Advertising and R&D: Theory and Evidence from France

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Abstract: Advertising and innovation are two engines for firms to escape competition and improve profits. We propose a model that encompasses both the static and dynamic interactions between R&D, advertising and competitive environment. It provides three main predictions. First, for a given competitive environment, quality leaders spend more in advertising in order to extract maximal rents; thus, lower costs of ads may favor R&D. Second, the inverted-U relation between competition and R&D still holds with the introduction of advertising. Third, more competition is associated with on average more advertising expenditures. Empirical evidence from a large panel of 59,000 French firms over 1990-2004 supports these three properties.

Keywords: advertising, R&D, innovation, competition, Lerner.

J.E.L. classification: D4, O31, D12.

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1 Introduction

In developed countries, both R&D and advertising expenditures are massive. They are two key engines for firms to escape competition and increase profits through a quality advantage or a better attraction power toward consumers. The aim of this paper is to study the joint decision for R&D and advertising efforts of firms according to the competitive environment. We build a theoretical model and test its main predictions using a large panel dataset of French firms containing information on both R&D and advertising investments

The issue is related to distinct literatures that analyze the two-by-two relations between the three variables advertising, R&D and competition.

The interplay between advertising and R&D is ambiguous. On the one hand, advertising and R&D can be strategic substitutes (Kaiser, 2005). If the returns associated to advertising are higher than the returns on R&D, favoring advertising may induce a substitution and thus a reduction of the R&D effort. This mechanism should be strengthened when firms face credit constraints or have to compel with short-run objectives. But, on the other hand, evidence supports that advertising and R&D can also be complements: some R&D intensive industries, like drugs, also have high advertising spending (Matraves, 1999; Kwong and Norton, 2007); in the automobile industry, investors react favorably to companies that launch innovations that are backed up by substantial advertising support (Srinivasan et al., 2009).

Following Nelson (1974), a large theoretical literature rationalizes these findings by looking at the effect of product quality (but not directly R&D) on advertising. It follows Nelson (1974) that predicts a positive effect especially for experience goods. Three main channels are explored: advertising as a signaling tool for firm efficiency (Milgrom and Roberts, 1986; Fluet and Garella, 2002), advertising to retain consumers when doing repeat-business, and advertising as a device to match products to buyers. The empirical literature offers mixed support for this prediction and theoretical papers stress that it depends on the environment faced by firms (see Bagwell, 2007 for a review).

Conversely, advertising may also favor innovation (and thus product quality). Advertising enables firms to acquire a reputation or to publicize a better quality, intensity in innovation or even fashionableness of products or services. If firms internalize that advertising helps to improve the information of consumers on the true quality of firms output (e.g. Nelson, 1974), they will have ex ante incentives to improve quality. Another classic argument is that a famous firm is reluctant to lose its reputation by offering an odd or outdated product (Fogg-Meade, 1901). Recently, Grossmann (2008) argues that advertising also increases sunk costs and makes entry more difficult; this in turn induces higher market concentrations with larger firms and enhances R&D investments of insider firms; however, this mechanism is not consistent with the recent results on the link between competition and R&D or advertising.

Actually, the debate on the impact of competition on R&D was long driven by the classic arguments of the controversy between Schumpeter and Arrow. More recently, the seminal growth models with endogenous technical change as well as the leading IO models of product differentiation and monopolistic competition, predict a negative relationship between competition and R&D, as more competition reduces the monopoly rents that reward successful innovators. However, this standard Schumpeterian prediction has been challenged by empirical evidence (Nickell, 1996; Blundell et al., 1999). Papers by Aghion and coauthors (1997, 2001) point out that the incentive to invest in R&D for firms actually depends on the difference between post-innovation and pre-innovation rents rather than only on post-innovation rents. When competition is high, firms have an incentive to escape from it by innovating in order to strengthen their technological and market position. However, when competition becomes really too harsh, there are no monopoly rents to be captured by technological leaders, and incentives to innovate therefore decrease. Aghion et al. (2005) nest these arguments in a unified framework and show, both theoretically and empirically, that innovation is an inverted U-shaped function of competition.

Finally, the connections between competition and advertising are unclear. Bagwell (2007) reports positive correlations but stresses that in-depth firm-level empirical investigations still remain relatively scarce to confirm this point. In addition, most theoretical models including goodwill effects and empirical studies fail to find an entry-deterrence effect of advertising (see Dukes, 2009, for a review).

Our paper complements these strands of the literature: we build a model that encompasses interactions between R&D, advertising and firms' competitive environment. Our motivation and contribution are to introduce competition to model jointly and better understand the static and dynamic complementarities between R&D and advertising.

We model sectors as duopolies. The product market consists in a continuum of consumers. Two shares of consumers have a preference for the product from each firm. The lower these shares, the lower the differentiation, the higher the proportion of undecided consumers and then the larger the room for price competition between the duopolists. The two firms can use costly advertising to convince undecided consumers.

Depending on past R&D expenditures, sectors are either *leveled* – both firms are technologically Neck and Neck and thus have a similar quality level (and production costs) – or *unleveled* – one firm is a quality leader and the other one a quality follower. The model is composed of two blocks. A first static block derives duopolists' advertising expenditures considering the state of their sector as exogenous. In order to explicitly model firms' R&D investment decisions and to introduce a dynamic trade-off between quality and preference advantages for firms, this first block of the model is plugged into a à la Aghion et al. (2005) framework. This second block endogenizes the state of the sector and then the relationships between competition, advertising and R&D decisions.

The main predictions of the model are the following. First, for a given competitive environment, quality leaders spend more in advertising than Neck and Neck firms or quality followers; they extract maximal rents from their twofold monopolist positions (in preferences and in quality). There is thus a dynamic complementarity between current advertising and past R&D efforts since past R&D stochastically determines the current quality level of the firms. Second, more competition pushes Neck and Neck firms to advertise more in order to attract the larger share of undecided consumers on their products or services. When the cost of ads is not too high, this positive relationship between sectors' competition toughness and advertising expenditures also holds in the long run, that is once the state of the sectors varies stochastically as a function of firms' endogenous R&D investment decisions. Third, a lower cost of advertising may stimulate R&D. Finally, the inverted-U relation between competition and R&D is robust to the introduction of advertising.

Using a large unbalanced panel of around 59,000 French firms over the 1990-2004 period, we test most of these assertions. The Centrale des Bilans database from the Banque de France provides very detailed data on firm performance and firm expenditures or investments including R&D and advertising. Within sectors, more productive firms spend more in advertising. Similarly, current advertising spending is positively correlated to past R&D efforts. These results are consistent with a dynamic complementarity between R&D and advertising. The empirical analysis also support the monotonic impact of competition on advertising.

This article is organized as follows. Section 2 lays out the market structure of the model and the role of advertising; it tests on French data the basic theoretical result that advertising effort is increasing with the technological leadership. Section 3 introduces the dynamics of the model and studies the links between competition, R&D and advertising, and the impact of advertising costs on the flows of innovation. Section 4 concludes.

2 Basic market structure and advertising

This section presents the market structure of the model and explores the role of advertising. Since our goal is to introduce dynamics and R&D decisions in the next section, we use a framework that will appear convenient for this: a duopoly operates on a mature market with a given size; it can be composed either of Neck and Neck competitors or leader/follower competitors.

In this static framework, one key theoretical prediction -a positive link between quality advantage and advertising - is tested using our unique French dataset. Dynamic properties are derived and tested in section 3.

2.1 Duopoly and quality

We consider markets as duopolies with firms A and B producing differentiated goods or services. We retain a quality rather than productivity ladder version of Aghion *et al.* (2005). The market can be in a Neck and Neck situation where there is no technological and thus quality gap between A and B or in an unleveled situation where a technological and thus quality leader (say A) and a follower (say B) coexist.

Knowledge spillovers between leader and follower are such that the maximum sustainable quality gap is one level of the quality ladder: if a firm is one step ahead and it innovates, the follower will automatically copy the leader's previous technology and so remain only one step behind. The state of a sector is then fully characterized by a pair of integers (l, m) where l is the leader's technology and $m = 1$ if the follower is lagging one step behind, or $m = 0$ if firms are Neck and Neck.

To structure the discussion, we introduce hedonic indexes of quantities. Hedonic indexes -volume and price- adjust for quality (J. Triplett, 2004). For example, a twomegahertz chipset will be considered equivalent to two one-megahertz chipsets: the hedonic factor is thus 2. Let x and $\hat{x}$ denote respectively the volume and the hedonic volume; let p and $\hat{p}$ be respectively the price and the hedonic price. In the leader-follower case, the leader enjoys a quality gap for similar production costs c: it produces goods with a better quality with a given hedonic factor $1+\epsilon$. We assume that ϵ is small, so we will work, from herein, with first order terms in ϵ.

Without loss of generality, in the Neck and Neck case, we take the normalization $x_A = \hat{x}_A$, $x_B = \hat{x}_B$, $p_A = \hat{p}_A$ and $p_B = \hat{p}_B$. Then, in the leader-follower case, if for example A is the leader: $\hat{x}_A = x_A(1+\epsilon)$, $x_B = \hat{x}_B$, $\hat{p}_A = p_A/(1+\epsilon)$ and $p_B = \hat{p}_B$. Note that we have always $px = \hat{p}\hat{x}$.

2.2 Consumers and advertising

We assume that ϵ also represents the *ex ante* valuation advantage firms have on specific consumers. These consumers have an initial preference for the goods from A or B. In-between these two categories, people may be classified as indifferent. Examples include the wine vs. beer US market of alcohol: Gallup's Consumption Habits polls show that Americans aged 50+ and women prefer drinking wine whereas men and younger drinkers still favor beer. Segmentation of consumers can also come from geographic constraints, e.g. customers prefer to buy in stores located in their neighborhood. But we assume that consumers have the same preference for quality, so we can use hedonic prices.[1]

We formalize this *ex ante* inclination of consumers by the existence of segments of captive consumers. The size f_j of these segments in market j is inversely proportional to the degree of competition in the market. To escape competition on the non-captive segments, firms can advertise to attract a share of the initially neutral consumers, but also some consumers that ex ante prefer the other good.

Formally, consider a continuum of consumers of mass one indexed by i. Their utility follows:

$$u_i = \int_0^1 \ln x_{ij} dj$$

where x_{ij} is the aggregate of two perfect substitutes A and B from two firms on the market

[1] See Villas-Boas (2004) on the communication strategies and the design of product lines when consumers differ by their preference for quality.

j defined by :

$$x_{ij} = (1+\epsilon)^{k_{ij}/2}\hat{x}_{Aj} + (1+\epsilon)^{-k_{ij}/2}\hat{x}_{Bj}$$

where k_{ij} takes value in $\{-1, 0, 1\}$.

a) Without advertising

On each market, without loss of generality, consumers can be aligned on the segment [0,1] by increasing order of preference for good B. Because there is no advertising, ex post preferences are the ex ante preferences. The fraction $f_j \in [0, 1/2]$ of non-indifferent consumers is defined such as:

$$k_{ij} = \begin{cases} 1 & \text{if} \quad i \in I_A = [0, f_j] \\ 0 & \text{if} \quad i \in I_0 =]f_j, 1-f_j[\\ -1 & \text{if} \quad i \in I_B = [1-f_j, 1] \end{cases}$$

Figure 1 provides an illustration of the distribution of preferences.

The log-preference assumption made in the first equation implies that individuals spend the same amount on each basket x_j. We normalize this common amount to unity by using expenditure as numeraire for the prices p_{Aj} and p_{Bj} at each date. Thus each consumer i chooses $\hat{x}_{Aj}$ and $\hat{x}_{Bj}$ to maximize x_{ij} subject to the budget constraint : $p_{Aj}x_{Aj} + p_{Bj}x_{Bj} = \hat{p}_{Aj}\hat{x}_{Aj} + \hat{p}_{Bj}\hat{x}_{Bj} = 1$. The demand function facing firm A is then:

$$\hat{p}_{Aj}\hat{x}_{Aj} = \begin{cases} 1 & \text{if} \quad \hat{p}_{Aj}/\hat{p}_{Bj} < (1+\epsilon)^{k_{ij}} \\ 1/2 & \text{if} \quad \hat{p}_{Aj}/\hat{p}_{Bj} = (1+\epsilon)^{k_{ij}} \\ 0 & \text{if} \quad \hat{p}_{Aj}/\hat{p}_{Bj} > (1+\epsilon)^{k_{ij}} \end{cases}$$

Indeed, for instance, on the $[0, f_j]$ segment, consumers have an ex ante preference for good A and consequently choose good A as long as its hedonic price is not superior to the hedonic price of good B multiplied the hedonic factor.

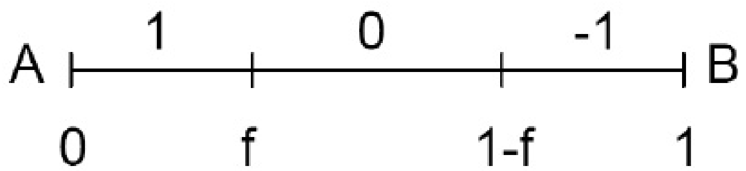
The demand function facing firm B is trivially obtained by inverting A and B in the expression above.

We drop the j subscript in the remaining of the text.

b) With advertising

Assume now that firms are given the opportunity to advertise their product. We

Figure 1: Initial distribution of consumers valuation advantage, k_{ij}, given to good A



develop a rather simple model of ads that can be plugged in the dynamic R&D environment in section 3.

Since the market size is given, we retain a classic framework with combative advertising. Precisely, advertising is viewed as a mean of modifying consumers' preferences by affecting their marginal rate of substitution; i.e. ads are persuasive. Also, since advertising expenditures are still primarily in general media, especially during the period covered by our data (1990-2004, i.e. before the boom of internet advertising), we assume that firms cannot target their advertising with respect to consumers' preferences.[2] We thus model advertising[3] according to the following stylized assumptions:

H1a: If a consumer receives ads from only one firm, her preferences are biased in favor of the product of this firm.

H1b: If a consumer receives ads from the two firms, she comes back to her ex ante preferences.

H2a: Each firm chooses a certain probability q_A (resp q_B) to reach a consumer by advertising. Firms cannot target their ads.

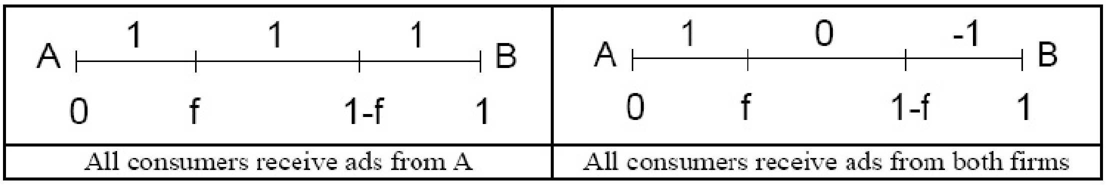
H2b: Each firm incurs a cost proportional to q, say ϕq for advertising, with $\epsilon/2 < \phi < \epsilon$.

Figure 2 gives consumers' valuation advantage k_i for good A in two polar cases. Recall that ϵ is small, so we work with first order terms in ϵ. Consequently: $(1+\epsilon)^2 = 1 + 2\epsilon$, $1/(1+\epsilon) = 1 - \epsilon$ and $1/(1+\epsilon)^2 = 1 - 2\epsilon$. Hence, the marginal rate of substitution (MRS) between buying the good to A and buying it to B is $1 + \epsilon$ if $k_i = 1$, 1 if $k_i = 0$, and $1 - \epsilon$ if $k_i = -1$.

[2] In 2004, the overwhelming majority of the French advertising market was on TV, radios, general Press and poster compagnain; Internet share was only 4%. With the rise of internet advertising based on consumers web search, a recent literature (e.g. Iyer et al., 2005) assumes that firms do have information on these individual preferences. This allows for targeted ads according to consumers' preferences.

[3] For alternative models of advertising in a duopoly framework, see Schoonbeek et al (2007) or Piga (2000).

Figure 2: Advertising and consumers valuation advantage, k_{ij}, given to good A



Innovations are dynamical and thus cancel the impact of past advertising. As a consequence, advertising is dissipative having just an immediate impact on preferences. [4]

H3: Each innovation step changes the competitive environment and thus cancels the effect of past advertising on consumers' preferences.

2.3 Firms: equilibrium prices and profits

Firms produce according to a constant-return production function, and take input prices as given. The cost of producing one unit of non-hedonic quantity of good is the same for both firms and is denoted c. This unit cost of production c of the two firms in a sector is independent of the quantities they produce.

Even though firms cannot target their ads, we suppose they are able to price discriminate consumers according to their *ex post* preferences. They may use for example price promotion for new clients or fidelity cards. Duopolies compete in prices for each consumer, leading to a Bertrand equilibrium. We now derive the explicit form of prices and profits depending on the technology configuration of the market. The subscript 1 will refer to the leader, subscript -1 to the follower, whereas subscript 0 refers to Neck and Neck firms.

The equilibrium prices and profits depend on the amount of advertising realized by each firm which is a function of the cost of advertising ϕ. We have again to separate the two states of the sector. This framework covers two main views of advertising. In an unleveled sector, ads help the leader to provide information to neutral consumers and thus to expand its profitable market share. In a leveled sector, both firms use ads to challenge the market positions.

a) leveled sector

[4] The large literature on dynamic advertising for which the advertising is a state variable assumes that the innovative environment is given (see Huang et al., 2012 for a review). Our paper departs from this literature by studying dynamic innovations that change the nature of the products that are advertised by firms.

Firms A and B are Neck and Neck. They choose their probability q_A and q_B to reach a consumer. Their game is formally similar to a mixed-strategy game with $q = 0$ and $q = 1$ the pure strategies. So, their choices are also the mixed Nash equilibrium of this latter game. On its ex ante captive segment, firm A can sell above its marginal cost only to consumers that have not received an ad from B or that have received ads from both firms. Its sales profits are then $f\epsilon(1 - q_B + q_B q_A)$. Similarly, sales profits of A on the central segment are $(1 - 2f)\epsilon(q_A - q_B q_A)$ and on the B captive segment $f\epsilon(q_A - q_B q_A)$. The profits of A are then $\pi_A = \epsilon[(1 - f)q_A - (1 - 2f)q_A q_B + f(1 - q_B)] - \phi q_A$. Assume that A chooses a mixed strategy; the support of this strategy is $q_A = 0$ and $q_A = 1$. Consequently the Nash mixed strategy for B is q_B such that $(\pi_A|q_A = 0) = (\pi_A|q_A = 1)$ i.e. $f(1-q_B) = f+(1-2f)(1-q_B)+f(1-q_B)-\phi/\epsilon \Longleftrightarrow (1-f)-(1-2f)q_B-\phi/\epsilon = 0$. Therefore, we have to distinguish 2 cases:

- if $\epsilon/2 < \phi < (1 - f)\epsilon$, then the Nash equilibrium is the symmetric strategy:

$$q_0 = q_A = q_B = \frac{1 - f - \phi/\epsilon}{1 - 2f} \in [0, 1]$$

- if $\epsilon(1 - f) < \phi < \epsilon$, then the Nash equilibrium is the symmetric strategy:

$$q_0 = q_A = q_B = 0$$

b) unleveled sector

We first prove that the follower has no interest to advertise. Assume that the follower makes some ads $q > 0$. By construction, its ads are more efficient when the leader does not advertise[5] . Take this case: the follower convinces a share q of consumer; however, the follower has to adjust its hedonic price to a level for which the technological leader makes no profits i.e. c; so the follower makes also no sales profits and incurs a cost $\phi q > 0$ for advertising. So even in the most favorable case for the follower, its profits are negative when q is positive. Consequently, the follower advertising probability is $q_{-1} = 0$ and its profit is $\Pi_{-1} = 0$.

Now consider the leader. It chooses a level of advertising q in order to maximize its profits. The leader's net revenue is $2f\epsilon$ on its ex ante captive segment; $(1-2f)(2\epsilon q+\epsilon(1-q))$ on the ex ante neutral segment; and $2f\epsilon q$ on the ex ante captive segment of the follower. This implies:

$$\Pi_1(q) = 2f\epsilon + 2(1 - 2f)\epsilon q + (1 - 2f)\epsilon(1 - q) + f\epsilon(1 - q) - \phi q = \epsilon + q(\epsilon - \phi).$$

[5]since $\pi_{-1}(q_1, q_{-1}) \leq \pi_{-1}(0, q_{-1}) \leq 0$; let us note that: $\pi_{-1}(0, 0) = 0$ and $\pi_{-1}(0, q_{-1}) = -q_{-1}\phi$

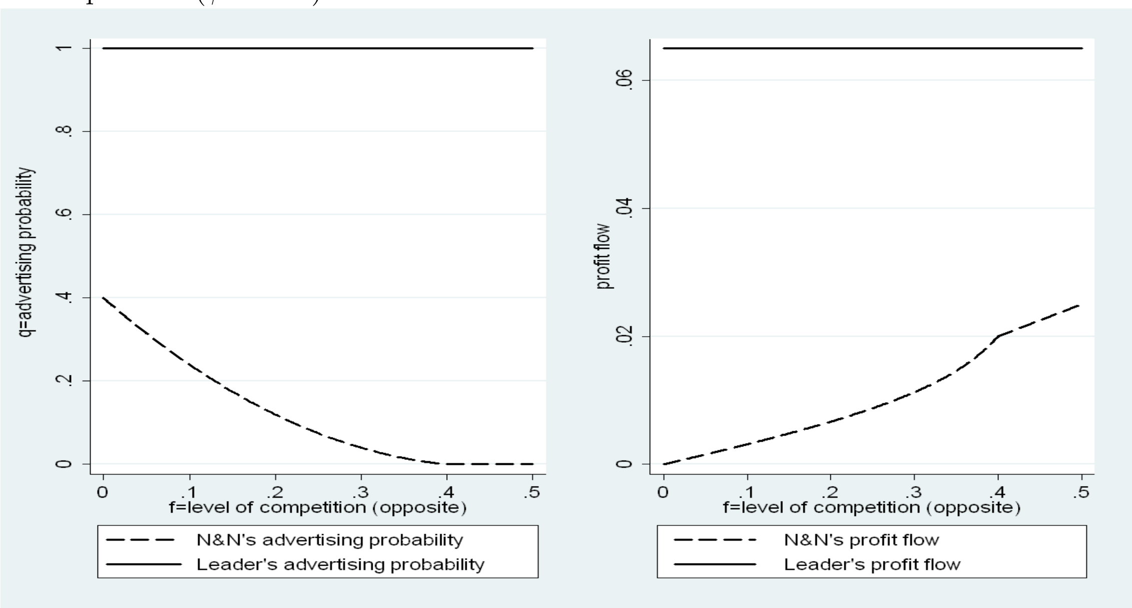
Now because $\epsilon > \phi$, the leader maximizes its profits when $q = q_1 = 1$ i.e. $\Pi_1 = 2\epsilon - \phi$.

Table 1 summarizes these results and figure 3 depicts the leader's and Neck and Neck's advertising levels when f varies between 0 and 1/2 and $\phi = 0.6\epsilon$. Π_0 being equal to $f\epsilon$ or to the product of two positive functions that are increasing with f, is also increasing with f.

Table 1: Firms advertising expenditure and profit

Follower	Leader	Neck&Neck
		- if $\epsilon/2 < \phi < (1-f)\epsilon$**:**
$q_{-1} = 0$	$q_1 = 1$	$q_0 = (1 - f - \phi/\epsilon)/(1 - 2f)$
		$\Pi_0 = f\epsilon(\frac{\phi/\epsilon - f}{1-2f})$
		- if $(1-f)\epsilon < \phi < \epsilon$**:**
$\Pi_{-1} = 0$	$\Pi_1 = 2\epsilon - \phi$	$q_0 = 0$
		$\Pi_0 = f\epsilon$

Figure 3: Leader's and Neck and Neck's advertising probabilities and profits as a function of competition ($\phi = 0.6\epsilon$):



For a given state of the sector (leveled or unleveled) advertising expenditures of Neck and Neck firms are increasing with competition, while expenditures of the leader or the follower are flat. Intuitively, when competition is tougher i.e. the ex-ante non-captive markets are large, firms try to escape competition through more ads. But, because we will see in the next section that competition has an impact on the state of the sector or more exactly on the probability that it is leveled or unleveled, we cannot conclude at that stage that a more competitive sector should exhibit larger advertising expenditures in average.

2.4 Advertising and technological position

From the previous static analysis, we can easily derive the following key proposition:

Proposition 1: For a given competitive environment, advertising expenditures increase with the technological advantage of firms: the leader advertises more than a Neck and Neck firm; and a Neck and Neck firm advertises more than the follower.

Intuitively, because it faces lower production costs, the quality leader has interest to try to capture both ex ante neutral and unfavorable segments. In addition it does not face the advertising competition of its competitor. So it advertises more than Neck and Neck firms for a given level of competition f. Neck and Neck firms advertise more than followers who do no advertise since they lose money if they do.

An empirical validation of this result is crucial for the robustness of the model when we will introduce the R&D dynamics. Now, evidence of a positive relation between quality and advertising efforts is mixed and it does not directly address the technological position of firms. We thus check ourselves if the first model prediction holds using French micro data. The originality of the data is to provide both R&D investment -as a proxy (and the theoretical determinant) of the technological position- and advertising spending for a large panel of firms. We now turn to the presentation of the data sources and then to the econometric estimations.

Data We use a subset of the FIBEN dataset provided by the *Observatoire des entreprises* at the Banque de France. Data from FIBEN are collected on a voluntary basis. Clerks in the different local establishments of the Bank of France contact firms to complete a survey. The FIBEN database is based on firms tax forms and includes all businesses with more than 500 employees and a fraction of smaller firms. It covers about 57% of employment for manufacturing but less for service sectors. A subset of FIBEN, the so called Centrale des Bilans contains more detailed information on firms' expenditures that are specifically devoted to increase their potential sales, with two special items on advertising and R&D

expenditures[6].

The clear value-added of these micro data compared to other sources on R&D is to include firms that have episodic R&D and to provide in the same time their advertising efforts. R&D can be considered either as expenditure or as investment in the French legal accounting setting. Broadly speaking, R&D costs concerning a well defined project and yielding almost certain return can be declared as investments whereas R&D expenditures linked to more uncertain projects have to be considered as current expenditures. In this paper, we add these two categories together.

Advertising expenditures in our data is a broad accounting category: it includes the classic ads in various media but also expenditures for exhibits, the publication of catalogs and the organization of public events as well as expenditures due to gifts and free samples offered to customers. Using this well-defined accounting category allows us to get exaustive data covering all businesses.

A Lerner index for each firm can be built using these data. We only observe sectorial price provided by the INSEE, but we have detailed information on costs. The Lerner index is supposed to measure the market power of the firm by the difference between price and marginal costs (which equals the negative inverse of demand elasticity). Since neither price nor marginal costs are available at the firm level, we compute the index using value-added net of depreciation and provisions minus the financial cost of capital (cost of capital*capital stock) over sales (in line with Aghion et al., 2005). The Fiben database contains very detailed balance sheet information that enables us to compute these Lerner indicators.[7] In our model the Lerner index is decreasing with f, the measure of competition.

Using measures of capital stocks in volume that account for differences in the average age of capital[8], we compute a total factor productivity index (TFP) for each firm based on a revenue function. TFP is computed as the ratio of value added over a Cobb-Douglas

[6]These items have a precise counterpart in the official accounting plan (*plan comptable général*). Advertising comes from category 623, whereas R&D expenditures are the sum of elements in categories 61, 62 and 64.

[7]Lerner=(value added-(depreciation cost of capital)*(capital Stock)-provision)/sales
Using the standard mnemonics of French tax forms: Lerner=[VA-(AQ+AS+AU+AW+AY- AQ-1-AS-1-AU-1-AW-1-AY-1)-0.085.capital-(DR-DR-1)]/FL.

[8]FIBEN includes balance sheet data only; namely, the value of physical assets that it reports is given at historical costs. Using standard methods based on the depreciation rate, we estimate the average age of capital to adjust for this price effect.

combination of labor and capital, where the parameter for labor is firm specific, taken as the time average of the share of the wage bill in value added and the parameter of the capital stock equals one minus the parameter of labor. Note that in our model, all firms have the same technology (same c) but the leader (say firm A) can set higher prices than Neck and Neck firms on I_B and I_0 due to hedonic advantage. Hence, on average, leaders enjoy higher TFP, based on a revenue function than Neck and Neck firms.

We have Lerner index, total R&D and marketing expenditures available for an unbalanced panel of 59 thousands firms from 1990 to 2004. This final sample contains around 480,000 firm-year observations, the number of firms present each year is around 30,000 and is relatively stable over time. In average a firm is observed in our sample during around 7 years.

Table 2 shows some aggregate descriptive statistics. On average advertising weights about 4.1% of firm value-added and R&D spending about 1.6%. This last figure is consistent with the national account ratio for market economy.

Table 2: Descriptive statistics for main variables

	Mean	Median	Std. Dev.	First decile	Last decile	Number of obs
Value added (1000'€)	6155.4	1296	93135.7	359	7623	515185
Advertising exp. (1000'€)	253.6	3.048	4758.0	0	117	515185
Advertising exp. (1000'€) per empl.	1.430	0.103	6.141	0	3.000	515185
R&D exp. (1000'€)	97.1	0	4313.1	0	3.2	515185
R&D exp. (1000'€) per employee	0.226	0	1.595	0	0.064	515185
Total factor productivity	.21	0.19	.1108	.092	.33	436945
Nb of employees	123	33	1542	9	172	515185
R&D stock (1000'€) per employee	0.844	0	5.953	0	0.810	326788
Lerner index	0.29	0.28	0.16	0.10	0.50	471503

Value added, advertising expenditure and R&D expenditure are given in thousands of 2004 euros. Advertising and R&D expenditure per employee and R&D stock per employee are given in 2004 euros.

Table 5 in appendix 2 presents the mean of advertising and R&D per worker by sector. Unsurprisingly, most business to consumers sectors (consumer goods manufacturing, retail trade, and the food industry) exhibit high levels of advertising (more than 2000 Euros per employee); whereas high level of R&D are observed in cars, equipment goods and energy sectors. One manufacturing sector has a very high level of advertising compared to R&D:

food industry, which partly reflects the downstream margin effects.

Samples and methodological choices We want to take advantage of our very rich data to show that the model's predictions apply to the whole economy. We thus present estimates using all firms in the sample. However, our model assumes that firms use ads to convince consumers to buy their products. It thus applies primarily to B2C sectors. To match as closely as possible to our modeling choices, we also systematically check the validity of the model's predictions using only sectors identified as being primarily B2C sectors: consumer goods manufacturing, retail trade, personal services, and the food industry. Unsurprisingly, these sectors are also the most intensive ones in terms of advertising expenditures (with the exception of personal services, see table 5).

Our model also assumes a mature market with constant market size. To match our empirical analysis as close as possible with this assumption, we run a robustness check excluding small and young firms that are more likely to be innovative start-ups developing new markets. To keep the exposition light, we present this check as well as a few others in an online empirical appendix. Finally, to avoid our results to be driven by differences in firm size, we normalize advertising and R&D expenditures by firms' number of employees.[9]

We apply three types of econometric models on the panel data: a simple OLS, a firm fixed effect (FE) model and a random effects (RE) model. Year dummies have been included as controls in all specifications. In all specifications, we cluster standard errors at the firm level as the error terms are likely to be correlated within firms.

Results Tables 3 and 4 test the prediction that the technological leader always has a level of advertising that is higher than the rest of the firms. In order to identify potential leaders, we first make the assumption that leaders enjoy better apparent total factor productivity (TFP) since its price margin is larger. For the OLS specifications, a leader should be considered as the leader in its industry for a given date, so we add detailed industries*date dummies as references in the regressions. Table 3 shows that higher TFP (coincident

[9]See online appendix for a check using non-normalized advertising and R&D expenditures. Note that we should not normalize R&D and advertising by sales as the positive effect of advertising on sales is a key feature of our model that allows us to derive the other predictions. We do find a positive effect of advertising on sales in our data (results not reported), consistent with our modeling choices and the huge empirical literature on this.

or lagged) is correlated with higher advertising. The average association between TFP and advertising is large; a 10% rise in TFP is associated with an increase in advertising expenditure ranging from 250 to 420 euros per employee. Consistent with the fact that our model is suited for B2C sectors, the link between TFP and advertising is even larger (about two third larger) in those sectors (see Panel B).

Table 3: Advertising and technological position. 1990-2004.

Dependent variable: advertising expenditure (in thousands 2004 euros) per employee						
	1:OLS	2:FE	3:RE	4:OLS	5:FE	6:RE
	Panel A: All sectors					
TFP	4.244***	2.932******	2.764***			
	(0.375)	(0.473)	(0.388)			
TFP (lagged)				4.097***	2.827***	2.594***
				(0.105)	(0.463)	(0.379)
Observations	436,945	436,945	436,945	378,809	378,809	378,809
Number of firms	52,885	52,885	52,885	49,818	49,818	49,818
R-squared	0.08	0.02	0.02	0.09	0.02	0.02
	Panel B: B2C sectors only					
TFP	6.170***	5.263***	4.775***			
	(1.073)	(1.171)	(0.932)			
TFP (lagged)				5.686***	5.384***	4.624***
				(1.149)	(1.179)	(0.980)
Observations	114,127	114,127	114,127	98,995	98,995	98,995
Number of firms	14,077	14,077	14,077	13,149	13,149	13,149
R-squared	0.084	0.038	0.038	0.084	0.038	0.038
(industry114, year) dummies	Yes	No	No	Yes	No	No
Year	No	Yes	Yes	No	Yes	Yes

Note: A control for firms' number of employees is included in all regressions. B2C sectors are Food and agricultural manufacturing, Consumer goods manufacturing, retail trade, and personal services. Standard errors clustered by firms in parentheses. * significant at 10%; ** significant at 5%, *** significant at 1%.

Assuming that the technological position can also be described by cumulative past R&D efforts, we build a rough proxy for a R&D stock by adding R&D expenditures over the past 4 years. The average R&D stock is around 950 Euros per employee. Table 4 shows that higher lagged R&D stock per employee is correlated with higher advertising. Unsurprisingly, the relationship between current R&D stock and advertising is much more blurred, since this former includes current R&D expenditures which should be equal to 0 for the quality leader according to the model (col. 1 to 3). When lagging the R&D stock (col. 4 to 6), findings support a complementarity between advertising efforts and the past innovation efforts of firm or their current technological level, in line with the prediction of our model. Also reassuring concerning our modeling choices, we find a much stronger relationship between past R&D and current advertising in B2C sectors (panel B). In those sectors, each euro invested in R&D in the past 4 years translates into 12 to 30 cents spent on advertising today.

Table 4: Advertising and gross R&D stock. 1990-2004.

Dependent variable: advertising expenditure (in thousands 2004 euros) per employee						
	1:OLS	2:FE	3:RE	4:OLS	5:FE	6:RE
	Panel A: All sectors					
R&D stock per employee	0.120*	-0.0375	-0.0004			
	(0.0711)	(0.0519)	(0.0574)			
R&D stock per employee (-1)				0.0709***	0.0211*	0.0311**
				(0.0169)	(0.0126)	(0.0139)
Observations	326,788	326,788	326,788	276,103	276,103	276,103
Number of firms	48,397	48,397	48,397	43,224	43,224	43,224
R-squared	0.087	0.017	0.017	0.091	0.091	0.091
	Panel B: B2C sectors only					
R&D stock per employee	0.146**	-0.0118	0.0226			
	(0.0695)	(0.0619)	(0.0642)			
R&D stock per employee (-1)				0.299***	0.129**	0.179***
				(0.0510)	(0.0561)	(0.0437)
Observations	86,872	86,872	86,872	73,591	73,591	73,591
Number of firms	12,996	12,996	12,996	11,673	11,673	11,673
R-squared	0.087	0.035	0.035	0.094	0.034	0.034
(industry114, year) dummies	Yes	No	No	Yes	No	No
Year	No	Yes	Yes	No	Yes	Yes

Note: A control for firms' number of employees is included in all regressions. B2C sectors are Food and agricultural manufacturing, Consumer goods manufacturing, retail trade, and personal services. Standard errors clustered by firms in parentheses. * significant at 10%; ** significant at 5%, *** significant at 1%.

We also check that we still find the results in table 3 (col. 1 to 3) and table 4 (col. 4 to 6) when firms younger than 20 years and with less than 20 employees are excluded from the sample or when we do not normalize advertising and R&D by firm size. We do find them both when we consider all sectors or only B2C sectors, with the exception of the relationship between TFP and advertising which is less significant when advertising is not normalized (see online appendix tables 6 and 7). We finally show that our empirical analysis is not driven by specific sectors: the model predictions are verified in most sectors for which we have more than 1,000 firms in our data (see online appendix table 8). To conclude, our model of advertising seems supported by empirical evidence for France. We can now introduce the dynamics of R&D.

3 Dynamics of R&D investment and aggregate advertising

In the model exposed in section 2, advertising depends on the state of the sector (leveled vs. unleveled) and on the quality position of the firm within the sector. We now analyze the link between competition and steady state aggregate advertising. This link crucially depends on the proportion of sectors being leveled or unleveled for a given level of competition. We derive analytically this proportion using a dynamic model for R&D in the spirit of Aghion et al. (2005).

Firms can develop a dynamic strategy to escape competition through becoming a quality leader and thus through innovation. The state of the market can move from Neck and Neck to leader-follower and vice-versa. The dynamics of R&D-driven innovations will determine the relations between the ex-ante competition level f and the advertising or R&D efforts. Firms do not conduct *ex ante* market research.[10]

As proved in the previous section, the profits of the two firms in the sector depend only on the gap m between the two firms and not on absolute levels of technology (because of Bertrand competition). We assume a quadratic cost function for R&D: it costs $n^2/2$ to firms to get a chance to move one quality step ahead with a Poisson hazard rate of n. We call n the "innovation rate" or "R&D intensity" of the firm. We also assume that a follower firm can move one step ahead with hazard rate h even if it spends nothing on R&D, by copying the leader's technology. Thus $n^2/2$ is the R&D cost of a follower firm moving ahead with a hazard rate $n + h$. Recall that each innovation step changes the competitive environment – as a sector switches from leveled to unleveled or vice-versa – and thus cancels the effect of past advertising on consumers' preferences.

[10] See Lauga and Ofeq (2009) on the interplay between market research and R&D.

3.1 Bellman equations

We now derive general equations for R&D investments using asset equations. Let V denote the steady state value of the firm. We have the following Bellman equations:

$$\begin{cases} rV_1 = \Pi_1 + (n_{-1} + h)(V_0 - V_1) - n_1^2/2 \\ rV_{-1} = \Pi_{-1} + (n_{-1} + h)(V_0 - V_{-1}) - n_{-1}^2/2 \\ rV_0 = \Pi_0 + n_0(V_1 - V_0) + \bar{n}_0(V_{-1} - V_0) - n_0^2/2 \end{cases} \quad (1)$$

The annuity value rV_1 of currently being a quality leader in a sector with gap 1 at date t equals the current profit flow Π_1 minus the current R&D cost $n_1^2/2$, plus the expected capital loss $(n_{-1} + h)(V_0 - V_1)$ from having the follower catch up with the leader. Similar arguments lead to equations for the value of a follower and a Neck and Neck firm.

Given that the quality gap between the leader and the follower cannot become larger than 1, the leader has no interest to innovate, i.e. $n_1 = 0$. Now, using the fact that each type of firm chooses its own R&D intensity to maximize its current value, i.e. to maximize the RHS of the corresponding equation, we obtain the first order conditions:

$$\begin{cases} n_{-1} = V_0 - V_{-1} \\ n_0 = V_1 - V_0 \\ n_1 = 0 \end{cases}$$

An increase in market competition diminishes profits of a Neck and Neck firm[11], and consequently its market value V_0 decreases. Hence, one could expect that an increase in market competition leads to an increase in n_0 and a decline in n_{-1}.

Equations (1) and (2) solve for n_0 and n_{-1}. Eliminating the V's between these equations yields the reduced-form R&D equations:

$$\frac{n_0^2}{2} + (r+h)n_0 - (\Pi_1 - \Pi_0) = 0$$
$$\frac{n_{-1}^2}{2} + (r+h+n_0)n_{-1} - (\Pi_0 - \Pi_{-1}) - \frac{n_0^2}{2} = 0 \quad (2)$$

This system is recursive, as the first equation solves for n_0, and then given n_0 the second equation solves for n_{-1}.We obtain:

$$n_0 = -r - h + \sqrt{(r+h)^2 + 2(\Pi_1 - \Pi_0)} \quad (3)$$

[11] This is a natural assumption that is supported by our theoretical framework where f is used to measure (the inverse of) competition: see formulas in Table 1 and Figure 3.

$$n_{-1} = -(r + h + n_0) + \sqrt{(r + h + n_0)^2 + n_0^2 + 2(\Pi_0 - \Pi_{-1})} \tag{4}$$

Using equation (3) to substitute $(r + h + n_0)^2$ in equation (4) yields the alternative expression for n_{-1}:

$$n_{-1} = -(r + h + n_0) + \sqrt{(r + h)^2 + n_0^2 + 2(\Pi_1 - \Pi_{-1})} \tag{5}$$

The R&D investment n_0 of a Neck and Neck firm is increasing in $(\Pi_1 - \Pi_0)$: the larger the difference between Neck and Neck firms and leader firms profit flows, the larger the incentive for a Neck and Neck firm to become a leader and thus the larger its R&D investment. Interpretation of equation 4, where n_{-1} is increasing in $(\Pi_0 - \Pi_{-1})$ for a given n_0, is also intuitive: the larger the follower incentive to catch-up the leader and become Neck and Neck with it, the greater its R&D investment. But it requires two successful investments for the follower to become a leader, and the innovation rate in the intermediate situation of Neck and Neck should also matter. This is captured by the presence of n_0 in equation (5): n_{-1} is decreasing[12] in n_0.

The innovation rate of a sector is $2n_0$ if the sector is leveled and n_{-1} if the sector is unleveled. But the average innovation rate of a sector in steady state also depends on the fraction of time a sector spends being leveled or unleveled. Formally, let μ_1 (resp. μ_0) denote the steady state probability of being an unleveled (resp. leveled) sector. During any unit time interval, the steady state probability that a sector moves from being unleveled to leveled is $\mu_1(n_{-1} + h)$, and the probability that it moves in the opposite direction is $2\mu_0 n_0$. In steady state, these two probabilities must be equal:

$$\mu_1(n_{-1} + h) = 2\mu_0 n_0$$

Because $\mu_1 + \mu_0 = 1$, this implies that the average flow of innovation is:

$$I = \mu_0 2n_0 + \mu_1 n_{-1} = \mu_1(2n_{-1} + h) = \frac{4n_0 n_{-1} + 2n_0 h}{2n_0 + n_{-1} + h} \tag{6}$$

As in Aghion et al. (2005), the general form of I is an inverted-U shape according to the level of competition. The escape competition effect dominates when competition is not too harsh.

Profit flows of firms A and B calculated in section 2 depend on the degree of competition, the ratio of valuations for goods A and B for a consumer in $[0, f]$, the quality gap

[12] Indeed $\partial n_{-1}/\partial n_0 = -1 + n_0/\sqrt{(r + h)^2 + n_0^2 + 2(\Pi_1 - \Pi_{-1})} < 0$.

and the cost of advertising ϕ. As a consequence, I is a function of exogenous parameters f, ϵ, r, h and ϕ.

Figure 4 (panel A) plots average innovation and advertising expenditures when $r = 0.05$, $h = 0.20$, $\epsilon = 0.05$, and the cost of advertising is moderate ($\phi = 4\epsilon/5 = 0.04$). As expected, innovation expenditures are an inverted U-shaped function of competition.

3.2 Competition and advertising

While in section 2 we could not conclude on a relation between competitive environment and advertising expenditures, we are now able to compute average advertising expenditures as a function of the sector degree of competition. The right side plot in Figure 4 shows a positive relationship between competition and average advertising effort. Actually, this finding is true for a large class of parameters: average advertising spending is increasing with competition when the cost of advertising is moderate:

Proposition 2: Average advertising expenditures $A = \phi(\mu_0 2q_0 + \mu_1 q_1)$ are increasing with competition.

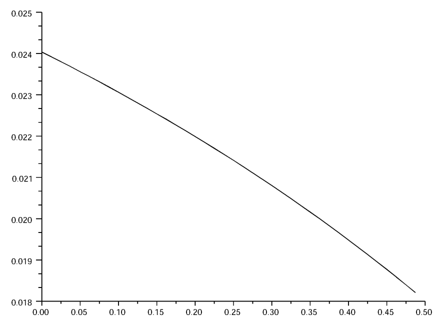
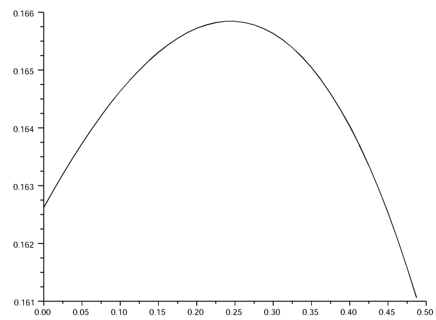
Intuitively, the stimulating effect of competition on the advertising behavior of Neck and Neck firms dominates composition effects. Proposition 2 is proved in appendix 1.

Note that through changes in competition, we may observe a negative firm-level relation between innovation flows and advertising efforts. Panel A of Figure 4 illustrates this point when the competitive environment is harsh (f small): a firm facing even more competition reduces current R&D but increases current advertising. However, this mechanism driven by competition does not mean that advertising and R&D are substitutes. Actually, the static results still hold: for a given competitive environment, innovative firms advertise more and firms innovate more when advertising is possible.

Statistics from the French dataset presented in section 2 support the theoretical results. Figure 4 (panel B) plots the average of R&D and advertising efforts as a function of the 20-ciles of firms' Lerner indexes. R&D effort appears inverted U-shaped in the measure of competition whereas average advertising is clearly and strongly increasing with competition. We still find these empirical relationships when we focus on B2C sectors only (see figure 6 in online appendix). Proposition 2 is also supported by an empirical analysis using OLS, fixed-effects and random effects models (see table 9 of the online appendix).

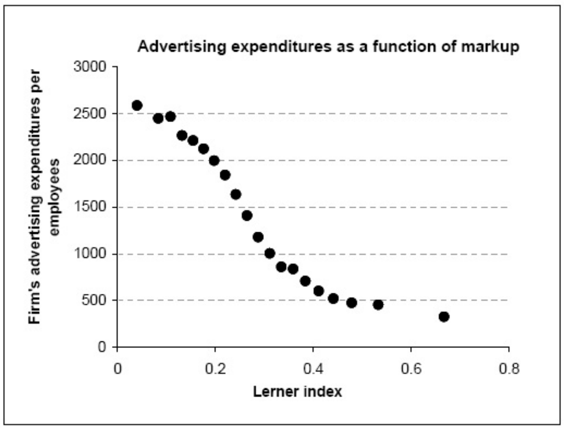
Figure 4: Advertising and innovation as a function of competition

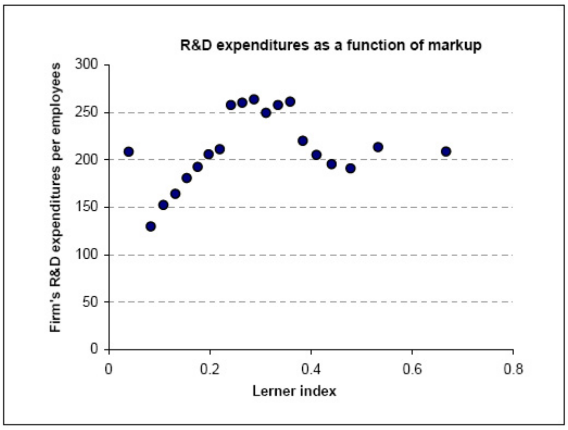
Panel A: simulation results

	
Advertising Effort	Flow of Innovation

Note: *Competition is a decreasing function of the proportion of captive consumers* f *on the x-axis.*

Panel B: evidence for a panel of French firms.





Note: *Competition is a decreasing function of the Lerner index on the x-axis.*

Source: FIBEN/Centrale des Bilans

3.3 Advertising costs and R&D efforts

Because of the interplay between R&D and advertising, changes in the advertising regulation or technologies may alter advertising costs and thus R&D. For example, Internet has opened a new facility for advertising. On the contrary, some countries heavily regulate ads in certain media; that is the case in France where the government has recently banished ads on all public TV after 8 pm.

Now, reducing the cost of advertising has the direct effect to stimulate advertising expenditures. But how this additional advertising does affect the firms' R&D efforts? This crucially depends on the relative effect of decreasing advertising costs on the follower, Neck and Neck and leader expected profits. We prove (see appendix) the following partial result:

Proposition 3: The total flow of innovation is decreasing with ϕ if competition is not too harsh.

In other words, the less expensive advertising is, the more R&D. Proposition 3 is proved in Appendix 1 for all values of f between $1 - \phi/\epsilon$ and $\frac{1}{2}$, i.e. when competition is not too high.Simulations (see figure 5 in appendix 2) show how I varies when f and ϕ vary: I is inverted U shape as a function of f (on the x axis) and, in line with proposition 3, it increases a lot when the cost of advertising is decreased from $\phi = \epsilon = 0.05$ to $\phi = \epsilon/2 = 0.025$ (y axis). Simulations actually show that for a large class of reasonable values for r, h and ϵ, innovation is also decreasing with the cost of advertising when competition is harsh (i.e. when f is close to 0). This is the case on Figure 5 when $r = 0.05$ and $h = 0.2$.

An extension of this paper would be to validate this result empirically. This would require identifying structural reforms impacting advertising costs or technological shocks. The emergence of massive advertising on internet would offer a relevant natural experiment when data will be available.

4 Conclusion

We have studied the interactions between competition, R&D and advertising through a static framework for advertising decisions embedded in a dynamic one for R&D decisions. Empirical evidence using a large dataset on French firms supports the main predictions of our theoretical model. Technological leaders spend more on advertising as they enjoy higher advertising returns by capturing the segment of neutral consumers and those who *ex ante* prefer the follower product. Consequently, for a class of parameters, the lower the cost of advertising, the higher the incentive to become a leader: lowering advertising cost through e.g. regulations may improve innovation. In addition, average advertising and R&D spending are respectively increasing and inverted-U shape with competition.

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Appendix 1: Proof of propositions 2 and 3

Proof of proposition 2: According to section 2, the advertising effort of the leader $q_1 = 1$ is at least twice the advertising effort of a Neck and Neck firm; indeed, if $\phi > \epsilon(1-f)$, $q_0 = 0$ and if $\phi < \epsilon(1-f)$, $q_0 = \frac{1-f-\phi/\epsilon}{1-2f} \leq \frac{1/2-f}{1-2f} = 0.5$ (since $\phi > \epsilon/2$). Both q_1 and q_0 are non-increasing with f, so non-decreasing with competition. Therefore, as $A = \phi(\mu_0 2q_0 + \mu_1 q_1) = 2q_0 + \mu_1(q_1 - 2q_0)$, proposition 2 is straightforward if the probability of being unleveled μ_1 is increasing with competition.

As shown in table 1, Π_0 is always increasing with f when $\phi \in [\epsilon/2, \epsilon]$, and then $\Pi_1 - \Pi_0$ is decreasing with f since Π_1 does not vary with f. Therefore according to equation 3, n_0 is increasing with competition (escape competition effect). In addition, as previously noted, n_{-1} is a decreasing function of n_0, while $\Pi_1 - \Pi_{-1} = 2\epsilon - \phi$ is constant. So, from equation 5, n_{-1} is decreasing with competition and the ratio $(n_{-1}+h)/n_0$ is decreasing with competition.

But $\mu_1(n_{-1}+h) = 2\mu_0 n_0$ and $\mu_0 + \mu_1 = 1$. Thus $\mu_1 = \frac{2}{2+(n_{-1}+h)/n_0}$ is indeed increasing with competition. QED

Proof of proposition 3: The proof proceeds in 4 steps:

1) If the R&D efforts n_0 and n_1 are both decreasing with ϕ, then the total flow of innovation I is also decreasing with ϕ.

2) n_0 is decreasing with ϕ.

3) $\frac{\partial n_0}{\partial \phi}$ and $\frac{\partial n_{-1}}{\partial \phi}$ have the same sign as soon as $n_0 > n_{-1}$.

4) $n_0(f = 1/2) > n_{-1}(f = 1/2)$ and n_0 is decreasing with f whereas n_{-1} is increasing with f. Thus $n_0 > n_{-1}$ for all $f \in [0, 1/2]$.

1), 2), 3) and 4) clearly imply that I is decreasing with ϕ, that is, reducing the cost of advertising increases the R&D effort.

Proof of 1): $\frac{\partial I}{\partial \phi}$ and $\frac{\partial ln(I)}{\partial \phi}$ have the same sign. Let n'_0 and n'_{-1} denote respectively $\frac{\partial n_0}{\partial \phi}$ and $\frac{\partial n_{-1}}{\partial \phi}$ and assume they are negative. From equation 6, we get:

$$
\begin{aligned}
\frac{\partial ln(I)}{\partial \phi} &= \frac{n_0'}{n_0} + \frac{2n_{-1}'}{2n_{-1}+h} - \frac{2n_0'+n_{-1}'}{2n_0+n_{-1}+h} \\
&\leq \frac{2n_0'}{2n_0+n_{-1}+h} + \frac{n_{-1}'}{n_{-1}+h+2n_0} - \frac{2n_0'+n_{-1}'}{2n_0+n_{-1}+h} \\
&\leq 0
\end{aligned}
$$

Proof of 2):

For values of ϕ between $\epsilon/2$ and ϵ, Π_1 is decreasing with ϕ whereas Π_0 is increasing or constant with ϕ. This implies that $\Pi_1 - \Pi_0$ is decreasing with ϕ. From equation 3, n_0 is decreasing with ϕ.

Proof of 3):

If $f > 1 - \frac{\phi}{\epsilon}$, differentiating equation 2 with respect to ϕ gives:

$n_{-1}n_{-1}' + (r+h+n_0)n_{-1}' + n_{-1}n_0' - n_0n_0' = 0 \iff n_{-1}' = n_0'(\frac{n_0-n_{-1}}{n_{-1}+n_0+r+h})$

So $\frac{\partial n_0}{\partial \phi}$ and $\frac{\partial n_{-1}}{\partial \phi}$ have indeed the same sign if $n_0 > n_{-1}$.

Proof of 4):

The fact that n_0 is decreasing with f and n_{-1} increasing with f has been proven in the proof of proposition 2. When $f = 1/2$, $q_0 = 0$ and $\Pi_0 = f\epsilon = \epsilon/2$ whereas $\Pi_1 = 2\epsilon - \phi$ remain independent of f. $\Pi_1 - \Pi_0 = 3\epsilon/2 - \phi$. $\Pi_1 - \Pi_{-1} = 2\epsilon - \phi$.

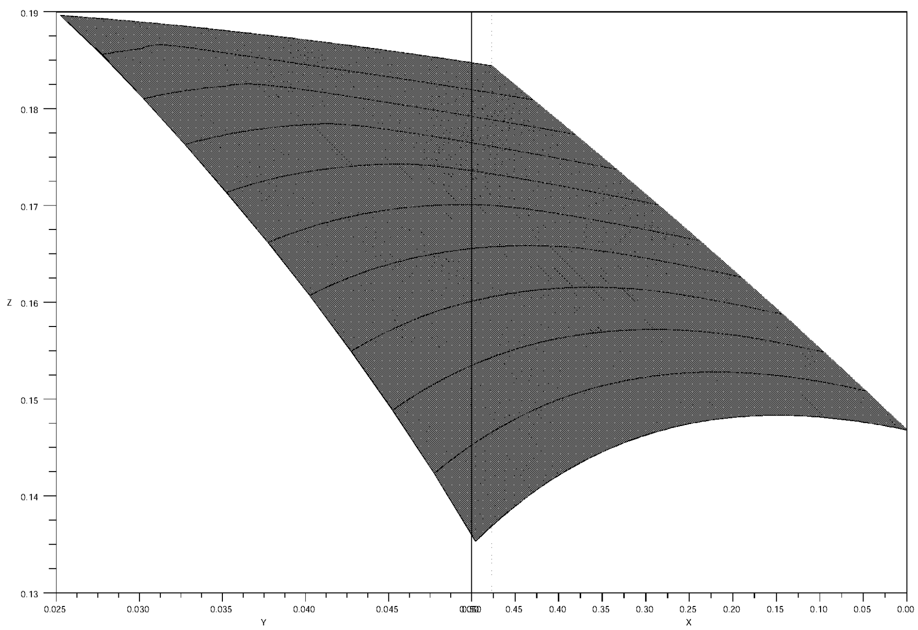
Substracting equation 5 to equation 3 we get:

$$
\begin{aligned}
n_0 - n_{-1} > 0 \quad &\Leftrightarrow \quad n_0 + \sqrt{(r+h)^2 + 3\epsilon - 2\phi} \geq \sqrt{(r+h)^2 + n_0^2 + 4\epsilon - 2\phi} \\
&\Leftrightarrow \quad n_0^2 + (r+h)^2 + 3\epsilon - 2\phi + 2n_0\sqrt{(r+h)^2 + 3\epsilon - 2\phi} \geq (r+h)^2 + n_0^2 + 4\epsilon - 2\phi \\
&\Leftrightarrow \quad 2n_0\sqrt{(r+h)^2 + 3\epsilon - 2\phi} \geq \epsilon \\
&\Leftrightarrow \quad \left(-(r+h) + \sqrt{(r+h)^2 + 3\epsilon - 2\phi}\right)\sqrt{(r+h)^2 + 3\epsilon - 2\phi} \geq \epsilon/2 \\
&\Leftrightarrow \quad -(r+h)\sqrt{(r+h)^2 + 3\epsilon - 2\phi} + (r+h)^2 + 5\epsilon/2 - 2\phi \geq 0 \\
&\Leftrightarrow \quad \left((r+h)^2 + 5\epsilon/2 - 2\phi\right)^2 \geq (r+h)^2\left((r+h)^2 + 3\epsilon - 2\phi\right) \\
&\Leftrightarrow \quad (5\epsilon - 4\phi)(r+h)^2 + (5\epsilon/2 - 2\phi)^2 \geq (r+h)^2(3\epsilon - 2\phi) \\
&\Leftrightarrow \quad 2(\epsilon - \phi)(r+h)^2 + (5\epsilon/2 - 2\phi)^2 \geq 0
\end{aligned}
$$

which is true since $\phi \leq \epsilon$. QED.

Appendix 2: Results from simulations and descriptive statistics

Figure 5: Average sectoral flow of innovation when the degree of competition (x axis) and the cost of advertising (y axis) vary



Note: Other parameters values are $r = 0.05$, $h = 0.20$ and $\epsilon = 0.05$.

Table 5: Sectoral mean of main variables (2004 euros)

	Number of observations	Advertising per Worker	Advertising over Value Added	R&D per Worker	R&D over Value Added	Lerner index
Business to Consumers sectors:						
Food and agricultural manufacturing	28852	4.610	0.075	0.165	0.003	0.197
Consumer goods manufacturing	43008	2.073	0.034	0.347	0.006	0.358
Retail trade	50554	2.571	0.062	0.033	0.001	0.171
Personal services	4321	1.067	0.020	0.049	0.001	0.396
Business to Business and mixed sectors:						
Agriculture, hunting, forestry, fishing	2802	0.912	0.017	0.354	0.005	0.294
Car manufacturing	4610	0.726	0.014	0.591	0.012	0.287
Equipment good manufacturing	46337	0.679	0.014	0.741	0.014	0.370
Intermediary good manufacturing	100522	0.561	0.011	0.233	0.004	0.327
Energy	1049	2.306	0.023	0.829	0.008	0.242
Construction	53735	0.346	0.007	0.030	0.001	0.391
Gross trade	100534	2.154	0.034	0.112	0.002	0.165
Transport	19485	0.431	0.009	0.028	0.000	0.348
Real estate	1171	1.828	0.025	0.065	0.001	0.345
Business services	23214	0.854	0.012	0.528	0.008	0.500
Total number of observations	480194	480194	480194	480194	480194	470128

Online empirical appendix

Table 6: Advertising and technological position or past R&D. 1990-2004. Firms older than 20 y.o. and with more than 20 employees

Dependent variable: advertising expenditure (in thousands 2004 euros) per employee						
	1:OLS	2:FE	3:RE	4:OLS	5:FE	6:RE
	Panel A: All sectors, firms >20y.o.& >20employees					
TFP	5.555***	4.700***	3.752***			
	(0.866)	(1.513)	(1.143)			
R&D stock per employee (-1)				0.0695***	0.0144	0.0268
				(0.0253)	(0.0124)	(0.0167)
Observations	162,923	162,923	162,923	120,238	120,238	120,238
Number of Firms	21,552	21,552	21,552	19,262	19,262	19,262
R-squared	0.122	0.022	0.022	0.131	0.019	0.019
	Panel B: B2C sectors only, firms >20y.o.& >20employees					
TFP	9.346***	9.262***	8.138***			
	(2.562)	(2.227)	(1.947)			
R&D stock per employee (-1)				0.298***	0.109**	0.172***
				(0.0675)	(0.0476)	(0.0414)
Observations	43,171	43,171	43,171	32,042	32,042	32,042
Number of Firms	5,761	5,761	5,761	5,184	5,184	5,184
R-squared	0.123	0.045	0.045	0.133	0.040	0.040
(industry114, year) dummies	Yes	No	No	Yes	No	No
Year	No	Yes	Yes	No	Yes	Yes

Note: A control for firms' number of employees is included in all regressions. B2C sectors are Food and agricultural manufacturing, Consumer goods manufacturing, retail trade, and personal services. Standard errors clustered by firms in parentheses. * significant at 10%; ** significant at 5%, *** significant at 1%.

Table 7: Advertising and technological position or past R&D. 1990-2004. Advertising and R&D not normalized

Dependent variable: advertising expenditure (in thousands 2004 euros)						
	1:OLS	2:FE	3:RE	4:OLS	5:FE	6:RE
	Panel A: All sectors					
TFP	32.68	191.7	0.153			
	(164.6)	(123.8)	(110.1)			
R&D stock (-1)				0.155***	0.0588***	0.128***
				(0.0347)	(0.0199)	(0.0381)
Observations	436,945	436,945	436,945	276,103	276,103	276,103
Number of firms	52,885	52,885	52,885	43,224	43,224	43,224
R-squared	0.039	0.002	0.002	0.162	0.011	0.011
	Panel B: B2C sectors only					
TFP	-228.3	1,129***	410.7			
	(672.2)	(434.7)	(372.5)			
R&D stock (-1)				0.319***	0.0981***	0.136***
				(0.105)	(0.0378)	(0.0152)
Observations	114,127	114,127	114,127	73,591	73,591	73,591
Number of Firms	14,077	14,077	14,077	11,673	11,673	11,673
R-squared	0.034	0.006	0.006	0.068	0.011	0.011
(industry114, year) dummies	Yes	No	No	Yes	No	No
Year	No	Yes	Yes	No	Yes	Yes

Note: B2C sectors are Food and agricultural manufacturing, Consumer goods manufacturing, retail trade, and personal services. Standard errors clustered by firms in parentheses. * significant at 10%; ** significant at 5%, *** significant at 1%. There is no control for firms size.

Table 8: Testing models predictions sector by sector. 1990-2004.

	B2C sectors			B2B sectors				
	Food and agricultural manufacturing	Consumer goods manufacturing	Retail trade	Equipment good manufacturing	Intermediary good manufacturing	Construction	Gross trade	Business services
TFP on advertising per emp. (OLS)	3.496	11.10***	3.379***	0.0726	1.404**	1.057***	8.214***	-0.127
	(3.040)	(1.733)	(1.269)	(0.234)	(0.601)	(0.205)	(0.835)	(0.355)
TFP on advertising per emp. (FE)	-4.398	8.732***	-0.141	1.074***	2.847**	1.094***	6.610***	0.640*
	(2.689)	(1.650)	(2.223)	(0.136)	(1.354)	(0.289)	(1.112)	(0.335)
lagged R&D stock on advertising per emp. (OLS)	1.204***	0.174***	0.391***	0.0102**	0.0308***	0.153	0.223***	0.0107**
	(0.242)	(0.0531)	(0.119)	(0.00476)	(0.00697)	(0.123)	(0.0531)	(0.00462)
lagged R&D stock on advertising per emp. FE)	0.359*	0.119*	0.208	-0.00104	0.0139***	0.00723	0.0441	-0.00938
	(0.187)	(0.0653)	(0.135)	(0.00135)	(0.00474)	(0.00752)	(0.0461)	(0.0139)

Note: The model predictions are tested sector by sector. We report point estimates and standard errors (clustered by firms) from OLS and fixed effects specification identical to those presented in tables 3 and 4, col. 1 and 2. A control for firms' number of employees is included in all regressions. * significant at 10%; ** significant at 5%, *** significant at 1%.

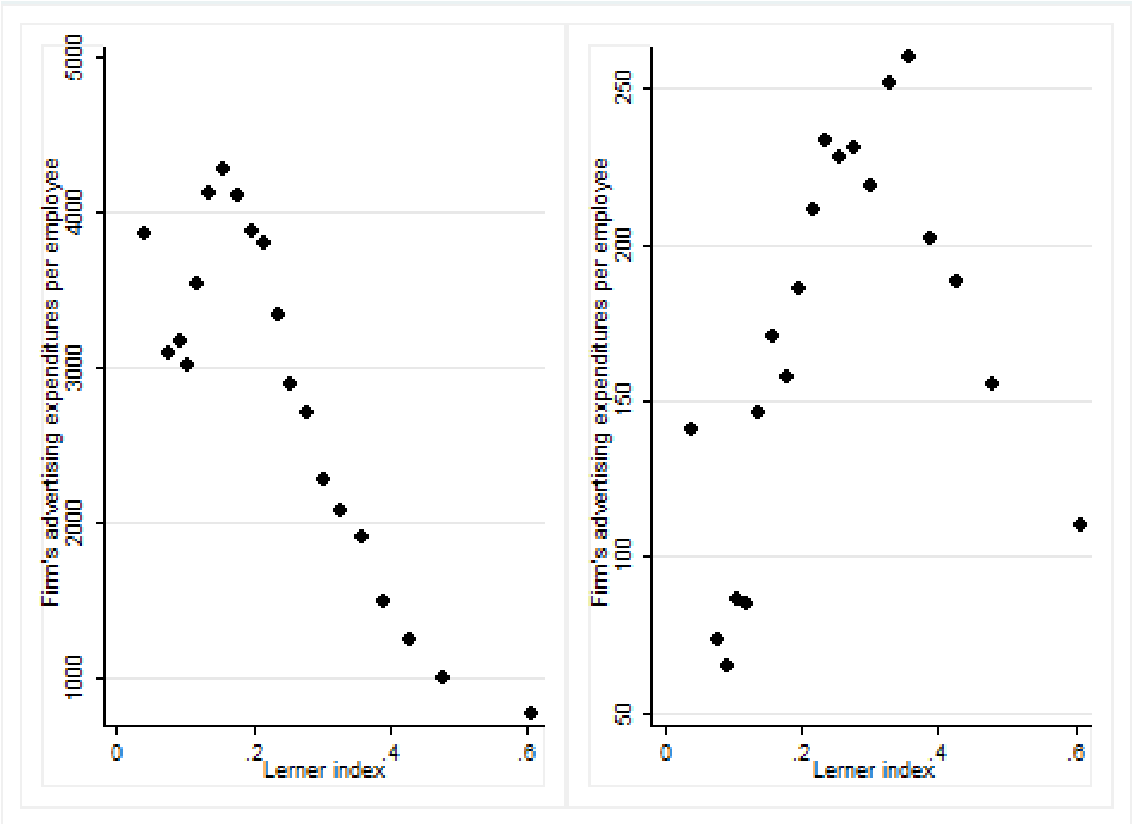
Table 9: Advertising and Competition. 1990-2004.

Dependent variable: advertising expenditure (in thousands 2004 euros) per employee						
	1:OLS	2:FE	3:RE	4:OLS	5:FE	6:RE
	Panel A: All sectors					
Avg lerner in sector (114)	-7.101***	-2.341***	-5.700***			
	(0.198)	(0.860)	(0.300)			
Firm lerner				-4.973***	-1.431***	-2.832***
				(0.128)	(0.166)	(0.120)
Observations	476,418	476,418	476,418	471,503	471,503	471,503
Number of firms	59,554	59,554	59,554	59,073	59,073	59,073
R-squared	0.023	0.018	0.018	0.024	0.018	0.018
	Panel B: B2C sectors only					
Avg lerner in sector (114)	-5.418***	-1.823	-4.912***			
	(0.489)	(2.586)	(0.495)			
Firm lerner				-6.195***	-3.672***	-4.785***
				(0.327)	(0.586)	(0.386)
Observations	125,515	125,515	125,515	124,232	124,232	124,232
Number of firms	16,085	16,085	16,085	15,983	15,983	15,983
R-squared	0.023	0.035	0.035	0.030	0.036	0.036
(industry114, year) dummies	No	No	No	No	No	No
Year	Yes	Yes	Yes	Yes	Yes	Yes

Note: The first explanatory variable is the average of all firms' Lerner indexes in the sector (we use 114 sectors in total). Results are qualitatively very similar if we exclude each observed firm own Lerner index when we compute the average Lerner index in its sector. A control for firms' number of employees is included in all regressions. B2C sectors are Food and agricultural manufacturing, Consumer good manufacturing, and Gross and retail trade. Standard errors clustered by firms in parentheses. * significant at 10%; ** significant at 5%, *** significant at 1%.

Lecture: In all specifications (OLS, FE RE), firms' advertising expenditures per employee are decreasing with the average of firms' lerner indexes in the sector, i.e. advertising is increasing with competition when competition is captured with the inverse of the average Lerner index in trhe sector. We also check that firms' advertising expenditures per employee are decreasing in their own Lerner index.

Figure 6: Advertising and innovation as a function of competition: evidence in B2C sectors. 1990-2004.



Note: Competition is a decreasing function of the Lerner index on the x-axis. We focus only on B2C sectors: Food and agricultural manufacturing, Consumer goods manufacturing, Retail trade.