# Firms' Strategies and Markets Advertising

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#### Introduction

Persuasive Advertising Informative advertising Signaling

Advertising boosts demand

### Introduction



- Worlwide amount of ad spending in 2019 is about 560 billion \$ ;
- ► More than 60% of this amount are digital advertising and mobile phone (growing)-the rest are mainly TV and radio (≈ 30%) or print medias (newspapers and magazine <5%);</p>
  - Google is the largest digital ad seller in the world in 2019;
  - Google and Facebook have a 60% market share of online advertising.
- The largest advertisers in 2017 are Samsung and Procter & Gamble ( >10 billions US \$ in 2017 for P&G)

#### Introduction

Persuasive Advertising Informative advertising Signaling

Advertising boosts demand

# Countries with highest advertising spending per person in 2016 (US



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Signaling

Advertising boosts demand

### Advertising boosts demand

#### Assumptions:

- The demand Q(p, A) is such that  $Q_p < 0$  and  $Q_A > 0$ .
- The firm faces a variable cost of production C(Q) with  $C_Q > 0$
- ▶ The cost of advertising is −A.

The monopoly maximizes its profit with respect to Q and A:

$$\max_{Q,A}\Pi(Q,A)=pQ(p,A)-C(Q(p,A))-A$$

The First Order Conditions are:

$$\Pi_{p} = (p - C_{Q})Q_{p} + Q = 0 \Rightarrow \frac{p - C_{Q}}{p} = \frac{-1}{\epsilon_{Q/p}}$$
$$\Pi_{A} = (p - C_{Q})Q_{A} - 1 = 0 \Rightarrow \frac{p - C_{Q}}{p} = \frac{1}{\epsilon_{Q/A}}\frac{A}{pQ}$$

#### Result

The advertising intensity is equal to the ratio of the advertising elasticity of demand and the price elasticity of demand:  $\frac{A}{pQ} = \frac{\epsilon_{Q/A}}{-\epsilon_{Q/p}}$ . Q/p ▶ • ≡ ▶ • ≣ ► ≣ = ∽ • • Dorfman-Steiner condition !

### Typology of advertising

- Persuasive Advertising enhances consumers' tastes for a given product
  - Advertising increases consumers' willingness to pay.
  - Advertising changes the distribution of consumers' tastes.
  - Advertising increases perceived product difference.
- Informative Advertising provides consumers with information about the existence, prices and characteristics of products. Consumers make better informed decision.
  - Information about prices
  - Information about product's existence.
- Signaling Quality: the amount of ads spent or the price indirectly convey information about the quality of the products to consumers.

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# Persuasive Advertising

#### Assumptions

- ► Game: Stage 1- Advertising & Stage 2- price competition;
- Consumers are distributed according to F(x) over [0,1]
- The cost of advertising intensity  $\lambda_i$  is  $a\lambda_i^2/2$ .



- Advertising increases consumers' willingness to pay:  $r_i(\lambda_i)$
- Advertising changes the distribution of consumers' tastes:
  F(x, λ<sub>i</sub>, λ<sub>j</sub>)
- Advertising increases perceived product difference :  $t(\lambda_i, \lambda_j)$

Benchmark: Without advertising Advertising increases consumers' willingness to pay Advertising changes the distribution of consumers' tastes Advertising increases perceived product differences

### Benchmark: Without advertising

#### Assumptions

We assume that there is no advertising.

The indifferent consumer address  $\hat{x}$  is such that:

$$\begin{aligned} r - t\hat{x} - p_1 &= r - t(1 - \hat{x}) - p_2 \\ \hat{x} &= \frac{1}{2} + \frac{p_2 - p_1}{2t} \\ \Pi_1 &= (p_1 - c)\hat{x}(p_1, p_2) \\ \Pi_2 &= (p_2 - c)(1 - \hat{x}(p_1, p_2)) \end{aligned}$$

Firms maximize their profit with respect to  $p_i$  and the reaction functions are symmetric and increasing : Prices are strategic complement!

$$Max_{p_i} \prod_{p_i} \Rightarrow p_i(p_j) = \frac{1}{2}(c+t+p_j)$$

#### Results

There is a symmetric equilibrium:  $p_1^* = p_2^* = c + t$  and  $\prod_{1=1}^* = \prod_{2=1}^* \frac{t}{2}$ .

Benchmark: Without advertising Advertising increases consumers' willingness to pay Advertising changes the distribution of consumers' tastes Advertising increases perceived product differences

### Advertising increases consumers' willingness to pay Assumptions

• We denote  $r_i(\lambda_i) = r + \beta \lambda_i$ 

The indifferent consumer address  $\hat{x}$  is such that:

$$r + \beta \lambda_1 - t\hat{x} - p_1 = r + \beta \lambda_2 - t(1 - \hat{x}) - p_2$$
$$\hat{x} = \frac{1}{2} + \frac{p_2 - p_1}{2t} + \beta \frac{\lambda_1 - \lambda_2}{2t}$$

$$\Pi_1 = (p_1 - c)\hat{x}(p_1, p_2, \lambda_1, \lambda_2) - a\lambda_1^2/2 \Pi_2 = (p_2 - c)(1 - \hat{x}(p_1, p_2, \lambda_1, \lambda_2)) - a\lambda_2^2/2$$

Firms maximize their profit with respect to  $p_i$  and the reaction functions are symmetric and increasing : Prices are strategic complement!

$$Max_{p_i} = p_i(p_j) = \frac{1}{2}(c + t + p_j + \beta\lambda_i - \beta\lambda_j)$$

Introduction Benchmark: Without advertising Persuasive Advertising Informative advertising advertising changes the distribution of consumers' tastes Signaling Advertising increases perceived product differences

The Nash equilibrium in prices is:

$$p_i(\lambda_i,\lambda_j)=c+t+rac{1}{3}eta(\lambda_i-\lambda_j)$$

$$\Pi_i(\lambda_i,\lambda_j) = rac{1}{18t}(3t+eta(\lambda_i-\lambda_j))^2 - a\lambda_i^2/2$$

In stage 1, each firm *i* maximizes its profit with respect to  $\lambda_i$  anticipating the stage 2 competition in prices:

$${\it Max} \Pi_i(\lambda_i,\lambda_j) \Rightarrow \lambda_i(\lambda_j) = rac{eta(3t-eta\lambda_j)}{9at-eta^2}$$

The best reaction functions are symmetric and decreasing: advertising investments are strategic substitutes!

#### Results

 $\lambda_1^* = \lambda_1^* = \frac{\beta}{3a}$ ,  $p_1^* = p_2^* = c + t$  and  $\Pi_1^* = \Pi_2^* = \frac{t}{2} - \frac{\beta^2}{18a} < \frac{t}{2}$ . Firms are worse-off with advertising. If they could coordinate, they would refrain from investing.

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### Advertising changes the distribution of consumers' tastes Assumptions

- ▶ We denote  $F(x, \lambda_1, \lambda_2) = (1 + \lambda_1 \lambda_2)x (\lambda_1 \lambda_2)x^2$  with a continuous density  $f(x, \lambda_1, \lambda_2) = (1 + \lambda_1 \lambda_2) 2x(\lambda_1 \lambda_2)$ .
- ▶ If  $\lambda_1 = \lambda_2$  we find a uniform distribution,  $\lambda_1 = 1$  and  $\lambda_2 = 0$  a distribution that favors firm 1. Distribution Function

The address of the indifferent consumer  $\hat{x}$  is such that:

$$r - t\hat{x} - p_1 = r - t(1 - \hat{x}) - p_2 \Rightarrow \hat{x} = \frac{1}{2} + \frac{p_2 - p_1}{2t}$$
$$Q_1 = F(\hat{x}, \lambda_1, \lambda_2), Q_2 = 1 - F(\hat{x}, \lambda_1, \lambda_2)$$
$$\Pi_1 = (p_1 - c)Q_1 - a\lambda_1^2/2 \text{ and } \Pi_2 = (p_2 - c)Q_2 - a\lambda_2^2/2$$

Maximizing their profit **simultaneously** with respect to  $p_i$  and  $\lambda_i$ , and focusing on the symmetric equilibrium:

### Results

 $p_1^* = p_2^* = c + t$  and  $\lambda_1^* = \lambda_2^* = \frac{t}{4a}$ .  $\Pi_1^* = \Pi_2^* = \frac{t}{2} - \frac{t^2}{32a} < \frac{t}{2}$ . Firms are worse-off with advertising. If they could coordinate, they would refrain from investing.

Benchmark: Without advertising Advertising increases consumers' willingness to pay Advertising changes the distribution of consumers' tastes Advertising increases perceived product differences

### Advertising increases perceived product differences

Assumptions Differentiation

• We denote 
$$t(\lambda_1, \lambda_2) = t + \beta \lambda_1 + \beta \lambda_2$$
.

It is immediate that at stage 2:

$$p_1(\lambda_1, \lambda_2) = p_2(\lambda_1, \lambda_2) = c + t + \beta \lambda_1 + \beta \lambda_2$$

$$\Pi_1 = (p_1 - c)\hat{x} - a\lambda_1^2/2$$
 and  $\Pi_2 = (p_2 - c)(1 - \hat{x}) - a\lambda_2^2/2$ 

In stage 1, maximizing their profit with respect to  $\lambda_i$ , and focusing on the symmetric equilibrium:

$$\lambda_1^* = \lambda_2^* = \frac{\beta}{2a} \text{ and } p_1^* = p_2^* = c + t + \frac{\beta^2}{a}$$
  
 $\Pi_1^* = \Pi_2^* = \frac{t}{2} + \frac{3\beta^2}{8a} > \frac{t}{2}$ 

#### Result

Advertising that increases perceived product difference relaxes competition and therefore firms' investment is profitable. Public good: coordination raises investment.

Introduction Benchmark: Without advertising Persuasive Advertising Informative advertising advertising changes the distribution of consumers' tastes Advertising increases perceived product differences

### Remember

- Advertising creates or boosts the demand for a product.
- In a competition framework: different types of persuasive advertising lead to different outcomes
  - Increasing the consumers' willingness to pay, or changing consumers' taste for a good at the expense of rivals may lead to a business stealing effect and result in an efficient advertising race.
  - Advertising characteristics of the products may increase the perceived differentiation among products and soften competition !
- Heavy regulation of ads in France:
  - Comparative ads are regulated (not authorized to depreciate/lie the product of a rival)!!
  - Law "Evin" (1991) forbids any ads on tobacco or alcool.
  - Law project under debate to forbid ads on some products that are bad for environment (high GHG emissions- SUV) or for health (food products listed by PNNS).

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### Informative advertising on prices Assumptions

- ► Consider a duopoly of homogenous products with marginal cost *c*.
- Consumers do not know the price charged by each firm.
- Consumers have a valuation v > c for the good.
- $\blacktriangleright$  Consumers have search cost: they can only discover one price (0 for one firm ,  $+\infty$  for two).

Without advertising on prices : consumers choose between the two firms randomly, check the price and buy if p < v. The two firms set p = v. With advertising : Competition is Bertrand like, because the product is

homogenous: p = c.

#### Result

Informative advertising on prices may intensify competition by reducing consumers' search costs.

► Argument often put forward in favor of "online" sales.

Information about prices Informative advertising on product's existence  $\ensuremath{\mathsf{Exercise}}\xspace 1$ 

### Informative advertising on product's existence Grossman & Shapiro (1984)

- Consumers unaware of a new product's existence: no utility and no demand.
- Consumers aware of a new product's existence
  - u(q) > 0 with u'(q) > 0 and u''(q) < 0.
  - Maximising u(q) pq where p is the price, we derive a demand q(p) > 0, with q'(p) < 0.

### Information about the existence of a product

Advertising can inform consumers about the very existence of a product!

Information about prices Informative advertising on product's existence  $\ensuremath{\mathsf{Exercise}}\xspace 1$ 

### Advertising is key to launch a new product

GLOBAL PERCENT MUCH/SOMEWHAT MORE LIKELY TO BUY A NEW PRODUCT WHEN LEARNED THROUGH THESE METHODS

TRADITIONAL ADVERTISING





INTERNET COMMUNICATIONS





#### Source: Nielsen Global Survey of New Product Purchase Sentiment, Q3 2012

Information about prices Informative advertising on product's existence  $\ensuremath{\mathsf{Exercise}}\xspace 1$ 

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### Remember

- In a competition framework: different types of informative advertising lead to different outcomes
  - It might increase competition when it vehicles information on prices.
  - Informative advertising is profitable when it reveals the product's existence (See Exercice 1).

Information about prices Informative advertising on product's existence  $\ensuremath{\textit{Exercise 1}}$ 

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### Exercise 1

#### Assumptions

- Consumers are uniformly distributed along a segment [0, 1]. A firm is localized in 0 and another firm in 1.
- ► A consumer who travels a distance x to buy one unit at price p has a utility U = v - p - tx if he buys and 0 if he does not buy. There is no utility for a second unit.
- A consumer buys only if he receives an ad. Let Φ<sub>i</sub> denote the share of consumers who have received an ad from *i*. The cost to reach this fraction of demand is A(φ) = aφ<sup>2</sup>/2 with a ≥ t/2.

#### Questions

1. What is the demand of consumers who receive only an ad from *i*?

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- 1. What is the demand of consumers who receive only an ad from *i*?
- The probability to receive an ad only from firm *i* is:  $\phi_i(1-\phi_j)$ .
- Consumers who buy are such that  $v p_i tx \ge 0$
- ►  $D_i = 1$  if  $x_0 = \frac{v-p}{t} > 1$  (covered market)!  $\Rightarrow$  We focus on this case for simplicity
- $D_i = \frac{v p_i}{t}$  otherwise (uncovered market).

Introduction Information about prices Informative advertising Informative advertising Signaling Exercise 1

- 2. What is the demand of consumers who receive an ad from *i* and *j*?
- The probability to receive an ad from both firms is:  $\phi_i \phi_j$ .
- Among them the address of the indifferent consumer  $\tilde{x}$  is such that  $v p_i tx = v p_j t(1 x)$  or  $\tilde{x} = \frac{1}{2} + \frac{(p_j p_i)}{2t}$ .
- $\tilde{x}$  (resp. 1- $\tilde{x}$ ) is the demand for *i* (resp. *j*) when the gap in price is not too high.

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What is the total demand for firm *i*? How the price elasticity of demand varies in φ in p<sub>i</sub> = p<sub>j</sub> = p and φ<sub>i</sub> = φ<sub>j</sub> = φ?

$$\blacktriangleright D_i = \phi_i [(1 - \phi_j) + \phi_j \tilde{x}]$$

• At point 
$$p_i = p_j = p$$
 and  $\phi_i = \phi_j = \phi$ , the elasticity  $\epsilon = \frac{-p_i \partial D_i / \partial p_i}{D_i} = \frac{p\phi}{t(2-\phi)}$  which increases in  $\phi$ .

A larger \u03c6 implies a larger the probability that consumers are informed of the existence of both goods: They are thus more sensitive to price.

- 4. Firms choose simultaneously their price and their ad level. Determine the symmetric Nash equilibrium of this game.
- The profit of firm i is:

$$\Pi_i = (p_i - c)D_i - A(\phi_i)$$

• with 
$$D_i = \phi_i[(1-\phi_j) + \phi_j \frac{p_i - p_j + t}{2t}] = \frac{\phi_i}{2t}[(1-\phi_j)2t + \phi_j(p_i - p_j + t)]$$

The first order conditions are :

$$2p_i = c + t + p_j + \frac{2(1 - \phi_j)t}{\phi_j}$$
$$\phi_i = (p_i - c)\frac{(1 - \phi_j + \phi_j\tilde{x})}{a}$$

► At the symmetric equilibrium  $p_i = p_j = p^* = c + \sqrt{2at}$  and  $\tilde{x} = \frac{1}{2}$ and  $\phi_i = \phi_j = \phi^* = \frac{2}{(1+\sqrt{2a/t})}$ .

## Advertising Signals

#### Assumptions

- ► One consumer with a valuation for a high quality good v<sub>H</sub> and for the low quality v<sub>L</sub> < v<sub>H</sub>.
- Production cost is the same,  $c < v_L$ , for a high or a low quality good.
- Two period game. The consumer wants one unit in each period. Experience good!
- Firms can choose to spend an advertising amount A which is observed by the consumer before he chooses to purchase in period 1.

### **Full Information**

Consumers know the quality and thus firms do not advertise.

A high quality firm sets  $p_H = v_H$  and gets  $\Pi_H = 2(v_H - c))$ ; A low quality firm sets  $p_L = v_L$  and gets  $\Pi_L = 2(v_L - c)$ .

### **Asymmetric Information**

We look for a separating equilibrium BOUTON. We assume that only advertising amounts (not price) can convey a signal about quality. The source  $\frac{1}{22/44}$ 

Price and Advertising signals Exercise 2

### Advertising Signals

Assume that there exists a separating equilibrium such that if a firm spends A in advertising, consumers believe that it is a high quality firm with probability 1.

In such separating equilibrium:  $\Pi_H = 2(v_H - c) - A$ , and  $\Pi_L = 2(v_L - c)$ .

#### **Participation constraint**

► Check that a high quality firm makes a positive profit i.e. Π<sub>H</sub> > 0, that is A < 2(v<sub>H</sub> - c).

#### Incentive constraints

- Check that a high quality firm is better off advertising! Its deviation profit is Π'<sub>H</sub> = v<sub>L</sub> + v<sub>H</sub> − 2c < Π<sub>H</sub> ⇒ A ≤ v<sub>H</sub> − v<sub>L</sub>
- ► Check that a low quality firm is better off not advertising! Its deviation profit is  $\Pi'_L = v_H + v_L 2c A < \Pi_L \Rightarrow A \ge v_H v_L$

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Price and Advertising signals Exercise 2

### Advertising Signals

Assume now that if a consumer was cheated in the first period, the firm is boycotted in the next period. The incentive constraint for the low quality firm becomes:

- ► A low quality firm is better off not advertising! Its deviation profit is  $\Pi'_L = v_H - c - A < \Pi_L \Rightarrow A \ge v_H - v_L - (v_L - c)$
- A separating equilibrium exists for  $A \in [v_H v_L (v_L c), v_H v_L]$ .
- In equilibrium the high quality firm chooses the minimum advertising amount A<sup>\*</sup> = v<sub>H</sub> − v<sub>L</sub> − (v<sub>L</sub> − c) and obtains a profit Π<sup>\*</sup><sub>H</sub> = v<sub>H</sub> − c + 2(v<sub>L</sub> − c) > Π'<sub>H</sub>

#### Result

Burning money through advertising can be a credible means for a firm to signal a high quality in particular in the case of experience good with repeated purchases.

Price and Advertising signals Exercise 2

### Price and Advertising signals

#### Milgrom and Roberts (1986)

#### Assumptions

- A firm has a new product of quality H or L and knows its quality.
- Consumers do not know the quality.
- Repeated purchase game. Consumers discover the quality after one purchase.
- $\pi(P, q, Q) A$ , expected present value of the profit of a firm where :
  - q true quality;
  - the introductory price is *P*;
  - the introductory advertising spending A
  - consumers believe the product is of quality Q.
- $\pi(P, q, Q)$  increases in Q (initial sales)

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- We define P<sup>q</sup><sub>Q</sub> = arg max<sub>P</sub>π(P, q, Q). P<sup>L</sup><sub>L</sub> and P<sup>H</sup><sub>H</sub> are full information optimal prices.
- ► We are looking for a SE such that there exists a couple (P, A) that makes consumers believe the quality is H (with proba 1) and L otherwise.

### Result 1

There exists a separating sequential equilibrium if and only if for some (P, A):

$$\pi(P, H, H) - \pi(P_L^H, H, L) \ge A \ge \pi(P, L, H) - \pi(P_L^L, L, L)$$
(1)

- π(P, H, H) − A ≥ π(P<sup>H</sup><sub>L</sub>, H, L): a firm of quality H earns a larger profit in selecting (P, A) which conveys the signal H to consumers than her best profit when consumers believe it is of quality L.
- π(P, L, H) − A ≤ π(P<sup>L</sup><sub>L</sub>, L, L): a firm of quality L earns a smaller
  profit in selecting (P, A) rather than its best profit when consumers
  believe its quality is L.

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Price and Advertising signals Exercise 2

- Isoprofit curves:
  - $A(P) = \pi(P, H, H) \pi(P_L^H, H, L)$  (Above)
  - $A(P) = \pi(P, L, H) \pi(P_L^L, L, L)$  (Below)



Price and Advertising signals Exercise 2

Elimination of equilibria with dominated strategies.

### Result 2

There exists a separating equilibrium if and only if there is some (P, A) such that eq(1) holds. At any separating equilibrium, the choice (P, A) of the high-quality firm must be a solution to the following programme (2):

$$\max_{P,A} \pi(P,H,H) - A$$
 subject to $\pi(P,L,H) - A \leq \pi(p_L^L,L,L)$ 

. If the solution  $(P^*,A^*)$  to (2) is such that  $A^*>0$ , then  $P^*$  solves

$$\max_{P} \pi(P, H, H) - \pi(P, L, H)$$
$$\Rightarrow \frac{\partial \pi(P, H, H)}{\partial P} = \frac{\partial \pi(P, L, H)}{\partial P}$$



- ► Assume  $\pi(P, H, H) \pi(P, L, H)$  has a maximum in *P*.
- $A(P) = \pi(P, L, H) \pi(P_L^L, L, L)$
- The other curve is  $\pi(P, H, H) A$
- The separating equilibrium is at the tangency point  $(P^T, A^T)$ .





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Assume that  $\pi(P, L, H)$  is strictly concave in P and that A(P) is positive on an interval  $(\underline{P}, \overline{P})$  with P > 0.

► A necessary condition for advertising to occur at equilibrium is  $P_{H}^{H} \in (\underline{P}, \overline{P})$  or, equivalently,

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

- ► Case in which P<sup>H</sup><sub>H</sub> > P: If a new high-quality product is very expensive to produce and is aimed at a limited market.
- ► Case in which P<sup>H</sup><sub>H</sub> < P: If the new high-quality product is very cheap to produce the introducing firm may set a low initial price or give away free samples in launching the product.</p>

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### Remember

- Burning money, i.e. a high level of advertising may signal a high quality
- ► Together with advertising, a high price (ie. higher than the high quality monopoly) may signal a high quality: it claims that the producer is confident enough in its product quality
- Together with advertising, a low price may signal a high quality (i.e lower than the high quality monopoly price): it claims that consumers that will taste it won't be disappointed.

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Price and Advertising signals Exercise 2

### Exercise 2

#### Advertising as a commitment device (Lal and Matutes, 1994)

#### Assumption

- Firms A and B are located at the extreme of a segment of lenght 1.
- Consumers are uniformly distributed along the segment and incur linear transport cost tx.
- A and B sell two products 1 and 2.
- Consumers have the same willingness to pay for each good, denoted H.
- Unless they receive an ad (catalog, leaflet,...), consumers are uninformed about prices but make rational expectations about prices.
- Each firm can choose to advertise one or two goods. Advertising costs F and vehicles the information about a product's price to all consumers.

Price and Advertising signals Exercise 2

### Exercise 2

1. What happens if no firm advertise any product?

### Exercise 2

- 1. What happens if no firm advertise any product?
- ► If there are no advertising, consumers rationally expect that all prices are equal to *H*.
  - Once at the store the firm knows that the transportation cost is sunk for the consumer and has an incentive to set a price *H*.
- Anticipating this, no consumer buy anything and therefore no profit for both firms.

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- 2 What happens if the two firm advertise both products? Is this an equilibrium?
- Assume that the two firms advertise both products at prices (p<sub>A1</sub>, p<sub>A2</sub>) and (p<sub>B1</sub>, p<sub>B2</sub>) which costs 2F to each firm!
- ▶ The indifferent consumer is such that the surplus it obtains in visiting *A*, i.e.  $2H p_{A1} p_{A2} t\hat{x}$  is the same as the surplus it obtains in visiting *B*, i.e.  $2H p_{B1} p_{B2} t(1 \hat{x})$

$$\hat{x} = \frac{p_{B1} + p_{B2} - p_{A1} - p_{A2} + t}{2t}$$

- A maximizes its profit  $(p_{A1} + p_{A2})\hat{x}$ , and B maximizes  $(p_{B1} + p_{B2})(1 \hat{x})!$
- This leads to  $p_A^* = p_{A1} + p_{A2} = t$  and  $p_B = p_{B1} + p_{B2} = t$ .

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- 2 What happens if the two firm advertise both products? Is this an equilibrium?
- The first important condition to check is that t < 2H. Then, the profit each firm realizes is  $\pi_i = \frac{t}{2} - 2F > 0 \rightarrow F < \frac{t}{4}$ .
- Another condition to check is that the marginal consumer has a positive surplus, i.e. that  $2H - t - \frac{t}{2} > 0 \rightarrow t < \frac{4H}{3}$  (covered market).
- To check whether this is an equilibrium, we check that a firm, say B, has no incentive to deviate unilaterally by only advertising one of its products, say 1.
  - Consumers rationnally expect that a product that is not advertised will be sold at H.

$$\hat{x} = \frac{p_{B1} + H - p_A^* + t}{2t}$$

- Maximizing its profit  $(p_{B1} + H)\hat{x}$  with respect to  $p_{B1}$ , we obtain  $p_{B1} = t - H$ .
- The profit obtained by firm B is therefore  $\pi_B = \frac{t}{2} F > \frac{t}{2} 2F$ : NO.



- 3. Determine the two types of equilibria of this game. For which conditions on H and F do these equilibria exist?
- There are two symmetric equilibria: (i) one firm advertises 1 and the other 2 or (ii) the two firms advertise the same good.
  - ► A and B advertise product 1. Consumers expect product 2 to be sold at price *H* at both stores.
  - The indifferent consumer is:

$$\hat{x} = \frac{p_{B1} + H - p_{A1} - H + t}{2t}$$

- A maximizes its profit  $(p_{A1} + H)\hat{x}$  whereas B maximizes  $(p_{B1} + H)(1 \hat{x})$ .
- We obtain  $p_{A1} = p_{B1} = t H$  and therefore the profit is  $\frac{t}{2} F > 0$ .



- 3. Determine the two types of equilibria of this game. For which conditions on *H* and *F* do these equilibria exist?
- There is no incentive for a firm to deviate towards no advertising as it brings no profit.
- ► There is no incentive to deviate towards advertising both products as it brings a lower profit <sup>t</sup>/<sub>2</sub> - 2F.
- ► A firm could deviate by advertising instead the other product. But as everything is symmetric here, it brings the same profit.
- ▶ From above it is immediate that there is another symmetric equilibrium in which *A* advertises 1 and *B* advertises 2 and conversely.

### References

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### Signaling Game

- Player 1 has a private information about his type θ ∈ Θ and chooses a signal s ∈ S.
- ▶ Player 2 observes *s* and chooses an action  $b \in B$ .
- Player 2 has prior belief about Player 1's type p(.). After observing s, Player 2 revises its beliefs according to the Baye's rule and has a posterior belief μ(./s) over Θ.
- Player 1 determines σ<sub>1</sub>(s/θ), the probability to send a signal s when being of type θ.
- Player 2 determines σ<sub>2</sub>(b/s), the probability to choose the action b given the signal s and posterior belief μ(./s).

**Definition** . A perfect Bayesian equilibrium of a signaling game is a strategy profile  $(\sigma_1^*, \sigma_2^*)$  in which each player's strategy is the best reaction to the other's strategy according to the posterior beliefs  $\mu(./s)$ .



### Types of equilibria

A **separating equilibrium** is an equilibrium where Players 1 of different types always choose different messages and therefore fully reveal their type to Player 2.

A **pooling equilibrium** is an equilibrium where Players 1 of different types always choose the same message and no information is revealed to Player 2.



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	Colgate	P&G CREST
Help reduce Cavities	***	***
Help brush away Plaque	**	*
Prevent Gingivitis	*	**
White teeth	**	*
Fresh feeling breath	*	$\star \star$