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Bidimensional vertical differentiation ☆

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ABSTRACT

In markets where product quality is important, more than one characteristic is usually necessary for producers to define product quality. Standard theory maintains that: (i) in a duopoly there will be a quality leader no matter whether the product can incorporate one or two vertical attributes; (ii) differentiation pertains only to one attribute. By contrast, in our set-up, there are also equilibria where the quality leader is better in two attributes, and others where there is cross leadership, namely a situation where each firm designs a product to dominate the other in one characteristic. Applications to Minimum Quality Standards and tax (subsidy) on quality products are sketched, showing spill-over effects from one to the other quality dimension.

1. Introduction

Firms seeking to differentiate their products from those offered by rivals devote considerable efforts to avoid defects, improve performance, ameliorate components and embellish the design. The term 'quality' is often used to group the result of all these activities under a single concept, referring to *a set* of measurable attributes which, if increased, lifts consumers' satisfaction. Hence quality is in effect multidimensional. However, the literature formalizing the analysis of oligopolistic competition in quality is shaped upon the Gabszewicz and Thisse (1979) and Shaked and Sutton (1982, 1983) basic framework with two firms and *one* quality dimension, which forms the skeleton for today's thinking about price and quality competition under vertical product differentiation. The best known result, there, is that two firms will differentiate their quality levels, possibly as much as they can, with one firm choosing the lowest possible quality — a result to be contrasted with the ('horizontal') Hotelling's (1929) *Principle of Minimum Differentiation*. In later works, it has been shown that if two quality dimensions define a product specification, only one of them will be used to differentiate, and the other will be equal across firms (Dos Santos Ferreira and Thisse, 1996; Neven and Thisse, 1990; Vandenbosch and Weinberg, 1995). This, at least in part, justifies the frequent adoption of a model with a single quality dimension. According to the standard unidimensional theory, therefore, under vertical differentiation one should expect that (i) *quality leaders* emerge among firms, while followers sell goods of inferior quality; (ii) quality leadership should be expressed by a difference in just *one* vertical attribute.[1] This description, however, seems only partially appropriate to the different patterns observable in many markets, and hence it cannot exhaust the industry configurations which could be encountered in an empirical analysis. In fact, one can easily think of cases where differentiation obtains in *all* attributes, as well as of cases where the products sold are characterized by different quality leaders in different dimensions. Consumer electronics is an appropriate example. A brand of Hi-Fi systems with excellent sound (possibly emphasized in the product description released to the customers) may have poor electronic facilities incorporated, as opposed to a rival brand with the reverse pattern of characteristics. Analogous

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[1] For the case of *horizontal* differentiation, multicharacteristics models, like Irmen and Thisse's (1998), find that maximum differentiation obtains along one dimension, while minimum differentiation is observed along all other dimensions. Vendorp and Majeed (1995) and Tabuchi (1994) obtain a similar result in a bidimensional setting.

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considerations may apply to analogical or digital photography as well, as there exist cameras with a limited number of technical facilities but extremely good lenses, in competition with others exhibiting the opposite mix. Cars and motorbikes are other examples of the same kind, with some being great performers but quite uncomfortable or mechanically delicate, and others being conversely very user-friendly, reliable but far from exciting.

In the base model we develop in the following sections, we analyze a case where products are specified by two attributes of vertical quality: attribute x, which we call *non-hedonic*, desirable at the same degree by every consumer, and attribute y, that corresponds to the definition of a *hedonic* characteristic: consumers desire more of it but with an intensity parameter, θ, that varies across individuals. The non-hedonic characteristic can also be interpreted as one for which the consumer does not know exactly the contribution to her own utility, but only the average over the population, for instance low cholesterol type of food that is known to reduce the average risk of heart related diseases. A third way of interpreting the non-hedonic attribute is in terms of firms' expectations. Firms' decisions are often taken on the basis of expectations rather than on certainties; in our case on what they *expect* to be the consumers' reactions to changes in their strategies. For the choice of price and product design, therefore, it is immaterial from the point of view of the analysis, whether an attribute really increases utility of all consumers by the same amount or if instead this simplification represents what firms can approximate as an expected reaction, in the absence of more precise forecasts. The assumption that x be non-hedonic is however relaxed in a discussion of cases where it enters the utility function of each individual as a function of θ, the consumer's intensity of preference for characteristics y.

We first set up a 'pure' model or base model, where only variable costs are considered, in order to single out several basic properties of prices and product differentiation; there the firms' incentives are determined by profits gross of any development costs. Then, we introduce fixed costs of developing both characteristics, as in Shaked and Sutton (1982, 1983), Ronnen (1991) and Motta (1993). Our analysis reveals that the addition of x to the model, together with the introduction of costs of developing the product that depend upon the two attributes, modifies the patterns of quality leadership otherwise prevailing in the pure model. We prove that, in general, the degrees of differentiation along the two dimensions are strategic substitutes. This feature appears to illustrate the presence of an underling mechanism whereby any reduction of differentiation along either characteristic is compensated by an increase along the other, to preserve profits. At equilibrium, there always exists one firm choosing the lowest specification in terms of the hedonic characteristic, while the competitor chooses a higher specification — possibly the highest feasible one. But the equilibrium choice of the non-hedonic characteristic may not coincide across firms. Then, one can have three types of equilibria: those where a firm is leader in only one characteristic, those where a firm is leader in both characteristics, and equilibria with cross-quality leadership, where the firm with a low hedonic characteristic chooses a higher non-hedonic one than its competitor.

In the base model we allow for the presence of a cost of introducing a positive level of the hedonic attribute in the sense that as far as this differs from the minimum technically feasible, the marginal cost for the product jumps to a positive constant level. We also check robustness of the results to the introduction of a marginal cost that depends upon the level of the hedonic attribute in a continuous way. Then we also check the robustness of the results to different distributions of consumer tastes, as far as the support remains unidimensional. This allows us to show that if consumers with higher willingness to pay for attribute y also have a higher taste for x, which then also becomes hedonic, the equilibria with double leadership can arise. By contrast, if the reverse pattern of preferences prevails, cross leadership can be an equilibrium. As real-world instances of the first type of dependence, one may think of high income consumers having higher willingness to pay for quality, however measured. The second case can represent consumers that are burdened by the introduction of components in mechanical or electronic devices that are appreciated by less sophisticated or "less skilled" consumers.

The model is then applied to two illustrative issues, in order to show its usefulness: the introduction of Minimum Quality Standards (MQS), and the introduction of taxes or subsides on the high quality product. The introduction of MQS regulation is widespread in manufacturing, chemicals, etc. An MQS on the non-hedonic characteristic is shown to trigger changes in the equilibrium choices of the *other* characteristic, which is not subject to regulation; in particular it may lead to an increase in the hedonic quality level of the high quality firm due to the presence of strategic substitutability between the two dimensions along which firms can differentiate their products. A tax on the product which incorporates the higher hedonic characteristic — like for instance a tax levied on flagship cars, or SUVs, while small city cars will be tax-exempt — is analyzed in turn. Such a tax will not only induce the taxed firm to contrive production, but may also generate a reduction in the taxed and non-taxed characteristic of that product, and an increase in the non-hedonic dimension of the other (non-taxed) product. This last framework is easily accommodated to analyze the effects of subsidies.

The policy implications for regulation and other issues are, therefore, rich and somewhat intricate. The lesson is that policy measures affecting one dimension of a product will have spill-overs on the other dimension as well, while the predictions based upon the standard unidimensional model may be partial or misleading.

The plan of the paper is the following. Section 2 describes the basic model under the assumption that firms incur no development costs for quality improvements. Section 3 analyzes the case where development costs take the form of fixed costs that depend upon the levels of the two characteristics in the product. Section 4 discusses the role of the distribution of consumers tastes and relaxes the hypothesis that variable x be non-hedonic. Section 6 contains two applications of the model accommodating MQS and taxation/subsidization policies. Section 5 concludes. The Appendix A contains one proof and some technical details of the analysis.

2. The base model

Here we focus on what we call the 'pure' case, in which only variable costs appear, to outline some relevant properties of strategic interaction in a bidimensional product differentiation environment. In a market for an indivisible good produced by two firms, labeled as 1 and 2, the quality of a good depends upon two attributes, x and y. Concerning attribute y, the product specification can range between a 'basic' level, y' and higher levels, y, such that $y' < y \leq y''$. If a firm decides to produce quality $y = y'$ it has no marginal cost, but if $y = y'$ it incurs a constant marginal cost, $c(y)$; hence marginal cost is (albeit in a simplified way) dependent upon y. Therefore, $c(y)$ is discontinuous in that

$$c(y) = 0 \text{ if } y = y' \text{ and } c(y) = c \text{ if } y > y'. \tag{1}$$

This allows us to analyze the implications of an increase in the marginal cost of a high quality product, without needless algebraic complications. Below, in Section 2, we shall also sketch the results for the case where marginal costs are defined as $c(y) = cy$. The choice of x, to simplify, is assumed to have no effect on variable costs. In this section only, it is also assumed that fixed costs, F, are independent of x and y, and indeed it is assumed that they are nil.