Price versus quantity in a duopoly of vertical differentiation with loss-averse consumers*

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Abstract

In a model à la Mussa and Rosen (1978) in which consumers are loss-averse, I check the robustness of the result obtained by Tanaka (2001). As he did, I find that the quantity contract is a dominant strategy for both firms. Thus, Cournot is the outcome in equilibrium. Finally, I find that loss aversion in general intensifies competition.

Keywords: Loss aversion; Price and quantity contracts; Vertical product differentiation.

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1 Introduction

Behavioral economics has shown that humans are averse to losses (Tversky and Kahneman (1991)). This means that the pain of a loss is greater than the pleasure of a gain of equal size. This discovery has been incorporated into recent models that analyze the pricing strategies of firms.[1] However, the seminal paper that analyzes the choice of a price or a quantity contract, Singh and Vives (1984), shows that the price contract is a dominant strategy for each firm if the goods are complements; otherwise, the dominant strategy is the quantity contract.[2] Moreover, in a model à la Mussa and Rosen (1978), Tanaka (2001) shows that the quantity contract is a dominant strategy for each firm. To my knowledge, there are no papers that analyze how the loss aversion of consumers affects competition on quantities. The objective of this paper is to analyze whether the quantity contract remains a dominant strategy in a vertical differentiation model in which consumers are loss averse.

Heidhues and Köszegi (2008) find that consumers' loss aversion increases the intensity of competition in a horizontal product differentiation model. Karle and Peitz (2014) modify that model and find that loss aversion in price is procompetitive, while loss aversion in taste is anticompetitive. These papers consider that the reference point arises endogenously, but I assume that it is determined exogenously as in Zhou (2011), who finds the same results as Karle and Peitz (2014).

Recent papers have developed monopoly models with vertically differentiated products and loss-averse consumers. In that framework, Carbajal and Ely (2016) study optimal price discrimination when consumers have reference-dependent preferences for the quality of the product. They find that optimal price discrimination may show efficiency gains relative to second-best contracts without loss aversion. Hahn et al. (2018) consider that consumers have reference-dependent preferences for the quality and price of the product. They show that offering menus with a small number of bundles is consistent with profit-maximizing firms that deal with loss-averse consumers. Courty and Nasiry (2018) apply loss aversion within a class of products of the same quality but not across quality classes. They show that uniform pricing can be optimal across quality classes up to a quality threshold. Finally, Martínez-Sánchez (2020) analyzes how the loss aversion of consumers

[1] See Heidhues and Koszegi (2018) for a review of the literature.

[2] See Matsumura and Ogawa (2012) for this analysis in a mixed duopoly.

affects the strategies of the government and the incumbent for preventing commercial piracy. He finds that those models that do not take into account the loss aversion of consumers overestimate the government's effort to deter piracy, but underestimate the incumbent's effort.

In this paper, I study the choice of a strategic variable (price or quantity) in a duopoly model of vertical product differentiation in which consumers are loss-averse. I show that Cournot is the outcome in equilibrium, and that loss aversion in general intensifies competition.

The rest of the paper is organized as follows: Section 2 describes the model formally. Section 3 presents the equilibrium. Finally, Section 4 concludes.

2 The model

There are two firms, 1 and 2. Firm $i = 1, 2$ produces a product of quality q_i and sells at price p_i, where $i = 1, 2$. I assume $q_2 < q_1$. There is a continuum of consumers indexed by $\theta \in [0, 1]$, where θ is assumed to follow a uniform distribution and represents consumers' tastes for the quality of a product. Each consumer is assumed to buy either a single unit of the product or none at all. I consider the utility of consumers to be reference-dependent. This means that they experience a psychological disutility when buying a non-reference product whose hedonic price is higher than that of reference product,[3] where a hedonic price is defined as the price/quality ratio of a product (p/q). I assume that a proportion ϕ of consumers take product 1 as the reference product, while the rest of consumers take product 2. If the reference product of a consumer θ is product 1, his/her utility is:

$$U(\theta) = \begin{cases} \theta q_1 - p_1 & \text{if he/she buys 1} \\ \theta q_2 - p_2 - \lambda \max\left\{0, \frac{p_2}{q_2} - \frac{p_1}{q_1}\right\} & \text{if he/she buys 2} \\ 0 & \text{if he/she does not buy,} \end{cases} \tag{1}$$

but if the reference product is the product 2, his/her utility is:

[3] Otherwise, consumers experience a psychological gain. As in Zhou (2011), I normalize the psychological gain utility to zero.

$$U(\theta)=\begin{cases}\theta q_1-p_1-\lambda\max\left\{0,\frac{p_1}{q_1}-\frac{p_2}{q_2}\right\} & \text{if he/she buys 1}\\ \theta q_2-p_2 & \text{if he/she buys 2}\\ 0 & \text{if he/she does not buy,}\end{cases}\tag{2}$$

where $\lambda>0$ is the degree of loss aversion of a consumer, which represents the consumer's sensitivity to the difference in hedonic price compared to the reference product. I assume that the degree of aversion to loss is the same for all consumers, and the degree of loss aversion is the same for the price and quality of a product.[4]

To obtain the demand functions of each firm, I first define indifferent consumers. Among those consumers whose reference product is 1, let $\widehat{\theta}_i$ be a consumer who is indifferent between buying product $i=1,2$ and not buying at all; and let $\widehat{\theta}$ be a consumer who is indifferent between buying product 1 and 2, where $\widehat{\theta}_1=p_1/q_1$,

$$\begin{aligned}\widehat{\theta}_2 &= \begin{cases}\frac{p_2}{q_2}+\frac{\lambda}{q_2}\left(\frac{p_2}{q_2}-\frac{p_1}{q_1}\right) & \text{if } \frac{p_1}{q_1}\leq\frac{p_2}{q_2},\\ \frac{p_2}{q_2} & \text{if } \frac{p_1}{q_1}\geq\frac{p_2}{q_2},\end{cases}\\ \widehat{\theta} &= \begin{cases}\frac{p_1-p_2}{q_1-q_2}+\frac{\lambda}{q_1-q_2}\left(\frac{p_1}{q_1}-\frac{p_2}{q_2}\right) & \text{if } \frac{p_1}{q_1}\leq\frac{p_2}{q_2},\\ \frac{p_1-p_2}{q_1-q_2} & \text{if } \frac{p_1}{q_1}\geq\frac{p_2}{q_2}.\end{cases}\end{aligned}$$

Furthermore, among those consumers whose reference product is product 2, let $\widetilde{\theta}_i$ be a consumer who is indifferent between buying product $i=1,2$ and not buying at all; and let $\widetilde{\theta}$ be a consumer who is indifferent between buying product 1 and 2, where $\widetilde{\theta}_2=p_2/q_2$,

$$\begin{aligned}\widetilde{\theta}_1 &= \begin{cases}\frac{p_1}{q_1} & \text{if } \frac{p_1}{q_1}\leq\frac{p_2}{q_2},\\ \frac{p_1}{q_1}+\frac{\lambda}{q_1}\left(\frac{p_1}{q_1}-\frac{p_2}{q_2}\right) & \text{if } \frac{p_1}{q_1}\geq\frac{p_2}{q_2},\end{cases}\\ \widetilde{\theta} &= \begin{cases}\frac{p_1-p_2}{q_1-q_2} & \text{if } \frac{p_1}{q_1}\leq\frac{p_2}{q_2},\\ \frac{p_1-p_2}{q_1-q_2}+\frac{\lambda}{q_1-q_2}\left(\frac{p_1}{q_1}-\frac{p_2}{q_2}\right) & \text{if } \frac{p_1}{q_1}\geq\frac{p_2}{q_2}.\end{cases}\end{aligned}$$

Since consumers are uniformly distributed in the unit interval [0,1], indifferent consumers are non-negative. Thus, $\widehat{\theta}=\widetilde{\theta}=0$ if $p_1/q_1<p_2/q_2$ because:

[4]Neumann and Böckenholt (2014) estimate that the loss aversion coefficient is 1.7 and find no general differences in loss aversion between price and quality.

$$\begin{aligned}\theta q_1 - p_1 &= q_1 (\theta - p_1/q_1) > q_1 (\theta - p_2/q_2) > q_2 (\theta - p_2/q_2) \\ &= \theta q_2 - p_2 > \theta q_2 - p_2 - \lambda \left(\frac{p_2}{q_2} - \frac{p_1}{q_1} \right).\end{aligned}$$

This implies that both those consumers whose reference is product 1 and those whose reference is product 2 prefer to buy product 1 than 2. Therefore, the demand for product 2 is zero when $p_1/q_1 < p_2/q_2$. So, firm 2 has an incentive to deviate and price less than p_1/q_1. Firm 2 will deviate if it makes a positive profit, which is true, as I demonstrate below. Therefore, in equilibrium, $p_1/q_1 > p_2/q_2$. This result means that those consumers whose reference product is 1 will not experience a psychological disutility from buying product 2. Thus, if the reference product of all consumers is 1 ($\phi = 1$), no consumer experiences that psychological disutility. From here on I only consider the case in which $p_1/q_1 > p_2/q_2$.

Let $\beta \equiv \lambda (1 - \phi) > 0$ be the degree of loss aversion in the market, where $1 - \phi$ is the proportion of consumers who take product 2 as their reference. These consumers suffer a psychological disutility when buying product 1 because $p_1/q_1 > p_2/q_2$. Thus, a higher proportion of these consumers implies greater loss aversion in the market.

Demand for products 1 and 2 is defined as follows:

$$\begin{aligned} d_1 (p_1, p_2) &= \phi \left(1 - \widehat{\theta}\right) + (1 - \phi) \left(1 - \widetilde{\theta}\right) \\ d_2 (p_1, p_2) &= \phi \left(\widehat{\theta} - \widehat{\theta}_2\right) + (1 - \phi) \left(\widetilde{\theta} - \widetilde{\theta}_2\right) \end{aligned} \tag{3}$$

I consider that the costs incurred by the firms in developing the products are a sunk cost and the marginal production costs are zero. Thus, the profit of firm $i = 1, 2$ is $\pi_i = p_i d_i$.

The game is as follows. In the first stage, each firm simultaneously chooses its strategic contracts (price or quantity). In the second stage, after observing the firms' decisions in the first stage, each firm simultaneously chooses the levels of its strategic variables.

In the next section, I seek to find the subgame perfect equilibrium (SPE) of the game by backward induction.

3 Equilibrium

3.1 Second stage

Since each firm decides between two strategic contracts, price and quantity, there are four possible subgames in the second stage, which I now solve.[5] Notice that firm 2 makes a positive profit in each subgame when $p_1/q_1 > p_2/q_2$. So firm 2 deviates in each subgame from setting a hedonic price higher than p_1/q_1. Therefore, in equilibrium, $p_1/q_1 > p_2/q_2$.

3.1.1 p-p subgame

In this game, both firms set prices. From (3) and the indifferent consumers, I obtain the demand functions, which are:

$$\begin{aligned} d_1(p_1, p_2) &= \frac{q_1 q_2 (q_1 - q_2) - p_1 q_2 (q_1 + \beta) + p_2 q_1 (q_2 + \beta)}{q_1 q_2 (q_1 - q_2)}; \\ d_2(p_1, p_2) &= \frac{(q_1 + \beta)(p_1 q_2 - p_2 q_1)}{q_1 q_2 (q_1 - q_2)}. \end{aligned}$$

By maximizing the firms' profits, I obtain the reaction function of each firm, which is:

$$p_1(p_2) = \frac{q_1 (p_2 (q_2 + \beta) + q_2 (q_1 - q_2))}{2 q_2 (q_1 + \beta)}; p_2(p_1) = \frac{q_2}{2 q_1} p_1.$$

From the intersection of these functions, I obtain the equilibrium prices and then the equilibrium quantities and profits, which are:[6]

$$\begin{aligned} p_1^{pp} &= \frac{2 q_1 (q_1 - q_2)}{4 q_1 - q_2 + 3\beta}; p_2^{pp} = \frac{q_2 (q_1 - q_2)}{4 q_1 - q_2 + 3\beta}; d_1^{pp} = \frac{2 (q_1 + \beta)}{4 q_1 - q_2 + 3\beta}; \\ d_2^{pp} &= \frac{q_1 + \beta}{4 q_1 - q_2 + 3\beta}; \pi_1^{pp} = \frac{4 q_1 (q_1 - q_2)(q_1 + \beta)}{(4 q_1 - q_2 + 3\beta)^2}; \pi_2^{pp} = \frac{q_2 (q_1 - q_2)(q_1 + \beta)}{(4 q_1 - q_2 + 3\beta)^2} \end{aligned} \tag{4}$$

[5] The second-order conditions are satisfied in all the subgames.

[6] Notice that $\frac{p_1^{pp}}{q_1} - \frac{p_2^{pp}}{q_2} = \frac{q_1 - q_2}{3\beta + 4q_1 - q_2} > 0$.

3.1.2 d-d subgame

When both firms choose the quantity contract, they face the following inverse demand functions:

$$\begin{aligned} p_1(d_1, d_2) &= \frac{q_1(\beta(1 - d_1 - d_2) + q_1 - d_1 q_1 - d_2 q_2)}{\beta + q_1}; \\ p_2(d_1, d_2) &= q_2(1 - d_1 - d_2). \end{aligned}$$

Note that d_i also represents the quantity chosen by firm $i = 1, 2$. By maximizing the firms' profits, I obtain the reaction function of each firm, which is:

$$d_1(d_2) = \frac{\beta + q_1 - d_2(\beta + q_2)}{2(\beta + q_1)}; d_2(d_1) = \frac{1 - d_1}{2}.$$

From the intersection of these functions, I obtain the equilibrium quantity and then the equilibrium prices and profits, which are:[7]

$$\begin{aligned} p_1^{dd} &= \frac{q_1(\beta + 2q_1 - q_2)}{3\beta + 4q_1 - q_2}; p_2^{dd} = \frac{q_2(\beta + q_1)}{3\beta + 4q_1 - q_2}; d_1^{dd} = \frac{\beta + 2q_1 - q_2}{3\beta + 4q_1 - q_2}; \\ d_2^{dd} &= \frac{\beta + q_1}{3\beta + 4q_1 - q_2}; \pi_1^{dd} = \frac{q_1(\beta + 2q_1 - q_2)^2}{(3\beta + 4q_1 - q_2)^2}; \pi_2^{dd} = \frac{q_2(\beta + q_1)^2}{(3\beta + 4q_1 - q_2)^2}. \end{aligned} \tag{5}$$

3.1.3 p-d subgame

In this game, firm 1 chooses the price contract and thus faces demand function (6), while firm 2 chooses the quantity contract and thus faces inverse demand function (7).

$$d_1(p_1, d_2) = \frac{(q_1 - p_1)(\beta + q_1) - d_2 q_1(\beta + q_2)}{q_1(\beta + q_1)}; \tag{6}$$

$$p_2(p_1, d_2) = q_2 \frac{p_1(\beta + q_1) - d_2 q_1(q_1 - q_2)}{q_1(\beta + q_1)}. \tag{7}$$

By maximizing the firms' profits, I obtain the reaction function of each firm, which is:

[7] Notice that $\frac{p_1^{dd}}{q_1} - \frac{p_2^{dd}}{q_2} = \frac{q_1 - q_2}{3\beta + 4q_1 - q_2} > 0$.

$$p_1(d_2) = \frac{q_1(\beta + q_1 - d_2(\beta + q_2))}{2(\beta + q_1)}; d_2(p_1) = \frac{(\beta + q_1)p_1}{2q_1(q_1 - q_2)}.$$

From the intersection of these functions, I obtain the equilibrium prices, quantities and profits, which are:[8]

$$\begin{aligned} p_1^{pd} &= \frac{2q_1(q_1 - q_2)}{\beta + 4q_1 - 3q_2}; p_2^{pd} = \frac{q_2(q_1 - q_2)}{\beta + 4q_1 - 3q_2}; d_1^{pd} = \frac{2(q_1 - q_2)}{\beta + 4q_1 - 3q_2}; \\ d_2^{pd} &= \frac{\beta + q_1}{\beta + 4q_1 - 3q_2}; \pi_1^{pd} = \frac{4q_1(q_1 - q_2)^2}{(\beta + 4q_1 - 3q_2)^2}; \pi_2^{pd} = \frac{q_2(q_1 - q_2)(\beta + q_1)}{(\beta + 4q_1 - 3q_2)^2}. \end{aligned}$$

3.1.4 d-p subgame

In this game, firm 2 chooses the price contract and thus faces demand function (9), while firm 1 chooses the quantity contract and thus faces inverse demand function (8).

$$p_1(d_1, p_2) = \frac{q_1(q_2(q_1 - q_2)(1 - d_1) + p_2(\beta + q_2))}{q_2(\beta + q_1)}; \tag{8}$$

$$d_2(d_1, p_2) = \frac{q_2 - p_2 - d_1 q_2}{q_2}. \tag{9}$$

By maximizing the firms' profits, I obtain the reaction function of each firm, which is:

$$d_1(p_2) = \frac{q_2(q_1 - q_2) + p_2(\beta + q_2)}{2q_2(q_1 - q_2)}; p_2(d_1) = \frac{q_2(1 - d_1)}{2}.$$

From the intersection of these functions, I obtain the equilibrium prices, quantities and profits, which are:[9]

$$\begin{aligned} p_1^{dp} &= \frac{(\beta + 2q_1 - q_2)q_1(q_1 - q_2)}{(\beta + q_1)(\beta + 4q_1 - 3q_2)}; p_2^{dp} = \frac{q_2(q_1 - q_2)}{\beta + 4q_1 - 3q_2}; d_1^{dp} = \frac{\beta + 2q_1 - q_2}{\beta + 4q_1 - 3q_2}; \\ d_2^{dp} &= \frac{q_1 - q_2}{\beta + 4q_1 - 3q_2}; \pi_1^{dp} = \frac{q_1(q_1 - q_2)(\beta + 2q_1 - q_2)^2}{(\beta + q_1)(\beta + 4q_1 - 3q_2)^2}; \pi_2^{dp} = \frac{q_2(q_1 - q_2)^2}{(\beta + 4q_1 - 3q_2)^2}. \end{aligned}$$

[8] Notice that $\frac{p_1^{pd}}{q_1} - \frac{p_2^{pd}}{q_2} = \frac{q_1 - q_2}{\beta + 4q_1 - 3q_2} > 0$.

[9] Notice that $\frac{p_1^{dp}}{q_1} - \frac{p_2^{dp}}{q_2} = \frac{(q_1 - q_2)^2}{(\beta + q_1)(\beta + 4q_1 - 3q_2)} > 0$.

3.2 Contract choice: Price and Quantity

I now look for the Nash equilibrium at the first stage of the complete game, which is summarized in Table 1.

Table 1: Price vs. Quantity		
Firm 1 \ 2	P	D
P	π_1^{pp},π_2^{pp}	π_1^{pd},π_2^{pd}
D	π_1^{dp},π_2^{dp}	π_1^{dd},π_2^{dd}

Given that $\pi_1^{dp} > \pi_1^{pp}$, $\pi_1^{dd} > \pi_1^{pd}$, $\pi_2^{pd} > \pi_2^{pp}$ and $\pi_2^{dd} > \pi_2^{dp}$, I find that the quantity contract is the dominant strategy for both firms. Thus, the setting in which both firms choose quantities, Cournot competition, is the SPE, as summarized in Proposition 1.

Proposition 1 *Cournot competition is the SPE.*

Proof of Proposition 1. Given that $q_1 > q_2$ and $\beta > 0$, the following emerges:

$$\pi_1^{dp} - \pi_1^{pp} = \frac{q_1(\beta+q_2)^2(q_1-q_2)\left(5\beta^2+10\beta(2q_1-q_2)+4q_1(4q_1-3q_2)+q_2^2\right)}{(\beta+q_1)(3\beta+4q_1-q_2)^2(\beta+4q_1-3q_2)^2} > 0$$

$$\pi_1^{dd} - \pi_1^{pd} = \frac{q_1(\beta+q_2)^2\left(\beta^2+2\beta(6q_1-5q_2)+4(q_1-q_2)(4q_1-q_2)+q_2^2\right)}{(\beta+4q_1-3q_2)^2(3\beta+4q_1-q_2)^2} > 0$$

$$\pi_2^{pd} - \pi_2^{pp} = \frac{8q_2(q_1-q_2)(\beta+q_2)(\beta+q_1)(\beta+2q_1-q_2)}{(\beta+4q_1-3q_2)^2(3\beta+4q_1-q_2)^2} > 0$$

$$\pi_2^{dd} - \pi_2^{dp} = \frac{q_2(\beta+q_2)(\beta+2q_1-q_2)\left(\beta^2+2\beta(4q_1-3q_2)+8q_1(q_1-q_2)+q_2^2\right)}{(\beta+4q_1-3q_2)^2(3\beta+4q_1-q_2)^2} > 0. \quad \blacksquare$$

This result coincides with that obtained by Tanaka (2001). Therefore, both firms choose the quantity contract when the classic vertical differentiation model is extended to consider that consumers are adverse to losses.

I find that prices in all subgames decrease with β, except p_2 when both firms compete à la Cournot. This exception is because those consumers whose reference product is 2 will experience a psychological disutility from buying product 1,[10] but those whose reference product is 1 will not experience a psychological disutility when buying 2. So firm 2 has an advantage over firm 1. This result is summarized in the following proposition:

Proposition 2 *All prices decrease with β, except p_2^{dd}.*

[10]Notice that $p_1^j/q_1^j > p_2^j/q_2^j \ \forall j = \{pp, dd, pd, dp\}$.

Proof of Proposition 2. Given that $q_1 > q_2$ and $\beta > 0$, it emerges that:

$\frac{\partial p_1^{pp}}{\partial \beta} = -\frac{6q_1(q_1-q_2)}{(3\beta+4q_1-q_2)^2} < 0$; $\frac{\partial p_2^{pp}}{\partial \beta} = -\frac{3q_2(q_1-q_2)}{(3\beta+4q_1-q_2)^2} < 0$; $\frac{\partial p_1^{dd}}{\partial \beta} = -\frac{2q_1(q_1-q_2)}{(3\beta+4q_1-q_2)^2} < 0$;

$\frac{\partial p_2^{dd}}{\partial \beta} = \frac{q_2(q_1-q_2)}{(3\beta+4q_1-q_2)^2} > 0$; $\frac{\partial p_1^{pd}}{\partial \beta} = -\frac{2q_1(q_1-q_2)}{(\beta+4q_1-3q_2)^2} < 0$; $\frac{\partial p_2^{pd}}{\partial \beta} = -\frac{q_2(q_1-q_2)}{(\beta+4q_1-3q_2)^2} < 0$;

$\frac{\partial p_1^{dp}}{\partial \beta} = -\frac{q_1(q_1-q_2)\left(\beta^2+2\beta(2q_1-q_2)+6q_1(q_1-q_2)+q_2(3q_2-2q_1)\right)}{(\beta+q_1)^2(\beta+4q_1-3q_2)^2} < 0$; $\frac{\partial p_2^{dp}}{\partial \beta} = -\frac{q_2(q_1-q_2)}{(\beta+4q_1-3q_2)^2} < 0$. ■

From Proposition 2, I conclude that loss aversion intensifies competition, although it is not clear when firms compete à la Cournot because p_2^{dd} increases with β. To clarify doubts I analyze the joint profit of both firms $(\pi_1 + \pi_2)$, which decreases with β. So loss aversion in general intensifies competition. This result is summarized in Proposition 3.

Proposition 3 $\pi_1^{dd} + \pi_2^{dd}$ *decreases with* β.

Proof of Proposition 3. Given that $q_1 > q_2$ and $\beta > 0$, it emerges that:

$\frac{\partial\left(\pi_1^{dd}+\pi_2^{dd}\right)}{\partial \beta} = -2\left(q_1 - q_2\right)\frac{q_1(4q_1-3q_2)+\beta(2q_1-q_2)}{(3\beta+4q_1-q_2)^3} < 0$. ■

4 Conclusions

In a model à la Mussa and Rosen (1978) in which consumers are loss-averse and are distributed uniformly according to their taste for quality, I find that the quantity contract is a dominant strategy for both firms. Thus, the Cournot model should be used more frequently when consumers are loss-averse. Finally, I find that loss aversion in general intensifies competition.

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