Consumer Sorting of Vertically Differentiated Goods

Peyton Ferrier* Qihong Liu†

August 28, 2008

Abstract

This paper shows the conditions where a monopolist prohibits or allows consumer sorting of goods for quality when sorting costs are asymmetric between high and low value consumers. Sorting of low quality goods dampens their substitutability with high quality goods and can raise profits even when sorting lowers revenue from low quality sales considered alone.

Keywords: Consumer sorting; Adverse selection; Vertical differentiation.
JEL Classification Codes: D43, L13.

1 Introduction

Many goods are marketed with significant quality variability that is not incorporated into price. For goods with exogenously distributed quality such as agricultural and natural resource goods, Stivers (2003, 2006) shows that the cost of information leads to only a limited number of grades being offered with each grade encompassing a range of qualities. Grading error (Chalfant et al, 1999; Heuth et al, 2007) and biological decomposition may also introduce variability into product categories. Quality variability then leads to consumer sorting where buyers expend effort to identify goods of higher quality within a grade or class of goods. Barzel (1977, 1982) argues that a buyer's right to voluntarily sort goods with heterogeneous quality is valuable to buyers, but that the seller will often seek to restrict that right when it only serves to redistribute qualities across consumers with no efficiency gains. Ferrier (2008) shows

*USDA, Economic Research Service, 1800 M Street NW, N-5058, Washington DC, 20036-5831. E-mail: pferrier@ers.usda.gov. Phone: (202) 694-5224. Fax: (202) 694-5820.
†Corresponding author. Department of Economics, University of Oklahoma, 729 Elm Ave, Norman, Ok 73019. E-mail: qliu@ou.edu. Phone: (405) 325-5846. Fax: (405) 325-5842.

that sorting can increases efficiency when consumer quality valuations are heterogeneous. Moreover, if sorting costs are heterogenous across consumers, sorting can also improve the firm's profit. This is because, when goods are sold at a single price but vary in quality, sorting facilitates quality discrimination by "redistributing" higher quality goods to lower value consumers (who have lower costs of sorting) and raising the price and profit.

While Ferrier considers only one class of goods, we allow for two classes of goods. Our analysis shows that sellers may allow consumer sorting of low quality goods even when it reduces the market clearing price and profit within the class of sorted goods. The key is that, by allowing sorting in the lowest class of goods, sellers lower the expected quality of the lower quality class to sellers who have a higher sorting cost. This makes the lower class goods less attractive to consumers who buy higher class goods, which enables the firm to raise price for the high class goods. If quality discrimination increases price for lower quality good as well, then the equilibrium price for the higher quality good will increase further.

2 The model

We utilize a vertical differentiation model. Consider a consumer with quality preference parameter θ. If she buys a product of quality q at price p, her indirect utility is $\theta q - p$. There are three types of consumers, identified by their quality preference parameters: θ_{1h}, θ_{1l} and θ_2 with fractions $\alpha\beta, \alpha(1-\beta)$ and $1-\alpha$ respectively. The ranking is $\theta_2 > \theta_{1h} > \theta_{1l}$.

A firms serves two product categories. The first one, with a measure of α which corresponds to the measure of θ_{1l} and θ_{1h} consumers, consists of two qualities. A fraction γ of them has quality q_{1h}, and $1-\gamma$ of has quality q_{1l}. Quality in the second category (with measure $1-\alpha$) is q_2 with no variation. The firm has constant marginal costs c_1 and c_2 for the two categories respectively. We assume that $q_2 > q_{1h} > q_{1l}$ and $c_2 \geq c_1 \geq 0$.

While the first category has two qualities, the firm can sell at only one price. If sorting is allowed, then consumers have the option of sorting through this category, and select the q_{1h} quality while paying the same price.

Whether a consumer will sort or not depends on her sorting cost. High quality preferences and high income level are often associated in the screening literature (e.g. Archaryya, 2005). Our model extends that association in assuming that consumers with higher quality preferences (θ_2 and θ_{1h}) have higher sorting costs than those with the lowest quality preferences (θ_{1l}). Specifically, we assume that the consumer type θ_2 and type θ_{1h} have infinite sorting cost, while type θ_{1l} have zero sorting cost. When sorting is allowed, the zero sorting consumer will come first and select the q_{1h} quality.[1] We assume that there are enough q_{1h} quality goods for the θ_{1l} consumer type, i.e., $1-\beta \leq \gamma$. After they select, type θ_{1h} (and θ_2) consumers will have the same probability of getting the remaining q_{1h} goods.

3 Analysis

We compare two cases depending on whether sorting is allowed or not. We begin with the case where sorting is not allowed.

3.1 Sorting is not allowed

We first derive the average quality a consumer expects to receive should she purchase from the first category. The quality is q_{1h} with probability γ, and q_{1l} with probability $1-\gamma$. Thus the average quality in category 1 is,

$$q_{1,avg}^{NS} = \gamma q_{1h} + (1-\gamma) q_{1l}. \tag{1}$$

There are several cases depending on whether the firm serves all or part of the consumer types.

Case A: All consumer types are served

In this case, the binding constraints are: the individual rationality (IR) constraint for type θ_{1l} consumers and the incentive compatibility (IC) constraint for type θ_2 consumers. Therefore, the equilibrium is characterized by

$$p_{1A}^{NS} = \theta_{1l} q_{1,avg}^{NS} \quad (\text{IR - } \theta_{1l}), \tag{2}$$

$$\theta_2 q_2 - p_{2A}^{NS} = \theta_2 q_{1,avg}^{NS} - p_{1A}^{NS} \quad (\text{IC - } \theta_2).$$

$$\Rightarrow p_{2A}^{NS} = \theta_2 (q_2 - q_{1,avg}^{NS}) + p_{1A}^{NS}. \tag{3}$$

Firm's profit is

$$\pi_A^{NS} = (1-\alpha)(p_{2A}^{NS} - c_2) + \alpha (p_{1A}^{NS} - c_1). \tag{4}$$

Case B: Only type θ_2 and θ_{1h} consumers are served

In this case, the equilibrium is characterized by

$$p_{1B}^{NS} = \theta_{1h} q_{1,avg}^{NS} \quad (\text{IR - } \theta_{1h}),$$

[1] Consumers with lower θ's can spend more time looking for better qualities, or even researching the pattern of when a grocery store adds new products.

$$p_{2B}^{NS} = \theta_2(q_2 - q_{1,avg}^{NS}) + p_{1B}^{NS} \quad \text{(IC - } \theta_2\text{)}.$$

Firm's profit is

$$\pi_B^{NS} = (1-\alpha)(p_{2B}^{NS} - c_2) + \alpha\beta(p_{1B}^{NS} - c_1).$$

Case C: Only type θ_2 consumers are served

Obviously the price and profit are,

$$p_{2C}^{NS} = \theta_2 q_2, \quad \pi_C^{NS} = (1-\alpha)(p_{2C} - c_2).$$

3.2 Sorting is allowed

With the assumption $1-\beta \leq \gamma$, all type θ_{1l} consumers get q_{1h}. Type θ_{1h} consumers have positive probability of getting q_{1h} quality. Their expected quality is

$$q_{1,avg}^{S} = \frac{(\gamma - (1-\beta))q_{1h} + (1-\gamma)q_{1l}}{\beta} < q_{1,avg}^{NS}. \quad (5)$$

Firm still has the option of serving all or part of the consumers.

Case C: Only type θ_2 consumers are served

If the firm serves only type θ_2 consumers, then sorting is irrelevant. Therefore, case C) here is same as the case C) analyzed previously.

Case B: Only two types of consumers are served

The firm may choose to serve either θ_{1h} or θ_{1l} consumers but not both, in addition to type θ_2 consumers. The type of consumers served depends on the ranking of $\theta_{1h}q_{1,avg}^{NS}$ and $\theta_{1l}q_{1h}$. To simplify the analysis, we assume that

$$\theta_{1h}q_{1,avg}^{NS} \geq \theta_{1l}q_{1h}.$$

By setting $p_{1B} = \theta_{1h}q_{1,avg}^{NS}$, firm can rule out type θ_{1l} consumers while still serving type θ_{1h} customers. Therefore, this assumption guarantees that when sorting is allowed, if the firm serves only two consumer types, then it must be type θ_{1l} who is left out, not type θ_{1h} consumers.[2]

Since case B and case C are the same as those cases when sorting is not allowed, we will focus on case A where the firm serves all consumer types. Under Case A, the IR constraint

[2] As we will show later, with this assumption, sorting lowers the alternative quality for θ_2 type consumers, and can increase, decrease or have no effect on prices and profit. Relaxing this assumption complicates our analysis without adding much insight.

will typically only bind for one type of consumers in the low value category (θ_{1h} or θ_{1l}). In particular, when $\theta_{1h} q^S_{1,avg} \geq \theta_{1l} q_{1h}$, the IR constraint for type θ_{1l} consumers is binding. Otherwise, type θ_{1h} consumers' IR constraint will bind. We further break case A down into two sub-cases (A1 and A2), depending on which consumer type's IR constraint is binding.

Case A1: IR constraint for type θ_{1l} consumers is binding

This is the case when the firms serve all types of consumers, and $\theta_{1h} q^S_{1,avg} \geq \theta_{1l} q_{1h}$. Equilibrium is characterized by

$$p^S_{1A} = \theta_{1l} q_{1h} \quad \text{(IR - } \theta_{1l}\text{)},$$

$$\theta_2 q_2 - p^S_{2A} = \theta_2 q^S_{1,avg} - p^S_{1A} \Rightarrow p^S_{2A} = \theta_2 (q_2 - q^S_{1,avg}) + p^S_{1A} \quad \text{(IC - } \theta_2\text{)}.$$

Firm's profit is

$$\pi^S_A = (1-\alpha)(p^S_{2A} - c_2) + \alpha(p^S_{1A} - c_1).$$

Now compare this with case A when sorting is not allowed, where the prices and profit are given in equations (2), (3) and (4). Since $q_{1h} > q^{NS}_{1,avg}$, we have $p^S_{1A} > p^{NS}_{1A}$. Thus profit from category 1 goes up. Next note that $p^S_{2A} > p^{NS}_{2A}$ for two reasons: (i) type θ_2 consumers' alternative price goes up ($p^S_{1A} > p^{NS}_{1A}$), (ii) their alternative quality goes down ($q^S_{1,avg} < q^{NS}_{1,avg}$). So profit from category 2 also goes up when sorting is allowed. Therefore $\pi^S_A > \pi^{NS}_A$, and sorting improves firms overall profit.

Case A2: IR constraint for type θ_{1h} consumers is binding

This happens when $\theta_{1h} q^S_{1,avg} < \theta_{1l} q_{1h}$. In this case, the IR constraint will only bind for θ_{1h} type consumers. The equilibrium is characterized by

$$p^S_{1A} = \theta_{1h} q^S_{1,avg} \quad \text{(IR - } \theta_{1h}\text{)},$$

$$p^S_{2A} = \theta_2 (q_2 - q^S_{1,avg}) + p^S_{1A}.$$

Firm's profit is

$$\pi^S_A = (1-\alpha)(p^S_{2A} - c_2) + \alpha(p^S_{1A} - c_1).$$

Sorting of the low quality good affects total profit through two mechanisms. First, by facilitating quality discrimination in its redistribution of qualities across the θ_{1h} and θ_{1l} consumer types, sorting can raise or lower the price of the lower quality good. Second, sorting lowers the expected quality of lower quality good available to θ_2 type consumers, thus relax the IC constraint for θ_2 type consumers.

When $\theta_{1h} q^S_{1,avg} \in [\theta_{1l} q^{NS}_{1,avg}, \theta_{1l} q_{1h})$, we can check that $p^S_{1A} = \theta_{1h} q^S_{1,avg} \geq \theta_{1l} q^{NS}_{1,avg} = p^{NS}_{1A}$. Intuitively, p_{2A} goes up when sorting is allowed, because type θ_2 consumers' alternative price (weakly) goes up while alternative quality (strictly) goes down. Since sorting increases profits from both quality categories, thus overall profit must rise.

If $\theta_{1h}q^S_{1,avg} < \theta_{1l}q^{NS}_{1,avg}$, then the price of the low quality good falls when sorting is allowed because

$$p^S_{1A} = \theta_{1h}q^S_{1,avg} < \theta_{1l}q^{NS}_{1,avg} = p^{NS}_{1A}.$$

Therefore, profit from the sorting category goes down. However, p_{2A} may go up or down when sorting is allowed, since there are now two opposite forces at work. On the one hand, type θ_2 consumers' alternative price (p^S_{1A}) goes down, putting downward pressure on p_{2A}. On the other hand, their alternative quality ($q^S_{1,avg}$) strictly goes down, thus p_{2A} increases. The effect of sorting on total profit is indeterminate without further specification. Intuitively, if p_{2A} goes down, or if p_{2A} goes up but only slightly, then firm's overall profit goes down when sorting is allowed. If an increase in p_{2A} more than offsets the decrease in p_{1A}, then although sorting lowers the firm's profit in the sorting category, it improves the firm's overall profit.[3] Focusing on the case where the firm serves all consumer types when sorting is allowed and when it is not, $\theta_{1h}q^S_{1,avg} < \theta_{1l}q^{NS}_{1,avg}$ (so that $p^{NS}_{1A} > p^S_{1A}$) is needed for sorting to lower profit from the sorted group. Sorting increases the firm's overall profit if,

$$(1-\alpha)(p^S_{2A} - p^{NS}_{2A}) + \alpha(p^S_{1A} - p^{NS}_{1A}) \geq 0 \Rightarrow \frac{p^S_{2A} - p^{NS}_{2A}}{p^S_{1A} - p^{NS}_{1A}} \geq \frac{\alpha}{1-\alpha}$$

$$\Rightarrow \frac{\theta_2(q^{NS}_{1,avg} - q^S_{1,avg})}{\theta_{1l}q^{NS}_{1,avg} - \theta_{1h}q^S_{1,avg}} - 1 \geq \frac{\alpha}{1-\alpha} \Rightarrow \frac{\theta_2(q^{NS}_{1,avg} - q^S_{1,avg})}{\theta_{1l}q^{NS}_{1,avg} - \theta_{1h}q^S_{1,avg}} \geq \frac{1}{1-\alpha},$$

where $q^{NS}_{1,avg}$ and $q^S_{1,avg}$ are given in equations (1) and (5) respectively.

4 Conclusion

We extend the finding that allowing sorting can increase profits to a multiple good setting. We find that allowing sorting can also increase profits even when it reduces profits within the class of goods being sorted by reducing the substitutability of the lower quality good with the higher quality one.

[3]If α is large and β is close to 1/2 (many θ_{1l} and θ_{1h} type consumers relative to θ_2 type consumers), then the firm is likely to serve all consumer types. In this case, if p^S_{1A} is only slightly less than p^{NS}_{1A}, then sorting lowers the firm's profit from the sorted group but increases its overall profit.

References

[1] Acharyya, R. 2005. Quality discrimination among income constrained consumers. *Economics Letters* 86(3), 245-251.

[2] Barzel, Y. 1977. Some fallacies in the interpretation of information costs. *Journal of Law and Economics* 20, 291-307.

[3] Barzel, Y. 1982. Measurement Costs and the Organization of Markets. *Journal of Law and Economics* 25, 27-48.

[4] Chalfant, J., J. James, N. Lavoie, and R. Sexton 1999. Asymmetric Grading Error and Adverse Selection: Lemons in the California Prune Industry. *Journal of Agricultural and Resource Economics* 24(1), 57-79.

[5] Ferrier, P. 2008. Cherry Picking: Should Sellers Let Buyers Sort? *Journal of Agricultural & Food Industrial Organization* 5.1.

[6] Hueth, B., P. Marcoul, and J. Lawrence 2007. Grader Bias in Cattle Markets? Evidence from Iowa. *American Journal of Agricultural Economics* 89(4), 890-903.

[7] Stivers, A. 2003. Quality standards with exogenously distributed quality. *Economics Letters* 80(1), 130-36.

[8] Stivers, A., 2006. Optimal number of standards under economies of scope in quality. *Economic Letters* 90(3), 368-372.