8]In this table, all the values of P^* and A^* are all multiplied by 1000.

There are five takeaways from the numerical examples:

- First, when C_H is much larger than C_L, equilibrium advertising will become negative, i.e., we cannot find a separating equilibrium with positive advertising. This illustrates the phrase "C_H does not exceed C_L by too great an amount" used by Milgrom and Roberts (1986) as one condition for a separating equilibrium.

- Second, as Columns (8) and (11) show, the impact of increasing the firm's death rates on equilibrium advertising can be ambiguous, depending on the values of the parameters, the initial augmented discount factors and their changes. This illustrates the findings of Proposition 1.

- Third, fixing L, C_L, and C_H, the impact of increasing the firm's death rates on equilibrium advertising is more likely positive under a smaller drop of δ_H. For instance, consider the row when $L = 0.40$, $C_L = 0.50$, and $C_H = 0.64$ in Example 1. When the drop in δ_H is relatively large, the change in equilibrium advertising is negative (Column (8)) whereas when the drop in δ_H is relatively mild, the change in equilibrium advertising is positive (Column (11)). The pattern is consistent with the above discussion on a relatively mild increase in the death rate of a type-H firm as θ increases.

- Fourth, fixing L and C_L, increasing C_H (but not by a large amount) tends to make increasing the firm's death rates more likely to increase advertising in both cases. This can be seen by Column (8) and Column (11). Furthermore, in Column (11) with a relatively mild drop in δ_H, a smaller increase in C_H is needed to turn the impact positive, relative to Column (8) with the relatively large drop in δ_H. This pattern is consistent with Proposition 2.

- Fifth, the above patterns hold up in both examples with two different values of L, which is the competition parameter in Hertzendorf and Overgaard (2001) to be discussed in section 6. In unreported analyses, we also investigate cases with different values of L and obtain similar results.

4.4 Possible drivers of an increase in firm's death rate

We extend the model of Milgrom and Roberts (1986) to incorporate the possibility of dying before the firm can reap its advertising returns through customer repurchase. The extension provides us with a theoretical framework to think about how factors threatening firms' survival affects advertising. Many factors threaten firms' survival; we briefly categorize them in five groups.

The first group are within-firm factors: mismanagement (such as frauds and financial misreporting), legal disputes, loss of key personnel due to illness (McKenzie and Paffhausen, 2019) and deaths (Nguyen and Nielsen, 2010), and the lack of successful innovations (Cefis and Marsili, 2005) can all threaten a firm's survival.

The second group are demand-side factors. Customers' troubles can propagate up the supply-chain and threaten the upstream firms' survival. Dai et al. (2021) find empirically that lending to these dying customers would not help stop the upstream firms from dying. Market size changes can also affect firm births and deaths. In the model of Hsu, Lu, and Ng (2014), an increase in the market size induces more homogeneous firms to enter the market. Studying the U.S. concrete industry, Syverson (2004) find that the required transportation (i.e., the use of concrete mixer trucks) makes concrete industry localized. Bigger markets induce more firms but firms of low productivity cannot exist.

The third group are supply-side factors, such as the reduction of talented labor (Docquier and Rapoport, 2012), key raw materials and financing. For instance, Sierra Leone's fishermen find themselves hard to survive if they fail to make any of the 5 ice retailers perceive them as 'loyal' customers (Ghani and Reed, 2022). As ice is a key determinant of their productivity (to keep their fish fresh), they cannot afford not to spend efforts in building a relation with the ice retailers, which is instrumental for getting trade finance from them.

The fourth group are market structure changes. Market structure changes can come from dominant firms' entries and exits. For instance, Matsa (2011) find that when Walmart enters a local market, the less efficient mom-and-pop grocery stores are forced to exit. The market structure can also change due to market conduct, such as collusive behaviors. Granitz and Klein

(1996) find evidence that in the 1870s, Standard Oil colluded with the upstream railways to make rival refineries pay higher transportation costs, forcing some of them to exit the refinery market.

The last group are other external factors. A number of macroeconomic factors can threaten firm's survival. Everett and Watson (1998) find the failures of many small businesses were associated with unemployment and inflation. Exchange rate regime changes can kill firms with the unlucky currency denomination; Swanson and Tybout (1988) document the failure of the Argentinian firms with dollar-denominated debts as Argentine exchange rate regime collapsed in the early 1980s. Technological changes can lead to firm exits too. One example is the shipping technological changes making it cheaper for foreign goods to enter the domestic market. Galdón-Sánchez and Schmitz Jr (2002) and Schmitz Jr (2005) find shipping technology breakthroughs making it cost-effective to sell Brazilian iron ores in the U.S. in the 1980s, forcing the closure of less efficient U.S. mines. Some regulatory changes can threaten firm's survival. The retirement of the Multi Fibre Arrangement gradually leading to the abolishing of the quota system in 2005 has led to the elimination of less efficient Belgium textile makers (De Loecker, 2011). Chile's country-wide reduction of trade barriers from 1974 to 1979 forced a number of Chilean manufacturing plants to exit (Pavcnik, 2002). Political changes can lead to interesting firm exit patterns. Fisman (2001) and Faccio and Parsley (2009) find the death of key political figures reduce the stock prices of those politically connected firms, potentially threatening their survival. Finally, natural disasters and pandemic can also induce firm exits (Miyakawa, Oikawa, and Ueda, 2021).

5. Empirical relevance

We discuss how our extension gives implications to the effects of competition on advertising. We view competition broadly as changes such that a need of humans is better satisfied by either new or copycat products, threatening the survival of the existing firms. Such kinds of dynamic competition likely encompass demand-side changes, supply-side changes (e.g., raw materials and financing) and market structure changes (affecting the entries and exits of firms as well as the market conduct of surviving firms). Toys used to be much more important in satisfying parents' needs to entertain, educate, or simply calm their children. iPad at least make some toys much less important in calming children.

5.1 Does competition increase advertising? The mixed empirical findings

Business managers spend a lot on advertising. Excluding political ads, advertising media made 763.2 billion U.S. dollars sales worldwide in 2021. About 37% of their sales were made in the U.S., accounting for about 1.24% of U.S.'s nominal GDP.[9] Yet, few things about advertising have reached a consensus in economics. Economists have long been regarding advertising beyond what is needed to inform buyers of the availability and specifics of the product as a waste if not a deceiving tool (Galbraith, 1967). Nelson (1974) first articulates advertising (again, beyond informing the basics) as a signal buyers use to infer hidden product quality, an idea later formalized by Milgrom and Roberts (1986).[10] Whether signaling explain advertising empirically, however, remains debatable (Horstmann and MacDonald, 1994, 2003).[11]

How competition causally affects advertising is one unsettled issue. This question can be mingled with the reverse causation: How advertising affects competition? One view is that advertising tells buyers the existence, locations, prices and characteristics of search goods and thus increases competition. Toys (Steiner, 1973), drugs (Cady, 1976), and eyeglasses (Benham, 1972) are documented examples. The opposite view places advertising as an anti-monopoly concern: Advertising makes customers perceive similar items as distinct products and thus

[9]See *Industries & Markets: Advertising worldwide* by Statista, 2022. Available at: https://www.statista.com/study/12264/global-advertising-market-statista-dossier

[10]Other recent theoretical studies in the literature examine advertising strategies of firms in different types of competitive environment; see, e.g., Brahim, Lahmandi-Ayed, and Laussel (2011); Bergemann and Bonatti (2011); Schroeder, Tremblay, and Tremblay (2021); Wang, Mei, and Zhong (2022); Yue, Weijun, and Shue (2023). But keep in mind that these studies are not directly related to ours because in our model, there is only one firm that can be producing high quality or low quality products.

[11]Becker and Murphy (1993), too, criticize the signaling approach by writing

> "We do not believe that the intensive advertising for Miller beer, Chevrolet cars, or Marlboro cigarettes, to take a few examples, is signaling exceptionally high product quality. But we shall not try to compare systematically the implications of our model of advertising as a good with a signaling model, beyond pointing out that in the signaling approach, demand can be affected by advertising even when consumers are not exposed to the content of the ads, whereas in our approach demand can be affected only through exposure. Moreover, the pure signaling interpretation implies that companies should advertise how much they spend on advertising, yet almost no companies do that."

decreases competition. Cigarettes (Nicholls, 1951), bleach (Peterman, 1968), and beers (Greer, 1971) are some documented examples. Mingling the two questions can be one reason why previous cross-industry studies have not been conclusive.[12]

Focusing on particular industries, two recent papers causally test whether competition increases advertising by using convincing instruments to address reverse causality. Chandra and Weinberg (2018) find that per capita advertising spending on beers is significantly higher among those local markets with less competition due to the 2008 Miller-Coors merger. Using rigid state franchise regulations that made car manufacturers difficult to cut excess dealers, Murry (2018) finds that dealers in those local markets facing increased competition due to the regulations spend less on advertising. The effect on car manufacturers' advertising, however, is mixed. Consistent with Telser (1964) and Dorfman and Steiner (1954), their results suggest competition decreases advertising in the beer and car dealer industries.

A causal check of whether their results hold across other industries is what Becker and Murphy (1993) did 30 years ago. Look up the top 10 advertising spenders in 2020: Amazon, Comcast, AT&T, Procter & Gamble, Walt Disney, Verizon, Charter Communications, AMEX, Google, and Walmart.[13] These big advertising spenders do not seem to lack competition. Another check of ours looks at whether firms across industries facing increase competition spend less on advertising. Restricting our sample to U.S. publicly-listed manufacturing firms with a commonly-used estimation to deal with the reverse causality, we do not find firms spending less on advertising when facing increased foreign competition.[14] It appears inconclusive as to how competition causally affects advertising.

5.2 An explanation of the mixed findings the model gives

To the extent that competition threatens firms' survival, investigating how increasing the firm's death rates affects advertising allows us to understand a particular channel through which

[12]Some of the earlier studies in this literature, including Sutton (1974), Brush (1976), Strickland and Weiss (1976) and Buxton, Davies, and Lyons (1984), mainly regress some measures of advertising intensity on market structure to document association between the two variables without dealing with the potential endogeneity issue.

[13]Becker and Murphy (1993)'s top 10 advertising spenders include: Noxell, William Wrigley, Jr. Kellogg, Warner-Lambert, Alberto-Culver, Adolph Coors, Hasbro, Schering-Plough, Coca-Cola, and Procter & Gambler. For the current list, see *Advertising & Marketing: Largest advertisers in the United States in 2020* by Statista. Available at: https://www.statista.com/statistics/275446/ad-spending-of-leading-advertisers-in-the-us

[14]An online appendix shows the empirical details.

competition affects advertising. Our model thus gives one potential explanation of the mixed empirical findings.

Let us begin with an example for which Nelson (1974)'s signaling theory may explain advertising. When MP3 players first came to the market, manufacturers had a hard time convincing buyers their new gadgets were of high quality. Those producing high quality spent on advertising, expecting those who like their players would buy one more for their spouses or kids. Those producing low quality expected fewer repurchase. Advertising therefore yielded a lower return for low quality manufacturers. In turn, initial buyers of the new gadget inferred advertised MP3 players were of high quality. Competition comes from entrepreneurs like Steve Jobs who came up with smartphones that made MP3 players somewhat obsolete, regardless of their product quality. During the transition, however, high quality MP3 players more likely hang on to the market longer than the low quality ones.[15] In this context, increasing competition can be understood as the shocks outside of the control of the MP3 players market that expedite the arrival of smartphones.

In this example, the arrival of smartphones imposed immense competitive pressure on the MP3 player makers and threatened their survival. On the other hand, the initial pricing and advertising of MP3 players unlikely affected the subsequent arrival of smartphones that made MP3 players obsolete. Such an exogenous nature of the disruptive innovation theoretically isolates the effect of competition on advertising from the effect of advertising on competition.

Our analysis can be viewed as incorporating the notion that competition threatens firms' survival in the inherently dynamic Nelson-Milgrom-Roberts's framework. Specifically, through (1), increasing death rates makes the firm discount period 2's payoff more. Another way to put it is that increased competition represents "a more intense process of natural selection" à la Alchian (1950). This notion of competition is consistent with Galdón-Sánchez and Schmitz Jr (2002)'s definition of competitive pressure as firms' death rates (iron ore mine closure in their

[15]One possible mechanism to justify this difference comes from Ng (2014). Firms faced with a disruptive innovation (a.k.a Schumpeter's gale) can experience liquidity shocks. Specifically, seeing the smartphone market arrives, it is conceivable that investors either pull their money out of the MP3 player market, or stop further investing. When they re-prioritize among the firms, they likely take into account the quality of the firms' products. It makes more business sense for them to first pull their money out of those offering low quality products. By the same token, other inputs, such as experienced programmers, can also leave the MP3 player industry and join the smartphone industry. The loss of critical labor is likely faster for lower quality firms.

context). It has also been used in the theoretical literature in the context of signaling. For instance, the model of Lai and Ng (2014) employs this notion of competition to study the effect of competition on firms' incentives to signal to talented workers using general (i.e., non firm-specific) training.

This minimal deviation from the canonical model solves at least two conceptual issues. The first issue is related to the inapplicable textbook definitions of competition. The product requiring signaling must have no other identical products (at least in period 1). It must be somewhat unique to render its quality unknown to begin with. How then could the standard competition definitions be incorporated? Therefore, no conventional measures such as the Herfindahl-Hirschman Index, 4-firm concentration ratio, number of firms, and mark-ups would apply.[16] A firm may enjoy a temporary monopoly when it offers a unique product to solve an underlying problem faced by customers. But it cannot free itself from future competition as others can come up with *different* products (or even copycat products similar to the firm's originally unique one) to solve the same underlying problem faced by customers. The second issue concerns repeated purchase as a driving force. Repeated purchase requires the subsequent periods of play after the product introductory period. It is the main driver of advertising in the inherently dynamic Nelson-Milgrom-Roberts's framework advertising. Incorporating a notion of competition through our minimal deviation from the canonical model preserves this main driver.

Empirical studies find that competition disproportionately weeds out weak firms faster. Such finding is consistent with $0 > \delta'_H > \delta'_L$, the reduction pattern of the augmented discounted factors in Proposition 2. Galdón-Sánchez and Schmitz Jr (2002) and Schmitz Jr (2005) find that

[16] Advertising, if used as a signaling of hidden product quality, by definition concerns products with no close substitutes and thus does not fit the textbook definitions of competition as Hayek (1948) points out long ago by writing:

> "The peculiar nature of the assumptions from which the theory of competitive equilibrium starts stands out very clearly if we ask which of the activities that are commonly designated by the verb "to compete" would still be possible if those conditions were all satisfied. Perhaps it is worth recalling that, according to Dr. Johnson, competition is "the action of endeavoring to gain what another endeavors to gain at the same time." Now, how many of the devices adopted in ordinary life to that end would still be open to a seller in a market in which so-called "perfect Competition" prevails? I believe that the answer is exactly none. Advertising, undercutting, and improving ("differentiating") the goods or services produced are all excluded by definition - "perfect" competition means indeed the absence of all competitive activities."

when shipping technology made it cost-effective to sell Brazilian iron ores in the U.S. together with market shrinkage in the 1980s, the closure of less efficient mines accounted for between 0 to 7% of the aggregate productivity gain of U.S. mines. Matsa (2011) finds when Wal-mart comes to a U.S. town, relative to the surviving mom-and-pop grocery stores, the exiting ones used to have more stockout, leaving customers unsatisfied. Syverson (2004) finds low-productivity concrete firms present in some local U.S. markets do not exist in those highly competitive local markets. After Chile aggressively reduced its non-tariff and tariff trade barriers from 1974 to 1979, Pavcnik (2002) find the exiting plants were on average about 8% less productive than the surviving ones.

Nonetheless, the notion that competition threatens firms' survival is not as conventional as textbook competition. In the context of the canonical model we extend, one can view it as a mere re-interpretation of the discount factor as the competition intensity. As discussed extensively in section 4.4, there exist other factors that threaten firms' survival. It is not our intention to refer to all these factors as competition.

5.3 The model suggests new empirical tests

Does the model gives us any new empirical implication for testing the signaling role of advertising?

Addressing this question can add to the empirical literature on whether signaling plays a role in explaining real world advertising spending. Even in theory, the literature is still debating as to whether signaling does explain advertising at all (Becker and Murphy, 1993). Horstmann and MacDonald (2003) criticize that the existing empirical tests of the signaling theory of advertising have weak statistical power.[17] Despite the theoretical appeal of advertising as a signal, they find that much of the empirical work centers around how advertising, quality and price correlate to one another. Sahni and Nair (2020) echo their concern.[18] Calling for more

[17] Sahni and Nair (2020) detail the econometric issues that weaken these tests' statistical power. They offer a field experiment to overcome some of these issues.

[18] Sahni and Nair (2020) write

> "Nelson (1970, 1974)'s celebrated idea that advertising can serve as a signal of product quality has proven difficult to test empirically. Consequently, more than 40 years since it was originally articulated, credible empirical evidence in favor of the signaling view of advertising has remained rare."

rigorous empirical tests, Sahni and Nair (2020) write about the significance:

> "Understanding whether advertising actually plays a signaling role and how this role materializes is important to assess the welfare consequences of advertising: if advertising can serve as a signal, it can improve the efficiency of markets with search frictions by helping buyers and sellers communicate."

Against this background, if competition is introduced and can be reasonably well-captured by some observable variables in future empirical studies, our answer to the question offers a new empirical test for the signaling role of advertising not previously discovered in the literature.

Proposition 2 suggests a joint test of both the signaling role of advertising in general and our specification of competition: increasing competition tends more likely to increase advertising the larger is the difference in production cost between high versus low quality goods. Our model therefore gives a new testable empirical implication of the signaling role of advertising for future research.

To illustrate, take our previous example. The arrival of smartphones threatens the survival of not just MP3 player makers but also game console makers. Since MP3 players and game consoles do continue to exist after the introduction of smartphones, it is reasonable for us to take them as cases fulfilling the "δ'_H is sufficiently small in magnitude" qualifier: that competition exerts a relative mild increase of the death rates of firms offering high-quality MP3 players or game consoles. The adoption of smartphones, however, varies in speed across regions. Japan, for instance, has a higher fraction of the population adopting smartphones earlier than, say, Indonesia. Such a variation represents variation in the competitive pressure faced by the two industries in different regions.

Suppose region X adopted smartphones faster and earlier than region Y where both industries had sales. In our model, it means that both industries faced more intense competition in region X than in region Y. Controlling for other relevant regional differences, which industry likely spent more on advertising in region X than region Y? Proposition 2 predicts that it would have been the industry with the production cost rising more rapidly with quality.

Compared with MP3 players, game consoles are a bit more sophisticated in terms of the integrated circuits, the software, and the chip requirements. It is reasonable to expect that game consoles have their production costs rising more rapidly with quality relative to MP3 players. Comparing the advertising spending of these two industries across the regions, if the game consoles industry did spend more on advertising in region X than it did in region Y, the pattern will be consistent with Proposition 2, giving one piece of supportive empirical evidence that advertising indeed plays a signaling role in these two markets. On the other hand, if the MP3 player industry but not the game consoles industry spent more on advertising in region X than they did in region Y, the pattern rejects Proposition 2 and is inconsistent with the notion that advertising has a signaling role.

6. The notion of competition in relation to the literature

To more critically assess our notion of competition, in this section we contrast our paper against the theoretical literature that gives implications on the effect of competition on advertising. Our paper belongs to the overlap of three strands of literature: [a] non-price advertising that is modelled as dissipative (i.e., not directly informative); [b] signaling of product quality where product quality does not vary overtime (thus, no moral hazard is involved); and [c] competition. To better group the papers, we label the following papers with groups a, b, or c.

Nelson (1974) [a,b] is the seminal paper to first articulate how conspicuous spending on seemingly uninformative and unproductive things (e.g., sponsoring sporting events) serves as a signal. Though not directly informative, they can indirectly convey unobserved product quality and are thus indirectly informative. The key driving force is that advertising is costly, but less so for a firm with a higher-quality good as more repeated purchases will result. It is because more customers are satisfied with a higher-quality good. Schmalensee (1978) [a,b] is the first attempt to formalize Nelson (1974)'s idea. In his model with multi-sellers, advertising is linked to repeat purchases. In some equilibria, however, low-quality firms advertise more than high-quality firms. In another multi-sellers model in which high and low product qualities co-exist and firms do not choose their prices, Kihlstrom and Riordan (1984) [a,b] show that advertising can signal high quality if producing high quality goods is sufficiently *less* costly.

This is because high-quality firms get to pocket a higher mark-up from a sale. Their model is somewhat restrictive as it applies to products with the costs of production falling with quality. Milgrom and Roberts (1986) [a,b] illustrate Nelson (1974)'s idea with a dynamic model in which both price and advertising can signal quality. Under some conditions, a separating equilibrium exists in which advertising is used not because price alone does not work, but because using both price and advertising to signal quality is cheaper. Unlike Kihlstrom and Riordan (1984), the costs of production does not have to fall with quality in the model of Milgrom and Roberts (1986). Among the many extensions of Nelson-Milgrom-Roberts's framework, one extension is Horstmann and MacDonald (1994) [a,b], who take consumer experience as a noisy signal of the product quality.[19] These papers do not give predictions on how competition affects the incentive for firms to signal with dissipative advertising.

The effect of competition on signaling incentives of firms is explicitly modelled in both Daughety and Reinganum (2008) [b,c] and Overgaard (1994) [b,c]. The model of Daughety and Reinganum (2008) features both horizontal and vertical differentiation among n firms, whereas the potential threat of an entry of a firm with a high quality product is modelled in Overgaard (1994). Their notions of competition are conventional. Adriani and Deidda (2011) [b,c] study the impact of competition on the signaling role of prices. They restrict their attention on prices as signals and thus their model features neither dissipative advertising nor repeated purchase. Their competition measure is the ratio of the number of buyers and sellers. Competition is weak when buyers outnumber sellers, and vice versa. They find that strong competition inhibits prices as signals. As a result, high quality sellers will be weeded out, which is the exact opposite of what our notion of competition implies. However, their models involve price-only signaling but not dissipative advertising. Therefore, these three papers cannot explain businesses' conspicuous spending that is seemingly uninformative.

Hertzendorf and Overgaard (2001) [a,b,c] is perhaps the closest to our paper in spirit. Their model studies a duopoly with vertically differentiated goods. Customers only know that one of the two firms offers a high quality product but cannot tell who that firm is. Both price and dissipative advertising can be used to signal to customers. However, their model does not

[19]Their extension guides their subsequent empirical testing of the signaling theory of advertising in the CD market (Horstmann and MacDonald, 2003), for which they cast doubt on using signaling to explain advertising.

feature repeated purchase, the driving force of Nelson-Milgrom-Roberts's framework.

Their notion of competition is also a parameter in our model (specifically, L); increasing the parameter intensifies competition in the sense that the two firms' products are less vertically differentiated. They show a non-monotonic relation between competition and advertising.[20] Therefore, our paper complements Hertzendorf and Overgaard (2001) by reinforcing their theoretical results that an ambiguous effect of competition on signaling incentives of firms holds not only in their vertically differentiated duopoly set-up without repeated purchase, but also in a repeated purchase setting where a firm offers something new to the market that is somewhat unique and therefore lacks an existing close substitute.

Our notion of competition is thus an addition to their notion of competition that gives us another angle to look at how competition affects advertising. Repeated purchase remains a driving force in our model, but absent in theirs.

7. Conclusion

We have studied theoretically the impact of increasing the firm's death rates on firms' advertising spending. We do so by modifying the signaling model of Milgrom and Roberts (1986) to make it possible for the firm to die before reaching period 2. Increasing the firm's death rates not just mechanically reduces advertising, but it also affects the profit difference between a type-L firm perceived correctly as carrying a low quality product versus incorrectly perceived as carrying a high quality product. A type-L firm can have a higher incentive to mimic a type-H firm through copying its advertising spending and pricing. This forces a type-H firm to strategically increase advertising to further deter a type-L firm from doing so. Thus, increasing the firm's death rates can have an ambiguous effect on advertising.

To the extent that increasing competition increases firms' death rates, our paper contributes to the empirical literature on the ambiguous effect of competition on advertising. The

[20]In Hertzendorf and Overgaard (2001), they write,

> "advertising to be used most intensively when a high-quality product competes against a supplier of a moderately close low-quality substitute, while we should not observe advertising when goods are poor substitutes."

inconclusive evidence begs a theoretical explanation, and we offer one in our paper: the effect of competition on advertising is indeed ambiguous when advertising serves as a signal of hidden product quality.

In those cases where it is not cheaper to produce a higher quality product, we find that increasing the production cost of a high quality product makes it more likely for increasing the firm's death rates to increase advertising. This empirical implication introduces a new way to test the signaling role of advertising in future studies. While testing this new implication of signaling is beyond the scope of this article, this new test responds to Sahni and Nair (2020)'s call for more credible statistical test of the signaling role of advertising.

We also add to the broader literature that examines how competition alters businesses' incentive to signal. Many business strategies can be conceptualized as signals of information hard to be conveyed to outsiders: from providing general training to signal to workers (Fan and Wei, 2010), to fancy bank buildings to signal to depositors, to dividend policies (Miller and Rock, 1985) and cross-listing (Doidge, Karolyi, and Stulz, 2004) to signal to current and prospective investors and creditors. Very little has been said, both theoretically and empirically, about how increased competition change firms' incentives to use these signals. An exception is Lai and Ng (2014), who study how competition affects businesses use general training to signal to workers. We extend this line of research by showing how competition changes businesses' incentive to signal to customers with advertising.

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Appendix

A. Proof of Lemma 1

Using (7), we can write:

$$\pi(P,s,s') = \left(1-\frac{P}{s'}\right)(P-C_s) \\ + \delta_s s\left(1-\max\left\{\frac{P}{s'},\frac{1+C_s}{2}\right\}\right)\left(\max\left\{\frac{P}{s'},\frac{1+C_s}{2}\right\}-C_s\right). \tag{A.1}$$

We consider the following two cases.

- **Case I: $\frac{P}{s'} \geq \frac{1+C_s}{2}$.** In this case, $\pi(P,s,s') = \left(1-\frac{P}{s'}\right)\left[(P-C_s)+\delta_s s\left(\frac{P}{s'}-C_s\right)\right]$. Profit maximization implies:

$$-\frac{1}{s'}\left[(P-C_s)+\delta_s s\left(\frac{P}{s'}-C_s\right)\right]+\left(1-\frac{P}{s'}\right)\left(1+\frac{\delta_s s}{s'}\right)=0$$
$$\Longrightarrow P = \left[\frac{1}{2}+\frac{(1+\delta_s s)C_s}{2(s'+\delta_s s)}\right]s'. \tag{A.2}$$

  Denote the above price as P_{I}^*. At $P=P_{\mathrm{I}}^*$, the inequality $\frac{P}{s'}\geq\frac{1+C_s}{2}$ is satisfied.

- **Case II: $\frac{P}{s'} \leq \frac{1+C_s}{2}$.** In this case, $\pi(P,s,s') = \left(1-\frac{P}{s'}\right)(P-C_s)+\delta_s s\left(1-\frac{1+C_s}{2}\right)\left(\frac{1+C_s}{2}-C_s\right)$. Profit maximization implies:

$$-\frac{1}{s'}(P-C_s)+\left(1-\frac{P}{s'}\right)=0 \Longrightarrow P=\frac{s'+C_s}{2}. \tag{A.3}$$

  However, at this price the inequality $\frac{P}{s'}\leq\frac{1+C_s}{2}$ is *not* satisfied since $s'\leq 1$. In other words, the inequality constraint should be binding. We denote $P_{\mathrm{II}}^*=\frac{(1+C_s)s'}{2}$ as the optimal price in this case.

Note that P_{II}^* also satisfies the inequality in the Case I (i.e., $\frac{P}{s'}\geq\frac{1+C_s}{2}$) but it is not chosen as the optimal price. By revealed preference, the firm can earn a higher profit at $P=P_{\mathrm{I}}^*$. Therefore, we can focus on the first case, i.e., the relevant profit function is given by (9). Besides, the second order derivative of $\pi(P,s,s')$ with respect to P is $-\frac{2(1+\delta_s s/s')}{s'}<0$, so that $P_{s'}^s$ given by (10) is the profit-maximizing price. □

B. The validity of the separating equilibrium

For (P^*,A^*) described in Lemma 2 to be an equilibrium, we need to check that under $C_H > C_L$ and "C_H does not exceed C_L by too great an amount," the pair satisfies the three conditions in

Milgrom and Roberts (1986) that ensure the existence of a separating equilibrium. The three conditions are:

[4] $\pi(P_H^H, L, H) > \pi(P_L^L, L, L)$,

[5] $\pi(P^*, L, H) > \pi(P_L^L, L, L)$,

[6] $\pi(P, H, H) - \pi(p, L, L)$ is pseudoconcave in P.

Checking if [4] holds Using (9) and (10), we can write:

$$\pi(P_H^H, L, H) = \left[1 - \left(\frac{1}{2} + \frac{C_H}{2}\right)\right]\left[(1 + \delta_L L)\left(\frac{1}{2} + \frac{C_H}{2}\right) - (1 + \delta_L L)C_L\right]$$
$$= \frac{(1 + \delta_L L)(1 - C_H)(1 + C_H - 2C_L)}{4}. \tag{B.1}$$

Using the above and (17), condition [4] can be rewritten as:

$$\frac{(1 + \delta_L L)(1 - C_H)(1 + C_H - 2C_L)}{4} > \frac{[(L - C_L) + \delta_L L(1 - C_L)]^2}{4L(1 + \delta_L)}$$
$$\implies \left\{L(1 + \delta_L)(1 + \delta_L L - L) + (1 - L)C_H^2\right\} - (1 + \delta_L L)(C_H^2 - C_L^2) > 0. \tag{B.2}$$

We note that the terms in the curly bracket are always positive. In order that the inequality holds, the second term of the left hand side means Milgrom and Roberts (1986)'s "C_H does not exceed C_L by too great an amount." On the other hand, the inequality must hold if $C_H = C_L$, as what Milgrom and Roberts (1986) describe on their page 817.

Checking if [5] holds Recall from Lemma 2 that $\pi(P^*, L, H) = (1 - \delta_L)(1 - P^*)(P^* - C_L)$ where $P^* = \frac{1}{2} + \frac{(C_H - C_L) + (\delta_H C_H - \delta_L L C_L)}{2(\delta_H - \delta_L L)}$. First consider the case of $C_H = C_L$. In this case, $P^* = \frac{1+C_L}{2}$ so that $1 - P^* = \frac{C_L - 1}{2}$ and $P^* - C_L = \frac{1-C_L}{2}$. Thus, condition [5] can be written as:

$$\frac{(1 + \delta_L L)(1 - C_L)^2}{4} > \frac{[(L - C_L) + \delta_L L(1 - C_L)]^2}{4L(1 + \delta_L)}$$
$$\implies L(1 + \delta_L)(1 + \delta_L L)(1 - C_L)^2 - [(L - C_L) + \delta_L L(1 - C_L)]^2 > 0. \tag{B.3}$$

The left hand side can be simplified as $(1 - L)[L(1 + \delta_L) - (1 + \delta_L L)C_L^2]$ which is always positive. In other words, [5] holds true when $C_H = C_L$.

Next, suppose we increase C_H while fixing C_L.

$$\frac{\partial \pi(P^*, L, H)}{\partial C_H} = (1 + \delta_L L)(1 + C_L - 2P^*)\frac{\partial P^*}{\partial C_H}. \tag{B.4}$$

Note that when $C_H > C_L$, $1 + C_L - 2P^* < 0$. Besides, differentiating (20) with respect to C_H gives $\frac{\partial P^*}{\partial C_H} = \frac{1+\delta_H}{2(\delta_H - \delta_L L)} > 0$. Overall, $\frac{\partial \pi(P^*,L,H)}{\partial C_H} < 0$. In other words, $\pi(P^*, L, H)$ in the left hand side of condition [5] decreases with C_H while $\pi(P_L^L, L, L)$ in the right hand side does not change with C_H.

It implies that as long as Milgrom and Roberts (1986)'s "C_H does not exceed C_L by too great an amount" holds true, then condition [5] in our case holds.

Checking if [6] holds From (15) and (16), we have:

$$\pi(P, H, H) - \pi(P, L, L) = (1 + \delta_H)(1 - P)(P - C_H) - (1 + \delta_L L)(1 - P)(P - C_L). \tag{B.5}$$

It is straightforward to show that its second derivative is $2(\delta_L L - \delta_H) < 0$. Therefore, this function is strictly concave, suggesting that [6] does hold.

C. Pooling equilibrium

While our analysis focuses on separating equilibria in which the firm of type-H spends on non-price dissipative advertising, it is still interesting to examine whether and under what conditions pooling equilibria exist.

In any pooling equilibrium, both types pick the same pair of introductory price and advertising. Since Nature randomly assigns the firm's product as high quality with probability β and low quality with probability $1 - \beta$, in any pooling equilibrium the customers consistently believe the firm offers a high quality product with probability β and a low quality product with probability $1 - \beta$ at the pair of equilibrium introductory price and advertising. The off-the-equilibrium-path belief can be characterized as customers' assigning zero probability to the firm offering a high quality product.

Intuitively, a positive advertising is due to signaling if it sustains a separating equilibrium. In any pooling equilibrium where a firm of high quality fails to distinguish itself from a possible low quality type, costly advertising confers no benefit and its existence violates profit maximization. Milgrom and Roberts (1986) also argue (without a proof) that a pooling equilibrium is less plausible because customers need to know more information about the firm in a pooling equilibrium than in a separating equilibrium.

The next step is a formal inquiry of whether and when a pooling equilibrium exists. Proposition 4 of Milgrom and Roberts (1986) states that when their condition (8) holds, then "a separating equilibrium exists and satisfies the Kreps criterion" and "no pooling equilibrium satisfies the Kreps criterion." Specifically, the condition requires that one of the following inequalities to hold:

$$[8a] \quad \left(\frac{\partial \pi^H}{\partial P}\right)\left(\frac{\partial \pi^H}{\partial P} - \frac{\partial \pi^L}{\partial P}\right) > 0,$$

$$[8b] \quad \frac{\partial \pi^H}{\partial \rho} - \frac{\partial \pi^L}{\partial \rho} > 0,$$

$$[8c] \quad \left(\frac{\partial \pi^L}{\partial P}\right)\left(\frac{\partial \pi^L/\partial P}{\partial \pi^L/\partial \rho} - \frac{\partial \pi^H/\partial P}{\partial \pi^H/\partial \rho}\right) > 0,$$

where all derivatives are evaluated at (P, ρ) and $\pi^s(P, \rho) \equiv \Pi(P, s, \rho)$.

Below we check whether condition [8b] holds in our context. Recall from (7) that $\pi^s = \left(1 - \frac{P}{\bar{s}}\right)(P - C_s) + \delta_s s \left(1 - \max\left\{\frac{P}{\bar{s}}, \frac{1+C_s}{2}\right\}\right)\left(\max\left\{\frac{P}{\bar{s}}, \frac{1+C_s}{2}\right\} - C_s\right)$ where $\bar{s} = \rho + (1-\rho)L$. We consider the following two cases.

- **Case I: $\frac{P}{\bar{s}} \geq \frac{1+C_s}{2}$.** In this case, $\pi^s = \left(1 - \frac{P}{\bar{s}}\right)\left[\left(1 + \frac{\delta_s s}{\bar{s}}\right)P - (1 + \delta_s s)C_s\right]$. Its derivative with respect to ρ is $\frac{\partial \pi^s}{\partial \rho} = (1-L)\frac{\partial \pi^s}{\partial \bar{s}} = -\frac{(1-L)P}{\bar{s}^2}\left[P - (1 + \delta_s s)C_s + \delta_s s\right]$. Therefore:

$$\frac{\partial \pi^H}{\partial \rho} - \frac{\partial \pi^L}{\partial \rho} = \frac{(1-L)P}{\bar{s}^2}[(1+\delta_H)C_H - \delta_H - (1+\delta_L L)C_L + \delta_L L]. \tag{C.1}$$

  [8b] holds only when $(1+\delta_H)C_H - \delta_H > (1+\delta_L L)C_L - \delta_L L$.

- **Case II: $\frac{P}{\bar{s}} \leq \frac{1+C_s}{2}$.** In this case, $\pi^s = \left(1 - \frac{P}{\bar{s}}\right)(P - C_s) + \frac{\delta_s s(1-C_s)^2}{4}$. Its derivative with respect to ρ is $\frac{\partial \pi^s}{\partial \rho} = (1-L)\frac{\partial \pi^s}{\partial \bar{s}} = -\frac{(1-L)P}{\bar{s}^2}(P - C_s)$. Therefore:

$$\frac{\partial \pi^H}{\partial \rho} - \frac{\partial \pi^L}{\partial \rho} = \frac{(1-L)P}{\bar{s}^2}(C_H - C_L). \tag{C.2}$$

  [8b] holds since we assume that $C_H > C_L$.

To sum up, condition (8) of Milgrom and Roberts (1986) can fail when $(1+\delta_H)C_H - \delta_H > (1+\delta_L L)C_L - \delta_L L$ does not hold in Case I. Consistent with Milgrom and Roberts (1986), some pooling equilibria can survive the Kreps criterion.

Online Appendix

We follow the recent trade literature by exploiting the variation of import penetration from China to the U.S. in different industries (e.g., Lu and Ng 2013, Autor, Dorn, and Hanson 2013, Acemoglu et al. 2016) and estimate the following:

$$\log(\text{Advertising expenditure})_{ijt} = \alpha_i + \gamma \log(\text{Import penetration})_{jt-1} + \zeta X_{ijt-2} + \theta_t + \varepsilon_{ijt}, \quad (1)$$

where i, j, and t are indexes for firm, industry, and year, respectively, X_{ijt-2} is a vector of firm-level covariates measured in year $t-2$, including firm size (proxied by total assets in log), profitability, growth opportunities (proxied by the market to book ratio), and financial leverage (total liabilities divided by total assets),[21] α_i is the firm fixed-effects, θ_t is year fixed-effects, and ε_{ijt} is the error term.

The coefficient of interest is γ. Estimating (1) by OLS has at least two econometric issues. First, since the extant literature suggests that a firm's advertising strategies can also affect market competition, reverse causality likely exist.[22] Second, unobserved factors correlated with import penetration may affect the firm's advertising expenditure, leading to the omitted variable bias. To address these issues, we follow Autor, Dorn, and Hanson (2013) and Acemoglu et al. (2016) to instrument the import penetration from China to the U.S. by the corresponding import penetration from China to other high-income countries comparable to the U.S., including Australia, Denmark, Finland, Germany, Japan, New Zealand, Spain, and Switzerland. Key to the identification is the assumption that conditional on the observables and the fixed-effects, changes in Chinese imports in other high-income countries are not correlated with factors (other than Chinese imports to the U.S.) that can affect firms' advertising strategies directly.

Compustat North America between 1992 and 2012 gives us the dependent variable and the firm-level control variables. It contains the financial and accounting data for the largest listed-firms in the U.S. Advertising expenditure comes from item **xad**, representing the cost of advertising media (radio, television, newspapers, periodicals) and promotional spending.

Only firms in the manufacturing industries (i.e., SIC industry codes 2000-3999) with available data on advertising expenditure are included. Not all firms report advertising expenditure. We cannot tell whether firms with missing values spend nothing on advertising or misreport for some reasons. Import penetration of the U.S. and other high-income countries come from Autor, Dorn, and Hanson (2013) and Acemoglu et al. (2016)[23]

After merging various data sources and data cleaning, our sample contains 10,866 firm-year observations, in 1,934 industry-year cells. Table 1 reports the summary statistics of the

[21] In the literature, studies find that these variables are relevant determinants of advertising, see, e.g., Dorfman and Steiner (1954), Willis and Rogers (1998), and Grullon, Kanatas, and Kumar (2006).

[22] See, e.g., Mueller and Rogers (1980), Sass and Saurman (1995).

[23] See these two papers for the details about the data sources and variable construction.

Table 1: Summary statistics

	N	Mean	S.D.	1st quartile	Median	3rd quartile
Firm-level variables						
Advertising expenditure (level)	10866	98.141	456.031	0.229	1.400	12.186
Advertising expenditure (log)	10866	0.604	2.983	−1.474	0.336	2.500
Total assets (log)	10866	4.861	2.639	3.041	4.638	6.570
Profitability	10866	−0.033	0.519	−0.014	0.096	0.166
Market to book ratio	10866	2.850	4.308	1.139	1.655	2.785
Financial leverage	10866	0.536	0.657	0.242	0.420	0.616
Industry-level Import penetration ratios						
China to the U.S.	1934	0.082	0.182	0.001	0.013	0.063
China to other high-income countries	1934	0.061	0.133	0.002	0.012	0.052

Note: Advertising expenditure is measured in million USD.

key variables.

Table 2 reports the results. In all specifications, standard errors are clustered at the industry level and are reported in parentheses. Column (1) regresses advertising expenditure on import penetration without firm controls and fixed-effects. The negative and significant coefficient of Chinese import penetration suggests that, unconditionally, firms in industry facing stronger foreign competition spend less on advertising. Column (2) includes other control variables (namely firm size, profitability, market-to-book ratio, and financial leverage) and firm and year fixed-effects. The coefficient of import penetration, while still negative, becomes statistically insignificant.

Table 2: Regression results

	(1)	(2)	(3)	(4)
Dependent variable:	Advertising expenditure (log)			Chinese import penetration (log)
Chinese import penetration (log)	−0.168***	−0.007	−0.020	
	(0.060)	(0.022)	(0.038)	
Instrument				0.779***
				(0.056)
Total assets (log)		0.543***	0.544***	0.044*
		(0.035)	(0.035)	(0.023)
Profitability		0.012	0.012	−0.024
		(0.066)	(0.066)	(0.029)
Market to book ratio		0.047***	0.047***	0.006
		(0.006)	(0.006)	(0.004)
Leverage		0.037	0.037	−0.015
		(0.062)	(0.061)	(0.037)
Specification	OLS	OLS	2SLS	OLS
Firm fixed-effects	No	Yes	Yes	Yes
Year fixed-effects	No	Yes	Yes	Yes
R^2	0.029	0.133		0.459
F-stat for weak id			192.407	

Note: $N = 10,866$. In Column (4), Chinese import penetration (to the U.S.) is instrumented by the Chinese import penetration to other high-income countries. Standard errors are clustered at the industry level and are reported in parentheses. *: significance at 10% level; **: significance at 5% level; ***: significance at 1% level.

Column (3) estimates with the instrumental variable to tackle endogeneity. The coefficient of import penetration remains negative and statistically insignificant. The high F-statistics for weak identification and the first-stage results shown in Column (4) indicate that the instrument is positive and significantly correlated with import penetration. Overall, our empirical results suggest that increased foreign competition does not make the publicly-listed manufacturing firms spend less on advertising.[24]

[24]Checking if our results hold for smaller firms is possible. Researchers with access to the micro-data from the Census of Manufactures may use their advertising expenditure data; see, for instance, Kehrig and Vincent (2018).