The Korean Economic Review
Volume 33, Number 1, Summer 2017, 35-53.

First-Mover and Second-Mover Advantages in a Bilateral Duopoly*

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This study examines a first-mover and a second-mover advantage in a vertical structure in which each upstream firm trades with an exclusive retailer and downstream retailers move sequentially. We provide two main claims. One is that, in Cournot (Bertrand) competition, the leader's upstream firm sets the input price equal to its marginal cost (equal to its marginal cost), while the follower's upstream firm sets the input price below its marginal cost (above its marginal cost). The other is that the follower's (leader's) upstream firm enjoys higher profits than the leader's (follower's) upstream firm in Cournot (Bertrand) competition.

JEL Classification: D43, L13, L14
Keywords: First- and Second-mover Advantage, Two-part Tariffs, Vertical Structure

I. Introduction

We have probably heard of the old proverbs, "The early bird gets the worm" and "The second mouse gets the cheese." What do those have to do with an economic

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Received: May 5, 2016. Revised: Aug. 21, 2016. Accepted: Sept. 23, 2016.

* We are especially indebted to two anonymous referees for careful and constructive comments. The first author acknowledges that this research is supported by Japan Society for the Promotion of Science, Grant-in-Aid for Scientific Research (B) Grant Number 15H03396 and Scientific Research (C) 15K03749. The corresponding author also acknowledges that this work was supported by the National Research Foundation of Korea Grant funded by the Korean Government (NRF-2014S1A3A2044643). Kyuchan Hwang acknowledges a grant from Tokai Gakuen University in 2015.

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theory? Your answer is the first- and the second-mover advantage in nine cases out of ten. The prime examples of a successful first mover are Coca-cola, eBay, Kleenex, Kellogg, and P&G's disposable diapers. However, being a first-mover is not a guarantee of a sustainable competitive advantage. Sometimes, followers were able to outmaneuver the first movers and walk away with a larger market share. The examples of the first-movers whose market shares were subsequently eroded by the second movers are Nintendo, Amazon, Google, Facebook, i-phone, Microsoft, Youtube, and so on.

During the last 30 years, the appropriateness of the equilibrium concept, Cournot (Bertrand) and Stackelberg, in classical oligopoly theory was dealt in various competitive settings and has been a major revival. This revision consists of two main strands. One strand compares the equilibrium payoffs of the two firms under perfect information. This strand includes Gal-or (1985) and Dowrick (1986).[1] From the viewpoint of firms, the strategic decision about whether to move early or late is a very important topic. A conventional wisdom about the first- and the second-mover advantage is that, in a sequential move game, the firm who moves first (leader) earns higher (lower) profits than the firm who moves second (follower) if the reaction functions are downwards (upwards) sloping.

The second strand deals with the issue of endogenous timing. In other words, the order of move between two given players should reflect each player own intrinsic incentive without exogenously determined timing structure. This strand includes Hamilton and Slutsky (1990), Amir (1995), and Amir and Stepanova (2006).[2]

This paper is related to the first strand and extends the first- and second-mover advantages in a vertically related market, in which each upstream firm trades with its exclusive downstream firm via two-part tariff contract. Many literatures in industrial organization have generally supposed that, in vertical separation, each upstream firm charges the franchise fee that can extract the full profit of its exclusive downstream firm.[3] It is also rare that upstream firms (producers) sell directly to consumers. Most commonly, they sell to distributors, who then sell to consumers. Therefore, we revisited the first- and the second-mover advantage in a vertical structure. Most relationships between producers and distributors consist of sophisticated contracts using more than the simple linear pricing rules. The sophisticated contracts are referred as to vertical restraints. Those are not only to set

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[1] Albaek (1990), Mailath (1993) and Daughety and Reinganum (1994) extended their models to cost uncertainty or signaling frameworks by adding an informational trade-off to leader-follower roles.

[2] Many studies are specific oligopolistic settings. They include Boyer and Moreaux (1987), Robson (1990), Deneckere and Kovenock (1992), van Damme and Hurkens (1999, 2004), Amir and Grilo (1999), Amir et al. (1999), among others.

[3] See, for details, Rey and Stiglitz (1988, 1995), Rey and Tirole (1986), Bonnano and Vickers (1988), and Saggi and Vettas (2002) and so on. The example of exclusive dealing can be seen in car dealership, franchise industry, and high quality brand-products distribution.

more general terms of payments, for example, two-part tariffs, quantity discounts, and royalties, but also to include terms limiting distributor's decisions, for example, resale price maintenance, exclusive dealing, and exclusive territories. Notably, this paper is the first study to consider the first- and the second-mover advantage in a vertically related duopoly.

Our study has two related objectives. One is to extend the conventional model to vertical structure. The other is to consider whether the classical results can be sustained in a vertical structure or not. The main results are as follows. In contrast to the canonical results in a one-tier market, we find that the upstream firm whose downstream firm moves first (leader) earns higher (lower) profits than the firm whose downstream firm moves second (follower) when downstream firms compete in price (quantity). The intuition of the result can be explained as follows. Let us see the downstream competition. It is straightforward that the first-mover (leader) sets larger quantity than the second-mover (follower) if the wholesale prices are equal. This is the conventional result. We now turn to the upstream competition. Notice that each upstream firm can extract all of the profits from its downstream firm via two-part tariff. Anticipating downstream competition, the follower's upstream firm sets the wholesale price as low as it can for its downstream firm to stand at advantage over downstream competition. The leader's upstream firm can also do so. In this case, market competition is so fierce. In the end, both firms' profits are lower than those in equilibrium in which the wholesale price for follower is lower than that for leader.

The remainder of this paper is organized as follows. Section 2 describes the model. In Section 3, we consider the benchmark case of the simultaneous-move quantity and price games. Section 4 considers the sequential-move quantity and price games. Finally, the concluding remarks appear in Section 5.

II. The Model

There are two differentiated goods in a market. We have a representative consumer who maximizes $\{U(\boldsymbol{q})-\sum_{i=1}^{2} p_i q_i : \boldsymbol{q}\in R_+^2\}$, where p_i is the price good i and $U(\cdot)$ is a differentially strictly concave utility function on R_+^2, which is differentially strictly monotone in a nonempty bounded region Q. Let $\boldsymbol{q}=(q_i,q_j)$ and $\boldsymbol{p}=(p_i,p_j)$ denote the vector of the quantities and the retail prices, respectively. A representative consumer by maximizing $U(\boldsymbol{q})-\sum_{i=1}^{2} p_i q_i$ gives rise to an inverse demand function $p_i = p_i(\boldsymbol{q}), i=1,2$, which is twice continuously differentiable in the interior of Q. Inverse demands will be downward sloping, $\frac{\partial p_i}{\partial q_i}<0$ and the cross effect $\frac{\partial p_i}{\partial q_j}<0, i\neq j$.[4] We assume that the inverse demand

[4] We assume that the goods are substitutes.

function $p_i = p_i(\boldsymbol{q})$ can be inverted to yield a direct demand function $q_i = q_i(\boldsymbol{p}), i = 1,2$. The bounded region in price space where demands are positive will be denoted by P. Direct demands are going to be downward sloping, $\frac{\partial q_i}{\partial p_i} < 0$ and $0 < \frac{\partial q_i}{\partial p_j}, i \neq j$. We assume that the own effect is larger than the cross effect.

$$\left|\frac{\partial p_i}{\partial q_i}\right| > \left|\frac{\partial p_i}{\partial q_j}\right| > 0 \text{ and } \left|\frac{\partial q_i}{\partial p_i}\right| > \left|\frac{\partial q_i}{\partial p_j}\right| > 0, \quad i, j = 1,2, \quad i \neq j. \qquad \textbf{(A1)}$$

Consider a manufacturing duopoly in which each upstream firm (i.e., manufacturer) sells its product to its own downstream firm (i.e., retailer). The inverse and direct demand function for downstream firm i are

$$p_i = p_i(q_i, q_j) \text{ and } q_i = q_i(p_i, p_j); \quad i, j = 1,2, \quad i \neq j, \qquad (1)$$

where q_i and q_j are the quantities, and p_i and p_j are the retail prices charged for product i and j, respectively. The marginal cost for each upstream firm is c. For simplicity, there are no retailing costs. In addition, we assume that each upstream firm prohibits its downstream firm from trading and distributing the product produced by the rival upstream firm, and that only one downstream firm serves a given upstream firm.

We posit a three-stage game. At stage one, each upstream firm offers a contract to its own downstream firm. The contract is composed of two variables: wholesale price w_i and franchise fee F_i. At stage two, downstream firm j (leader) sets quantity q_j (retail price p_j) in the sequential move quantity (price) game. Finally, at stage three, downstream firm i (follower) sets quantity q_i (retail price p_i) in the sequential move quantity (price) game.[5]

III. Benchmark

As a benchmark, we first consider Cournot (Bertrand) competition in which each downstream firm simultaneously sets a quantity (price).

At stage two, given the wholesale price w_i and rival downstream firm j's

[5] Given the market structure, one could imagine all sorts of different variants of sequential-move games. For example, (i) upstream firms move sequentially first, then downstream firms move sequentially afterwards (ii) upstream firm i and downstream firm i make their moves, then upstream firm j and downstream firm j move sequentially afterwards (iii) it may be a benefit for an upstream firm to move first (second) as long as downstream competition is à la Cournot (Bertrand). While there are situations where different timing games may have another solution, it is left to future research to develop the analysis more generally.

quantity q_j (price p_j), downstream firm i sets the quantity (price) so as to maximize its profit. Downstream firm i's maximization problems are as follows:

$$\max_{q_i} \pi_i(q_i, q_j, w_i) = [p_i(q_i, q_j) - w_i]\, q_i - F_i;\ i, j = 1,2, i \neq j\ .$$
$$\max_{p_i} \pi_i(p_i, p_j, w_i) = [p_i - w_i]\, q_i(p_i, p_j) - F_i;\ i, j = 1,2, i \neq j\ .$$

where p_i is the retail price, q_i is the quantity, and F_i is the franchise fee. Note that quantity $q_i(p_i)$ is independent of F_i.

The first-order condition for downstream firm i is expressed as follows:

$$\frac{\partial \pi_i}{\partial q_i} = p_i(q_i, q_j) - w_i + \frac{\partial p_i(q_i, q_j)}{\partial q_i} q_i = 0\ ,\ \ i, j = 1,2, i \neq j\ . \qquad (2\text{-}1)$$
$$\frac{\partial \pi_i}{\partial p_i} = q_i(p_i, p_j) + p_i \frac{\partial q_i(p_i, p_j)}{\partial p_i} - w_i \frac{\partial q_i(p_i, p_j)}{\partial p_i} = 0\ ,\ \ i, j = 1,2, i \neq j\ . \qquad (2\text{-}2)$$

We assume that the second-order conditions $\frac{\partial^2 \pi_i}{\partial q_i^2} < 0$ ($\frac{\partial^2 \pi_i}{\partial p_i^2} < 0$) are satisfied. Solving Eq. (2-1) and (2-2), we obtain the unique equilibrium quantities $\hat{q}_i, \hat{q}_j$ (prices $(\hat{p}_i, \hat{p}_j)$), where the superscript "^" denotes the equilibrium at stage two.

Let $\boldsymbol{w} = (w_i, w_j)$ denote the vector of the wholesale prices set by upstream firms at stage one. To understand how $\boldsymbol{w} = (w_i, w_j)$ affect $\boldsymbol{q} = (q_i, q_j)$ and $\boldsymbol{p} = (p_i, p_j)$, let us see the total differential of Eq. (2-1) and (2-2). Differentiating Eq. (2-1) and (2-2), we have

$$\begin{bmatrix} \dfrac{\partial^2 \pi_i}{\partial q_i^2} & \dfrac{\partial^2 \pi_i}{\partial q_i \partial q_j} \\ \dfrac{\partial^2 \pi_j}{\partial q_j \partial q_i} & \dfrac{\partial^2 \pi_j}{\partial q_j^2} \end{bmatrix} \begin{bmatrix} dq_i \\ dq_j \end{bmatrix} = \begin{bmatrix} dw_i \\ dw_j \end{bmatrix}. \qquad (3\text{-}1)$$

$$\begin{bmatrix} \dfrac{\partial^2 \pi_i}{\partial p_i^2} & \dfrac{\partial^2 \pi_i}{\partial p_i \partial p_j} \\ \dfrac{\partial^2 \pi_j}{\partial p_j \partial p_i} & \dfrac{\partial^2 \pi_j}{\partial p_j^2} \end{bmatrix} \begin{bmatrix} dp_i \\ dp_j \end{bmatrix} = \begin{bmatrix} dw_i \\ dw_j \end{bmatrix}. \qquad (3\text{-}2)$$

For $i, j = 1,2, i \neq j$, we make the following assumption.

$$\frac{\partial^2 \pi_i(q_i, q_j)}{\partial q_i^2} + \left| \frac{\partial^2 \pi_i(q_i, q_j)}{\partial q_i \partial q_j} \right| < 0\ ,\ \text{for all}\ \ q_i\ \ \text{in the interior of}\ \ Q$$

$$i, j = 1,2, i \neq j \,. \tag{A2}$$

$$\frac{\partial^2 \pi_i(p_i, p_j)}{\partial p_i^2} + \left| \frac{\partial^2 \pi_i(p_i, p_j)}{\partial p_i \partial p_j} \right| < 0 \quad \text{for all} \quad p_i \quad \text{in the interior of}$$

$$i, j = 1,2, i \neq j \,. \tag{A3}$$

This assumption ensures that Cournot reaction functions have slope less than one in absolute value. Therefore, there exists unique Cournot equilibrium. Note that the assumption does not put any restriction on the sign of the slope of the reaction functions.[6]

Under (A2) and (A3), the stability conditions of the equilibrium are satisfied by

$$D^C = \frac{\partial^2 \pi_i(q_i, q_j)}{\partial q_i^2} \frac{\partial^2 \pi_j(q_i, q_j)}{\partial q_j^2} - \frac{\partial^2 \pi_i(q_i, q_j)}{\partial q_i \partial q_j} \frac{\partial^2 \pi_j(q_i, q_j)}{\partial q_j \partial q_i} > 0 \,,$$

$$D^B = \frac{\partial^2 \pi_i(p_i, p_j)}{\partial p_i^2} \frac{\partial^2 \pi_j(p_i, p_j)}{\partial p_j^2} - \frac{\partial^2 \pi_i(p_i, p_j)}{\partial p_i \partial p_j} \frac{\partial^2 \pi_j(p_i, p_j)}{\partial p_j \partial p_i} > 0 \,,$$

where the superscripts C and B, respectively, denote simultaneous move Cournot and Bertrand game.

We have the following results.

$$\frac{dq_i}{dw_i} < 0, \quad \frac{dq_i}{dw_j} > 0, \quad \frac{dq_j}{dw_i} > 0, \quad \frac{dq_j}{dw_j} < 0, \quad \frac{dp_i}{dw_i} < 0, \quad \frac{dp_i}{dw_j} < 0,$$

$$\frac{dp_j}{dw_i} < 0, \quad \frac{dp_j}{dw_j} < 0 \,.$$

At stage one, upstream firm i's maximization problems are as follows:

$$\max_{w_i, F_i} u_i(w_i, w_j) = (w_i - c)\hat{q}_i + F_i$$

$$s.t. \quad \pi_i = (p_i - w_i)\hat{q}_i - F_i \geq 0 \quad \text{and} \quad w_i \geq 0$$

and

$$\max_{w_i, F_i} u_i(w_i, w_j) = (w_i - c)q_i + F_i$$

$$s.t. \quad \pi_i = \left(\hat{p}_i - w_i\right)q_i - F_i \geq 0 \quad \text{and} \quad w_i \geq 0 \,.$$

[6] See, for detail, Kolstad and Mathiesen (1987).

Note that the first constraint is binding. Therefore, we rewrite the maximization problems as follows:

$$\max_{w_i F_i} u_i(w_i, w_j) = [p_i(\hat{q}_i(w_i, w_j), \hat{q}_j(w_i, w_j)) - c]\hat{q}_i(w_i, w_j)$$
$$s.t. \quad w_i \geq 0,$$

and

$$\max_{w_i} u_i(w_i, w_j) = [\hat{p}_i(w_i, w_j) - c]q_i(\hat{p}_i(w_i, w_j), \hat{p}_j(w_i, w_j))$$
$$s.t. \quad w_i \geq 0$$

The first-order conditions are

$$\frac{\partial u_i}{\partial w_i} = \left[\frac{\partial p_i}{\partial \hat{q}_i}\frac{\partial \hat{q}_i}{\partial w_i} + \frac{\partial p_i}{\partial \hat{q}_j}\frac{\partial \hat{q}_j}{\partial w_i}\right]\hat{q}_i + p_i\frac{\partial \hat{q}_i}{\partial w_i} - c\frac{\partial \hat{q}_i}{\partial w_i} = 0, \quad i, j = 1, 2, i \neq j, \qquad (4\text{-}1)$$

$$\frac{\partial u_i}{\partial w_i} = (\hat{p}_i - c)\left[\frac{\partial q_i}{\partial \hat{p}_i}\frac{\partial \hat{p}_i}{\partial w_i} + \frac{\partial q_i}{\partial \hat{p}_j}\frac{\partial \hat{p}_j}{\partial w_i}\right] + q_i\frac{\partial \hat{p}_i}{\partial w_i} = 0, \quad i, j = 1, 2, i \neq j. \qquad (4\text{-}2)$$

We assume that the second-order condition $\frac{\partial^2 u_i}{\partial w_i^2} < 0$ is satisfied. Solving Eq. (4-1) and (4-2), we obtain the equilibrium wholesale price $\boldsymbol{w}^{\boldsymbol{C}} = (w_i^C, w_j^C)$ and $\boldsymbol{w}^{\boldsymbol{B}} = (w_i^B, w_j^B)$, respectively.

IV. Sequential Move Game

4.1. Sequential Move Quantity Game

We now turn to the sequential move quantity game in which downstream firm j (Leader) moves at stage two and downstream firm i (Follower) moves at stage three. At stage three, given the wholesale price w_i and its rival's quantity q_j, downstream firm i sets the quantity q_i so as to maximize its profit. Downstream firm i's maximization problem is as follows:

$$\max_{q_1} \pi_i(q_i, q_j, w_i) = [p_i(q_i, q_j) - w_i]q_i - F_i; \quad i, j = 1, 2, i \neq j.$$

Note that the quantity q_i is independent of F_i. The first-order condition for downstream firm i is expressed as follows:

$$\frac{\partial \pi_i}{\partial q_i} = p_i(q_i, q_j) - w_i + \frac{\partial p_i(q_i, q_j)}{\partial q_i} q_i = 0\,, \quad i, j = 1, 2, i \neq j\,. \tag{5}$$

It is assumed that the second-order condition $\frac{\partial^2 \pi_i}{\partial q_i^2} = 2\frac{\partial p_i}{\partial q_i} + \frac{\partial^2 p_i}{\partial q_i^2} q_i < 0$ is satisfied. Solving Eq. (5), we obtain the equilibrium quantity $q_i^* = q_i^*(q_j)$, where the superscript * denotes the equilibrium of the sequential move game. To see how change in q_j affects q_i, let us see the total differential of Eq. (5). Differentiating Eq. (5), we have

$$\left[2\frac{\partial p_i(q_i, q_j)}{\partial q_i} + \frac{\partial^2 p_i(q_i, q_j)}{\partial q_i^2} q_i\right] dq_i = \left[\frac{\partial p_i(q_i, q_j)}{\partial q_j} + \frac{\partial^2 p_i(q_i, q_j)}{\partial q_i \partial q_j} q_i\right] dq_j\,. \tag{6}$$

To guarantee the sing of the comparative static, we need a further assumption.

$$\frac{\partial^2 p_i}{\partial q_i^2} < 0\,, \quad \frac{\partial^2 p_i}{\partial q_i \partial q_j} > 0\,, \quad \frac{\partial^2 q_i}{\partial p_i^2} < 0\,, \text{ and } \quad \frac{\partial^2 q_i}{\partial p_i \partial p_j} < 0\,, \quad i, j = 1, 2, i \neq j\,. \tag{\textbf{A4}}$$

These assumptions mean that both products are substitutes.[7] In addition, to guarantee the stability condition for a sequential move game, we make an additional assumption.

$$\boldsymbol{p}^* = (p_i^*, p_j^*) > c\,. \tag{\textbf{A5}}$$

This assumption means that the equilibrium price is higher than the marginal cost of leader. Duopoly market will be sustained by the assumption.

From the second-order condition and (**A4**), we obtain that

$$\frac{dq_i}{dq_j} = \left[\frac{\dfrac{\partial p_i(q_i, q_j)}{\partial q_j} + \dfrac{\partial^2 p_i(q_i, q_j)}{\partial q_i \partial q_j} q_i}{2\dfrac{\partial p_i(q_i, q_j)}{\partial q_i} + \dfrac{\partial^2 p_i(q_i, q_j)}{\partial q_i^2} q_i}\right] < 0\,. \tag{7}$$

At stage two, given the wholesale prices (w_i, w_j), downstream firm j sets the quantity q_j so as to maximize its profit. Downstream firm j's maximization problem is as follows:

[7] If the sign of the cross derivatives is reverse, both products are complements.

$$\max_{q_j} \pi_j(q_j, w_j) = [p_j(q_i^* q_j, q_j) - w_j] q_j - F_i\,; \quad i, j = 1,2, i \neq j\,.$$

The first-order condition for downstream firm j is expressed as follows:

$$\frac{\partial \pi_j}{\partial q_j} = (p_j - w_j) + \left[\frac{\partial p_j}{\partial q_j} + \frac{\partial p_j}{\partial q_i^*} \frac{\partial q_i^*}{\partial q_j} \right] q_j = 0 \quad i, j = 1,2, i \neq j\,. \tag{8}$$

Assume that the second-order condition $\frac{\partial^2 \pi_j}{\partial q_j^2} < 0$ is satisfied. Solving Eq. (8), we obtain the equilibrium quantity q_j^* at stage two.

Let $\boldsymbol{w} = (w_i, w_j)$ denote the vector of the wholesale prices set by upstream firms at stage one. To understand how $\boldsymbol{w} = (w_i, w_j)$ affect $\boldsymbol{q} = (q_i, q_j)$, let us see the total differential of Eq. (5) and Eq. (8). Differentiating Eq. (5) and Eq. (8), we have

$$\begin{bmatrix} \dfrac{\partial^2 \pi_i}{\partial q_i^2} & \dfrac{\partial^2 \pi_i}{\partial q_i \partial q_j} \\ \dfrac{\partial^2 \pi_j}{\partial q_j \partial q_i} & \dfrac{\partial^2 \pi_j}{\partial q_j^2} \end{bmatrix} \begin{bmatrix} dq_i \\ dq_j \end{bmatrix} = \begin{bmatrix} dw_i \\ dw_j \end{bmatrix}. \tag{9}$$

Under (**A2**), the stability condition of the equilibrium is satisfied by

$$D = \frac{\partial^2 \pi_i(q_i, q_j)}{\partial q_i^2} \frac{\partial^2 \pi_j(q_i, q_j)}{\partial q_j^2} - \frac{\partial^2 \pi_i(q_i, q_j)}{\partial q_i \partial q_j} \frac{\partial^2 \pi_j(q_i, q_j)}{\partial q_j \partial q_i} > 0\,.$$

We have

$$\frac{dq_i}{dw_i} = \frac{\partial^2 \pi_j(q_i, q_j) / \partial q_j^2}{D} < 0\,. \tag{10-1}$$

$$\frac{dq_i}{dw_j} = -\frac{\partial^2 \pi_i(q_i, q_j) / \partial q_i \partial q_j}{D} > 0\,. \tag{10-2}$$

$$\frac{dq_j}{dw_i} = -\frac{\partial^2 \pi_j(q_i, q_j) / \partial q_j \partial q_i}{D} > 0\,. \tag{10-3}$$

$$\frac{dq_j}{dw_j} = \frac{\partial^2 \pi_i(q_i, q_j) / \partial q_j^2}{D} < 0\,. \tag{10-4}$$

At stage one, given the wholesale price w_j and the franchise fee F_j, upstream firm i sets the wholesale price w_i and the franchise fee F_i so as to maximize its profit. It's maximization problem is as follows:

$$\max_{w_i, F_i} u_i = (w_i - c)q_i^* + F_i$$
$$s.t. \quad \pi_i = (p_i - w_i)q_i^* - F_i \geq 0 \text{ and } w_i \geq 0 .$$

Note that the first constraint is binding. Therefore, we rewrite the maximization problem as follows:

$$\max_{w_i} u_i = [p_i(q_i^*(q_j^*(w_i, w_j)), q_j^*(w_i, w_j)) - c]q_i^*(q_j^*(w_i, w_j))$$
$$s.t. \quad w_i \geq 0 .$$

The first-order condition is

$$\frac{\partial u_i}{\partial w_i} = \left[\frac{\partial p_i}{\partial q_i^*} \frac{\partial q_i^*}{\partial q_j^*} \frac{\partial q_j^*}{\partial w_i} + \frac{\partial p_i}{\partial q_j^*} \frac{\partial q_j^*}{\partial w_i} \right] q_i^* + (p_i - c) \frac{\partial q_i^*}{\partial q_j^*} \frac{\partial q_j^*}{\partial w_i} = 0 . \tag{11}$$

We assume that the second-order condition $\frac{\partial^2 u_i}{\partial w_i^2} < 0$ is satisfied.

On the other hand, upstream firm j's maximization problem is as follows:

$$\max_{w_j, F_j} u_j = (w_j - c)q_j^* + F_j$$
$$s.t. \quad \pi_j = (p_j - w_j)q_j^* - F_j \geq 0 \text{ and } w_j \geq 0 .$$

Note that the first constraint is binding. Therefore, we rewrite it as follows:

$$\max_{w_j} u_j = [p_j(q_i^*(q_j^*(w_i, w_j)), q_j^*(w_i, w_j)) - c]q_j^*$$
$$s.t. \quad w_j \geq 0 .$$

The first-order condition is [8]

[8] For the comparative static on w_i and w_j in equilibrium, we need some additional assumptions. Without any additional assumption, we consider it with a linear demand. Suppose a linear demand function as $p_i = a - q_i - dq_j$, where p_i is price, q_i is quantity, $a > 0$, and $d \in (0,1)$ which represents the degree of product differentiation. Differentiating upstream firm i's and j's maximization problem with respect to w_i and w_j, respectively, we obtain $w_i = [2c(8 - 6d^2 + d^4) - d^2(4 - 2d - d^2)a - 2dw_j]/(16 - 16d^2 + 3d^4)$ and $(c - w_j)/(2 - d^2) = 0$. Therefore, w_i is decreasing in w_j and w_j is independent on w_i.

$$\frac{\partial u_j}{\partial w_j}=\left[\frac{\partial p_j}{\partial q_i^*}\frac{\partial q_i^*}{\partial q_j^*}\frac{\partial q_j^*}{\partial w_j}+\frac{\partial p_i}{\partial q_j^*}\frac{\partial q_j^*}{\partial w_j}\right]q_i^*+(p_j-c)\frac{\partial q_j^*}{\partial w_j}=0\ . \tag{12}$$

We assume that the second-order condition $\frac{\partial^2 u_j}{\partial w_j^{\ 2}}<0$ is satisfied. Solving Eq. (11) and Eq. (12), we obtain the equilibrium wholesale price $\boldsymbol{w}^{C^*}=(w_i^{C^*},w_j^{C^*})$, where the superscript "C^*" denotes a sequential move quantity game.

Noting Eq. (5), Eq. (12) can be changed as follows:

$$\begin{aligned}\frac{\partial u_i}{\partial w_i}&=\left[p_i-w_i+\frac{\partial p_i}{\partial q_i^*}q_i^*\right]\frac{\partial q_i^*}{\partial q_j^*}\frac{\partial q_j^*}{\partial w_i}+(w_i-c)\frac{\partial q_i^*}{\partial q_j^*}\frac{\partial q_j^*}{\partial w_i}+\frac{\partial p_i}{\partial q_j^*}\frac{\partial q_j^*}{\partial w_i}q_i^*\\&=(w_i-c)\frac{\partial q_i^*}{\partial q_j^*}\frac{\partial q_j^*}{\partial w_i}+\frac{\partial p_i}{\partial q_j^*}\frac{\partial q_j^*}{\partial w_i}q_i^*=0\ .\end{aligned}$$

From the above equation, we have the following result:

$$w_i^{C*}-c=-\frac{\frac{\partial p_i}{\partial q_j^*}\frac{\partial q_j^*}{\partial w_i}q_i^*}{\frac{\partial q_i^*}{\partial q_j^*}\frac{\partial q_j^*}{\partial w_i}}<0\ . \tag{13}$$

In the end, we have that $w_i^{C^*}<c$.

Noting Eq. (7), Eq. (11) can be changed as follows:

$$\begin{aligned}\frac{\partial u_j(w_i,w_j)}{\partial w_j}&=\left[p_j-w_j+\frac{\partial p_i}{\partial q_i^*}\frac{\partial q_i^*}{\partial q_j^*}q_j+\frac{\partial p_i}{\partial q_j^*}q_j\right]\frac{\partial q_j^*}{\partial w_j}+(w_j-c)\frac{\partial q_j^*}{\partial w_j}\\&=(w_j^{C^*}-c)\frac{\partial q_j^*}{\partial w_j}=0\ .\end{aligned}$$

In the end, we have

$$w_j^{C^*}=c\ . \tag{14}$$

We summarize these findings in Lemma 1.

Lemma 1: *Consider a vertical duopoly where one downstream firm (the leader) chooses its quantity before the other downstream firm (the follower). At the sub-game perfect equilibrium of this three stage game, The follower's upstream firm sets the wholesale* *price below its marginal cost, while the leader's upstream firm sets the wholesale price equal to its marginal cost.*

Proposition 1: *The follower's upstream firm enjoys higher profits than the leader's upstream firm does.*

Proof: Let us check the first order condition for the upstream firm i when $w_i^{C^*} = c$. Rearranging Eq. (11) yields

$$\frac{\partial u_i}{\partial w_i} = \left[p_i - w_i + \frac{\partial p_i}{\partial q_i^*} q_i^* \right] \frac{\partial q_i^*}{\partial w_i} + (w_i - c) \frac{\partial q_i^*}{\partial w_i} + \frac{\partial p_i}{\partial q_j^*} \frac{\partial q_j^*}{\partial w_i} q_i^* .$$

Noting that $w_i^{C^*} = c$, the first-term and the second-term of the right-hand side of the above equation are equal to zero. We also know that the sign of the third-term is negative from Eq. (10-3) and $\frac{\partial p_i}{\partial q_j^*} < 0$. The first-order condition that Eq. (11) < 0 when $w_i^{C^*} = c$ is satisfied. Therefore, we obtain the result that $w_i^{C^*} < c$ at equilibrium. In the end, $u_j^{C^*}(w_j^{C^*}) < u_i^{C^*}(w_i^{C^*})$. **Q.E.D.**

The intuition behind Proposition 1 can be explained as follows. Let us see the downstream competition. It is straightforward that the first-mover (leader) sets larger quantity than the second-mover (follower) if the wholesale prices are equal. This is the conventional result. We now turn to the upstream competition. Notice that each upstream firm can extract all of the profits from its downstream firm via two-part tariff. Anticipating downstream competition, the follower's upstream firm sets the wholesale price as low as it can for its downstream firm to stand at advantage over downstream competition. The leader's upstream firm can also do so. In this case, market competition is so fierce. In the end, both firms' profits are lower than those in equilibrium in which the wholesale price for follower is lower than that for leader.

4.2. Sequential Move Price Game

We now turn to the sequential move price game. At stage three, downstream firm i's maximization problem is

$$\max_{p_i} \pi_i = (p_i - w_i) q_i(p_i, p_j) - F_i ; \quad i, j = 1, 2, i \neq j .$$

Note that the price p_i is independent of F_i.

The first-order condition for downstream firm i is expressed as follows:

$$\frac{\partial \pi_i}{\partial p_i} = q_i(p_i, p_j) + p_i \frac{\partial q_i(p_i, p_j)}{\partial p_i} - w_i \frac{\partial q_i(p_i, p_j)}{\partial p_i} = 0, \quad i, j = 1,2, i \neq j. \tag{15}$$

It is assumed that the second-order condition $\frac{\partial^2 \pi_i}{\partial p_i^2} = 2\frac{\partial q_i}{\partial p_i} + \frac{\partial^2 q_i}{\partial p_i^2}(p_i - w_i) < 0$ is satisfied. Solving Eq. (15), we obtain the unique equilibrium for quantity p_i^*, where the superscript * denotes the equilibrium at stage three. To understand how p_j affect p_i, let us see the total differential of Eq. (15). Differentiating Eq. (15), we have

$$\left[2\frac{\partial q_i}{\partial p_i} + \frac{\partial^2 q_i}{\partial p_i^2}(p_i - w_i)\right] dp_i = \left[2\frac{\partial q_i}{\partial p_i} + \frac{\partial^2 q_i}{\partial p_i \partial p_j}(p_i - w_i)\right] dp_j. \tag{16}$$

From (**A4**) and $\frac{\partial q_i}{\partial p_i} < 0$, we have the following result:

$$\frac{dp_i}{dp_j} = \left[\frac{2\frac{\partial q_i}{\partial p_i} + \frac{\partial^2 q_i}{\partial p_i \partial p_j}(p_i - w_i)}{2\frac{\partial q_i}{\partial p_i} + \frac{\partial^2 q_i}{\partial p_i^2}(p_i - w_i)}\right] > 0. \tag{17}$$

At stage two, given the wholesale prices (w_j, w_j), downstream firm j sets the price p_j so as to maximize its profit. Downstream firm j's maximization problem is as follows:

$$\max_{p_j} \pi_j = (p_j - w_j) q_j[(p_i(p_j), p_j)] - F_i; \quad i, j = 1,2, i \neq j.$$

The first-order condition for downstream firm is j expressed as follows:

$$\frac{\partial \pi_j}{\partial p_j} = q_j(p_i(p_j), p_j) + (p_j - w_j)\left[\frac{\partial q_j}{\partial p_i^*}\frac{\partial p_i^*}{\partial p_j} + \frac{\partial q_j}{\partial p_j}\right] = 0, \quad i, j = 1,2, i \neq j. \tag{18}$$

Assume that the second-order condition is satisfied. Solving Eq. (18), we obtain the equilibrium p_j^* at stage two.

Let $\boldsymbol{w} = (w_i, w_j)$ denote the vector of the wholesale prices set by upstream firms at stage one. To understand how $\boldsymbol{w} = (w_i, w_j)$ affect $\boldsymbol{p} = (p_i, p_j)$, let us see the total differential of Eq. (15) and Eq. (18). Differentiating Eq. (15) and Eq. (18), we have

$$\begin{bmatrix} \dfrac{\partial^2 \pi_i}{\partial p_i^2} & \dfrac{\partial^2 \pi_i}{\partial p_i \partial p_j} \\ \dfrac{\partial^2 \pi_j}{\partial p_j \partial p_i} & \dfrac{\partial^2 \pi_j}{\partial p_j^2} \end{bmatrix} \begin{bmatrix} dp_i \\ dp_j \end{bmatrix} = \begin{bmatrix} dw_i \\ dw_j \end{bmatrix}. \tag{19}$$

Under (**A3**) and (**A4**), the stability condition of the equilibrium is satisfied by

$$D = \frac{\partial^2 \pi_i(p_i, p_j)}{\partial p_i^2} \frac{\partial^2 \pi_j(p_i, p_j)}{\partial p_j^2} - \frac{\partial^2 \pi_i(p_i, p_j)}{\partial p_i \partial p_j} \frac{\partial^2 \pi_j(p_i, p_j)}{\partial p_j \partial p_i} > 0 .$$

We have

$$\frac{dp_i}{dw_i} = \frac{\partial^2 \pi_j(p_i, p_j) / \partial p_j^2}{D} < 0 . \tag{20-1}$$

$$\frac{dp_i}{dw_j} = -\frac{\frac{\partial^2 \pi_i(p_i, p_j)}{\partial p_i \partial p_j}}{D} > 0 . \tag{20-2}$$

$$\frac{dp_j}{dw_i} = -\frac{\frac{\partial^2 \pi_j(p_i, p_j)}{\partial p_j \partial p_i}}{D} > 0 . \tag{20-3}$$

$$\frac{dp_j}{dw_j} = \frac{\partial^2 \pi_i(p_i, p_j) / \partial p_j^2}{D} < 0 . \tag{20-4}$$

At stage one, given the wholesale price w_j and the franchise fee F_j, upstream firm i sets the wholesale price w_i and the franchise fee F_i so as to maximize its profit. It's maximization problem is as follows:

$$\max_{w_i, F_i} u_i = (w_i - c) q_i [p_i^*(p_j^*(w_i, w_j)), p_j^*(w_i, w_j)] + F_i$$
$$s.t.\ \pi_i = (p_i^*(w_i, w_j) - w_i) q_i [p_i^*(p_j^*(w_i, w_j)), p_j^*(w_i, w_j)] - F_i \geq 0 \quad \text{and} \quad w_i \geq 0 .$$

Note that the first constraint is binding. Therefore, we rewrite the maximization problem as follows:

$$\max_{w_i} u_i = (p_i^*(w_i, w_j) - c) q_i [p_i^*(p_j^*(w_i, w_j)), p_j^*(w_i, w_j)]$$
$$s.t. \quad w_i \geq 0 .$$

The first-order condition is[9]

$$\frac{\partial u_i}{\partial w_i}=\frac{\partial p_i^*}{\partial p_j^*}\frac{\partial p_j^*}{\partial w_i}q_i+(p_i^*-c)\left[\frac{\partial q_i}{\partial p_i^*}\frac{\partial p_i^*}{\partial p_j^*}\frac{\partial p_j^*}{\partial w_i}+\frac{\partial q_i}{\partial p_j^*}\frac{\partial p_j^*}{\partial w_i}\right]=0. \qquad (21)$$

We assume that the second-order condition $\frac{\partial^2 u_i}{\partial w_i^2}<0$ is satisfied.

On the other hand, upstream firm j's maximization problem is as follows:

$$\max_{w_j,F_j} u_j=(w_j-c)q_j[p_i^*(p_j^*(w_i,w_j)),p_j^*(w_i,w_j)]+F_j$$
$$s.t.\ \pi_j=(p_j^*(w_i,w_j)-w_j)q_j[p_i^*(p_j^*(w_i,w_j)),p_j^*(w_i,w_j)]-F_j\geq 0 \ \text{ and } \ w_j\geq 0.$$

Note that the first constraint is binding. Therefore, we rewrite it as follows:

$$\max_{w_j} u_j=(p_j^*(w_i,w_j)-c)q_j^*(p_i^*(p_j^*(w_i,w_j)),p_j^*(w_i,w_j))$$
$$s.t.\quad w_j\geq 0.$$

The first-order condition is

$$\frac{\partial u_j}{\partial w_j}=\frac{\partial p_j^*}{\partial w_j}q_j+(p_j^*-c)\left[\frac{\partial q_j}{\partial p_i^*}\frac{\partial p_i^*}{\partial p_j^*}\frac{\partial p_j^*}{\partial w_j}+\frac{\partial q_j}{\partial p_j^*}\frac{\partial p_j^*}{\partial w_j}\right]=0. \qquad (22)$$

We assume that the second-order condition $\frac{\partial^2 u_j}{\partial w_j^2}<0$ is satisfied. Solving Eq. (21) and Eq. (22), we obtain the equilibrium wholesale price $\boldsymbol{w}^{\boldsymbol{B}*}=(w_i^{B*},w_j^{B*})$, where the superscript "B^*" denotes a sequential move price game.

Noting Eq. (15), Eq. (21) can be changed as follows:

$$\frac{\partial u_i}{\partial w_i}=\left[(p_i^*-w_i)\frac{\partial q_i}{\partial p_i^*}+q_i\right]\frac{\partial p_i^*}{\partial p_j^*}\frac{\partial p_j^*}{\partial w_j}+(w_i-c)\frac{\partial q_i}{\partial p_i^*}\frac{\partial p_i^*}{\partial p_j^*}\frac{\partial p_j^*}{\partial w_j}+(p_i^*-c)\frac{\partial q_i}{\partial p_j^*}\frac{\partial p_j^*}{\partial w_i}$$
$$=(w_i-c)\frac{\partial q_i}{\partial p_i^*}\frac{\partial p_i^*}{\partial p_j^*}\frac{\partial p_j^*}{\partial w_j}+(p_i^*-c)\frac{\partial q_i}{\partial p_j^*}\frac{\partial p_j^*}{\partial w_i}=0.$$

[9] For the comparative static on w_i and w_j in equilibrium, we need some additional assumptions. Without any additional assumption, we consider it with a linear demand. Suppose a linear demand function as $q_i=[a(1-d)-p_i+dp_j]/(1-d^2)$, where p_i is price, q_i is quantity, $a>0$, and $d\in(0,1)$ which represents the degree of product differentiation. Differentiating upstream firm i's and j's maximization problem with respect to w_i and w_j, respectively, we obtain $(c-w_i)/(2-d^2)=0$ and $w_j=[2c(8-10d^2+3d^4)+d^2(1-d)(4+2d-d^2)a+d(2-d^2)w_i]/(16-16d^2+3d^4)=0$. Therefore, w_i is independent on w_j and w_j is increasing in w_i.

From Eq. (20-1) and Eq. (20-3), we have the following result:

$$w_i^{B^*} - c = -\frac{(p_i^* - c)\frac{\partial q_i}{\partial p_j^*}\frac{\partial p_j^*}{\partial w_i}}{\frac{\partial q_i}{\partial p_i^*}\frac{\partial p_i^*}{\partial p_j^*}\frac{\partial p_j^*}{\partial w_j}} > 0 \tag{23}$$

In the end, we have that $w_i^{B^*} > c$.

Noting Eq. (18), Eq. (22) can be changed as follows:

$$\frac{\partial u_j(w_i, w_j)}{\partial w_j} = \left[q_j + (p_j - w_j)\frac{\partial q_j}{\partial p_j} + (p_j - w_j)\frac{\partial q_j}{\partial p_i^*}\frac{\partial p_i^*}{\partial p_j} \right]\frac{\partial q_j}{\partial w_j}$$
$$+(w_j - c)\left[\frac{\partial q_j}{\partial p_i^*}\frac{\partial p_i^*}{\partial p_j} + \frac{\partial q_j}{\partial p_j} \right]\frac{\partial p_j}{\partial w_j} = (w_j - c)\left[\frac{\partial q_j}{\partial p_i^*}\frac{\partial p_i^*}{\partial p_j} + \frac{\partial q_j}{\partial p_j} \right]\frac{\partial p_j}{\partial w_j} = 0$$

In the end, we have

$$w_j^{B^*} = c. \tag{24}$$

We summarize these findings in Lemma 2.

Lemma 2: *Consider a vertical duopoly where one downstream firm (the leader) chooses its price before the other downstream firm (the follower). At the sub-game perfect equilibrium of this three stage game, The follower's upstream firm sets the wholesale price above its marginal cost, while the leader's upstream firm sets the wholesale price equal to its marginal cost.*

Proposition 2: *The leader's upstream firm enjoys higher profits than the follower's upstream firm does.*

Proof: Let us check the first order condition for the upstream firm i when $w_i^{B^*} = c$. Rearranging Eq. (21) yields

$$\frac{\partial u_i}{\partial w_i} = \left[(p_i^* - w_i)\frac{\partial q_i}{\partial p_i^*} + q_i \right]\frac{\partial p_i^*}{\partial w_i} + (w_i - c)\frac{\partial q_i}{\partial p_i^*}\frac{\partial p_i^*}{\partial w_i} - (p_i^* - c)\frac{\partial q_i}{\partial p_j^*}\frac{\partial p_j^*}{\partial w_i}$$

Noting that $w_i^{B^*} = c$, the first-term and the second-term of the right-hand side of the above equation are equal to zero. We also know that the sign of the third-term is positive from Eq. (20-3) and $\frac{\partial q_i}{\partial p_j^*} > 0$. When $w_i^{B*} = c$, the first-order condition that Eq. (21) > 0 is satisfied. Therefore, we obtain the result that $w_i^{B*} > c$ at equilibrium. In the end, $u_j^{B*}(w_j^{B*}) > u_i^{B*}(w_i^{B*})$. **Q.E.D.**

The intuition behind Proposition 2 is the same logic as Proposition 1. Let us see the downstream competition. It is straightforward that the second-mover (follower) sets lower price than the first-mover (leader) if the wholesale prices are equal. This is the conventional result. We now turn to the upstream competition. Notice that each upstream firm can extract all of the profits from its downstream firm via two-part tariff. Anticipating downstream competition, the leader's upstream firm sets the wholesale price as low as it can for its downstream firm to stand at advantage over downstream competition. The follower's upstream firm can also do so. In this case, market competition is so fierce. In the end, both firms' profits are lower than those in equilibrium in which the wholesale price for leader is lower than that for follower.

V. Concluding Remarks

We study the issue of first- and second-mover advantages in a vertical structure in which each upstream firm trades with its exclusive downstream firm via two-part tariffs. We show that the upstream firm, whose downstream firm moves first (second), sets lower input price than its rival upstream firm, whose downstream firm moves second (first), does under price (quantity) competition. In the end, when the goods are substitutes, the upstream firm, whose downstream firm moves first (second), earns higher (lower) profits than its rival upstream firm, whose downstream firm moves second (first), under Bertrand (Cournot) competition. This result is in stark contrast to the conventional results of a one-tier market.

We conclude by discussing the limitations and extensions of our study. We exogenously compare the equilibrium profits of two upstream firms under perfect information. If it is possible to bargain for the input price between upstream and downstream, what will happen? In addition, we do not consider asymmetric costs between downstream firms. Finally, it is also interesting to consider the issue of endogenous timing in a vertical structure. Extending our model in these directions is left for future research.

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