Endogenous Choice of Price or Quantity Contract with Upstream RD Investment: Linear Pricing and Two-part Tariff Contract with Bargaining

Lee, DongJoon and Choi, Kangsik and Nariu, Tatsuhiko

Nagoya University of Commerce and Business, Pusan National University, Kyoto University

22 July 2016

Endogenous Choice of Price or Quantity Contract with Upstream R&D Investment: Linear Pricing and Two-part Tariff Contract with Bargaining

DongJoon Lee*
Faculty of Management, Nagoya University of Commerce and Business

Kangsik Choi†
Graduate School of International Studies, Pusan National University

Tatsuhiko Nariu‡
Graduate School of Business and Administration, Kyoto University

This version: 22 July 2016

Abstract

We investigate the endogenous choice of strategic variable (a price or a quantity) by downstream firms in a two-tier industry in which an upstream firm performs the R&D investment. We show that when the upstream firm offers either linear discriminatory or uniform input price, it is a dominant strategy for each downstream firm to choose Bertrand competition when two products become relatively differentiated. Second, from the viewpoint of downstream firms, we show that Bertrand competition is more efficient than Cournot competition in some boundaries of Cournot equilibrium, which implies that each downstream firm faces a prisoners' dilemma under the Cournot equilibrium. However, when the downstream firms involve in centralized bargaining with an upstream firm to determine the two-part tariff discriminatory (uniform) input pricing contracts, we find that choosing price (quantity) contract is the dominant strategy for downstream firms. In this case, we further show that the level of social welfare is the same regardless of the mode of product market competition (i.e., Bertrand or Cournot).

JEL Classification: D43, L13, M21.
Keywords: Endogenous Choice, Bertrand competition, Cournot competition, Upstream Investment, Bargaining

*Faculty of Management, Nagoya University of Commerce and Business, 4-4 Sagamine, Komenoki-cho Nissin-shi, Aichi 470-0913, Japan. Tel:+81-561-73-2111, Fax:+81-561-73-1202, E-mail: dongjoon@nucba.ac.jp.

†Corresponding author. Graduate School of International Studies, Pusan National University, Busandaehak-ro 63 beon-gil 2, Geumjeong-gu, Pusan 46241, Republic of Korea. Tel:+82-51-510-2532, Fax:+82-51-581-7144, E-mail: choipnu@pusan.ac.kr.

‡Graduate School of Business and Administration, Kyoto University, Yoshidahonmachi, Sakyo-ku, Kyoto 606-8501, Japan. Tel:+81-75-753-3481, Fax:+81-75-753-3492, E-mail: nariu@econ.kyoto-u.ac.jp.

1 Introduction

It is well known that Bertrand and Cournot competition are two classical models in the theory of oligopoly. What are the effects of Bertrand and Cournot competition on profit and welfare? In a seminal work, Singh and Vives (1984) show that both firms earn higher profits under Cournot than under Bertrand competition, while social welfare is higher under Bertrand than under Cournot competition. Also, they show that adopting quantity (price) contract is a dominant strategy for both firms if the goods are substitutes (complements). However, it has received little attention to the endogenous choice of strategic variable, either price or quantity, in a vertically related market. Hence, we revisit the endogenous choice of strategic variable, either price or quantity, in a vertically related market in which an upstream monopolist undertakes cost reducing R&D investment.

An anecdotal evidence of our analysis is as follows. Most commonly, an upstream firm sells its product to downstream firms, who then sell it to consumers. In such a market, R&D investment by the upstream firm inevitably affects the profits of the downstream firms. The upstream firm undertakes investments in R&D, which leads to low input prices for the downstream firms. For example, over the last 40 years, Intel, which provides CPUs for many computer companies, has exploited opportunities in CPUs with a prime concern. Pursuing maximal profits for each new generation of CPUs was always a key priority, with goals of minimizing costs and reducing prices. Intels CEO, Paul Otellini, announced that R&D investment was a blueprint for Intel to maintain its technology leadership and competitive advantage.

The work by Singh and Vives (1984) has been extended in two separate streams. One stream focuses on comparisons of the profits and social welfare in Bertrand and Cournot Equilibrium. The other stream focuses on the endogenous choice of strategic variable, either price or quantity. The first framework that focuses on extensions and generalizations of their study, for example, Dastidar (1997), Lambertini (1997), Hackner (2000), Amir and Jin (2001), and Zanchettin (2006), shows the counter-results of the first stream by allowing for cost and demand asymmetry.[1] Qiu (1997) shows that Cournot competition yields a higher level of cost-reducing investment than Bertrand. He also shows that Cournot competition is more efficient than Bertrand when products are close substitutes, high investment efficiency and large investment spillover.[2] For a vertically related market, there are Correa-Lopez and Naylor (2004), Arya et al. (2008), Mukherjee et al. (2012), Alpranti et al. (2014), and Lee and Choi (2015), among others. They also compare Bertrand with Cournot by introducing cost

[1]Cheng (1985) and Vives (1985) generalize these results, respectively, by explaining a graphical description and by considering the n-firm oligopolistic case. Okuguchi (1987) points out the sensitivity of the results in Singh and Vives (1984). Dastidar (1997) shows that Bertrand equilibrium prices may not be lower than Cournot equilibrium price under the equal sharing rule with asymmetric costs.

[2]Symeonidis (2003) finds that quality is higher under Cournot competition than under Bertrand, and that output, consumer surplus and social welfare are higher under Cournot competition than under Bertrand if R&D spillovers are large and products are not too differentiated. See also Lin and Saggi (2002), Breton et al. (2004) and Hinloopen and Vandekerckhove (2009).

reducing R&D investment, unionized market, technological differences, and two-part tariff contracts, and so on.

Correa-Lopez and Naylor (2004) shows that Bertrand profits may exceed Cournot profits when decentralized bargaining over labor cost is introduced. Arya et al. (2008) examine how the standard conclusions about Bertrand and Cournot competition can alter when the production of a key input is outsourced to a vertically integrated retail competitor. They show that Bertrand competition leads to higher prices, higher industry profits, lower consumer surplus, and lower total surplus than Cournot competition. Mukherjee et al. (2012) compare Bertrand and Cournot competition in a vertical structure. They show that downstream firms' profits depend on the technological differences between downstream firms. Alipranti et al. (2014) compare Bertrand and Cournot competition in a vertical structure in which the upstream firm bargains with each downstream firm via two-part tariff contracts. Alipranti et al. (2014) show that Cournot competition yields higher output (or lower price), consumers' surplus, and total welfare than Bertrand competition. Lee and Choi (2015) compare Bertrand with Cournot competition in a vertically related market in which an upstream monopolist invests in cost reducing R&D. They show, from the viewpoint of downstream firms, a trade-off between monopolistic (i.e., less competitive) effect and lower wholesale price effect induced by upstream investment. They investigate that Bertrand profit is higher than Cournot profit when the first effect is overwhelmed by the second effect.

Another stream addresses the endogenous choice of strategic variable. During the past 30 years, there exist a few papers examining the counter-results of the endogenous choice of strategic variable, either price or quantity contract. The framework that focuses on the endogenous choice of strategic variable, for example, Correa-Lopez (2007), Basak and Wang (2016), Choi (2012), and Matsumura and Ogawa (2012), reveal the counter-results of the second stream. Correa-Lopez (2007) shows that it may be a dominant strategy for each firm to choose the price competition, when both products are sufficiently substitutive and the wage is the result of decentralized firm-union bargain. Basak and Wang (2016) also consider the endogenous choice of strategic variable in a vertically related market in which an upstream firm proposes two-part tariff contracts to its downstream firms. They find that it may be a dominant strategy for each downstream firm to choose Bertrand competition when the input price is determined by the result of Nash bargaining contract. On the other hand, Choi (2012) and Matsumura and Ogawa (2012) show the counter-results of the conventional wisdom in a mixed duopoly.

Our paper also shows the counter-results of the conventional wisdom about the endogenous choice of strategic variable. Our result is in stark contrast with the existing literature. Even though the above mentioned papers hold the same result with Singh and Vives (1984), these papers analyze the endogenous choice of strategic variable in different environment and game, for example, Nash bargaining game and mixed duopolistic environment. However, we follow the Singh and Vives's traditional approach.

Our paper investigates the endogenous choice of strategic variable, either price or quantity, in a vertical related market in which an upstream monopolist undertakes cost reducing R&D investments. We show, from the standpoint of downstream firms when the upstream firm offers either linear discriminatory or uniform input price, that they are confronted by a trade-off between monopolistic effect (i.e., less competitive effect) and lower input price effect. Hence, it is a dominant strategy for each downstream firm to choose price competition when the first effect is overwhelmed by the second effect. Second, from the standpoint of downstream firms when the upstream firm offers either linear discriminatory or uniform input price, even though Bertrand competition is more efficient than Cournot competition, both downstream firms will choose Cournot competition in some boundaries (i.e., prisoner's dilemma). However, when the downstream firms involve in centralised bargaining with an upstream firm to determine the two-part tariff discriminatory (uniform) input pricing contracts, we find that choosing price (quantity) contract is the dominant strategy for downstream firms. In this case, we further show that the level of social welfare is the same regardless of the mode of product market competition (i.e., Bertrand or Cournot).

The remainder of the paper is organized as follows. In Section 2, we set up the model. Section 3 examines three games (Cournot, Bertrand, and Asymmetry Game). In Section 4, we present our main results. In Section 5, we give some concluding remarks.

2 The Model

In this section, we describe the basic notation and common elements of the models to be examined in the remainder of the paper. Consider an economy with two differentiated final goods producers, downstream firms D_1 and D_2. These firms require a critical input, which is produced by upstream firm U. We assume that the representative consumers utility is a quadratic function given by

$$CU = a(q_i + q_j) - \frac{q_i^2 + q_j^2 + 2dq_iq_j}{2} + m; i, j = 1, 2, i \neq j,$$

where q_i denotes the output of downstream firm $i(i = 1, 2)$ and m is the numeraire good. Parameters a is positive constant and $d \in (0, 1)$ represents the degree of product differentiation:[3] a smaller d indicates a larger degree of product differentiation. Hence, consumers' inverse and direct demands for D_i's final good are:

$$p_i = a - q_i - dq_j \text{ and } q_i = \frac{a(1-d) - p_i + dp_j}{1 - d^2}; i, j = 1, 2, \ i \neq j, \tag{1}$$

[3]See Singh and Vives (1984) for details regarding the derivation of the demand functions from the representative consumer's utility maximization problem

where p_i is D_i's price.

The marginal cost for the upstream firm is $\max[0, c - x]$, where c is the initial marginal cost and x is the cost reduction undertaken as a result of investment by the upstream firm. To simplify, assume that the investment cost is given by $\frac{vx^2}{2}$, where the parameter $v > 0$ relates to investment efficiency. Thus, we assume that the upstream firm produces one input and sells it at one price. For simplicity, one unit of the final product needs exactly one unit of the input and the cost of transforming the input into the final product is normalized to zero.

We posit a four-stage game. In the first stage, each downstream firm simultaneously and independently chooses the type of the binding contract to offer consumers. There are two possible types of contract: the quantity contract and the price contract. In the second stage, the upstream firm sets the investment level (x). In the third stage, the upstream firm sets the input price (w). Finally, in the fourth stage, two downstream firms make its optimal level of their strategic variable contingent on the type of contract committed at stage one.

3 Equilibrium Outcomes under Linear Uniform Input Pricing

We solve a sub-game perfect Nash equilibrium through backward induction.

3.1 Cournot Competition with Linear Uniform Input Pricing

At stage four, downstream firm D_i chooses q_i in order to maximize its profits for given the input price w, and the rival's quantity q_j. The downstream firm D_i's maximization problem is as follows:

$$\max_{q_i} \pi_i(w, q_i, q_j) = (p_i - w)q_i = (a - q_i - dq_j - w)q_i.$$

The resulting reaction functions are

$$q_i(w, q_j) = \frac{a - w - dq_i}{2}. \tag{2}$$

Note that the decrease in the input price charged to D_i shifts out its reaction function and turns it into a more aggressive downstream competitor. Solving the reaction functions (2), we obtain the quantities in terms of the input price w as follows:

$$q_i(w) = \frac{a - w}{2 + d}.$$

At stage three, it is straightforward to derive the equilibrium payoff for the upstream firm and the upstream firm's maximization problem is as follows:

$$\max_{w} \Pi(x, w) = (w - c_0)(q_i + q_j) - \frac{vx^2}{2} = \frac{2(a - w)(w - c + x)}{2 + d} - \frac{vx^2}{2},$$

where $c_0 = c - x$. The equilibrium input price for the upstream firm is as follows:

$$w(x) = \frac{a + c_0}{2}.$$

At stage two, the upstream firm sets its investment level (x) so as to maximize its profit. The upstream firms maximization problem is as follows:

$$\max_x \Pi(x) = (w - c_0)(q_i + q_j) - \frac{vx^2}{2} = \frac{(a - c_0)^2}{2(2 + d)} - \frac{vx^2}{2}.$$

If $v > \frac{a}{(2+d)c}$, the equilibrium investment is derived as follows:

$$x^C = \frac{a - c}{(2 + d)v - 1}, \tag{3}$$

where the superscript "C" denotes Cournot competition. Note that the second-order condition is $v > \frac{1}{2+d}$ for Cournot competition.

We obtain the equilibrium input price (w^C), quantities ($q_i^C = q_j^C$), prices ($p_i^C = p_j^C$), upstream firm's profit Π^C, and downstream firms' profit ($\pi_i^C = \pi_j^C$):

$$w^C = c + \frac{(a - c)[(2 + d)v - 2]}{2[(2 + d)v - 1]}, \quad q_i^C = \frac{(a - c)v}{2[(2 + d)v - 1]}, \tag{4}$$

$$p_i^C = c + \frac{(a - c)[(3 + d)v - 2]}{2[(2 + d)v - 1]}, \quad \Pi^C = \frac{(a - c)^2 v}{2[(2 + d)v - 1]}, \quad \pi_i^C = \frac{(a - c)^2 v^2}{4[(2 + d)v - 1]^2}, \tag{5}$$

$$CS^C = \frac{(a - c)^2(1 + d)v^2}{4[(2 + d)v - 1]^2}, \quad SW^C = \frac{(a - c)^2 v[(7 + 3d)v - 2]}{4[(2 + d)v - 1]^2}. \tag{6}$$

3.2 Bertrand Competition with Linear Uniform Input Pricing

We next turn to Bertrand competition in which each downstream firm sets a price. At stage four, downstream firm D_i chooses p_i in order to maximize its profits for given the input price w, and the rival's price p_j. The downstream firm D_i's maximization problem is as follows:

$$\max_{p_i} \pi_i(w, p_i, p_j) = (p_i - w)q_i = \frac{(p_i - w)[a(1 - d) - p_i + dp_j]}{1 - d^2}.$$

The resulting reaction function is

$$p_i(w, p_j) = \frac{a(1 - d) + w + dp_j}{2}. \tag{7}$$

Note that a decrease in the input price charged to D_i shifts in its reaction function and turns it into a more aggressive competitor. Solving (7), we obtain the equilibrium prices in terms of the input price:

$$p_i(w) = \frac{a(1 - d) + w}{2 - d}.$$

At stage three, the upstream firm sets the input price (w), so as to maximize its profit for the given investment level (x). The upstream firm's maximization problem is as follows:

$$\max_{w} \Pi(x,w) = (w-c_0)(q_i+q_j) - \frac{vx^2}{2} = \frac{2(a-w)(w-c_0)}{2+d-d^2} - \frac{vx^2}{2}.$$

The equilibrium input price is as follows:

$$w = \frac{a+c_0}{2}.$$

At stage two, the upstream firm sets its investment level (x) so as to maximize its profit. The upstream firm's maximization problem is as follows:

$$\max_{x} \Pi(x) = \frac{(a-c_0)^2}{2(2+d-d^2)} - \frac{vx^2}{2}.$$

If $v > \frac{a}{(2+d-d^2)c}$, the equilibrium investment is derived as follows:

$$x^B = \frac{a-c}{(2+d-d^2)v-1}, \tag{8}$$

where the superscript "B" denotes Bertrand competition. Note that the second-order condition is $v > \frac{1}{2+d-d^2}$ for Bertrand competition. We obtain the equilibrium input price, quantities, prices, upstream firms profit, and downstream firms profit under Bertrand competition:

$$w^B = c + \frac{(a-c)[(2+d-d^2)v-2]}{2[(2+d-d^2)v-1]}, \quad q_i^B = \frac{(a-c)v}{2[(2+d-d^2)v-1]}, \tag{9}$$

$$p_i^B = c + \frac{(a-c)[(1+d)(3-2d)v-2]}{2[(2+d-d^2)v-1]}, \quad \Pi^B = \frac{(a-c)^2 v}{2[(2+d-d^2)v-1]}, \quad \pi_i^B = \frac{(1-d^2)(a-c)^2v^2}{4[(2+d-d^2)v-1]^2}, \tag{10}$$

$$CS^B = \frac{(a-c)^2(1+d)v^2}{4[(2+d-d^2)v-1]^2}, \quad SW^B = \frac{(a-c)^2 v[(1+d)(7-4d)v-1]}{4[(2+d-d^2)v-1]^2}. \tag{11}$$

3.3 Asymmetric Competition with Linear Uniform Input Pricing

We now turn to the asymmetric case in which downstream firm i sets a price, while downstream firm j sets a quantity. At stage four, downstream firm i sets a price p_i so as to maximize its profit for a given rival's quantity q_j, investment level (x), and input price (w). Downstream firm i's maximization problem is as follows:

$$\max_{p_i} \pi_i(w,p_i,q_j) = (p_i-w)q_i = (p_i-w)(a-p_i-dq_j).$$

The resulting reaction function is

$$p_i(w,q_j) = \frac{a+w-dq_j}{2}. \tag{12}$$

On the other hand, downstream firm j chooses q_j so as to maximize its profit for given rival's price p_i, and input price w. Downstream firm j's maximization problem is as follows:

$$\max_{q_j} \pi_i(w, p_i, q_j) = (p_j - w)q_j = [a(1-d) - w + dp_i - (1-d^2)q_j]q_j.$$

The resulting reaction function is

$$q_j(w, p_i) = \frac{a(1-d) - w + dp_i}{2(1-d^2)}. \tag{13}$$

Solving Eq. (12) and (13), we obtain the equilibrium price p_i and the equilibrium quantity q_j as a function of input prices w as follows:

$$p_i(w) = \frac{a(2-d-d^2) + (2+d-2d^2)w}{4-3d^2}, \quad q_j(w) = \frac{(2-d)(a-w)}{4-3d^2}.$$

At stage three, the upstream firm sets the input price w, so as to maximize its profit for given investment level x. The upstream firm's maximization problem is as follows:

$$\max_{w} \Pi(x, w) = (w - c_0)(q_i + q_j) - \frac{vx^2}{2} = \frac{(w-c_0)(4-2d-d^2)(a-w)}{4-3d^2} - \frac{vx^2}{2}.$$

The equilibrium input price is derived as follows:

$$w = \frac{a + c_0}{2}.$$

At stage two, the upstream firm sets its investment level x, so as to maximize its profit. The downstream firms maximization problem is as follows:

$$\max_{x} \Pi(x) = (w - c_0)(q_i + q_j) - \frac{vx^2}{2} = \frac{(4-2d-d^2)(a-c_0)^2}{4(4-3d^2)} - \frac{vx^2}{2}.$$

If $v > \frac{(4-2d-d^2)a}{2(4-3d^2)c}$, the equilibrium investment is derived as follows:

$$x^P = x^Q = \frac{(4-2d-d^2)(a-c)}{2(4-3d^2)v - (4-2d-d^2)}, \tag{14}$$

where the superscripts "P" and "Q" denote the price-setting downstream firm and the quantity-setting downstream firm in the asymmetric competition mode, respectively. Note that the second-order condition is $v > \frac{(4-2d-d^2)}{2(4-3d^2)}$ for the asymmetric competition. Thus, we obtain the equilibrium input price ($w^P = w^Q$), quantities (q_i^P, q_j^Q), prices (p_i^P, p_j^Q), upstream firm's profit ($\Pi^Q = \Pi^P$), and the downstream firms' profit (π_i^P, π_j^Q).

$$q_i^P = \frac{(1-d)(2+d)(a-c)v}{(8-6d^2)v-(4-2d-d^2)}, \quad q_j^Q = \frac{(2-d)(a-c)v}{(8-6d^2)v-(4-2d-d^2)}, \tag{15}$$

$$p_i^P = c + \frac{(a-c)[(6-d-4d^2)v-(4-2d-d^2)]}{(8-6d^2)v-(4-2d-d^2)}, \tag{16}$$

$$p_j^Q = c + \frac{(a-c)[(6-d-5d^2+d^3)v-(4-2d-d^2)]}{(8-6d^2)v-(4-2d-d^2)}, \tag{17}$$

$$\pi_i^P = \frac{(1-d)^2(2+d)^2(a-c)^2v^2}{[(8-6d^2)v-(4-2d-d^2)]^2}, \quad \pi_j^Q = \frac{(1-d^2)(2-d)^2(a-c)^2v^2}{[(8-6d^2)v-(4-2d-d^2)]^2}, \tag{18}$$

$$w^Q = w^P = c + \frac{(a-c)[v(4-3d^2)-(4-2d-d^2)]}{(8-6d^2)v-(4-2d-d^2)}, \tag{19}$$

$$\Pi^Q = \Pi^P = \frac{(4-2d-d^2)(a-c)^2v}{2[(8-6d^2)v-(4-2d-d^2)]}, \quad CS^P = CS^Q = \frac{(a-c)^2(8-10d^2+3d^4)v^2}{2[(8-6d^2)v-(4-2d-d^2)]^2} \tag{20}$$

$$SW^P = SW^Q = \frac{(a-c)^2v[(4-3d^2)(14+8d+3d^2)-v(4-2d-d^2)^2]}{2[(8-6d^2)v-(4-2d-d^2)]^2} \tag{21}$$

3.4 Endogenous Choice of Contract with Linear Uniform Input Pricing

In the previous section, we analyzed Cournot, Bertrand, and asymmetric equilibria. In this section, we examine the endogenous choice of the strategic variable. For simplicity, we set the following assumptions in order to guarantee that all possible variables are positive in equilibrium. Specifically, this assumption takes the following form[4]:

$$v \geq \frac{a}{(1+d)c} \equiv v^a, \tag{A1}$$

It will be shown below that (A1) guarantees positive, post-investment costs of production in Bertrand, Cournot and asymmetric competition.

Comparing the prices among Bertrand, Cournot, and asymmetric case, we obtained the following result[5]:

$$p_i^B < p_i^P < p_i^Q < p_i^C \text{ and } q_i^C < q_i^Q < q_i^P < q_i^B,$$

when $d \in (0,1)$. Hence, we summarize this result in Lemma 1.

Lemma 1. *The price (quantity) under Cournot competition is always higher (smaller) than that under Bertrand competition.*

[4] For general discussion in terms of assumption, see Section 5 for the investment level of upstream firm.

[5] $p_i^Q - p_i^P = \frac{(a-c)(1-d)d^2v}{2(4-3d^2)v-(4-2d-d^2)} > 0$, $p_i^P - p_i^B = \frac{(a-c)(1-d)d^2v[4(1+d)v-1]}{2[(2+d)v-1][(2(4-3d^2)v-(4-2d-d^2)]} > 0$, and $p_i^C - p_i^Q = \frac{(a-c)d^2v[2(2-d^2)v-1+d]}{2[(2+d)v-1][2(4-3d^2)v-(4-2d-d^2)]} > 0$.

From the standpoint of downstream firms, Lemma 1 means that each downstream firm has an incentive to choose Cournot competition other things being equal.

However, comparing the R&D investment level among all competition modes, we obtained the following result[6]:

$$x^C < x^A < x^B,$$

when $d \in (0, 1)$. Hence, we summarize this result in Lemma 2.

Lemma 2. *The R&D investment level under Bertrand competition is always larger than that under Cournot competition.*

Noting Eq. (4), Eq. (8), and Eq. (12), downstream firm has an incentive to choose Bertrand competition other things being equal. Therefore, from Lemma 1 and Lemma 2, it is obvious that each downstream firm faces on a trade-off between monopolistic power and investment incentive.

The pay-off matrix for the price-quantity game is summarized in Table 1.

Table 1: Payoff Matrix for Downstream Firms

Firm i\Firm j	Quantity	Price
Quantity	$\pi_i^C, \quad \pi_j^C$	$\pi_i^Q, \quad \pi_j^P$
Price	$\pi_i^P, \quad \pi_j^Q$	$\pi_i^B, \quad \pi_j^B$

To understand the endogenous choice of the strategic variable, it is useful to compare the payoffs described above. Comparing π_i^C with π_i^P, we obtain the following results:

$$\pi_i^C - \pi_i^P = \frac{1}{4}(a-c)^2 v^2 \left\{ \frac{1}{[(2+d)v-1]^2} - \frac{4(2-d-d^2)^2}{[(8-6d^2)v-(4-2d-d^2)]^2} \right\}.$$

Applying the above equation to a discriminant, we obtain two roots $v^\dagger \equiv \frac{1}{2d}$ and $v^* \equiv \frac{8-4d-3d^2}{2(8-6d^2-d^3)}$. Note that assumption (A1) guarantees $v^a > v^*$. Thus, the inequality that $\pi_i^C - \pi_i^P > 0$ holds when $v > \frac{1}{2d}$.

Similarly, comparing π_i^B with π_i^Q, we obtain the following results:

$$\pi_i^B - \pi_i^Q = \frac{1}{4}(a-c)^2 v^2 \left\{ \frac{1-d^2}{[(2+d-d^2)v-1]^2} - \frac{4(2-d)^2(1-d^2)}{[(8-6d^2)v-(4-2d-d^2)]^2} \right\}.$$

Through the same calculation process, we also obtain two roots $v^\dagger \equiv \frac{1}{2d}$ and $v^{**} \equiv \frac{8-4d-d^2}{2(8-6d^2+d^3)}$. Note that assumption (A1) guarantees $v^a > v^{**}$. Thus, the inequality that $\pi_i^B - \pi_i^Q > 0$ holds when $v < \frac{1}{2d}$.

Figure 1 illustrates critical values, $v^\dagger$ and v^a in the (v, d) space.

[6] $x_i^B - x_i^A = \frac{(a-c)d^2(2-d-d^2)v}{[(2-d)(1+d)v-1][2(4-3d^2)v-(4-2d-d^2)]} > 0$, and $x_i^A - x_i^C = \frac{(a-c)(2-d)d^2 v}{2[(2+d)v-1][2(4-3d^2)v-(4-2d-d^2)]} > 0$.

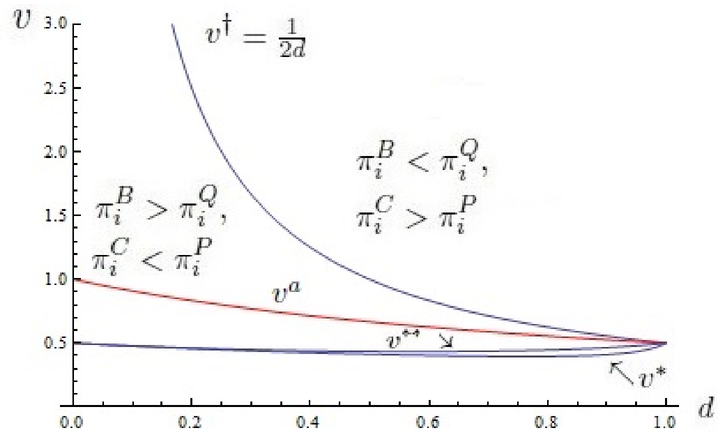

Figure 1: Equilibrium Area for Strategic Variables

$(v^* \equiv \frac{8-4d-3d^2}{2(8-6d^2-d^3)}, v^{**} \equiv \frac{8-4d-d^2}{2(8-6d^2+d^3)}, v^a \equiv \frac{a}{(1+d)c}$ from (A1) when $\frac{a}{c} = 1)$

If $v < \frac{1}{2d}$, each downstream firm chooses Bertrand competition and each downstream firm chooses Cournot competition if $v > \frac{1}{2d}$. In region of critical values, if $v < (>) \frac{1}{2d}$ with assumption (A1) above v^a line, it is a dominant strategy for the downstream firm to choose Bertrand (Cournot) competition. We summarize these findings in Proposition 1.

Proposition 1. *Under (A1), if $v < \frac{1}{2d}$, each downstream firm chooses Bertrand competition.*

Proposition 1 suggests that it is a dominant strategy for each downstream firm to choose Bertrand competition as products become more differentiated and the investment efficiency parameter v becomes smaller, and vice versa. The profit effect for each downstream firm can be decomposed into two opposing effects. One is an investment incentive effect. The other is a monopolistic effect. The monopolistic effect refers to the fact that, according to Lemma 1, downstream firms may prefer to choose Cournot instead of Bertrand competition, since Cournot competition yields higher prices and lower output than Bertrand. The investment incentive effect has to do with the fact that, according to Lemma 2, the upstream supplier invests more in R&D under Bertrand than under Cournot competition. The latter translates into lower per unit of input price under Bertrand than under Cournot competition, or in other words, the downstream firms face lower marginal cost under Bertrand competition. As a consequence, they may prefer to choose Bertrand instead of Cournot competition. Therefore, our results come from a trade-off between investment incentive and monopolistic effect. As the products become more differentiated (i.e, d is sufficiently small), the difference between the investment levels in R&D under Bertrand and Cournot competition decreases, and thus the "investment incentive effect becomes weaker.

The intuitive explanation behind Proposition 1 may lie on two effects: The first effect is related to the fact that as the products become closer substitutes the market competition becomes fiercer, and thus firms prefer to choose Cournot than Bertrand competition, since the former mode of competition is less competitive than the latter. The second effect is related to the fact that the upstream undertakes higher investments in R&D under Bertrand than under Cournot competition, that translates into lower wholesale prices for the downstream firms under Bertrand than under Cournot competition, and thus firms may prefer to choose Bertrand instead of Cournot competition. When the products are not close substitutes, the first effect is relatively weak and thus the second effect dominates, therefore firms choose price competition. When the products become closer substitutes, the first effect becomes stronger, the second effect becomes weaker, and thus the first effect dominates. Therefore, firms choose quantity competition. Even though this paper produces the similar result as Correa-Lopez (2007) and in Basak and Wang (2016), our result is in stark contrast with the existing literature. They demonstrate the endogenous choice of Bertrand equilibrium in a bargaining model, while we demonstrate it in a non-cooperative game with upstream firm's investment.

Finally, on the basis of the result of Lee and Choi (2015), we discuss the Bertrand-Cournot welfare comparison.

$$CS^B > CS^C \text{ and } SW^B > SW^C$$

if (A1) and $v \geq \frac{2(3+d-d^2)}{12+10d-5d^2-3d^3}$ are satisfied.[7] Note that $v \geq \frac{2(3+d-d^2)}{12+10d-5d^2-3d^3}$ is guaranteed by (A1). This result is correspond to Singh and Vives's (1984) result that Bertrand competition is more efficient than Cournot competition from the standpoint of consumer surplus and social surplus.

We now focus on downstream firms' profits. It is also important to examine whether Bertrand and Cournot equilibrium are efficient or not. From Lee and Choi (2015), we obtain the following results.

Lemma 3: *Under (A1), each downstream firm's profit under Bertrand competition is higher than under Cournot competition, if* $v^a < v < \frac{1+d+\sqrt{1-d^2}}{2d(1-d)}$.

This result has already been shown in Lee and Choi (2015) under (A1).[8] From Proposition 1, Lemma 3 and Figure 2, we have the following proposition.

[7] For detail, see Lee and Choi (2015).
[8] For detail, see Lee and Choi (2015).

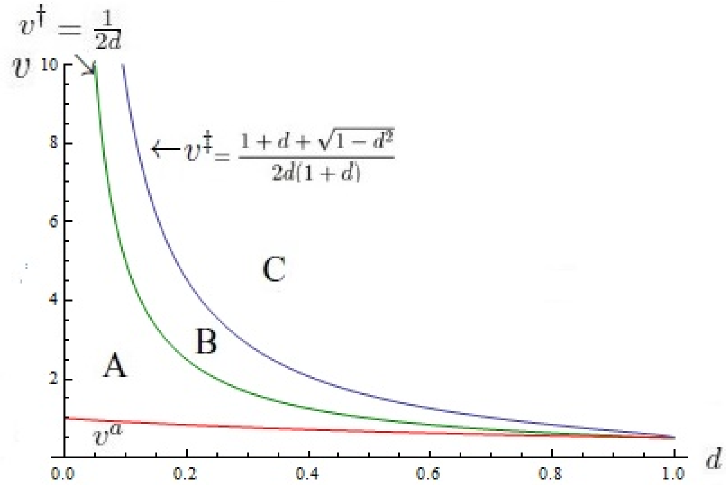

Figure 2: Equilibrium Area and Comparisons
($v^\dagger \equiv \frac{1}{2d}, v^\ddagger \equiv \frac{1+d+\sqrt{1-d^2}}{2d(1-d)}, v^a \equiv \frac{a}{(1+d)c}$ from (A1) when $\frac{a}{c} = 2$)

Proposition 2: *Under (A1), Cournot equilibrium under* $\frac{1}{2d} < v < \frac{1+d+\sqrt{1-d^2}}{2d(1+d)}$ *is a prisoner's dilemma from the viewpoint of downstream firms.*

Let us see Figure 2. Region A (Region C) means that it is a dominant strategy for both downstream firms to choose Bertrand (Cournot) competition. However, in region B, both downstream firms choose Cournot competition endogenously. Note that $\pi_i^C < \pi_i^B$ in region B. Therefore, each downstream firm faces a prisoners' dilemma in region B and then the equilibrium is a Pareto inferior. This is because $\pi_i^Q > \pi_i^B > \pi_i^C > \pi_i^P$ when $v^\dagger(\equiv \frac{1}{2d}) < v < v^\ddagger$.

4 Equilibrium Outcomes with Linear Discriminatory Input Pricing

Up to now, we consider the model with discriminatory input price between upstream and downstream firms including linear pricing contract. Here, suppose that the upstream firm offers discriminatory input price in the sense that it is able to adopt an optimal ex post input price that could be different (hence "discriminatory") between the two downstream firms; i.e. the input price is conditional on the realized investment by upstream firm. Let w_1 and w_2 be the discriminatory input price.

4.1 Cournot Competition with Linear Discriminatory Input Pricing

Using previous sections with uniform input price, downstream firm's profit motive yields $\max_{q_i} \bar{\pi}_i^C = (p_i - w_i)q_i = (a - q_i - dq_j - w_i)q_i$. Thus, solving these two reaction functions simultaneously in fourth stage is given by $\bar{q}_i = \frac{a(2-d)-2w_i+dw_j}{4-d^2}$. Given this, D_i's the profit reduces to $\bar{\pi}_i^C = (\bar{q}_i^C)^2$. At stage three, the upstream firm's maximization problem is as follows:

$$\bar{\Pi}^C = \frac{2(2-d)[c_0(w_i+w_j) - a(2c_0 - w_i - w_j)] - 4(w_i^2 - dw_iw_j + w_j^2) - (4-d^2)vx^2}{2(4-d^2)},$$

Solving these two reaction functions yields the equilibrium per-unit discriminatory input price as

$$\bar{w}_i^C = \frac{a+c_0}{2}$$

At stage two, the upstream firm sets its investment level (x) so as to maximize its profit: $\max \bar{\Pi}_x = \frac{a-c_0-2vx-dvx}{2+d}$, which implies that the first-order condition for the upstream firm's maximization problem is given by

$$\bar{x}^C = \frac{a-c}{(2+d)v-1}, \tag{22}$$

Note that if $v > \frac{a}{(2+d)c} \equiv v^D$, the equilibrium investment is derived. Thus, we obtain the equilibrium outcomes with Cournot competition under linear discriminatory input pricing as follows:

$$\bar{q}_i^C = q_i^C, \quad \bar{w}_i^C = w^C, \quad \bar{p}_i^C = p_i^C, \quad \bar{\Pi}^C = \Pi^C, \quad \bar{\pi}_i^C = \pi_i^C \quad \bar{CS}^C = CS^C, \quad \bar{SW}^C = SW^C.$$

4.2 Bertrand Competition with Linear Discriminatory Input Pricing

As in Bertrand competition with uniform input pricing, repeating same process with w_i and w_j. At stage four, downstream firm D_i chooses p_i in order to maximize its profits for given the input price w_i, and the rival's price p_j. The downstream firm D_i's maximization problem is as follows:

$$\max_{p_i} \bar{\pi}_i = (p_i - w_i)q_i = \frac{(p_i - w_i)[a(1-d) - p_i + dp_j]}{1-d^2}.$$

Solving the first order conditions we obtain the equilibrium output of the ith firm $\bar{p}_i = \frac{a(2-d-d^2)+dw_i+2w_j}{4-d^2}$. At stage three, the upstream firm's maximization problem is as follows:

$$\max_{w_i} \bar{\Pi}^B = \frac{(2-d^2)w_i^2 - a(2-d-d^2)(2c_0 - w_i - w_j) + 2dw_iw_j - (2-d^2)w_j^2 + c_0(2-d-d^2)(w_i+w_j)}{4-5d^2+d^4} - \frac{vx^2}{2},$$

Solving these two reaction functions yields the equilibrium per-unit discriminatory input price as $\bar{w}_i^B = \frac{a+c_0}{2}$.

At stage two, the upstream firm sets its investment level (x) so as to maximize its profit. The upstream firms maximization problem is as follows: $\max_x \bar{\Pi}^B = \frac{(a-c_0)^2}{2(2-d)(1+d)} - \frac{vx^2}{2}$, which implies that the equilibrium investment is derived as follows:

$$\bar{x}^B = \frac{a-c}{(2-d)(1+d)v-1}. \tag{23}$$

Hence, we obtain the equilibrium outcomes with Bertrand competition under linear discriminatory input pricing as follows:

$$\bar{q}_i^B = q_i^B, \quad \bar{w}_i^B = w^B, \quad \bar{p}_i^B = p_i^B, \quad \bar{\Pi}^B = \Pi^B, \quad \bar{\pi}_i^B = \pi_i^B, \quad \bar{CS}^B = CS^B, \quad \bar{SW}^B = SW^B.$$

4.3 Asymmetric Competition with Linear Discriminatory Input Pricing

We now turn to the asymmetric case in which downstream firm i sets a price, while downstream firm j sets a quantity. At stage four, downstream firm i sets a price p_i so as to maximize its profit for a given rival's quantity q_j, investment level (x), and discriminatory input price (w_i). Downstream firm i's maximization problem is as follows:

$$\max_{p_i} \bar{\pi}_i = (p_i - w_i)q_i = (p_i - w_i)(a - p_i - dq_j).$$
$$\max_{q_j} \bar{\pi}_j = (p_j - w_j)q_j = [a(1-d) - w_j + dp_i - (1-d^2)q_j]q_j.$$

Repeating same process in uniform input price and solving two reaction functions yield

$$\bar{p}_i = \frac{a - dq_j + w_i}{2}, \quad \bar{q}_j = \frac{a(1-d) + dp_i + w_j}{2(1-d^2)}.$$

At stage three, it is straightforward to derive the equilibrium payoff for the upstream firm and the upstream firm's maximization problem is as follows:

$$\max_{w_i} \bar{\Pi}^P = \frac{(w_j - c_0)[a(2-d) + dw_i - 2w_j]}{4-3d^2} + \frac{(w_i - c_0)[a(2-d-d^2) - w_i(2-d^2) + dw_j]}{4-3d^2} - \frac{vx^2}{2},$$
$$\max_{w_j} \bar{\Pi}^Q = \frac{(w_j - c_0)[a(2-d) + dw_i - 2w_j]}{4-3d^2} + \frac{(w_i - c_0)[a(2-d-d^2) - w_i(2-d^2) + dw_j]}{4-3d^2} - \frac{vx^2}{2}.$$

Solving these two reaction functions yields the equilibrium per-unit discriminatory input price as

$$\bar{w}_i^P = \bar{w}_i^Q = \frac{a + c_0}{2}.$$

At stage two, the upstream firm sets its investment level (x) so as to maximize its profit. The upstream firm's maximization problem is as follows:

$$\max_x \bar{\Pi} = \frac{1}{4}\left[\frac{(a-c_0)^2(4-2d-d^2)}{4-3d^2} - 2vx^2\right],$$

which implies that the equilibrium investment is derived as follows:

$$\bar{x}^P = \bar{x}^Q = \frac{(4-2d-d^2)(a-c)}{2(4-3d^2)v - (4-2d-d^2)}. \tag{24}$$

Thus, we obtain the equilibrium outcomes under discriminatory input pricing that are the same with linear uniform input priceing.

$$q_i^P = \bar{q}_i^P, \quad q_j^Q = \bar{q}_j^Q, \quad p_i^P = \bar{p}_i^P, \quad p_j^Q = \bar{p}_j^Q, \quad \pi_i^P = \bar{\pi}_i^P, \quad \pi_i^Q = \bar{\pi}_i^Q, \quad w^Q = w^P = \bar{w}_i^Q = \bar{w}_i^P,$$
$$\bar{\Pi}^Q = \Pi^Q = \Pi^P = \bar{\Pi}^P, \quad CS^P = CS^Q = \bar{CS}^Q = \bar{CS}^P, \quad SW^P = SW^Q = \bar{SW}^Q = \bar{SW}^P.$$

Finally, by comparing linear input pricing contract between uniform and discriminatory input prices yield the following proposition.

Proposition 3: *Regardless of the nature of goods, all equilibrium outcomes can obtain the same equilibrium between linear uniform and discriminatory input pricing. Thus, the same properties can obtain with Propositions 1 and 2 under linear discriminatory input pricing.*

5 Two-part Tariff Contract with Bargaining and Discriminatory Input Pricing

In the previous subsections, we have derived equilibria associated with absence in bargaining between upstream and downstream firm. We now compare the effectiveness in terms of the bargaining power impact under varying degrees of investment efficiency, v. In what follows, we will analyze the model with bargaining between upstream and downstream firms including two-part tariff contract. Borrowing Basak and Wang (2016), we extend to to revisit the classic question of price and quantity contract where the downstream firms involve in centralised bargaining with an upstream firm to determine the two-part tariff contracts with discriminatory input pricing.

At stage 1, each downstream firm simultaneously chooses whether to adopt quantity contract or price contract. At stage 2, the upstream firm sets the investment level (x). At stage 3, the upstream firm is involved in a centralised 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, $f_i, i = 1, 2$, and a per-unit discriminatory input price, w_i. At stage 4, firms compete contingent to the decisions made in stage 1.

We work out the equilibrium outcomes under each of these strategy combinations. We assume that upstream firm bargains with a representative of D_1 and D_2 to determine the terms of the two-part tariff contracts involving fixed fee, f_i, and a per-unit discriminatory input price, w_i.

At stage 3, the upstream firm, the monopoly upstream firm and a representative of D_1 and D_2 determine the terms of the two-part tariff contract by maximizing the following generalized Nash bargaining expression:

$$\max_{f_i^k, w_i^k} \left\{ \sum_{i=1}^{2} [(w_i^k - c_0^k) q_i^k + f_i^k - \frac{v(x^k)^2}{2}] \right\}^{\beta} \left\{ \sum_{i=1}^{2} (\pi_i^k - f_i^k) \right\}^{1-\beta}, \tag{25}$$

Maximizing Eq. (25) with respect to f_i gives the following

$$f_i^k = \frac{1}{2} \left\{ \beta \sum_{i=1}^{2} \left[\pi_i^k - \frac{v(x^k)^2}{2} \right] - (1-\beta) \left[\sum_{i=1}^{2} q_i^k (w_i^k - c_0) \right] + \frac{v(x^k)^2}{2} \right\}. \tag{26}$$

Substituting (27) in (26), we get the maximization problem as

$$\max_{w_i^k} \left\{ \beta \left[\sum_{i=1}^{2} \pi_i^k + q_i^k (w_i^k - c_0) - \frac{v(x^k)^2}{2} \right] + \frac{v(x^k)^2}{2} \right\}^{\beta} \left\{ (1-\beta) \left[\sum_{i=1}^{2} [\pi_i^k + q_i^k (w_i^k - c_0)] - \frac{v(x^k)^2}{2} \right] \right\}^{1-\beta}. \tag{27}$$

Using the envelope theorem, Eq. (27) shows that the per-unit discriminatory input price is determined to maximize the industry profit (i.e., the total profits of Π, D_1 and D_2), since the profit of a monopoly final goods producer, producing both the products at $\max[0, c-x]$ marginal cost of production.

5.1 Cournot Competition with Discriminatory Input Price

Using previous Sections with uniform input price, downstream firm's profit motive yields $\max_{q_i} \hat{\pi}_i^C = (p_i - w_i)q_i - f_i = (a - q_i - dq_j - w_i)q_i - f_i$. Thus, solving these two reaction functions simultaneously in fourth stage is given by $\hat{q}_i^C = \frac{a(2-d)-2w_i+dw_j}{4-d^2}$. Given this, D_i's the profit reduces to $\hat{\pi}_i^C = (\hat{q}_i^C)^2 - f_i$. At stage three, maximizing Eq. (27) subject to $\hat{q}_i^C = \frac{a(2-d)-2w_i+dw_j}{4-d^2}$ and $\hat{\pi}_i^C$ with solving these two reaction functions give the equilibrium per-unit discriminatory input price and fixed fee as

$$\hat{w}_i^C = c_0 + \frac{a-c_0}{2(1+d)}, \quad \hat{f}_i^C = \frac{1}{4}\left[(1-\beta)v(x^C)^2 - \frac{(a-c_0)^2[\beta - d(1-\beta)]}{(1+d)^2}\right].$$

At stage two, the upstream firm sets its investment level (x) so as to maximize its profit. The upstream firms maximization problem is given by $\max_x \hat{\Pi}^C = \frac{1}{2}\left[\frac{(a-c_0)^2}{1+d} - vx^2\right]$. Thus, if $v > \frac{a}{(1+d)c}$, the equilibrium investment is derived as follows

$$\hat{x}^C = \frac{a-c}{(1+d)v-1}, \tag{28}$$

Using Eq. (28), we obtain the equilibrium outcomes under Cournot competition under two-part tariff contract with discriminatory input price as follows:

$$\hat{q}_i^C = \frac{(a-c)v}{2[(1+d)v-1]}, \quad \hat{w}_i^C = c + \frac{(a-c)(dv-2)}{2[(1+d)v-1]}, \quad \hat{p}_i^C = c + \frac{(a-c)[v(1+d)-2]}{2[(1+d)v-1]}, \tag{29}$$

$$\hat{f}_i^C = \frac{(a-c)^2 v[1 - dv + \beta(v(1+d)-1)]}{4[(1+d)v-1]^2}, \quad \hat{\pi}_i^C = \frac{(a-c)^2(1-\beta)v}{4[(1+d)v-1]}, \tag{30}$$

$$\hat{CS}^C = \frac{(a-c)^2(1+d)v^2}{4[(1+d)v-1]^2}, \quad \hat{SW}^C = \frac{3(a-c)^2(1+d)v^2}{4[(1+d)v-1]^2}. \tag{31}$$

5.2 Bertrand Competition with Discriminatory Input Pricing

We next turn to Bertrand competition in which each downstream firm sets a price. At stage four, downstream firm D_i chooses p_i in order to maximize its profits for given the input price w_i, and the rival's price p_j. The downstream firm D_i's maximization problem is as follows:

$$\max_{p_i} \hat{\pi}_i = (p_i - w_i)q_i - f_i = \frac{(p_i - w_i)[a(1-d) - p_i + dp_j]}{1-d^2} - f_i.$$

Similar to previous subsection, equilibrium price in fourth stage is given by $\hat{p}_i = \frac{a(2-d-d^2)+dw_i+2w_j}{4-d^2}$. Given this, D_i's the profit reduces to $\hat{\pi}_i^B = (\hat{q}_i^B)^2 - f_i$ where $\hat{q}_i^B = \frac{a(2-d-d^2)+dw_i-(2-d^2)w_j}{4-5d^2+d^4}$. At stage three, maximizing Eq. (27) subject to $\hat{p}_i^B = \frac{a(2-d-d^2)+dw_i+2w_j}{4-d^2}$ and $\hat{\pi}_i^B = (\hat{q}_i^B)^2 - f_i$ with solving these two reaction functions gives the equilibrium per-unit discriminatory input price and fixed fee as

$$\hat{w}_i^B = c_0 + \frac{(a-c_0)d}{2}, \quad \hat{f}_i^B = \frac{(a-c_0)^2(\beta-d)+(1+d)(1-\beta)vx^2}{4(1+d)}.$$

At stage two, the upstream firm sets its investment level (x) so as to maximize its profit. The upstream firm's maximization problem is given by the upstream firm's profit function. Thus, the equilibrium investment is derived as follows:

$$\hat{x}^B = \frac{a-c}{(1+d)v-1} = \hat{x}^C. \tag{32}$$

Using Eq. (32), we obtain the equilibrium outcomes under Bertrand competition as follows:

$$\begin{aligned}
&\hat{q}_i^B = \hat{q}_i^C, \quad \hat{w}_i^B = \hat{w}_i^C, \quad \hat{p}_i^B = \hat{p}_i^C, \quad \hat{\pi}_i^B = \hat{\pi}_i^C, \quad \hat{CS}^B = \hat{CS}^C, \quad \hat{SW}^B = \hat{SW}^C. \\
&\hat{f}_i^B = \frac{(a-c)^2v[1-\beta-(1+d)(d-\beta)v]}{4[v+dv-1]^2}.
\end{aligned}$$

5.3 Asymmetric Competition with Discriminatory Input Pricing

We now turn to the asymmetric case in which downstream firm i sets a price, while downstream firm j sets a quantity. At stage four, downstream firm i sets a price p_i so as to maximize its profit for a given rival's quantity q_j, investment level (x), and discriminatory input price (w_i). Downstream firm i's maximization problem is as follows:

$$\begin{aligned}
&\max_{p_i} \hat{\pi}_i = (p_i - w_i)q_i - f_i = (p_i - w_i)(a - p_i - dq_j) - f_i, \\
&\max_{q_j} \hat{\pi}_j = (p_j - w_j)q_j - f_j = [a(1-d) - w_j + dp_i - (1-d^2)q_j]q_j - f_j.
\end{aligned}$$

Repeating same process in uniform input price and solving two reaction functions yield

$$\hat{p}_i = \frac{(1-d)[a(2+d)+2(1+d)w_i - dw_j]}{4-3d^2}, \quad \hat{q}_j = \frac{a(2-d)+dw_i-2w_j}{4-3d^2}. \tag{33}$$

At stage three, maximizing Eq. (27) subject to Eq. (33) gives the equilibrium per-unit discriminatory input price and upfront fixed fee as

$$\begin{aligned}
&\hat{w}_i^P = c_0 + \frac{(a-c_0)d}{2(1+d)}, \quad \hat{w}_j^Q = c_0 + \frac{(a-c_0)d}{2}, \\
&\hat{f}_i^P = \hat{f}_j^Q = \frac{(a-c_0)^2[2(1+d)\beta - d(2+d)]}{8(1+d)^2} + \frac{(1-\beta)vx^2}{4}.
\end{aligned}$$

At stage two, the upstream firm sets its investment level (x) so as to maximize its profit. The upstream firms maximization problem is given by the upstream firm's profit. Thus, the equilibrium investment is derived as follows:

$$\hat{x}^P = \hat{x}^Q = \hat{x}^B = \hat{x}^C. \tag{34}$$

Using Eq. (34), we obtain the same equilibrium outcomes regardless of the mode of product market competition as follows:

$$\hat{q}_i^P = \hat{q}_j^Q = \hat{q}_i^C = \hat{q}_i^B, \quad \hat{w}_j^Q = c + \frac{(a-c)(dv-2)}{2[v(1+d)-1]}, \quad \hat{w}_i^P = c + \frac{(a-c)[dv(1+d)-2]}{2[v(1+d)-1]}, \tag{35}$$

$$\hat{p}_i^P = \hat{p}_j^Q = c + \frac{(a-c)[v(1+d)-2]}{2[v(1+d)-1]}, \tag{36}$$

$$\hat{f}_i^P = \hat{f}_j^Q = \frac{(a-c)^2 v[(2-2d-d^2)v + 2\beta(v+dv-1)]}{8[v(1+d)-1]^2}, \tag{37}$$

$$\hat{\pi}_i^P = \frac{(a-c)^2 v[2\beta - 2 + 2v + 2dv + d^2 v - 2\beta v - 2d\beta v]}{8[v(1+d)-1]^2}, \tag{38}$$

$$\hat{\pi}_j^Q = \frac{(a-c)^2 v[2\beta - 2 + 2v + 2dv - d^2 v - 2\beta v - 2d\beta v]}{8[v(1+d)-1]^2}, \tag{39}$$

$$CS^P = CS^Q = \frac{(a-c)^2(1+d)v^2}{4[v(1+d)-1]^2}, \quad SW^P = SW^Q = \frac{3(a-c)^2(1+d)v^2}{4[v(1+d)-1]^2}. \tag{40}$$

5.4 Endogenous Choice of Contract with Bargaining and Discriminatory Input Pricing

In the previous section, we analyzed Cournot, Bertrand, and asymmetric equilibria under two-part tariff contract with bargaining. In this section, we examine the endogenous choice of the strategic variable with bargaining and discriminatory input price.

To understand the endogenous choice of the strategic variable, it is useful to compare the payoffs described above. Noting that assumption (A1) guarantees $v^a > v^D$, comparing $\hat{\pi}_i^C(\hat{\pi}_i^B)$ with $\hat{\pi}_i^P(\hat{\pi}_i^Q)$ yields the following results:

$$\hat{\pi}_i^C - \hat{\pi}_i^P = \frac{-(a-c)^2 d^2 v^2}{8[v(1+d)-1]^2} < 0, \quad \hat{\pi}_i^B - \hat{\pi}_i^Q = \frac{(a-c)^2 d^2 v^2}{8[v(1+d)-1]^2} > 0.$$

Thus, we have the following result.

Proposition 4: *Suppose that the downstream firms involve in centralised bargaining with an upstream firm to determine the two-part tariff vertical discriminatory pricing contracts, Then, under (A1), choosing price contract is the dominant strategy for downstream firms when the two-part-tariff pricing contract is determined through centralized Nash bargaining. Furthermore, the level of social welfare is the same regardless of the mode of product market competition (i.e., Bertrand or Cournot or asymmetric competition).*

6 Two-part Tariff Contract with Bargaining and Uniform Input Pricing

Up to now, we will analyze the model with bargaining and uniform input price, w between upstream and downstream firms including two-part tariff contract.

At stage 1, each downstream firm simultaneously chooses whether to adopt quantity contract or price contract. At stage 2, the upstream firm sets the investment level (x). At stage 3, the upstream firm is involved in a centralised 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, $f_i, i = 1, 2$, and a per-unit uniform input price, w. At stage 4, firms compete contingent to the decisions made in stage 1.

We work out the equilibrium outcomes under each of these strategy combinations. We assume that upstream firm bargains with a representative of D_1 and D_2 to determine the terms of the two-part tariff contracts involving fixed fee, f_i, and a per-unit uniform input price, w.

At stage 3, the upstream firm, the monopoly upstream firm and a representative of D_1 and D_2 determine the terms of the two-part tariff contract by maximizing the following generalized Nash bargaining expression:

$$\max_{f_i^k, w^k} \left\{ \sum_{i=1}^{2} [(w^k - c_0^k) q_i^k + f_i^k - \frac{v(x^k)^2}{2}] \right\}^{\beta} \left\{ \sum_{i=1}^{2} (\pi_i^k - f_i^k) \right\}^{1-\beta}, \tag{41}$$

where $c_0^k = c - x^k$, k denotes C, B, Q and P in contract and $\beta \in (0, 1)$ (resp. $(1 - \beta)$) shows the bargaining power of the downstream (resp. upstream) firm. Maximizing Eq. (41) with respect to f_i gives the following

$$f_i^k = \frac{1}{2} \left\{ \beta \sum_{i=1}^{2} \Big[\pi_i^k - \frac{v(x^k)^2}{2} \Big] - (1 - \beta) \Big[\sum_{i=1}^{2} q_i^k (w^k - c_0) \Big] + \frac{v(x^k)^2}{2} \right\}. \tag{42}$$

Substituting (42) in (41), we get the maximization problem as

$$\max_{w^k} \left\{ \beta \left[\sum_{i=1}^{2} \pi_i^k + q_i^k (w^k - c_0) - \frac{v(x^k)^2}{2} \right] + \frac{v(x^k)^2}{2} \right\}^{\beta} \left\{ (1 - \beta) \left[\sum_{i=1}^{2} [\pi_i^k + q_i^k (w^k - c_0)] - \frac{v(x^k)^2}{2} \right] \right\}^{1-\beta}. \tag{43}$$

Eq. (43) shows that the per-unit uniform input price is determined to maximize the industry profit (i.e., the total profits of Π, D_1 and D_2), since the profit of a monopoly final goods producer, producing both the products at $\max[0, c - x]$ marginal cost of production.

6.1 Cournot Competition with Uniform Input Price

Similar to Basak and Wang (2016) and using previous sections with liner contract, downstream firm's profit motive yields $\max_{q_i} \pi_i^C = (p_i - w) q_i - f_i = (a - q_i - dq_j - w) q_i - f_i$. Thus, similar equilibrium output in fourth stage is given by $\bar{\bar{q}}_i^C = \frac{a-w}{2+d}$. Given this, D_i's the profit reduces to $\pi_i^C = (q_i^C)^2 - f_i$. At stage three, maximizing Eq. (43) subject to $\bar{\bar{q}}_i^C = \frac{a-w}{2+d}$ and $\bar{\bar{\pi}}_i^C$ gives the equilibrium per-unit uniform input price and fixed fee as

$$\bar{\bar{w}}^C = c_0 + \frac{(a - c_0)d}{2(1 + d)}, \quad \bar{\bar{f}}_i^C = \frac{1}{4} \left[(1 - \beta) v(x^C)^2 - \frac{(a - c_0)^2 [\beta - d(1 - \beta)]}{(1 + d)^2} \right].$$

At stage two, the upstream firm sets its investment level (x) so as to maximize its profit. The upstream firm's maximization problem is given by $\bar{\bar{\Pi}}^C = (w^C - c + x^C)(q_i^C + q_j^C) - \frac{v(x^C)^2}{2}$. Thus, the equilibrium investment is derived as follows:

$$\bar{\bar{x}}^C = \frac{a-c}{(1+d)v-1}, \tag{44}$$

Using Eq. (44), we obtain the equilibrium outcomes under Cournot competition as follows:

$$\bar{\bar{q}}_i^C = \frac{(a-c)v}{2[(1+d)v-1]}, \quad \bar{\bar{w}}^C = c + \frac{(a-c)(2-dv)}{2[(1+d)v-1]}, \quad \bar{\bar{p}}_i^C = c + \frac{(a-c)[(1+d)v-2]}{2[(1+d)v-1]}, \tag{45}$$

$$\bar{\bar{f}}_i^C = \frac{(a-c)^2 v[1-dv-\beta(1-v(1+d))]}{4[(1+d)v-1]^2}, \quad \bar{\bar{\pi}}_i^C = \frac{(a-c)^2(1-\beta)v}{4[(1+d)v-1]}, \tag{46}$$

$$\bar{\bar{CS}}^C = \frac{(a-c)^2(1+d)v^2}{4[(1+d)v-1]^2}, \quad \bar{\bar{SW}}^C = \frac{(a-c)v[(3+d)v-2\beta(1-v(1+d))]}{4[(1+d)v-1]^2}. \tag{47}$$

6.2 Bertrand Competition with Uniform Input Price

We next turn to Bertrand competition in which each downstream firm sets a price. At stage four, downstream firm D_i chooses p_i in order to maximize its profits for given the input price w, and the rival's price p_j. The downstream firm D_i's maximization problem is as follows:

$$\max_{p_i} \pi_i = (p_i - w)q_i - f_i = \frac{(p_i - w)[a(1-d) - p_i + dp_j]}{1-d^2} - f_i.$$

Thus, similar to previous subsection, equilibrium price in fourth stage is given by $\bar{\bar{p}}_i = \frac{a(1-d)+w}{2-d}$. Given this, D_i's the profit reduces to $\bar{\bar{\pi}}_i^B = \frac{(1-d)(a-w)^2}{(2-d)^2(1+d)} - f_i$. At stage three, maximizing Eq. (43) subject to $\bar{\bar{p}}_i = \frac{a(1-d)+w}{2-d}$ and $\bar{\bar{\pi}}_i^B = \frac{(1-d)(a-w)^2}{(2-d)^2(1+d)} - f_i$ gives the equilibrium per-unit uniform input price and fixed fee as

$$\bar{\bar{w}}^B = c_0 + \frac{(a-c_0)d}{2}, \quad \bar{\bar{f}}_i^B = \frac{(a-c_0)^2(\beta-d) + (1+d)(1-\beta)vx^2}{4(1+d)}.$$

At stage two, the upstream firm sets its investment level (x) so as to maximize its profit. The upstream firm's maximization problem is given by the upstream firm's profit function. Thus, the equilibrium investment is derived as follows:

$$\bar{\bar{x}}^B = \frac{a-c}{(1+d)v-1} = \bar{\bar{x}}^C. \tag{48}$$

Using Eq. (48), we obtain the equilibrium outcomes under Bertrand competition as follows:

$$\bar{\bar{q}}_i^B = \frac{(a-c)v}{2[(1+d)v-1]}, \quad \bar{\bar{w}}^B = c + \frac{(a-c)[(1+d)vd-2]}{2[(1+d)v-1]}, \quad \bar{\bar{p}}_i^B = c + \frac{(a-c)[v(1-d)-2]}{2[(1+d)v-1]}, \tag{49}$$

$$\bar{\bar{f}}_i^B = \frac{(a-c)^2 v[1-dv-\beta+v\beta(1+d)]}{4[(1+d)v-1]^2}, \quad \bar{\bar{\pi}}_i^B = \frac{(a-c)^2(1-\beta)v}{4[(1+d)v-1]}, \tag{50}$$

$$\bar{\bar{CS}}^B = \frac{(a-c)^2(1+d)v^2}{4[(1+d)v-1]^2}, \quad \bar{\bar{SW}}^B = \frac{(a-c)v[(3+d)v-2\beta(1-v(1+d))]}{4[(1+d)v-1]^2}. \tag{51}$$

6.3 Asymmetric Competition with Uniform Input Price

We now turn to the asymmetric case in which downstream firm i sets a price, while downstream firm j sets a quantity. At stage four, downstream firm i sets a price p_i so as to maximize its profit for a given rival's quantity q_j, investment level (x), and input price (w). Downstream firm i's maximization problem is as follows:

$$\max_{p_i} \pi_i = (p_i - w)q_i - f_i = (p_i - w)(a - p_i - dq_j) - f_i.$$

The resulting reaction function is

$$p_i = \frac{a + w - dq_j}{2}. \tag{52}$$

On the other hand, downstream firm j chooses q_j so as to maximize its profit for given rival's price p_i. Downstream firm j's maximization problem is as follows:

$$\max_{q_j} \pi_j = (p_j - w)q_j - f_j = [a(1-d) - w + dp_i - (1-d^2)q_j]q_j - f_j.$$

Solving best response functions, we obtain the equilibrium price p_i and the equilibrium quantity q_j as follows:

$$\bar{\bar{p}}_i = \frac{(1-d)[a(2-d-d^2) - (2+d+2d^2)w]}{4-3d^2}, \quad \bar{\bar{q}}_j = \frac{(a-w)(2-d)}{4-3d^2}. \tag{53}$$

At stage three, maximizing Eq. (43) subject to Eq. (53) gives the equilibrium per-unit input price and upfront fixed fee as

$$\bar{\bar{w}}^P = \bar{\bar{w}}^Q = \frac{(a-c_0)(2-d-d^2)(4-2d-d^2)}{16-20d^2+6d^4},$$
$$\bar{\bar{f}}_i^P = \bar{\bar{f}}_j^Q = \frac{1}{8}\left\{\frac{(a-c_0)^2(4-2d-d^2)^2(2-d)(d-\beta)}{(2-d^2)^2(4-3d^2)} + 2(1-\beta)vx^2\right\}.$$

At stage two, the upstream firm sets its investment level (x) so as to maximize its profit. The upstream firms maximization problem is given by the upstream firm's profit. Thus, the equilibrium investment is derived as follows:

$$\bar{\bar{x}}^P = \bar{\bar{x}}^Q = \frac{(a-c)(4-2d-d^2)^2}{2(8-10d^2+3d^4)v - (4-2d-d^2)^2}. \tag{54}$$

Using Eq. (54), we obtain the same equilibrium outcomes regardless of the mode of product market competition as follows:

$$\bar{\bar{q}}_i^P = \frac{(a-c)(2-d-d^2)(4-2d-d^2)v}{2(8-10d^2+3d^4)v-(4-2d-d^2)^2}, \quad \bar{\bar{q}}_j^Q = \frac{(a-c)(8-8d+d^3)v}{2(8-10d^2+3d^4)v-(4-2d-d^2)^2} \tag{55}$$

$$\bar{\bar{w}}^Q = \bar{\bar{w}}^P = c + \frac{(a-c)[(4-2d-d^2)^2-(2-d)d(4-3d^2)v]}{2(8-10d^2+3d^4)v-(4-2d-d^2)^2}, \tag{56}$$

$$\bar{\bar{f}}_i^P = \bar{\bar{f}}_j^Q = \frac{(a-c)^2v(4-2d-d^2)^2v\{(4-2d-d^2)(1-\beta)-2(4-3d^2)[2d-d(1-\beta)-2\beta]v\}}{4[2(8-10d^2+3d^4)v-(4-2d-d^2)^2]^2}, \tag{57}$$

$$\bar{\bar{\pi}}_i^P = \frac{(a-c)^2(4-2d-d^2)^2vA}{4[2(8-10d^2+3d^4)v-(4-2d-d^2)^2]^2}, \quad \bar{\bar{\pi}}_j^Q = \frac{(a-c)^2(4-2d-d^2)^2vB}{4[2(8-10d^2+3d^4)v-(4-2d-d^2)^2]^2} \tag{58}$$

$$\text{where} \quad A = (4-2d-d^2)^2(1-\beta)+2\{8(1-\beta)-d^2[10(1-\beta)-2d+5d^2(5-3\beta)]\}v \tag{59}$$

$$B = (4-2d-d^2)^2(1-\beta)+2\{8(1-\beta)-d^2[10(1-\beta)+2d-d^2(1+3\beta)]\}v \tag{60}$$

$$C\bar{\bar{S}}^P = C\bar{\bar{S}}^Q = \frac{(a-c)^2v^2(8-10d^2+3d^4)(4-2d-d^2)^2}{2[2(8-10d^2+3d^4)v-(4-2d-d^2)^2]^2}, \tag{61}$$

$$S\bar{\bar{W}}^P = S\bar{\bar{W}}^Q = \frac{(a-c)^2(4-2d-d^2)^2v[(4-2d-d^2)^2\beta+(4-3d^2)(6+4\beta+4d+d^2+2d^3\beta)v]}{2[(4-2d-d^2)^2-2(8-10d^2+3d^4)v]^2}. \tag{62}$$

6.4 Endogenous Choice of Contract with Bargaining and Uniform Input Pricing

In the previous section, we analyzed Cournot, Bertrand, and asymmetric equilibria under two-part tariff contract with bargaining. In this section, we examine the endogenous choice of the strategic variable.

To understand the endogenous choice of the strategic variable, it is useful to compare the payoffs described above. Comparing $\bar{\bar{\pi}}_i^C(\bar{\bar{\pi}}_i^B)$ with $\bar{\bar{\pi}}_i^P(\bar{\bar{\pi}}_i^Q)$, we obtain the following results:

$$\bar{\bar{\pi}}_i^C - \bar{\bar{\pi}}_i^P = \frac{1}{4}(a-c)^2v^2\left\{\frac{1-\beta}{(1+d)v-1} - \frac{(4-2d-d^2)^2vA}{4[2(8-10d^2+3d^4)v-(4-2d-d^2)^2]^2}\right\},$$
$$\bar{\bar{\pi}}_i^B - \bar{\bar{\pi}}_i^Q = \frac{1}{4}(a-c)^2v^2\left\{\frac{1-\beta}{(1+d)v-1} - \frac{(4-2d-d^2)^2vB}{4[2(8-10d^2+3d^4)v-(4-2d-d^2)^2]^2}\right\}.$$

Applying the above equation to a discriminant, we obtain one root

$$v^b \equiv \frac{(4-2d-d^2)^2(4+d-d\beta)}{2(32+8d-40d^2-10d^3+10d^4+5d^5-8d\beta+10d^3\beta-3d^5\beta)}.$$

Thus, given that $\beta \in (0,1)$ is constant, the inequalities that $\bar{\bar{\pi}}_i^C > \bar{\bar{\pi}}_i^P$ and $\bar{\bar{\pi}}_i^Q > \bar{\bar{\pi}}_i^B$ hold when $v > v^b$ and vice versa. However, assumption (A1) guarantees $v^a > v^b$. Thus, the inequalities that $\bar{\bar{\pi}}_i^C > \bar{\bar{\pi}}_i^P$ and $\bar{\bar{\pi}}_i^Q > \bar{\bar{\pi}}_i^B$ hold always even when $v < v^b$ since its condition of $v < v^b$ violates assumption (A1). Figure 3 illustrates critical values, v^b and v^B in the (v,d) space.

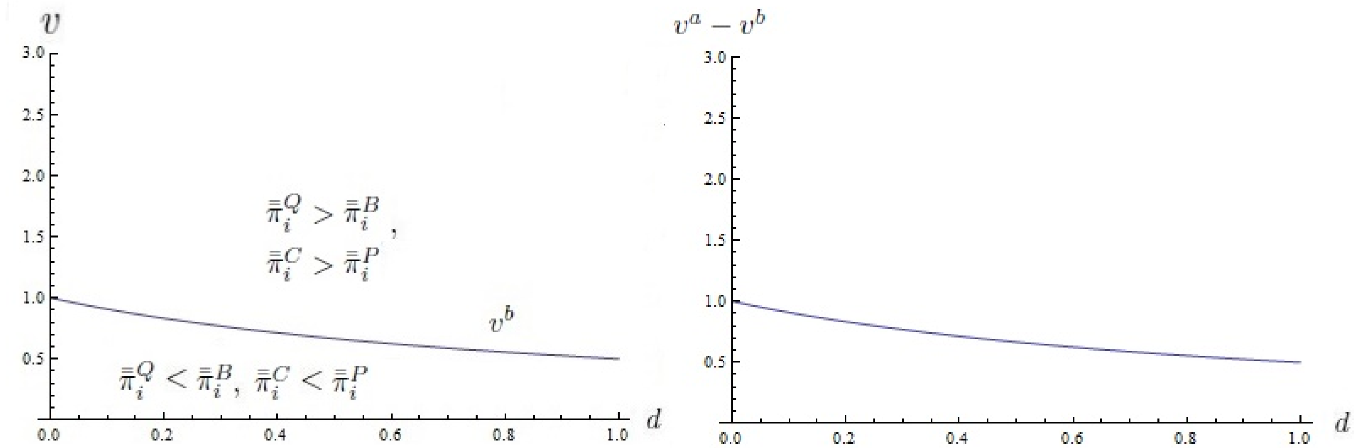

Figure 3: Equilibrium Area for Strategic Variables

($v^b \equiv \frac{(4-2d-d^2)^2(4+d-d\beta)}{2(32+8d-40d^2-10d^3+10d^4+5d^5-8d\beta+10d^3\beta-3d^5\beta)}$ from (A1) when $\frac{a}{c}=1$)

Thus, we have the following result.

Proposition 5: *Suppose that the downstream firms involve in centralised bargaining with an upstream firm to determine the two-part tariff vertical pricing contracts, Then, under (A2) and (A3), choosing quantity contract is the dominant strategy for downstream firms when the two-part-tariff pricing contract is determined through centralized Nash bargaining. Furthermore, the level of social welfare is the same regardless of the mode of product market competition (i.e., Bertrand or Cournot).*

7 Concluding Remarks

In this paper, we investigate the endogenous choice of strategic variable (a price or a quantity) by downstream firms in a two-tier industry in which an upstream firm performs the R&D investment. Suppose each downstream firm can choose either a price competition or a quantity competition. We show, from the viewpoint of each downstream firm when the upstream firm offers either linear discriminatory or uniform input price, that the price competition has the advantage of providing a greater incentive for the upstream firm to invest, but has the disadvantage of inducing a weaker monopolistic power. On the other hand, the quantity competition has the advantage of allowing a stronger monopolistic power, but has the disadvantage of weakening the incentive for the upstream firm to invest. Our main claim is that, from the viewpoint of each downstream firm when the upstream firm offers either linear discriminatory or uniform input price, it is a dominant strategy for each downstream firm to choose Bertrand competition when two products become relatively differentiated. The other is, in equilibrium, that Bertrand competition is more efficient than Cournot competition. However, when the downstream firms involve in centralized bargaining with an upstream firm to determine the two-part tariff discriminatory (uniform) input pricing contracts, we find that choosing price (quantity) contract is the dominant strategy for downstream firms. In this case, we further show that the level of social welfare is the same regardless of the mode of product market competition (i.e., Bertrand or Cournot). This result contrasts with the findings of Singh and Vives (1984), in whose research it is the dominant strategy for each firm to choose a quantity contract.

We conclude by discussing the limitations of our paper. We have used a simple linear demand structure and a single upstream firm. It is worth to consider our results in the nonlinear demand structure and in the bilateral duopoly structure. It is also interesting to consider whether our results are maintained or not under uncertainty. The extension of our model in these directions is left for future research.

References

[1] Alipranti, M., C. Milliou and E. Petrakis, 2014, "Price vs. Quantity Competition in a Vertically Related Market," *Economics Letters* 124, 122-126.

[2] Amir, R. and J. Y. Jin, 2001, "Cournot and Bertrand Equilibria Compared: Substitutability, Complementarity and Concavity," *International Journal of Industrial Organization* 19, 303-317.

[3] Arya, A., B. Mittendorf, and D. E. M. Sappington, 2008, "Outsourcing, Vertical Integration, and Price vs. Quantity Competition," *International Journal of Industrial Organization* 26, 1-16.

[4] Banerjee, S. and P. Lin, 2003, "Downstream R&D, Raising Rivals Costs, and Input Price Contracts," *International Journal of Industrial Organization* 21, 79-96.

[5] Basak, D. and L. F. S. Wang, 2016, "Endogenous Choice of Price or Quantity Contract and the Implications of Two-part-tariff in a Vertical Structure," *Economics Letters* 138, 53-56.

[6] Breton, M., A. Turki, and G. Zaccour, 2004, "Dynamic Model of R&D, Spillovers, and Efficiency of Bertrand and Cournot Equilibria," *Journal of Optimization Theory and Applications* 123, 1-25.

[7] Cheng, L., 1985, "Comparing Bertrand and Cournot Equilibria: A Geometric Approach," *Rand Journal of Economics* 16, 146-152.

[8] Choi, K., 2012, "Price and Quantity Competition in a Unionized Mixed Duopoly: The Cases of Substitutes and Complements," *Australian Economic Papers* 51, 1-22.

[9] Correa-Lopez, C. M. 2007, "Price and Quantity Competition in a Differentiated Duopoly with Upstream Suppliers," *Journal of Economics and Management Strategy* 16, 469-505.

[10] Correa-Lopez, C. M. and R. A. Naylor, 2004,"The CournotBertrand Profit Differential: A Reversal Result in a Differentiated Duopoly with Wage Bargaining,"*European Economic Review* 48, 681-696.

[11] Dastidar, K. G., 1997, "Comparing Cournot and Bertrand in a Homogenous Product Market," *Journal of Economic Theory* 75, 205-212.

[12] Hackner, J., 2000, "A Note on Price and Quantity Competition in Differentiated Oligopolies," *Journal of Economic Theory* 93, 233-239.

[13] Hinloopen, J. and J. Vandekerckhove, 2009, "Dynamic Efficiency of Cournot and Bertrand Competition: Input versus Output Spillovers," *Journal of Economics* 98, 119-136.

[14] Lambertini, L., 1997, "Prisoners' Dilemma in Duopoly (Super) Games," *Journal of Economic Theory* 77, 181-191.

[15] Lee, D. and K. Choi, 2015, "Bertrand vs. Cournot Competition with Upstream Firm Investment," forthcoming in *Bulletin of Economic Research.*

[16] Lin, P. and K. Saggi, 2002, "Product Differentiation, Process R&D, and the Nature of Market Competition," *European Economic Review* 46, 201-211.

[17] Matsumura. T. and, A. Ogawa, 2012, "Price versus Quantity in a Mixed Duopoly," *Economics Letter* 116, 174-177.

[18] Mukherjee, A., U. Broll and S. Mukherjee, 2012, "Bertrand versus Cournot Competition in a Vertical Structure: A Note," *The Manchester School* 80, 545-559.

[19] Okuguchi, K., 1987, "Equilibrium Prices in the Bertrand and Cournot Oligopolies," *Journal of Economic Theory* 42, 128-139.

[20] Qiu, L. D., 1997, "On the Dynamic Efficiency of Bertrand and Cournot Equilibria," *Journal of Economic Theory* 75, 213-229.

[21] Singh, N. and X. Vives, 1984, "Price and Quantity Competition in a Differentiated Duopoly," *Rand Journal of Economics* 15, 546-554.

[22] Symeonidis, G., 2008, "Downstream Competition, Bargaining, and Welfare," *Journal of Economics and Management Strategy* 17, 247-270.

[23] Symeonidis, G., 2003, "Comparing Cournot and Bertrand Equilibria in a Differentiated Duopoly with Product R&D," *International Journal of Industrial Organization* 21, 39-55.

[24] Vives, X., 1985, "On the Efficiency of Bertrand and Cournot Equilibria with Product Differentiation," *Journal of Economic Theory* 36, 166-175.

[25] Zanchettin, P., 2006, "Differentiated Duopoly with Asymmetric Costs," *Journal of Economics and Management Strategy* 15, 999-1015.