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Nonlinear pricing and competition intensity in a Hotelling-type model with discrete product and consumer types ☆

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ABSTRACT

This paper develops a Hotelling model with discrete product and consumer types. We analyze the impact of horizontal differentiation (competition intensity) on relative prices. We find that the optimal price ratio of high- to low-quality products decreases with less competition.

1. Introduction

Since the seminal work of Mussa and Rosen (1978) and Maskin and Riley (1984) analyzing nonlinear pricing under monopoly, there has been an increasing number of studies that extend the analysis to settings where firms compete.[1] These models assume that firms compete via a collection of quality (quantity)-price pairs. Consumers self-select, choosing both a particular firm and a quality-price pair. In this context, competition is likely to affect both the level of prices and the structure of relative prices within a price schedule. A limitation, however, of general models postulating continuous product and consumer types concerns the ambiguity of the effect of competition on relative prices (for example, Stole, 1995; Rochet and Stole, 2002). Discrete models provide a better framework for examining the impact of competition on nonlinear pricing strategies.

In line with Villas-Boas and Schmidt-Mohr (1999) and Liu and Serfes (2006), we develop a simple Hotelling-type model with two firms offering two products, differentiated by quality, and two consumer types. We further assume that high quality is proportionately higher than low quality by a specific scalar. This critical assumption allows us to solve the model as a two-stage non-cooperative game and identify a subgame-perfect symmetric equilibrium. We find that the price ratio of high- to low-quality products decreases with less competition. We also extend the model in two directions and obtain similar results.

The remainder of this paper is organized as follows. Section 2 presents the model. Section 3 discusses the model prediction and two model extensions. Section 4 concludes.

2. The model

Consider two firms located at the ends of a unit-length interval, with Firm 1 at zero and Firm 2 at one. Each firm offers two products, a low-quality product q_L at price p_L and a high-quality product q_H at price p_H. The firms have identical technologies and costs. To produce a unit of quality q, a firm incurs in cost $cq (c \geq 0)$. There are also fixed costs of producing a good of quality q equal to $q^2 2$.[2]

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[1] See Stole (2007) for a detailed literature review.

[2] Convex costs are sufficient to solve the model.

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Consumer preferences differ regarding both quality and location. These preferences are unobservable and noncontractable. An individual who purchases product (q,p) from Firm 1 enjoys utility $U(\theta,q,p,d)=v+\theta q-p-td^2$, where $v>0$ is the reservation utility obtained from making a purchase of zero quality, θ is the marginal preference for vertical differentiation (quality), t is the per-unit transportation costs, and d is the disutility from horizontal differentiation (location).[3] The marginal preference for quality θ and horizontal location d are independent. Conversely, an individual who purchases product (q,p) from Firm 2 enjoys utility $U(\theta,q,p,d)=v+\theta q-p-t(1-d)^2$. These utility functions imply that firms are only able to sort consumers with respect to their marginal preference for quality.

Assume two types of consumers in the vertical dimension. There is a fraction λ of individuals with low marginal preferences for quality denoted by θ_L (hereafter low-type consumers) and a fraction $1-\lambda$ with high marginal preferences for quality denoted by θ_H (hereafter high-type consumers), where $\theta_H>\theta_L$. Each consumer type is uniformly distributed over the unit-length interval with a unit mass. Further assume that the reservation utility v is sufficiently high so that there is full market coverage.

Firm i's decision problem, $i=1,2$, consists of offering quality-price pairs (q_{iL},p_{iL}) and (q_{iH},p_{iH}) that maximize profits subject to incentive-compatibility (IC) and participation constraints, given the other firm's quality-price pairs. Formally,

$$\underset{p_{iL},p_{iH},q_{iL},q_{iH}}{\text{Max}}\ \pi_i=\lambda[(p_{iL}-cq_{iL})x_{iL}]-\frac{q_{iL}^2}{2}+(1-\lambda)[(p_{iH}-cq_{iH})x_{iH}]-\frac{q_{iH}^2}{2}\,s.t.$$

$$\theta_H q_{iH}-p_{iH}\geq\theta_H q_{iL}-p_{iL}, \tag{IC$_H$}$$

$$\theta_L q_{iL}-p_{iL}\geq\theta_L q_{iH}-p_{iH}, \tag{IC$_L$}$$

$$q_{iL},q_{iH},p_{iL},p_{iH}>0,$$

where x_{iL} and x_{iH} are the demands for Firm i's low- and high-quality products. The IC constraints imply that truth-telling is a dominant strategy for all customers. It can be shown that Firm 1's demand functions are given by

$$x_{1L}=d_L=\frac{t+\theta_L(q_{1L}-q_{2L})-(p_{1L}-p_{2L})}{2t}, \tag{1}$$

$$x_{1H}=d_H=\frac{t+\theta_H(q_{1H}-q_{2H})-(p_{1H}-p_{2H})}{2t}. \tag{2}$$

The participation constraint regarding the competition for customers with the other firm is embedded in these demand functions. The second participation constraint is the standard individual-rationality (IR) constraint, which is assumed slack for all consumers due to the full-market coverage assumption.

We further assume that high quality is proportionately higher than low quality by a scalar $\delta>1$, where $q_{iH}=\delta q_{iL}$, $i=1,2$. This assumption allows us to solve the model as a two-stage non-cooperative game and derive a subgame-perfect symmetric equilibrium where the IC$_H$ constraint binds and the IC$_L$ constraint does not.[4] In the first stage, firms set quality, while in the second stage, they compete in prices.[5]

For clarity of exposition, we normalize $c=0$, $\lambda=0.6$, $\delta=2$, and $\theta_L=0.5$. The optimal price and quality expressions p_L^*, p_H^*, q_L^*, and q_H^* are then given by

$$p_L^*=t-\frac{\left(0.53\theta_H^2+0.2\theta_H\right)t}{25t+0.3\theta_H-0.6\theta_H^2}, \tag{3}$$

$$p_H^*=t+\frac{\left(0.79\theta_H^2+0.29\theta_H\right)t}{25t+0.3\theta_H-0.6\theta_H^2}, \tag{4}$$

$$q_L^*=\frac{(1.33\theta_H+0.5)t}{25t+0.3\theta_H-0.6\theta_H^2}, \tag{5}$$

$$q_H^*=\frac{(2.67\theta_H+1)t}{25t+0.3\theta_H-0.6\theta_H^2}. \tag{6}$$

3. Results

We now turn to the main model prediction. Following Villas-Boas and Schmidt-Mohr (1999), the degree of horizontal differentiation captured by the per-unit transportation cost t serves as an index for the level of competition among firms. A decrease in t is equivalent to an increase in the intensity of competition. We can then examine how the optimal price ratio p_H^*/p_L^* varies with changes in t.

Proposition 1. *Under the conditions described above, the optimal price ratio p_H^*/p_L^* decreases with a lower competition intensity (higher t).*

Without the loss of generality, Fig. A.1 presents the impact of t on p_H^*/p_L^* for $\theta_H=1$ and $t\geq0.1$.[6] The optimal price ratio decreases with less competition (higher t) or, alternatively, increases with more competition (lower t). The prices of both the low- and high-quality product decrease with more competition, but the price of the low-quality product decreases proportionately more than the price of the high-quality product. Firms compete more intensively for low-type consumers when they face more competition.

Intuitively, the decrease in absolute prices with a lower t is consistent with the lower market power enjoyed by firms. The purchase of the high-quality product must leave a higher net surplus for high-type consumers because they can also purchase the low-quality product. With an increased competition, firms worry less about providing additional informational rents to high-type consumers since they enjoy higher information rents with a lower t.

[3] The model yields similar predictions under both linear and quadratic transportation costs.

[4] The assumption that IC$_H$ binds and IC$_L$ does not is standard in these models. Two other possible structures where separation still occurs and all consumers are served are when both IC$_H$ and IC$_L$ do not bind or when IC$_L$ binds and IC$_H$ does not. It can be readily shown that the model yields similar predictions in these two other cases.

[5] The details of the derivations are presented in a separate appendix available upon request.

[6] The stability condition, which is sufficient to guarantee the existence of a subgame-perfect equilibrium, requires that $t\geq0.09$ for $\theta_H=1$.