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Price and Quantity Competition under Vertical Pricing

Debasmita Basak [1,2]

[1] Nottingham University Business School, University of Nottingham, Jubilee Campus, Wollaton Road, Nottingham NG8 1BB, UK; debasmita.basak@nottingham.ac.uk; Tel.: +44-115-748-4090; Fax: +44-115-846-6667
[2] UNEC Energy Economics Centre, Azerbaijan State University of Economics, Baku AZ1001, Azerbaijan

Abstract: We consider a vertically related market where one quantity-setting and another price-setting downstream firm negotiate the terms of a two-part tariff contract with an upstream input supplier. In contrast to the traditional belief, we show that the price-setting firm produces a higher output and earns a higher profit than the quantity-setting firm when bargaining is decentralised. Additionally, both firms produce the same output, whereas the profit is higher under the price-setting firm than the quantity-setting firm when bargaining is centralised.

Keywords: bargaining; Bertrand; Cournot; two-part tariffs; vertical pricing

JEL Classification: D43; L13; L14

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1. Introduction

In a seminal paper, Singh and Vives [1] show that in a competitive input market, firms' profits are higher (lower) under Cournot compared to Bertrand competition when the goods are substitutes (complements). They further show that choosing a quantity (price) contract is the dominant strategy for both firms when the goods are substitutes (complements). Since Singh and Vives [1], there has been a significant amount of work that has extended and generalised the results in various ways. For example, Cheng [2] and Vives [3] expanded upon these findings by utilising a geographic approach and examining the case of an oligopoly model with multiple firms and general demand functions. In contrast, Dastidar [4] and Häckner [5] highlighted the sensitivity of the results in Singh and Vives' [1] work to the specific sharing rules governing oligopoly and the type of product differentiation.

While the above studies in oligopoly theory exclusively focus on either quantity (Cournot) or price (Bertrand) competition, mixed competition (i.e., Cournot–Bertrand) has gained prominence in recent years. Considering a setting where one firm participates in quantity competition and the other firm engages in price competition, Tremblay and Tremblay [6] demonstrate that both Cournot- and Bertrand-type firms coexist when the products are sufficiently differentiated. However, in the absence of differentiation, only the Cournot-type firm survives, resulting in a perfectly competitive outcome. In a similar context, Semenov and Tondji [7] find that the firm setting quantities earns higher profit than its rival that sets prices when both firms invest in cost reducing R&D. Both of these studies, however, assume a perfectly competitive input market. However, in reality, it is often the case that input suppliers and the final goods producers engage in two-part tariff vertical pricing contracts. They are commonly observed in the bottled water industry (Bonnet and Dubois, [8] and [9]) and the yogurt industry (Berto Villa-Boas, [10]). This brings us to an important consideration that we address in this paper.

It would be logical at this point to draw some connections between our framework and real-life examples. For example, in the small car industry, which encompasses multiple levels of the supply chain, Honda and Subaru set quantities while Saturn and Scion set prices (Tremblay et al. [11]) [1]. Flath [12] shows that in 30 out of 70 Japanese industries, companies use some form of mixed competition. Sato [13] argues that in the Japanese home electronics industry, Matsushita adopts a quantity strategy whereas Sanyo employs a pricing strategy.

Given this backdrop, we consider a vertical structure where one quantity-setting and another price-setting downstream firm negotiate the terms of two-part tariff contract with an upstream firm either through decentralised or centralised bargaining. We formulate a demand function that accounts for both Bowley [14] type and Shubik and Levitan [15] type demand functions and hence measures the degree of market saturation. Our results show that when bargaining is decentralised, the price-setting firm produces more and earns a higher profit than the quantity-setting firm, whereas when bargaining is centralised, both firms produce the same output but the price-setting firm earns a higher profit. Our results hold both under Bowley [14] type and Shubik and Levitan [15] type demand function. This is in stark contrast to the existing results alluded to earlier.

Our work complements the literature on contracting in vertically related markets that predominantly focuses on the quantity and price competition. Arya [16] found that when a retail competitor acquires an essential input from a vertically integrated provider, price competition can lead to higher retail prices and industry profit. Mukherjee et al. [17] demonstrated that in a vertical structure with a profit-maximising upstream firm, the profitability in the downstream market under Bertrand or Cournot competition depends on the technological differences between the downstream firms and the pricing strategy employed by the upstream firm. Alipranti et al. [18] showed that when a monopoly input supplier and two final goods producers determine the two-part tariff vertical pricing contracts through a decentralised generalised Nash bargaining process, the equilibrium profits of the final goods producers and social welfare are higher under Cournot competition. In a similar setting, albeit with centralised bargaining, Basak and Wang [19] reveal that Cournot competition results in higher output, lower wholesale prices, lower final prices. Manasakis and Vlassis [20], and Chirco and Scrimitore [21] have also addressed the Cournot–Bertrand debate in the context of unionised market and network industry, respectively, although their findings mostly align with the results of Singh and Vives [1].

In contrast, our study addresses the novel issue of mixed competition, where one firm engages in quantity competition while its rival competes on prices, under a non-linear two-part tariff contract that takes the form of either decentralised or centralised bargaining. By exploring this aspect, our work offers valuable insights on the previous line of research.

The rest of the paper is organised as follows. Section 2 presents the model and discusses the main results under decentralised and centralised bargaining, respectively. Section 3 concludes the paper. All proofs are relegated to Appendix A.

2. The Model

We consider an economy with two downstream firms, denoted by D_i producing differentiated products where $i, j = 1, 2$ and $i \neq j$. The downstream firms require a critical input for production that they purchase from a monopoly input supplier, U, through two-part tariff contracts involving an up-front fixed-fee and a per-unit price. U produces the inputs at a constant marginal cost of production, $c \geq 0$. We assume that one unit of input is required to produce one unit of the output, and D_i and D_j can convert the inputs to the final goods without incurring any further cost.

We consider a demand equation that combines the demand functions found in Bowley [14] and Shubik and Levitan [15]. The difference between the two approaches is the degree of the market-expansion effect. While in Bowley's [14] formulation of demand function the aggregate market size increases with a higher degree of product substitutability, the formulation by Shubik and Levitan [15] reveals that the aggregate market size is independent of the degree of product substitutability. We represent the inverse demand function as:

$$P_i = a - \theta q_i - \gamma q_j \tag{1}$$

where P_i denotes the price and q_i denotes the output of ith downstream firm where $i, j = 1, 2$ and $i \neq j$. We take $\gamma \in (0, 1)$ to denote the degree of product differentiation. The parameter $\theta = 1 + \sigma(1 - \gamma)$ measures the degree of market expansion, where the upper boundary, $\sigma = 1$, corresponds to no market expansion effect, i.e., the market is saturated as in Shubik and Levitan [15] and the lower boundary, $\sigma = 0$, corresponds to full market expansion as in Bowley [14]. If $\gamma = \theta = 1$, the goods are perfect substitutes and if $\gamma = 0$ the goods are isolated.

We develop a model of two stage game. At stage 1, U is involved either in a decentralised bargaining or centralised bargaining with D_1 and D_2 to determine the terms of the two-part tariff contracts involving an up-front fixed-fee, F_i, and a per-unit price, w_i, $i = 1, 2$. At stage 2, D_1 competes in quantity and D_2 competes in price. We solve the game through backward induction.

2.1. Market Competition Stage

We begin our discussion at stage 2 where D_1 chooses quantity and D_2 chooses price. The maximisation problem of the downstream firms yields

$$\underset{q_1}{\text{Max}} \quad \Pi_1^D = \pi_1 - F_1$$

$$= \left[a - \theta q_1 - \frac{\gamma}{\theta}(a - P_2 - \gamma q_1) - w_1\right] q_1 - F_1 \tag{2}$$

And,

$$\underset{P_2}{\text{Max}} \quad \Pi_2^D = \pi_2 - F_2$$

$$= \frac{1}{\theta}(P_2 - w_2)(a - P_2 - \gamma q_1) - F_2 \tag{3}$$

Maximising (2) and (3) and solving the first order conditions give the equilibrium quantity and price of D_1 and D_2, respectively.

$$q_1 = \frac{a(\gamma - 2\theta) + 2\theta w_1 - \gamma w_2}{3\gamma^2 - 4\theta^2} \tag{4}$$

$$P_2 = \frac{a(\gamma - \theta)(\gamma + 2\theta) - \gamma\theta w_1 + 2(\gamma^2 - \theta^2) w_2}{3\gamma^2 - 4\theta^2} \tag{5}$$

Hence, the profit Equations in (2) and (3) reduce to $\prod_1^D = \left(\frac{\theta^2 - \gamma^2}{\theta}\right) q_1^2 - F_1$ and $\prod_2^D = \theta q_2^2 - F_2$.

Next, we solve stage 1 of the game where the equilibrium contract terms are determined. We begin our discussion with decentralised bargaining and discuss the equilibrium outcomes. We repeat the same exercise under centralised bargaining in a subsequent section. For notational reasons, we use superscripts $\{d, r\}$ to denote, respectively, the equilibrium values under decentralised and centralised bargaining.

Decentralised bargaining is commonly observed in Germany, Sweden, the Netherlands and Italy. Conversely, centralised bargaining is prevalent in most continental European countries, such as Germany (Hirsch et al. [22]). In the context of strategic input-price determination, Calmfors and Driffill [23], and Danthine and Hunt [24] argue that collective bargaining is more widely accepted as it internalises various negative externalities, such as unemployment. For this reason, we examine scenarios where the downstream firms engage in both decentralised and centralised bargaining with an upstream input supplier to determine the equilibrium input price.

2.2. Decentralised Bargaining

First, assume decentralised bargaining, where U bargains simultaneously and separately with D_i over (w_i, F_i). It is well-known that as the bargaining parties dispose of two instruments, they use w_i to maximise their excess joint surplus and F_i to apportion the maximised excess joint surplus to the two parties according to their bargaining powers (see, Milliou and Petrakis, [25]; Rey and Vergé, [26]). In particular, w_i and F_i are determined by maximising the following generalised Nash bargaining expression:

$$\underset{F_i, w_i}{\text{Max}} \quad [(w_i - c)q_i + F_i]^{\beta}[\pi_i - F_i]^{1-\beta} \tag{6}$$

where $(w_i - c)q_i + F_i$ and $(\pi_i - F_i)$ denote, respectively, the net profit of the upstream and downstream firms and β (resp. $(1-\beta)$) shows the bargaining power of the input supplier (resp. final goods producers). We restrict our analysis to $\beta \in (0, 1)$.

Maximising the above with respect to F_i gives the following:

$$F_i = \frac{1}{2}[\beta\pi_i - (1-\beta)(w_i - c)q_i] \tag{7}$$

Substituting (7) in (6), we obtain the maximisation problem as

$$\underset{w_i}{\text{Max}} \quad [\beta(\pi_i + (w_i - c)q_i)]^{\beta}[(1-\beta)(\pi_i + (w_i - c)q_i)]^{1-\beta} \tag{8}$$

Solving (8), we obtain the equilibrium wholesale prices and fixed fees as [2]

$$w_1^d = c + \frac{(a-c)\gamma^2(\theta-\gamma)[(2\theta+\gamma)(2\theta-\gamma)+2\gamma\theta]}{10\theta^3(\theta+\gamma)(\theta-\gamma)+5\theta(\theta^2-\gamma^2)^2+\theta^5} \tag{9}$$

$$w_2^d = c - \frac{(a-c)\gamma^2[\theta^2+(\theta-\gamma)(3\theta+\gamma)]}{10\theta^2(\theta+\gamma)(\theta-\gamma)+5(\theta^2-\gamma^2)^2+\theta^4} \tag{10}$$

$$F_1^d = \frac{2(a-c)^2(\gamma-\theta)^2(\gamma^2-2\gamma\theta-4\theta^2)^2[\beta(2\theta^2-\gamma^2)-\gamma^2]}{\theta(5\gamma^4-20\gamma^2\theta^2+16\theta^4)^2} \tag{11}$$

$$F_2^d = \frac{(a-c)^2(\gamma^2+2\gamma\theta-4\theta^2)^2[\theta^2+(\theta+\gamma)(\theta-\gamma)][\gamma^2+2\beta(\theta+\gamma)(\theta-\gamma)]}{\theta(5\gamma^4-20\gamma^2\theta^2+16\theta^4)^2} \tag{12}$$

Using the above, we derive the equilibrium outputs and the profits of the downstream firms

$$q_1^d = \frac{2(a-c)(\gamma-\theta)(\gamma^2-2\gamma\theta-4\theta^2)}{5\gamma^4-20\gamma^2\theta^2+16\theta^4};\ q_2^d = \frac{(a-c)(\gamma^2+2\gamma\theta-4\theta^2)(\gamma^2-2\theta^2)}{5\gamma^4\theta-20\gamma^2\theta^3+16\theta^5}$$

$$\prod_1^{D,d} = \frac{2(a-c)^2(1-\beta)(\gamma-\theta)^2(\gamma^2-2\gamma\theta-4\theta^2)^2(2\theta^2-\gamma^2)}{\theta(5\gamma^4-20\gamma^2\theta^2+16\theta^4)^2}$$

$$\prod_2^{D,d} = \frac{2(a-c)^2(1-\beta)(\gamma^2-\theta^2)(\gamma^2+2\gamma\theta-4\theta^2)^2(\gamma^2-2\theta^2)}{\theta(5\gamma^4-20\gamma^2\theta^2+16\theta^4)^2}$$

The following results are immediate from the above.

Proposition 1. *(i) The upstream firm charges a lower input price to the price-setting downstream firm than a quantity-setting downstream firm such that* $w_2^d < c < w_1^d$.

(ii) The price-setting downstream firm produces a higher output and earns a higher profit than the quantity-setting downstream firm.

Note that the price-setting downstream firm is charged a wholesale price which is less than the upstream firm's marginal cost, i.e., U subsidises the price-setting firm's production. As a result, the price-setting firm, D_2 sets a lower market price which in turn reduces the quantity-setting firm, D_1's output and increases its own profit. This increased profit is then partly transferred to the upstream firm via the fixed fee. The opposite is true for the quantity-setting downstream firm D_2, hence it is charged a wholesale price above U's marginal cost.

As the price-setting downstream firm faces substantially lower wholesale prices, naturally, it produces more and earns higher profits than its quantity-setting rival.

2.3. Centralised Bargaining

Now, assume that bargaining is centralised. In this case, the monopoly input supplier U is involved in a bargaining with a representative of D_1 and D_2 to determine the terms of the two-part tariff contracts involving an up-front fixed-fee, F_i, and a per-unit price. They maximise the following generalised Nash bargaining expression:

$$\underset{F_i,w_i}{\text{Max}} \quad \left[\sum_{i=1}^{2}((w_i-c)q_i+F_i)\right]^{\beta}\left[\sum_{i=1}^{2}(\pi_i-F_i)\right]^{1-\beta} \tag{13}$$

where, $\sum[(w_i-c)q_i+F_i]$ and $\sum(\pi_i-F_i)$ denote, respectively, the total profit of the upstream and downstream firms and β (resp. $(1-\beta)$) shows the bargaining power of the input supplier (resp. final goods producers). Maximising the above with respect to F_i gives the following:

$$F_i=\frac{1}{2}\left[\beta\sum_{i=1}^{2}\pi_i-(1-\beta)\sum_{i=1}^{2}(w_i-c)q_i\right] \tag{14}$$

Substituting (14) in (13), we obtain the maximisation problem as

$$\underset{w_i}{\text{Max}} \quad \left[\beta\sum_{i=1}^{2}(\pi_i+(w_i-c)q_i)\right]^{\beta}\left[(1-\beta)\sum_{i=1}^{2}(\pi_i+(w_i-c)q_i)\right]^{1-\beta} \tag{15}$$

Solving (15), we obtain the equilibrium wholesale prices and fixed fees as [3]

$$w_1^r=c+\frac{(a-c)\gamma}{2\theta} \tag{16}$$

$$w_2^r=c+\frac{(a-c)\gamma}{2(\gamma+\theta)} \tag{17}$$

$$F_1^r=F_2^r=\frac{(a-c)^2\left[2\beta\theta^2-\gamma^2-2(1-\beta)\gamma\theta\right]}{8\theta(\gamma+\theta)^2} \tag{18}$$

Next, we calculate the equilibrium outputs and the profits of the downstream firms

$$q_1^r=q_2^r=\tfrac{a-c}{2(\gamma+\theta)};\ \prod_1^{D,r}=\tfrac{(a-c)^2\left[2(1-\beta)\gamma\theta+2(1-\beta)\theta^2-\gamma^2\right]}{8\theta(\gamma+\theta)^2};$$
$$\prod_2^{D,r}=\tfrac{(a-c)^2\left[\gamma^2+2(1-\beta)\gamma\theta+2(1-\beta)\theta^2\right]}{8\theta(\gamma+\theta)^2}$$

Comparing the above, we obtain the following.

Proposition 2. *(i) The upstream firm charges a lower input price to the price-setting downstream firm than a quantity-setting downstream firm such that* $c<w_2^r<w_1^r$.

(ii) The price-setting downstream firm and the quantity-setting downstream firm produce the same level of output.

(iii) The price-setting downstream firm earns a higher profit than the quantity-setting downstream firm.

As the upstream firm becomes more opportunistic when bargaining is centralised, it no longer subsidises the price-setting downstream firm's production. However, analogous to Proposition 1(i), it still charges a lower input price to the price-setting firm compared to the quantity-setting firm.

To analyse Proposition 2(ii), let us recall Equation (15). Note that,

$$\sum_{i=1}^{2}[\pi_i + (w_i - c)q_i] = \sum_{i=1}^{2}[(P_i - w_i)q_i + (w_i - c)q_i] = \sum_{i=1}^{2}(P_i - c)q_i$$

Which is the profit of a monopoly final goods producer, producing both the products at the marginal cost of production c. Therefore, maximising (15) is equivalent to maximising the profit of a monopoly final goods producer. Hence, it is intuitive that the equilibrium per-unit input prices are such that they generate the same total output and industry profit under Cournot and Bertrand competition. Further, in line with Proposition 1(ii), the price-setting firm earns a higher profit as it faces a lower input price compared to its quantity-setting rival.

3. Conclusions

We consider a vertical structure where one downstream firm sets quantity and another sets price and determine the terms of a two-part tariff contract with an upstream firm either through decentralised or centralised bargaining. We find that when bargaining is decentralised, the price-setting firm produces a higher output and earns a higher profit than its quantity-setting rival, whereas under centralised bargaining, both firms produce the same output but the price-setting firm earns a higher profit. This holds true regardless of the degree of market saturation.

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Appendix A

Proof of Proposition 1:

$$q_1^d - q_2^d = -\frac{(a-c)\gamma^4}{\theta(5\gamma^4 - 20\gamma^2\theta^2 + 16\theta^4)} = -\frac{(a-c)\gamma^4}{(1+\sigma-\gamma\sigma)\left[5\gamma^4 - 20\gamma^2(1+\sigma-\gamma\sigma)^2 + 16(1+\sigma-\gamma\sigma)^4\right]} < 0.$$

$$\begin{aligned}\prod_1^{D,d} - \prod_2^{D,d} &= -\frac{4(a-c)^2(1-\beta)\gamma^5(\gamma-\theta)\left(\gamma^2-2\theta^2\right)}{\theta\left(5\gamma^4-20\gamma^2\theta^2+16\theta^4\right)^2} \\ &= -\frac{4(a-c)^2(1-\beta)(1-\gamma)\gamma^5(1+\sigma)\left[2(1+\sigma-\gamma\sigma)^2-\gamma^2\right]}{(1+\sigma-\gamma\sigma)\left[5\gamma^4-20\gamma^2(1+\sigma-\gamma\sigma)^2+16(1+\sigma-\gamma\sigma)^4\right]^2} < 0.\end{aligned}$$

□

Proof of Proposition 2:

$$w_1^r - w_2^r = \frac{(a-c)\gamma^2}{2\theta(\gamma+\theta)} = \frac{(a-c)\gamma^2}{2(1+\sigma-\gamma\sigma)(1+\gamma+\sigma-\gamma\sigma)} > 0.$$

$$\prod_1^{D,r} - \prod_2^{D,r} = -\frac{(a-c)^2\gamma^2}{4\theta(\gamma+\theta)^2} = -\frac{(a-c)^2\gamma^2}{4(1+\sigma-\gamma\sigma)(1+\gamma+\sigma-\gamma\sigma)^2} < 0.$$

□

Notes

1. The automobile manufacturers rely on the manufacturers for the provision of various components and parts, such as engines, transmissions, or electrical systems that are necessary for the production of the vehicles.
2. Note that $F_1^d < 0$ for $\beta < \frac{\gamma^2}{(2-\gamma^2)+2\sigma(1-\gamma)(2+\sigma-\gamma\sigma)}$ $(=\hat{\beta})$ meaning that the upstream firm subsidises the downstream firm when its bargaining power is small. We, however, assume that $\beta > \hat{\beta}$ so that it charges a positive fixed fee to the final goods producers.
3. Note that $F_i^r < 0$ for $\beta < \frac{\gamma[2+\gamma+2\sigma(1-\gamma)]}{2(1+\sigma-\gamma\sigma)(1+\gamma+\sigma-\gamma\sigma)}$ $(=\overline{\beta})$ meaning that the upstream firm subsidises the downstream firm when its bargaining power is small. We, however, assume that $\beta > \overline{\beta}$ so that it charges a positive fixed fee to the final goods producers.

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