PRICE COMPETION WHEN ONLY SOME CONSUMERS PERCIEVE THE GOODS AS DIFFERENTIATED: DISCRETE STRATEGY AND TWO-CONSUMER CASE

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NOUR SAMEER ALZAZA

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STATEMENT OF ACADEMIC HONESTY

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ABSTRACT

We study a version of the price competition duopoly model in Evrenk (2019) under the assumptions that there are two firms and the strategy set (possible prices) is finite. The consumers are price-taking, each buy at most one unit of the good, and one of them perceives the goods as differentiated (one being more desirable than the other), while the other one sees the goods identical (therefore, buys the one with the lower-price). The former consumer is referred to as the discriminator, and the latter as the non-discriminator consumer. The firm whose product is valued more by the discriminator is referred as the Brand firm, while the other firm is referred to as the Generic firm. The cost functions of the firms are assumed to be identical with zero fixed cost and constant marginal cost. It is also assumed that the firms announce their prices simultaneously and independently.

We show that, as speculated in Evrenk (2019), pure strategy Nash Equilibrium (PSNE) exists in the discrete price case on a particular set of parameters over which PSNE fails to exist in the continuous price case. In that PSNE, the Generic firm charges a price equal to the willingness to pay of the non-differentiator consumer, while the Brand firm charges a price less than the differentiator consumer's willingness to pay. There is also a set of parameters on which PSNE exists under both continuous and discrete prices, and a set under which no PSNE whether the prices are discrete or continuous.

Keywords: duopoly, Nash equilibrium, price competition, differentiated goods.

ÖZ

SADECE BAZI TÜKETİCİLERİN KALİTE FARKI GÖRDÜĞÜ BİR DÜOPOL PİYASASINDA FİYAT REKABETİ: SÜREKLİ OLMAYAN FİYATLAR VE İKİ TÜKETİCİ DURUMU

SAMEER ALZAZA, NOUR.
İşletme Yüksek Lisans Programı
Tez Danışmanı: Prof. Dr. Haldun Evrenk
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Bu çalışmada, Evrenk (2019)'da çalışılan düopol modelinin fiyatların sürekli olmadığı ve iki tüketicinin olduğu bir versiyonu çözülmüştür. Tüketicilerin fiyatları veri kabul ettiği ve her bir tüketicinin en fazla bir adet ürün aldığı bu dünyada, bir tüketici ürünler arasında kalite farkı olduğunu düşünmekte (ve yüksek kaliteli ürüne daha fazla ödemeye razı), diğer tüketici arada bir kalite farkı görmemekte (dolayısıyla, fiyatı daha düşük olan ürünü tercih etmektedir). Birinci tüketici ayrımsayan tüketici, ikincisi ayrımsamayan tüketici olarak adlandırılmıştır. Ayrımsayan tüketicinin tercih ettiği ürünü üreten firma Marka, diğer firma Eşdeğer olarak adlandırılmıştır. Her iki firmanın maliyet yapısının aynı olduğu (sıfır sabit maliyet, ve sabit marjinal maliyet), ve her iki firmanın fiyatlarını aynı anda ve birbirinden bağımsız belirlediği varsayılmıştır.

Evrenk (2019)'daki iddia ispat edilmiş, Pür strateji Nash dengesi (PSND)'nin fiyatların sürekli değişkenler olduğu bir durumda var olmadığı bir parametreler kümesinin bir alt kümesinde, fiyatların kesikli değişkenler olduğu bir durumda var olduğu gösterilmiştir. Bu PSND'de Eşdeğer firma ürününü ayrımsamayan tüketicinin ürün için ödeyebileceği en yüksek fiyattan satmakta, Marka ürününü ayrımsayan tüketicinin ödeyebileceği en yüksek fiyatın altında bir fiyattan satmaktadır. Yukarıdaki parametre kümesi dışında, fiyatın sürekli ve kesikli değişkenler olduğu durumlarda PSND'nin var olduğu ve olmadığı parametre kümeleri ve PSND fiyatlarının görünüşü aynıdır.

Anahtar Kelimeler: duopoly, Nash dengesi, fiyat rekabeti, farklılaştırılmış mallar.

DEDICATION

To my lovely father and mother,

Thank you for your support and encouragement all time.

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I would like to express my grateful thanks for my teacher and advisor Haldun Evrenk , for his continuous support of my research, for his patience, and enormous knowledge. His guidance helped me in all the time...

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CHAPTER 1
INTRODUCTION

Following the path breaking work of Cournot (1838), the way price(s) are determined in imperfectly competitive markets have been studied by many researchers, -for a review of earlier work see Friedman (1977), an updated review is provided in Belleflemme and Pietz (2015). In these studies, several alternative modeling assumptions have been employed: Cournot (1838) assumes that firms set quantities simultaneously, Bertrand (1883), on the other hand, argued that such an assumption was unrealistic and studied what happens when the firms choose prices independently and simultaneously. Even though the latter assumption seems more realistic, its prediction is not: in the classic symmetric Bertrand oligopoly (with constant marginal and zero fixed cost and issues such as repeated interaction aside) equilibrium price is equal to the marginal cost, a result known as the *Bertrand paradox*. Starting with the seminal work of Hotelling (1929), models of differentiated product oligopolies provide a solution to that paradox. In such models, typically price is above the marginal cost.

To the best of our knowledge, a common trait of models of product differentiation is the assumption that all customers agree whether the products are differentiated or not. Evrenk (2019) instead studies a setup in which some of the consumers perceive the products as differentiated, while the rest does *not*. We study a version of that model in which the strategy set of the firms is discrete. Evrenk (2019) finds that when the set of strategies is a continuum, pure strategy Nash Equilibrium (PSNE) does not exists under a certain set of parameters. He speculates that the equilibrium would exist within a subset of that set of parameters if one discretizes the strategy set. We show that this indeed is the case.

In the model there are two profit-maximizing firms. Since such an interpretation makes the discussion easier to follow, we refer the good as the drug, and the firms as the Generic firm, G, and the Brand firm, B. For simplicity, we assume that there are only two price-taking consumers, and one of them perceives the goods as differentiated (one being more desirable than the other), while the other one sees the goods identical. The former is referred to as the customer A (and, sometimes as the differentiator), and the latter as the customer Z (and, sometimes as the non-differentiator). Each consumer buys at most one unit of the good. We assume that both firms have the same cost function (zero fixed cost and constant marginal cost), and they announce their prices simultaneously and independently.

Another important difference with the literature is that the valuations of the customers allowed to vary in different ways: it is assumed that the differentiator customer A values the Brand product more than the non-differentiator customer Z values it. It is also assumed that the value of the products to the customers exceed the marginal cost of the products, meaning that production by both firms is the socially efficient outcome. Yet, the consumers do not buy based on social efficiency: a consumer buys the product, if any, that provides her the highest surplus. If no product provides a non-negative consumer's surplus (if the price of each product is higher than its value to the consumer), then she does not buy. Otherwise, consumer Z buys from the firm that charges the lowest price (if both firms charge the same price, she buys from the Brand), and consumer A buys from the Brand provided that the price difference between the firms is less than the difference in the values of the products according to her.

We focus on the PSNE that gives rise to the socially efficient outcome, i.e., PSNE in which both firms are active. Evrenk (2019) shows that other types of PSNE (one in which either the

Generic firm or the Brand firm supplies the whole market), does not exist when the strategy set is a continuum. We find that, PSNE is identical to the PSNE of the model with a continuous strategy space when the latter has any PSNE. That happens when the non-differentiator customer Z values the generic product at least as much as the differentiator customer values it (Cases 1 and 3 below). In that case, both Brand and Generic firms behave as monopolists in their respective markets, charging the highest price their customers are willing to pay. There will be some competition between them when the discriminator customer's valuation of the Generic product exceeds that of the non-discriminator customer. In that case, when the Generic charges the monopoly price for the non-discriminator customers, the Brand cannot charge its monopoly price to the discriminator customers, as that price leaves zero net consumers' surplus to that group of customers, but buying from the Brand, they could get some non-negative consumers' surplus. Such an equilibrium, however, exists, only under certain parameters. More specific, the valuation of the non-differentiator customers (thus, the price Generic charges) must be close to the marginal cost. Thus, in that equilibrium the Generic charges a price close to the marginal cost, while the Brand charges marginal cost plus a difference. That difference is equal to the difference in the value of the products of the Brand and the Generic firms according to the discriminating customer. When the value of the good to the non-discriminator consumers is not too close to the marginal cost, there is no PSNE in which both firms are active even with the discretized strategy space.

1.1 Generic vs. Brand competition in pharmaceuticals

Since we interpret the model in terms of Brand versus Generic drugs, it may be helpful to describe the market for these products in the US and several studies. Before 1984, the prices of medicines in general were high and the competition between pharmaceutical companies were absent or rare due to the high cost of safety tests, known as clinical trials, that were obligatory for each drug weather it was a new discovery drug (Brand drug) or bioequivalent active ingredient for an existing drug (Generic drug). Waxman-Hatch act of 1984 simplified the entrance of generic drugs, and reduced the entry cost significantly, by allowing the generic companies to relay on clinical trials of brand company for the same bioequivalent drug. it also regulated the brand companies patent duration, that prevent any entry for generic drugs until the end of allowed patent period, -for more see Kanavos, Costa-Font and Seely (2008).

After the Waxman-Hatch act, the economic forecast was that the price of brand companies will fall, but Caves, Whinston and Hurwitz (1991) and Grabowski and Vernon (1992) show that the price of brand drugs continued at a constant price or slightly increased. An explanation is that the Brand consumers may think that a drug with a brand is better than a generic type, although it is chemically identical, perhaps because the brand's seller has better quality control. So, drugs began to be differentiated for customer, -see Sloan and Hsieh (2012, p. 384-6) for a review, and Frank and Salkever (1995) for an empirical analysis.

As Morton and Kyle (2011) notes, generic companies responded by acquiring deals with insurance companies that sells them the same medicine at a lower cost. Consumers therefore have started to use generic drugs and thus convince them that their effectiveness is the same in 1980s. Then, the main challenge for the drug companies became to innovate, Frank and Salkever (1995).
Note that many economic and political factors affect the pattern of competition between pharmaceutical companies, such as regulation. Some countries have imposed a fixed price margin for the generic drugs, while other countries that do not have fixed regulation are affected by brand differentiation determined by the physician’s prescription. Thus, the US market or its current regulatory structure is not the only one.

CHAPTER 2
THE MODEL

Consider price competition among two profit maximizing firms. Below we refer to them as pharmaceutical companies, and their product as the drug, since such an interpretation is both possible and plausible. The first company is the Brand Company, B, the second is the Generic company, G. Assume that both have the same marginal cost, C, i.e., the active ingredient is the same, and zero fixed cost.

To simplify the calculations, assume that there are two[1] (potential) customers, A and Z. These customers differ in the way they perceive the products of the companies. Customer A sees them as differentiated products and always has a higher value for the drug produced by the brand company than the one produced by the Generic company, $V_B > V_G$, while customer Z sees them as homogenous products and values both products at V. Each customer decides which drug, if any, to buy based on the net consumers surplus the drug provides. If both drugs produce the same net consumer's surplus for a customer, then the customer buys the one produced by the brand. Formally, let the net consumer's surplus for consumer $i \in \{A, Z\}$ to be denoted by NS_i when this consumer buys the good. We have

$$NS_A = \max\{V_B - P_B, V_G - P_G\} \; and \; NS_Z = V - \min\{P_B, P_G\}. \quad (1)$$

Consumer i will not buy the good when $NS_i < 0$, as she can always get a zero net consumer's surplus by not buying it. Yet, assume that the production by either company is socially valuable, i.e.,

[1] A more general modelling assumption would be to assume that there is a continuum of type A and Z consumers with measures respectively μ and$1 - \mu$, where μ is strictly between zero and one. Evrenk (2019) studies this case and also considers the price as a continuous variable.

$$Min \{V_G, V\} > C.$$

Furthermore, assume that customer A values the brand drug more than it is valued by customer Z, i.e.,

$$V_B > V.$$

These assumptions impose only the following relationships on the parameters of the mode $V_B > V_G > C$, $V_B > V > C$. Therefore, we have three possible cases:

- Case 1: $V_B > V_G > V > C$,
- Case 2: $V_B > V > V_G > C$,
- Case 3: $V_B > V_G = V > C$.

CHAPTER 3
THE EQUILIBRIA

The setup described above can be considered as a game. In that game the strategy of each player (firm) is its price, they simultaneously and independently decide on their prices. Unlike Evrenk (2019), we assume that each firm can charge a price that is a multiple of 0.01. Likewise, we assume that the values of goods to consumers are also in exact multiples of 0.01. Let $\mathbb{R}_{0.01}$ denote all the non-negative rational numbers that are exact multiples of 0.01, i.e., $\mathbb{R}_{0.01} = \{0, 0.01, 0.02, 0.03, \ldots \ldots .\}$. Then, the strategy set for firm B is given by $S_B = [\mathrm{V}_B, C] \cap \mathbb{R}_{0.01}$, and $S_G = [\max\{\mathrm{V}_G, \mathrm{V}\}, C] \cap \mathbb{R}_{0.01}$ for firms B and G respectively. The objective of each firm is to maximize its profit, Π_j. Let P_j denote the price and N_j denote the output of firm $j \in \{B, G\}$. The profit of firm j is given by

$$\Pi_j = (P_j - C)N_j. \qquad (2)$$

For our game, the Nash equilibrium is a strategy profile, where no player has anything to gain by changing only his or her own price unilaterally. Formally, (S,Π) is the game, where S is the set of all strategy profiles and Π is the set of payoff profiles defined on these strategy profiles. When each player $j \in \{\mathrm{B}, \mathrm{G}\}$ chooses strategy $P_j \in S_j$ resulting in strategy profile P = (P_B, P_G) then player j obtains payoff Π_j(P). A strategy profile P*∈ S is a pure strategy Nash equilibrium (PSNE) if none of the firms have a profitable deviation.

In theory, there may be an equilibrium in which one of the firms serves the whole market, and, thus, we can have three different types of Nash equilibria. More specific, let NB* and NG* denote the number of customers each firm serves in the equilibrium. Since there are only two customers and since they each buy at most one unit, we know that NB* + NG* =2. By abusing the convention, sometimes we refer to a (type of) Nash equilibrium by the firms supplying the market. In Type B equilibrium we have the Brand firm supplying to both customers, while the Generic firm sells none, i.e., NB* = 2, and NG*=0. Type G equilibrium is the symmetric of Type B equilibrium, i.e., we have NB* = 0, and NG*=2. Finally, in Type BG equilibrium, we have each firm supplying to one consumer, NB* = NG*=1. In this study, Type BG equilibria will be our main focus. Evrenk (2019) shows that other type of equilibrium does not exists in the continuous version of this game.

For PSNE we need one condition: given the price of the other firm, neither firm should be able to increase its profit by changing its price. But, since price changes have different effects on different customers, following Evrenk (2019) below we check this condition separately for the direction of the price change and the firm. Thus, we check the following two conditions for each firm in each Type BG equilibria.

No Profitable Deviation to a Lower Price for firm j (NPDLPj): None of the firms must be able to increase its profit by reducing its price. Note that if a firm increases its profit by reducing its price, then it must be the case that the firm is selling more units at that lower price. Another point to note that is, in Type BG equilibrium, the decrease in price required to attract the other firm's customer may be higher than the smallest increment allowed (0.01 in our analysis). To see why, consider a Type BG equilibrium for the case $V_B > V > V_G$, and assume that Firm B charges a price equal to V_B and that Firm G charges a price equal to V. Now, if Firm B wants to sell to customer Z, who pays V for the drug she buys from Firm G, Firm B cannot achieve this by simply reducing its price to $V_B - 0.01$ since the goods are not differentiated for customer Z, a small decrease in the already high price of Firm B is not enough to convince her to switch the suppliers.

No Profitable Deviation to a Higher Price for firm j (NPDHPj): None of the firms must be able to increase its profit by increasing its price. Note that if a firm increases its profit by increasing its price, then we have two possibilities: either it still sells the same number of units at a higher price, or it is selling fewer units at a sufficiently higher price. Therefore, when checking whether this condition holds, in Type BG equilibria, we need to consider prices that will and will not make the consumer of the firm switch to the other firm.

3.1. PSNE when $V_B > V_G > V > C$

Note that for Type BG equilibria, we must have customer A buying from Firm B (the brand company). Since $V_B > V$, brand company gets a higher profit when selling to customer A. Customer A will buy it only when her NCS_B is no less than her NCS_G, formally when $V_B - P_B \geq V_G - P_G$. This condition can be rewritten as,

$$P_B \leq V_B - V_G + P_G. \tag{3}$$

We also know that $P_B > P_G$, otherwise this would not be a Type BG equilibrium. Because from our third equation P_B is equal to P_G plus the difference between V_B-V_G and it is a positive number, so $P_B > P_G$. Finally, we should have $P_G \geq C$, otherwise Firm G could simply choose not to produce and increase its profit (by cutting its loss).

Now, $NPDHP_B$ implies that Firm B would charge the highest price it can charge provided that it can keep its customer. Thus, equation (3) becomes

$$P_B = V_B - V_G + P_G. \tag{4}$$

On the other hand, $NPDLP_B$ implies that by reducing its price to

P_G (because this is the only way for Firm B to sell to Consumer Z), Firm B should not be able to increase its profit. Formally, (P_B -C) (1) ≥ (P_G -C)(2). Using Equation (4), we have (V_B -V_G + P_G - C) (1) ≥ (P_G -C) (2), which can be further simplified as,

$$V_B - V_G + C \geq P_G \quad (5)$$

Next, we should consider the implications of $NPDHP_G$ and $NPDLP_G$. First, note that, since Firm G is selling to Z in this (Type BG) equilibrium, we must have $P_G \leq V$. By equation (5), P_B is higher than P_G. Thus, $NPDHP_G$ implies that

$$P_G = V. \quad (6)$$

Combining the last two equations we know that when $V_B > V_G > V$, for a Type BG equilibrium to exist we need

$$V \leq V_B - V_G + C. \quad (7)$$

Likewise, by reducing its price (and, by selling its drug to Customer A), Firm G should not be able to increase its profit. Firm G makes a profit of (P_G- C) in a Type BG equilibrium, and by reducing its price slightly it would make a profit of (P_G- C - .01) (2) when $V_B > V_G > V$. Thus, we must have

$$C + .02 \geq P_G. \quad (8)$$

Equation (6), i.e., $P_G = V$, implies that

$$V \leq \min\{C + 0.02, V_B - V_G + C\}. \quad (9)$$

Note that the above equation is a condition on the parameters of the model, i.e., equilibrium exists only if the value of the good is not too high for Z. The above analysis implies the following result.

Proposition 1: When $V_B > V_G > V > C$, type BG Nash equilibrium exists only if $V \leq \min\{C + 0.02, V_B - V_G + C\}$. There are three PSNE:

i. $P_G = C$, $P_B = C + V_B - V_G$
ii. $P_G = C + 0.01$, $P_B = C + V_B - V_G + 0.01$
iii. $P_G = C + 0.02$, $P_B = C + V_B - V_G + 0.02$

In these equilibria the generic company sets a price close to or slightly higher than the marginal cost, and since customer A values the generic drug more than customer Z values it, firm B makes sure that the price difference between P_B and P_G is no more than the value difference between the brand and generic drugs according to customer A, V_B-V_G.

3.2 PSNE when $V_B > V > V_G > C$

We are looking for a BG equilibrium, so customer A is buying from Firm B, and Z is buying from Firm G. Thus, we have

$$P_G \leq V, \qquad (10a)$$

$$P_B \leq V_B. \qquad (10b)$$

Note that in this case the condition comparing the surpluses of customer A from both firms,

$$V_B - P_B \geq V_G - P_G,$$

will not be binding when V_G-P_G is less than zero.

Now, $NPDHP_B$ implies that Firm B would charge the highest price it can charge provided that it can keep its customer. Thus, if $P_G \geq V_G$, $NPDHP_B$ implies that

$$P_B = V_B. \qquad (11)$$

Then, $NPDHP_G$ implies that

$$P_G = V. \qquad (12)$$

The question is, can we have another type BG PSNE, one in which we have $P_B < V_B$ and $P_G < V$? As the above discussion shows, for this to happen, we need $P_G < V_G$. Then, $NPDHP_G$ would imply that

$$P_G = P_B - 0.01 \quad (13)$$

But we know that then the condition that gives rise to equation (4) will kick in, and we will have

$$P_B = P_G + V_B - V_G \quad (14)$$

The only way that both (13) and (14) will hold is

$$V_B - V_G = 0.01.$$

Since this is a non-generic condition, below we will assume that $V_B - V_G \neq 0.01$. Then, for (11) and (12) to characterize PSNE, we need to check for $NPDLP_B$ conditions.

We want to check the PSNE when $P_B= V_B$, $P_G=V$, When brand company sells to customer A, generic company sells to customer Z

$$V_B-P_B=0 \geq V_G-P_G . \quad (15)$$

Replacing P_B and P_G, we have $V_B-V_B \geq V_G-V$. Since we have $V>V_G$, the inequality is strict.

The profit of Brand Company when it sells to customer A is

$$\Pi_B = (P_B-C)\,(1) = V_B-C$$

The profit of the Generic Company when it sells to customer Z is

$$\Pi_G= (P_G-C)\,(1) = V-C$$

The condition $NPDLP_B$ implies that the Brand Company should not be able to increase its profit by reducing its price. The only way it can increase its profit is by selling to two customers. For that to happen, it should reduce its price to V. Then, we need to check whether $V_B-C < 2V-2C$. This implies, $V_B-V< V-C$. So, for this to be a BG equilibrium, we need

$$V_B – V \geq V – C \qquad (16)$$

This condition does *not* necessarily hold. And, when it does not hold, the brand company benefits from reducing its price to V.

Now, we also need to check for the generic company, i.e., $NPDLP_G$. To be able to increase its profit by reducing its price, given that Firm B charges V_B, Firm G should charge $V_G – 0.01$. Thus, for G not to deviate, we need

$$V - C \geq 2(V_G - 0.01 - C)$$

This can be rewritten as,

$$V - V_G \geq V_G - C - .02 \qquad (17)$$

Thus, we need both $V_B – V \geq V - C$ and $V - V_G \geq V_G - C - 0.02$. The above analysis implies the following result.

Proposition 2: When $V_B > V > V_G > C$, if (i) $V_B – V_G$ is not equal to 0.01, (ii) $V_B – V \geq V – C$, and (iii) $V - V_G \geq V_G - C - 0.02$, then the game has a unique BG type PSNE in which $P_B = V_B$, and $P_G = V$.

3.3 Type BG PSNE when $V_B > V_G = V > C$

The analysis of this case turns out to be identical to that of

Case 1. For Type BG equilibria, we must have customer A buying from Firm B (the brand company). Since $V_B > V_G$ so brand company can get higher profit when selling to the customer A, She will do it only when her NCS_B is no less than her NCS_G, formally when $V_B - P_B \geq V_G - P_G$. This condition can be rewritten as,

$$P_B \leq V_B - V_G + P_G. \qquad (18)$$

Now, $NPDHP_B$ implies that Firm B would charge the highest price it can charge provided that it can keep its customer. Thus, equation (18) becomes

$$P_B = V_B - V_G + P_G. \qquad (19)$$

We also know that $P_B > P_G$, otherwise this would not be a Type BG equilibrium. From (19), we have $P_B > P_G$. Finally, we should have $P_G \geq C$, otherwise Firm G could simply choose not to produce and increase its profit (by cutting its loss).

On the other hand, $NPDLP_B$ implies that by reducing its price to P_G (because this is the only way for Firm B to sell to Consumer Z), Firm B should not be able to increase its profit. Formally, $(P_B - C)(1) \geq (PG - C)(2)$. Using equation (19), we have $(V_B - V_G + P_G - C)(1) \geq (PG - C)(2)$, which can be further simplified as,

$$V_B - V_G + C \geq P_G \quad (20)$$

Next, we should consider the implications of $NPDHP_G$ and $NPDLP_G$. First, note that, since Firm G is selling to Z in this Type BG equilibrium, we must have $P_G = V$. By equation (20), P_B is higher than P_G. Thus, $NPDHP_G$ implies that

$$P_G = V. \quad (21)$$

Thus, combining the last two equations we know that when $V_B > V_G = V$, for a Type BG equilibrium to exist we need

$$V \leq V_B - V_G + C. \quad (22)$$

Likewise, by reducing its price (and, by selling its drug to Customer A), Firm G should not be able to increase its profit. Firm G makes a profit of $(P_G - C)$ in a Type BG equilibrium, and by reducing its price slightly it would make a profit of $(P_G - C - .01)(2)$ when $V_B > V_G = V$. Thus, we must have

$$C + .02 \geq P_G. \quad (23)$$

Since we have $P_G = V$, see equation (21), we must have

$$V \leq \min\{C + 0.02, V_B - V_G + C\}. \quad (24)$$

Note that the above equation is a condition on the parameters of the model, i.e., the equilibrium exists only if the value of the good is not too high for Z. The above analysis implies the following result.

Proposition 3: When $V_B > V_G = V > C$, if $V \leq \min\{C + 0.02, V_B - V_G + C\}$ then there exists three type BG PSNE. These are as follows:

i. $P_G = C$, $P_B = C + V_B - V_G$
ii. $P_G = C + .01$, $P_B = C + V_B - V_G + .01$
iii. $P_G = C + .02$, $P_B = C + V_B - V_G + .02$

In this equilibrium generic company sets a price close to or slightly higher than the marginal cost, and since customer A values the generic drug more than customer Z value it, firm B make sure that the price different between P_B and P_G is no more than the value difference between the brand and generic drugs according to customer A, V_B-V_G.

CHAPTER 4
NUMERICAL EXAMPLES OF PSNE

This section will present numerical examples to illustrate the equilibria calculated in the theoretical part above. Assume that customer A values the brand drug at 1, while customer Z value both brand and generic drugs at .5, the marginal cost of the output is .25. Lets present the PSNE for the following values of V_G

(i) $V_G = 0.26$

(ii) $V_G = 0.75$

(iii) $V_G = 0.5$

4.1. $V_B > V > V_G > C$, $V_G = .26$

Lets first check whether the required inequalities

(i) $V_B - V_G$ is not equal to 0.01

(ii) $VB - V \geq V - C$

(iii) $V\text{-}VG \geq VG - C - 0.02$

are satisfied.

We have,

(I) $V_B - V_G = 1 - .26 \neq .01$

(II) $VB - V \geq V - C \quad 1 - .05 \geq .5 - .25$

$.5 \geq .25$

(III) $V\text{-}VG \geq VG - C - 0.02 \quad .5 - .26 \geq .26 - .25 - 0.02$

$.24 \geq -.01$

All condition match so our PSNE is $P_B = 1$, $P_G = .5$

4.2 $V_B > V_G > V > C$, $V_G = .75$

For these values, our conditions become as follows.

NS_A: $V_B - P_B \geq V_G - P_G$

$P_B \leq 1 - .75 + P_G$

$P_B^* \leq .25+P_G$

NPDHP$_B$: $P_B = V_B - V_G + P_G$.

$P_B^* = .25+P_G$

NPDLP$_B$: $(P_B - C)(1) \geq (P_G - C)(2)$

$(P_G+.25 - C)(1) \geq (P_G - C)(2)$

$.5 \geq P_G$

For Customer Z to buy from the generic firm the net customer surplus should be higher:

$V_G - P_G > V_B - P_B$

$P_B > P_G + .5$

NPDHP$_G$: $V \leq V_B - V_G + C$

$P_G = V = .5$

NPDLP$_G$: $(P_G - C) \geq (P_G - C - .01)(2)$

$.25+.02 \geq P_G^*$

Thus, we have $P_B = .25+P_G$, $P_G^* \leq .02+C$, three type BG Nash equilibria are as follows:

i. $P_G = .25$, $P_B = .5$
ii. $P_G = .26$, $P_B = .51$
iii. $P_G = .27$, $P_B = .52$

4.3 $V_B > V_G = V > C$, $V_G = .5$

In this case, the theoretical inequalities and conditions becomes as follows.

NCS$_A$: $V_B - P_B \geq V_G - P_G$

$P_B^* \leq .5+P_G$

$NPDHP_B$: $P_B^* = .5 + P_G$

$NPDLP_B$: $(P_B - C)(1) \geq (P_G - C)(2)$.

$(.5 + P_G - C)(1) \geq (P_G - C)(2)$

$.75 \geq P_G$

$NPDHP_G$: $P_G \leq V_B - V_G + C$

$P_G \leq .75$

$NPDLP_G$: $(P_G - C) \geq (P_G - C - .01)(2)$

$.27 \geq P_G^*$

Therefore we have $P_B^* = .5 + PG$, $P_G^* \leq .27$, our Nash equilibrium for this case are

i. $P_G = .25$, $P_B = .75$
ii. $P_G = .26$, $P_B = .76$
iii. $P_G = .27$, $P_B = .77$

CHAPTER 5
CONCLUSION

In this thesis, we studied a version of Evrenk (2019) with discrete prices. As speculated in there, we found that there exists a PSNE for the case in which the value of the generic good for the non-discriminator consumer is less than or equal to its value for the discriminator consumer. The equilibrium exists only when the value of the generic good for the non-discriminator consumer is close to the marginal cost. In such equilibrium the Brand firm does not charge a price that extracts all the surplus possible form the discriminator consumers. The equilibria in other cases were identical to the equilibria found in the continuous prices found in Evrenk (2019).

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CURRICULUM VITAE

Personal Information:

First Name: Nour
Last Name: Alzaza
E-mail (1): Nouralzaza@std.sehir.edu.tr
E-mail (2): Pharma_91@yahoo.com

Education:

2009-2014 ……………… Bachelors in pharmacy, Amman Ahlie University, Jordan.

2018 – 2019 …………… Master's in Business Administration, Istanbul Sehir University, Turkey.

Work Experience:

2014 - 2018 ……………… Pharmacist .

2014 -2017 …………….. Logistic and purchasing officer .