Technology adoption, brand strength and consumption externalities

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Abstract

We study a vertically differentiated market, where two firms (a branded and an unbranded one) must choose whether to adopt a new identical technology or to continue to use their previous ones. The branded firm is initially endowed with a superior technology and its product receives an additional evaluation because of its brand (a proxy for additional characteristics such as design, material, reliability, post-sale assistance). There are consumption externalities: the branded product receives additional value from its exclusiveness. We find that consumption externalities play a similar role of product differentiation to soften competition. Moreover, simultaneous adoption of a new technology may emerge in vertically differentiated markets when brand strength is sufficiently strong. Finally, consumption externalities favor the adoption of new technologies, especially for unbranded firms and (in some cases) may limit the adoption of new technologies for branded one.

Keywords: Vertical differentiation, Technology adoption, consumption externalities.
1 Introduction

There is a general consensus that top-class branded products receive a price premium due to their superior technology. Think, for example, to a Ferrari sport-car, or to a Burberry coat, or to a Sony Vaio portable computer. Additional characteristics, such as design, material, reliability, post-sale assistance also concur to justify a higher price of the product. This compound explanation for top-class branded product price premium is consistent with the characteristic approach to consumer theory (Lancaster, 1966): consumers assign a positive value to product characteristics so that a branded product with superior attributes receives a higher evaluation and therefore are sold at a higher price.

However, there are other top-class branded products that receive a price premium although produced with an inferior technology. Also in this case, examples are abundant. Most prestigious watches (e.g. Patek Philippe, Rolex, Vacheron Constantin) incorporate a mechanical movement which does not reach the accuracy even of the cheapest watches based on a quartz movement. Similarly, a twenty century icon, such as Harley-Davinson motorbike is payed more than its closest competitors in the cruiser category, although most of them are superior for manageableness, fuel consumption, and acceleration.¹

Premium brand - inferior technology outcome can be seen as the result of a historical process. In the past, now well established firms have gained a premium position by producing with a superior technology. For example, in the age of mechanical watches, the use of the turbillon mechanism guaranteed a more precise measurement of time with respect to the pin-lever movement.² Harley-Davinson demonstrated its superiority dominating most of the US (dirt-track) races at the expenses of its national competitor (Indian). In more recent years, in face of an innovation (e.g. the invention of the quartz movement), well-established branded firms decided to maintain the old technology while almost all unbranded firms have moved to the new and superior one.

Since in some cases the branded firm has the ability to innovate but they do not, it is paramount to provide an explanation for their choice of not adopting the new technology. From this, it is paramount to evaluate whether the factors explaining the technology adoption of the branded firm favor or reduce the adoption by unbranded firms.

We study a vertically differentiated market, where two firms (a branded and an unbranded one) must choose whether to adopt a new identical technology or to continue to

¹According to Friedman (2009), in the segment of the cruise motorbikes, Harley-Davidson V-RON priced $16,995 has an inferior quarter-mile acceleration (11.91 sec.) with respect to Yamaha V-MAX (11.62 sec.) whose price is about 36 per cent lower ($10,899).

²The turbillon as well as the pin-lever movements are oscillators introduced in portable watches to contrast the bias induced by gravitation forces and increase accuracy of the measurement. For a detailed economic history of watches, see: Landes (1991).
use their previous ones. The branded firm is initially endowed with a superior technology and its product receives an additional evaluation because of its brand (a proxy for additional characteristics such as design, material, reliability, post-sale assistance). In order to capture a phenomenon that characterizes many final markets, we explicitly consider the presence of consumption externalities, and we focus on the case in which the branded product receives additional value from its exclusiveness. When brand strength and consumption externalities are null, standard literature suggests that only one of the two firms will adopt the new technology. Asymmetric adoption allows firms to soften price competition, and, therefore, to escape from the Bertrand competition trap. Being the branded firm more likely to be a first mover, it follows that, in many cases, it will be able to block the adoption of the new technology by the other firm.

In the absence of consumption externalities, we find that brand strength operates as a source of product differentiation. In particular, when brand strength is high (with respect to the size of the innovation), both firms will adopt the new technology. The adoption of an identical technology does not reduce too much the vertical product differentiation and therefore competition will not to be too fierce. Interesting, for intermediate values of brand strength, irrespective to the timing of the game (simultaneous or sequential), only the branded firm will adopt the new technology and the other will not.

When there are consumption externalities, we identify two main differences with respect to the previous case. First, the parameter set from which both firms adopt the new technology increases at the expense of the area in which only the branded firm wants to innovate. This result emerges from the fact that consumption externalities make the branded firm less aggressive. Second, for intermediate values of brand strength and for high values of consumption externalities, irrespective to the timing of the game, only the unbranded firm will adopt the new technology. This occurs when the exclusiveness of the product is reduced by the adoption of the same technology of the opponent. In this case, the branded firm loses its technological leadership but gains from having larger consumption externalities.

We find that consumption externalities play a similar role of product differentiation to soften competition. Two remarks emerge from this consideration. First, simultaneous adoption of a new technology may emerge in vertically differentiated markets when brand strength is sufficiently strong. In many cases, horizontal product differentiation, when limited to technological characteristics of the product seems too weak to explain this point while an explanation based on the role of consumption externalities seems to be more in line with the empirical evidence, at least, for many markets. Second, consumption externalities favor the adoption of new technologies, especially for unbranded firms and
(in some cases) may limit the adoption of new technologies for branded one. We suggest that this explanation can fit with the empirical evidence for some markets where branded firms producing top-quality goods decide not to adopt a new technology (e.g. top-class branded clock producers, such as Patek Philippe, Rolex, Vacheron Constantin, or top-class motorbike producers, such as Harley-Davinson).

This paper is related to the literature on competition and vertical product differentiation. First contributions (Gabszewicz and Thisse, 1979, 1980; Shaked and Sutton, 1982, 1983) have focused on the impact of the degree of differentiation on equilibrium prices and the profits. They find that the firm producing the lower-quality good gets higher profits when the quality of its good is not too similar to that of the other firm. This is because as qualities get closer, products are less differentiated, the competitive pressure increases, and therefore price-cost margins and profits reduce. Furthermore, they show that when production costs are independent from the production quality, or they do not increase too much (Jing, 2006), offering a higher-quality good is more profitable than offering a lower-quality one. More recently, Wauthy (1988, 1996) furtherly investigates quality choice and product competition for the duopoly case. Further literature analyzes the case of uncertainty (Gabszewicz and Grilo, 1992), multi-dimensional qualities (Lauga, Ofek, 2011) or reputational effects (Rogerson, 1983), but our work is less related with these.

This paper is also related to the literature on innovation and interpersonal effects. Although interpersonal effects may involve both bandwagon and snob effects (Leibenstein, 1950), to our best knowledge the literature on innovation has focused only on the former one, especially with reference to network externalities (David, 1985; Farell and Soloner, 1985; Katz and Shapiro, 1985; Besan and Farrell, 1994). The contribution of this paper is therefore to offer an analysis of the technology adoption in case of the second type of consumption externalities. We will show that phenomena as lock-in effects well known in case of network externalities (Farell and Soloner, 1985; Katz and Shapiro, 1985) also emerge in our setup.

The remaining of the paper is organized as follows. In Section 2, we introduce the model of vertical differentiation with branded firms and consumption externalities. Sections 3 and 4, respectively, discuss how to obtain the demand and the equilibrium prices. Section 5 presents the results and Section 6 concludes.

3 More specifically, Choi and Shin (1992) show that the lower-quality firm sets a quality level which is a fixed proportion of the higher quality firm’s choice.
2 The model

We study the technology adoption in a vertically differentiated market (Shaked and Sutton, 1983) with consumption externalities (Leibstein, 1950), where there are two single-product firms: a branded one, called 1; and an unbranded one, called 0. Both firms independently choose whether to switch to a new technology \( \tau_2 \), or to maintain their respective technologies \( \tau_1 \) and \( \tau_0 \). Let \( \tau_j \) be both the technology adopted by a firm and, with a little abuse of notation, the corresponding level of technology. We assume that before the adoption choice the branded firm has a superior technology, and that the new technology dominates the previous ones, or: \( \tau_2 > \tau_1 > \tau_0 > 0 \).

Moreover, we assume that the perceived quality of the product of firm \( i \) employing technology \( \tau_j \) is \( \theta_{ij} = \beta_i + \tau_j \), where \( \beta_i \) (the brand) accounts for all tangible and intangible attributes of the product except technology (e.g. design, assistance, etc.). We set \( \beta_1 = \beta > 0 \) and \( \beta_0 = 0 \), supporting the fact that branded firms have a superior quality, even if the same technology is in place. Production costs are null and adoption costs are \( C_i \geq 0 \).

Consumers are atomistic and indexed by \( v \in [0, 1] \), with total mass normalized to one. There are consumption externalities, meaning that consumer overall evaluation of a product does depend not only on product quality (technology and brand) but also on the choice of other consumers (e.g. whether other consumers have a product with the same or other technology, whether the branded product is acquired by many or by a few consumers). We focus on a particular type of consumption externalities, which is caused by a snob attitude of consumers. Following Leibstein (1950), consumers are snob if the smaller the people making their choice, the larger their utility. The utility that a snob consumer \( v \in [0, 1] \) receives from buying a product from firm \( i = 0, 1 \) employing technology \( \tau_j \) when firm \( i' = 1 - i \) produces with technology \( \tau_{j'} \) is:

\[
  u(v, i, j, j') = \theta_{ij}v + s(j, j') (\tilde{s}_i - \mu(V_i))^+ - p_i, \tag{1}
\]

where \( p_i \) is the price charged by firm \( i \), \( \theta_{ij} > 0 \) is the above measure of the quality of the product; \( \mu(X) = \int_{x \in X} dx \) is a Lesbegue measure; \( V_i \subset V \), with \( \mu(V) = 1 \), is the set of consumers buying the product \( i \); \( s(j, j') > 0 \) is a measure of the intensity of the consumption externalities which depends on the technology employed by the two firms and by the consumer snobbish attitude (explanation will follow); and \( \tilde{s}_i \in [0, 1] \) is the threshold from which, consumption externalities are at work. We set \( \tilde{s}_i = i \) meaning that

\[\text{The unmodeled part of the story comprises a situation in which there are initially two unbranded firms producing with the same technology } \tau_0, \text{ and, at a certain point in time, the branded one vertically differentiates by adopting a superior technology } \tau_1, \text{ while the unbranded one was not able to follow. In the modeled part, a new technology } \tau_2, \text{ which is better to the previous ones, becomes available.}\]
(un)branded products (never) always obtain a premium from being consumed by a small number of people. Thus, consumption externalities do not concern unbranded products.

Table 1: Technological snobbism

<table>
<thead>
<tr>
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<th>Firm 1 does not adopt ($\tau_1 \rightarrow \tau_1$)</th>
<th>Firm 1 adopts ($\tau_1 \rightarrow \tau_2$)</th>
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<tr>
<td>Firm 0 does not</td>
<td>$t_H = t$</td>
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<td>adopt ($\tau_0 \rightarrow \tau_0$)</td>
<td>$t_V = 0$</td>
<td>$t_V = 0$</td>
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<td></td>
<td>$t_E = t$</td>
<td>$t_E = t$</td>
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<tr>
<td>Firm 0 adopts</td>
<td>$t_H = 0$</td>
<td>$t_H = 0$</td>
</tr>
<tr>
<td>($\tau_0 \rightarrow \tau_2$)</td>
<td>$t_V = t$</td>
<td>$t_V = 0$</td>
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<td>$t_E = t$</td>
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In analogy to our modeling choice on product quality decomposition into brand and technology, we consider two sources of snobbism, which affect the intensity of the consumption externalities $s$. The first one, the brand snobbism, $b > 0$, directly follows from the fact that the product is sold by a branded firm. The second one, the technological snobbism, $t(j,j') \geq 0$, is jointly determined by the technology adopted by the two firms and by the consumer snobbish attitude. We distinguish three classes of consumers with respect to their snobbish attitude. Exclusivist consumers $E$ receive extra utility when technology employed in the branded product differs from that of other product. Vintage consumers $V$ get extra utility from buying a branded product based on a technology which is older than that of the unbranded one. High-tech consumers $H$ get extra utility from buying a branded product based on a technology which is newer than (and therefore superior to) that of the unbranded product. Table 1 summarizes the value of technological snobbism depending on the technology choice of the two firms and the three different consumer classes.

The sequence of the game is as follows. First, firms (simultaneously or sequentially) decide whether or not to update their technology. Second, firms simultaneously charge their prices. Third, consumers choose whether to buy or not the product, and in the latter case, which firm to patronize. We assume that consumers have perfect foresight, i.e. they are able to correctly anticipate the behaviour of the others and therefore they correctly evaluate the impact of the snob effect. We will show that under this hypothesis, consumer demand is uniquely determined; there is no risks of multipla equilibria; and we can focus on the reduced game (where the third stage is replaced by the demand function of branded and unbranded products), which is one of perfect information. The appropriate solution concept is Perfect Nash Equilibrium. We solve the game by backward induction.
3 Demand for branded and unbranded products

The existence of snob effects implies that the valuation of consumers depends on the number of consumers who will buy the product. We assume perfect foresight, i.e. consumers are able to evaluate the right number of buyers in the market and therefore to evaluate the size of the snob effect, and taking their decisions accordingly. In order to identify demand for the branded product, we have to identify a situation for which, by perfectly anticipating the behaviour of other players, each consumer has no incentive to modify her choice. In other terms, let us define the set of consumers that will buy the product when the number of consumers buying 1 is \( m \). Let \( V_m = \{ v|\theta_1 v + s (1 - m) - p_1 \geq \max (\theta_0 v - p_0)^+ \} \) the set of consumers buying the product offered by firm 1 when prices charged by the two firms are \( p_0 \) and \( p_1 \) and consumers expect that the size of consumers buying a branded product is \( m \). We assume that \( p_0 \in [0, \theta_0] \) and \( p_1 \in [0, s + \theta_1] \).

We start considering the case in which \( \theta_1 > \theta_0 \). Note that for \( \theta_1 v + s (1 - m) - p_1 \geq \max (0, \theta_0 v - p_0) \), i.e. \( V_m \neq \emptyset \), firm 1 always serves the richest segment \( V_m = [v_m, 1] \) with \( v_m \in [0, 1] \) and when \( n \leq m, V_m \subseteq V_n \), i.e. \( \mu (V_m) \leq \mu (V_n) \). Moreover, \( \mu (V_m) \) is continuous in \( m \). Monotonicity and continuity of \( \mu \) imply that \( V_1 \), the set of consumers that will buy the product 1, when firms 0 and 1 respectively charge \( p_0 \) and \( p_1 \), is uniquely determined by:  

\[
V_1 = \{ v|\theta_1 v + s (1 - \mu (V_1)) - p_1 \geq (\theta_0 v - p_0)^+ \}. \tag{2}
\]

From (2) and previous considerations, it follows that \( V_1 = [v_1, 1] \) with \( v_1 \in [0, 1] \), and \( \mu (V_1) = 1 - v_1 \). We denote \( v_1 = 1 \) and \( V_1 = \emptyset \) the case in which firm 1 does not supply to any consumer.

Let \( V_0 \) be the set of consumers buying from firm 0. Since (1) is increasing in \( v \) and from (2), it follows that 

\[
V_A = \begin{cases} 
[v_0, 1] & \text{if } v_1 > v_0 \\
\emptyset & \text{otherwise} 
\end{cases}, \tag{3}
\]

where \( v_0 = p_0/\theta_0 \) is the marginal consumer for product 0, when 1 is not available. Now, when both firms sell a positive quantity, i.e. \( (\theta_1 + s) p_0/\theta_0 < p_1 < p_0 + \theta_1 + s - \theta_0 \), \( v_1 = (p_1 - p_0)/((\theta_1 + s - \theta_0)) \). When only firm 1 is involved, i.e. \( p_1 \leq (\theta_1 + s) p_0/\theta_0 \), then \( v_1 = p_1/((\theta_1 + s)) \); while when only firm 0 is involved, i.e. \( p_1 \geq p_0 + \theta_1 + s - \theta_0 \) then \( v_1 = 1 \).

\footnote{Intuitively, for small values of \( m \), consumers, who want to buy the product are larger than \( m \) and therefore this is not the consumers equilibrium. Similarly, for large values of \( m \), the size of consumers is too small. By continuity and monotonicity, there exists only one \( m \) for which there is an equilibrium.}

7
Therefore, the demand for products 0 and 1 are, respectively:

\[
D_0 = \mu(V_0) = \mu([v_0, v_1]) = \left( \min \left\{ 1 - \frac{p_0}{\theta_0}, 1 - \frac{p_1 - p_0}{\theta_1 - \theta_0 + s} \right\} \right)^+ \quad (4)
\]

\[
D_1 = \mu(V_1) = \mu([v_1, 1]) = \left( \min \left\{ 1 - \frac{p_1}{\theta_1 + s}, 1 - \frac{p_1 - p_0}{\theta_1 - \theta_0 + s} \right\} \right)^+ \quad (5)
\]

We now consider the case in which \( \theta_1 \leq \theta_0 \). Here, the solution is reversed: the branded product is bought by the rich segment and the unbranded one by the poor one. More specifically, following the previous reasoning it is easy to show that firm 0 serves consumers with higher evaluation i.e. the segment \([v_1, 1], v_1 \in (0, 1)\), and firm 1 will serve the remaining segment \([v_0, v_1], v_0 \in [0, v_1]\).

When both firms sell a positive quantity, i.e. \((s + \theta_1)(\theta_1 - \theta_0 + p_0)/\theta_1 < p_1 < s + \theta_1 p_0/\theta_0\), the consumer indifferent between the two products is: \(v_1 = (s (1 + v_0) - p_1 + p_0)/(\theta_0 - \theta_1 + s)\). Similarly, the consumer indifferent between buying or not from firm 1 is given by: \(v_0 = (p_1 - s (1 - v_1))/(s + \theta_1)\). Combining previous expressions, when both firms are active, we obtain:

\[
v_0 = \frac{(\theta_0 - \theta_1) p_1 - s (\theta_0 - \theta_1 - p_0)}{\theta_1 (\theta_0 - \theta_1) + s \theta_0},
\]

\[
v_1 = \frac{\theta_1 (p_0 - p_1) + s (\theta_1 + p_0)}{\theta_1 (\theta_0 - \theta_1) + s \theta_0}
\]

When only firm 0 is active, then \(v_1 = v_0 = p_0/\theta_0\), and when only firm 1 is active, then \(v_1 = 1\) and \(v_0 = p_1/(\theta_1 + s)\). Therefore:

\[
D_0 = \mu([v_1, 1]) = \left( \min \left\{ 1 - \frac{p_0}{\theta_0}, 1 - \frac{\theta_1 (p_0 - p_1) + s (\theta_1 + p_0)}{\theta_1 (\theta_0 - \theta_1) + s \theta_0} \right\} \right)^+ \quad (6)
\]

\[
D_1 = \mu([v_0, v_1]) = \left( \min \left\{ 1 - \frac{p_1}{\theta_1 + s}, 1 - \frac{\theta_1 p_0 + \theta_0 (s - p_1)}{\theta_1 (\theta_0 - \theta_1) + s \theta_0} \right\} \right)^+ \quad (7)
\]

### 4 Pricing stage

Revenue functions of firms 0 and 1 are respectively \(R_0 = D_0 p_0\) and \(R_1 = D_1 p_1\). From (4)-(7), it emerges that revenue functions are both continuous and quasi-concave and therefore there is an equilibrium in pure strategies (Nash, 1950; Dasgupta and Manskin, 1986). Simple reasoning can be applied to show that both firms are active in equilibrium.
for any parameter range, and therefore there is a unique and interior price solution:

\[
p_0 = \begin{cases} 
\frac{\theta_0 (s + \theta_1 - \theta_0)}{4s + 4\theta_1 - \theta_0} & \text{if } \theta_1 \geq \theta_0 \\
\frac{(2s\theta_0 - s\theta_1 + 2\theta_0\theta_1 - 2\theta_1^2) \theta_0}{4s\theta_0 + 4\theta_0\theta_1 - \theta_1^2} & \text{if } \theta_1 < \theta_0
\end{cases}
\] (8)

\[
p_1 = \begin{cases} 
\frac{2(s + \theta_1)(s + \theta_1 - \theta_0)}{4s + 4\theta_1 - \theta_0} & \text{if } \theta_1 \geq \theta_0 \\
\frac{(s + \theta_1)(2s\theta_0 - \theta_1^2 + \theta_0\theta_1)}{4s\theta_0 - \theta_1^2 + 4\theta_0\theta_1} & \text{if } \theta_1 < \theta_0
\end{cases}
\] (9)

Some considerations directly emerge from the inspection of (8) and (9). First, when \(s = 0\), and \(\theta_0 = \theta_1\), we go back the Bertrand outcome: \(p_0 = p_1 = 0\). Interestingly, the presence of snob effects, even in the absence of product differentiation (\(\theta_1 = \theta_0\)), allow firms to price above marginal costs. Market power of both firms increases with the strength of the snob effect. The corresponding revenue functions are:

\[
R_0 = \begin{cases} 
\frac{\theta_0 (s + \theta_1)(s + \theta_1 - \theta_0)}{(4s + 4\theta_1 - \theta_0)^2} & \text{if } \theta_1 > \theta_0 \\
\frac{\theta_0^2 (s + \theta_1)(2s\theta_0 - s\theta_1 - 2\theta_0\theta_1 + 2\theta_1^2) \theta_0}{(s\theta_0 - \theta_1^2 + \theta_0\theta_1)(4s\theta_0 - \theta_1^2 + 4\theta_0\theta_1)^2} & \text{if } \theta_1 \leq \theta_0
\end{cases}
\] (10)

\[
R_1 = \begin{cases} 
\frac{4(s + \theta_1)^2(s + \theta_1 - \theta_0)}{(4s + 4\theta_1 - \theta_0)^2} & \text{if } \theta_1 > \theta_0 \\
\frac{\theta_0^2 (s + \theta_1)^2(2s\theta_0 - \theta_1^2 + \theta_0\theta_1)^2 \theta_0}{(s\theta_0 - \theta_1^2 + \theta_0\theta_1)(4s\theta_0 - \theta_1^2 + 4\theta_0\theta_1)^2} & \text{if } \theta_1 \leq \theta_0
\end{cases}
\] (11)

Moreover, payoff functions are continuous in \(\theta_0\), \(\theta_1\) and \(s\).

## 5 Results

The technology adoption of the two firms is influenced by four factors. First, firms may sustain a cost to adopt the new technology which limits the intention to innovate. Second, firms want to increase differentiation in order to weaken the price competition. This plays against the simultaneous adoption of the new technology. Third, firms gain from a higher quality of the product, so that, all else equal, they want to adopt the new technology. Forth, consumption externalities indirectly affect the quality of the product of the branded firm and consequently that of its opponent. More specifically, when consumers are high-tech there is an additional incentive for the branded firm to innovate; when they are vintage
the branded firm is more interested in maintaining the old technology; and, finally, when consumers are exclusivist the branded firm is more prone to diversification. Since we are considering snob consumers, the three types of effects should make the branded firm less aggressive.

Before discussing the results of the model, we first introduce some simplifying assumptions. Then, we first consider the case where there are no consumption externalities. Finally, we will discuss the three cases emerging by the three different types of consumers. Because of the high nonlinearity of the profit functions when we deal with consumption externalities, the results of the model are computed by simulations.

5.1 Assumptions

In order to simplify the discussion of the results we introduce the following assumptions:

(a) Technology jumps: \( \tau_0 = 1, \tau_1 - \tau_0 = \tau_2 - \tau_1 = \tau \), with \( \tau \in [0, 1] \).

(b) Normalization: \( \tau + \beta = 1 \).

(c) Proportionality: \( t = \sigma \tau; b = \sigma \beta \), with \( \sigma \in [0, 1] \)

(d) Costs: \( C \in \{0, \bar{C}\} \), where \( \bar{C} \) is such that innovation is never profitable.

Assumption (b) introduces a normalization of the parameters in the analysis. Assumption (a) implies that technology jumps are uniform. Moreover, when \( \tau < \frac{1}{2} \) (i.e. \( \beta > \frac{1}{2} \)), innovation technology adoption has a minor effect on the perceived quality of the product. In particular, firm \( 0 \) cannot leapfrog firm \( 1 \) (i.e. have a larger quality of the product) even if firm \( 1 \) does not adopt. On the contrary, when \( \tau > \frac{1}{2} \), technology choice has a major effect on the quality of the product. Assumption (c) introduces some symmetry in the model. It states that the there is proportionality of the strength between the two components of perceived quality (brand and technology) and the corresponding effects on snob components of consumer preferences. Finally, Assumption (d) limit the analysis of innovation adoption to three scenarios: \( C_0 = C_1 = 0 \) in which both firms take into consideration the decision to innovate, \( C_0 = 0, C_1 = \bar{C} \) in which only the unbranded firm may innovate, and \( C_0 = \bar{C}, C_1 = 0 \) where only the branded firm may innovate.

In the next we will describe an equilibrium strategy of the game with the pair \((x, y)\), where \( x \) and \( y \) stands for the technology choices \( \tau_x \) and \( \tau_y \) respectively adopted by firms 0 and 1, with \( x = 0, 2 \) and \( y = 1, 2 \).
5.2 No consumption externalities

The study of the model in the absence of consumption externalities provides the baseline results.

**Proposition 1** In absence of consumption externalities ($\sigma = 0$):

1. If $C_0 = \tilde{C}$, $C_1 = 0$, for any $\beta$, the equilibrium profile is $(0, 2)$.
2. If $C_0 = 0$, $C_1 = \tilde{C}$, there are two thresholds $\tilde{\beta} \simeq 0.46$ and $\tilde{\beta} \simeq 0.86$, such that: for $\beta \in [\tilde{\beta}, \tilde{\beta}]$, the equilibrium profile is $(0, 1)$; otherwise, the equilibrium profile is $(2, 1)$.
3. If $C_0 = C_1 = 0$, there are two thresholds $\tilde{\beta} \simeq 0.12$ and $\tilde{\beta} \simeq 0.69$, such that: for $\beta \in (\tilde{\beta}, 1]$, the equilibrium profile is $(2, 2)$; for $\beta \in (\tilde{\beta}, \tilde{\beta}]$, the equilibrium profile is $(0, 2)$; and for $\beta \in (0, \tilde{\beta}]$, there are two equilibria: $(0, 2)$ and $(2, 1)$.

**Proof** See Appendix. ■

Part (1) of the Proposition indicates that, provided that firm 0 does not innovate, the dominant strategy for firm 1 is to innovate. This is because it increases the quality of its product and the degree of differentiation.

Part (2) refers to the case in which firm 1 cannot innovate. The result comes from the fact that the adoption of the new technology by firm 0 increases the perceived quality of its product and therefore the willingness to pay of consumers, but, at the same time, it may reduce the vertical differentiation of the product thus inducing stronger competition. In this case, when firm 0 arrives sufficiently close to the perceived quality of the opponent i.e. in a circle of $\beta = \frac{1}{2}$, it prefers not to adopt. Note that when $\beta \in [\tilde{\beta}, \frac{1}{2}]$, the unbranded firm can leap-frog the branded one, but it does not since it would stay so close to the opponent that its profits should reduce.

Part (3) analyzes the case where both firms can innovate. The first region, corresponding to high values of brand strength $(\tilde{\beta}, 1]$, is characterized by the fact that both firms want to adopt the new technology. Their decision is simply explained by the fact that firm 1’s dominant strategy is to adopt because it always expands the product differentiation, and by the fact that firm 0 benefits from higher product quality, without excessively incurring in a price war, since product differentiation is high also after the adoption (remember that when $\tau$ is low $\beta$ is high). In the second region, corresponding to intermediate values of brand strength $\beta \in (\tilde{\beta}, \tilde{\beta}]$, firm 1 continues to innovate but now firm 0 prefers not to adopt the new technology because now the quality effect is dominated by the competition effect. Finally, in the third region $\beta \in (0, \tilde{\beta}]$, there are two equilibria, where only one of the two firms wants to adopt the new technology. Indeed, if both firms simultaneously adopt the new technology, there is too much competition since products are only weakly differentiated.
5.3 High-tech consumer

The first type of consumption externalities occurs when consumers are high-tech. As we have mentioned in Section 2, the technological component of consumption externalities is only present when firm 1 has a better technology than firm 0. As Figure 1 shows, consumption externalities have a differentiated result on the equilibrium. When Firm 1 cannot innovate, because consumption externalities make it less aggressive, the opportunity of firm 0 to innovate is larger. That is consumption externalities favor the adoption of the new technology by the laggard firm. Interestingly, the same effect emerges when both firms can adopt the new technology. Indeed, the parameter set from which both firms innovate increases at the expense of the area in which only the branded firm wants to innovate. The parameter set for which both firms can innovate remains substantially unchanged.

5.4 Vintage consumer

The second type of consumption externalities occurs when consumers are vintage. In this case, when firm 1 cannot adopt due to high costs $C_1 = \bar{C}$, consumption externalities play in favor of the unbranded firm adoption of the new technology. The explanation clearly follows from the fact that when there are vintage consumers, firm 1 has an advantage by keeping the older technology. When both firms can innovate, there is a mix of different effects creating more complex situations. First of all, there is a area for intermediate

![Figure 1: Innovation adoption with high-tech consumers.](image-url)
values of $\beta$ and high values of $\sigma$, only firm 0 will adopt the new technology. This can be explained by the fact that the incentive to innovate of firm 1 is damped by larger consumption externalities it can receive when it stays on the old technology. Starting from this, when consumption externalities becomes weaker, the original situation emerges. Moreover, when the technological effects become weaker, both firms will choose to adopt the new technology. Finally, compared to the high-tech case, the parameter set for which we observe multiple equilibria has considerably grown. It can be interpreted as the fact that when consumers are vintage, the uncertainty about the technology adoption is large and the timing of the technological adoption plays a major role. When firm 1 cannot adopt the new technology, firm 0 does not adopt the new technology only for limited values of $\sigma$.

5.5 Exclusivist consumer

The last type of consumption externalities occurs when consumers are exclusivist. This case combines the previous ones, i.e. $t_E = t_H + t_V$. Exclusivist consumers are those that are simultaneously high-tech and vintage. In other terms they add a positive evaluation to the product of firm 1 when they have a different technology from the other. Although Figures 2 and 3 are not perfectly identical, nevertheless, this case is very similar to the vintage case, which we have already discussed in the previous sub-section.
6 Conclusions

In this paper we have shown that technological diffusion in vertically differentiated markets is affected by the brand strength and by the size of consumption externalities. Contrary to most of the literature on technology adoption which investigates the case in which there are network externalities, we consider the case where consumers prefer consuming exclusive products. In this case, there is a softening of the competition and, in general, it is more likely that suggests that there is ample scope for catch-up by laggard firms. In some cases, we also find that leading firms may end up producing with the inferior technology.
References


