The Korean Economic Review
Volume 30, Number 2, Winter 2014, 247-271.

Entry Invoking

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We consider a vertically integrated incumbent and an entrant who is privately informed of his production cost and is going to enter the downstream industry. We introduce the concept of the entry invoking behavior of a potential entrant. By "entry invoking behavior," we mean the entrant's offer of a higher input price than his first best price under full information to convey the information that his entry benefits the incumbent as well. A high price signals a low cost of the entrant and accordingly a high profit of the integrated firm in a separating equilibrium. In a separating equilibrium, only the efficient (low-type) entrant enters the market, although some efficiency loss in signaling may be incurred. This signaling consideration casts a doubt on the efficiency of the retail-minus access price regulation. We also discuss the possibility of inefficient entry in a pooling equilibrium.

JEL Classification: D82, L15
Keywords: Entry Invoking, Foreclosure, Signal, Vertical Integration

I. Introduction

It has been a long controversy whether a vertically integrated firm will try to exclude unintegrated downstream rivals by controlling the input supplies. The traditional market foreclosure theory, which was predominant in court cases until the 1970s, asserted that the vertically integrated firm may have an incentive to foreclose the downstream rivals by denying their access to its input to monopolize the downstream sector by extending the monopoly power in the upstream sector. On the other hand, the Chicago School (e.g. Bork [1978]) criticized the foreclosure theory by arguing that a vertically integrated firm has no incentive to exclude its

Received: Dec. 5, 2013. Revised: May 9, 2014. Accepted: June 10, 2014.
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rivals, since it cannot gain additional market power by exclusion.

However, the argument of the Chicago School has been also challenged by many scholars. In fact, it can be supported only in a model with the following features; homogeneous downstream goods, upstream monopoly and observable two-part contracts.[1] Whether foreclosure is beneficial or not will depend on the competition mode, the degree of product differentiation and the various parameters regarding production costs including the cost of inputs, retail costs of the integrated firm and the entrant. Accordingly, the entrant is often in a better position to tell whether it is beneficial for the integrated firm to deter entry or to accommodate it into the downstream market. For example, it is usually better informed of the cost of the new technology that is going to be introduced and the degree of differentiation of its own products from the existing one. Moreover, since entry may be beneficial to the incumbent integrated firm, the entrants will be likely to have a strong bargaining power enough to determine the input price as far as entry can be beneficial to the incumbent integrated firm. This asymmetry in the bargaining power could be more stark if there are competing integrated firms.

Depending on industry conditions, entry may be socially either efficient or inefficient. If it is efficient, entry can be beneficial to the incumbent as well as the entrant. If it is inefficient, it cannot be mutually beneficial. The point is, however, that only the entrant knows whether entry is efficient or not. From this consideration, we introduce the concept of the entry invoking behavior of the entrant. By "entry invoking behavior", we mean an informed entrant's attempt to send a signal to the incumbent in order to convince him that entry is efficient, that is, beneficial to the incumbent as well. Knowing its own cost, the potential entrant who is going to enter the downstream market proposes an input price to the integrated firm. As such, the input price can be a signal regarding the profitability to the incumbent when he accommodates entry. Usually, a high input price invokes entry, while a low price does not. If the entrant has a low production cost, entry is profitable to both the entrant and the incumbent and so it will have an incentive to enter even if it pays an excessively high input price. This is why a high input price can be interpreted as efficient entry. On the other hand, if its cost is high, it cannot afford to pay a high price, so it will stay out of the market (by demanding a low price which will be rejected by the integrated firm). In this separating equilibrium, only the efficient (low-type) entrant enters the market. Such a separating equilibrium is possible mainly due to a difference in the signalling cost. A high input price is more costly to a high type. In a pooling equilibrium, however, inefficient entry whereby an inefficient entrant enters may occur if a high-type

[1] For example, Rey and Tirole (2007) showed that with secret contracts under which the dominant firm cannot commit to the monopoly downstream quantity, foreclosure is beneficial in order to recover the monopoly power.

entrant can successfully mimic the low-type entrant. Excessive foreclosure whereby an efficient entry cannot enter never occurs in a pooling equilibrium. It only occurs in a separating equilibrium that could be obtained if the incumbent's mixed strategies are allowed.

To the best of our knowledge, there is no paper which considers the entrant's signaling incentive in a vertically related industry with the upstream sector and the downstream sector except Vareda (2010). Vareda also considers a privately informed entrant. The entrant is either efficient (in the sense that it can capture a high demand) or inefficient. In his model, however, the entrant signals to the uninformed regulator (not the incumbent) by choosing to capture low demand, i.e., shirk (not by choosing a high access price). Other authors take the opposite information structure. For example, Sarmento (2003) considers a model where the incumbent has private information about demand size and uses the price as a signal to the regulator who has to decide if entry will be allowed or not. White (2007) considers a situation in which the upstream firm has private information about its cost. She obtains the result that a low type of upstream firm has a perverse incentive to integrate the downstream firm to reduce output which would be otherwise over-produced.

This theory of entry invoking can be applied to many situations. The most notable example is the situation in which the incumbent serving the local telecommunications market and the long-distance telecommunications market faces an entrant into the long-distance sector. Another example which is currently a hot issue is a situation where MNOs (Mobile Network Operators) face the threat of potential MVNOs (Mobile Virtual Network Operator) who are attempting to enter the market by purchasing a wholesale service from one of the MNOs. It has been a common perception that the incumbent is unwilling to provide the access service to the potential entrant. However, the incumbent has no reason to deny the access if it is paid enough for it. Thus, it is just an issue of access charge determination. In particular, if there are many MNOs, they may compete for a high access fee, so an MVNO who has the bargaining power can make a take-it-or-leave-it offer to the MNOs. This is a unique feature of this paper. Moreover, we extend the existing results in the literature of access charge by introducing asymmetric information about the entrant's cost and investigating his signaling decision to enter the market. In fact, there are several papers arguing about the voluntary vertical relationship among MNOs and MVNOs. Dewenter and Haucap (2007) showed that the incentives to voluntarily grant MVNOs access increases under Bertrand competition and Stackelberg competition as the services are more differentiated, and that MNOs will always invite MVNOs under Cournot competition insofar as the market is sufficiently large. Banerjee and Dippon (2009) also derive sufficient conditions for voluntary strategic partnerships among MNOs and MVNOs. However, none of the papers considers the issue of the voluntary relationship in the context of asymmetric information.[2] Vickers (1995) also addressed the optimal access price regulation problem under incomplete information. Our paper is distinguished form his paper in that we do not consider the social planner (or mediator) nor the optimal regulation problem, but only consider the voluntary interaction between the incumbent and the entrant.

This analysis also has some policy implication of wholesale price regulation. Many countries including Korea use the retail-minus regulation. Under this regulation, the wholesale price cannot exceed the retail price minus the avoidable cost due to not participating in the downstream production. We argue that this regulation of access charge may not be socially desirable because it may increase the possibility of inefficient entry in a pooling equilibrium.

The article is organized as follows. In Section 2, we set up a benchmark model of complete information. In Section 3, we provide an analysis for the case of incomplete information. In Section 4, we discuss the implications on access price regulations. Concluding remarks and caveats follow in Section 5. All of the proofs are presented in the appendix.

II. Complete Information

We consider a vertically integrated firm (firm 1) and a potential entrant (firm 2) into the downstream market. The integrated firm produces the final good as well as the input. The products that firm 1 and firm 2 sell in the downstream market are horizontally differentiated. The demand functions for the final goods are given by $q_1 = D_1(p_1, p_2)$ and $q_2 = D_2(p_1, p_2)$ where $\partial D_i / \partial p_i < 0$, $\partial D_i / \partial p_j > 0$, $\partial^2 D_i / \partial p_i^2 \leq 0$ and $\partial^2 D_i / \partial p_i \partial p_j \geq 0$, for $i = 1,2$ and $j \neq i$. The second inequality implies that the two final goods are substitutes and the last inequality implies that the prices are strategically complements. Weak inequalities are to include the case of linear demands. In the linear demand case, $\partial D_i / \partial p_j$ captures the degree of product differentiation.

Let c_0 and c_1 be the marginal production costs of firm 1 in the upstream sector and in the downstream sector, and let c_2 be the marginal cost of firm 2 in the downstream sector. We assume that no fixed production cost of firm 1 is incurred. If the input price is w, the post-entry profits of each firm are given by

$$\pi_1(p_1, p_2) = (p_1 - c_0 - c_1) D_1(p_1, p_2) + (w - c_0) D_2(p_1, p_2), \quad (1)$$

$$\pi_2(p_1, p_2) = (p_2 - w - c_2) D_2(p_1, p_2). \quad (2)$$

[2] Laffont and Tirole (1994) simply mentions the possibility of a mechanism with a nonlinear transfer function of the quantity to be produced without any formal analysis.

In addition, the entrant incurs the fixed entry cost K.

To compare the post-entry profit with the pre-entry profit, we denote the monopoly demand of firm 1 by $D(p_1)$ and make some assumptions on it; (i) $D_1(p_1, p_2) < D(p_1)$ for all $p_1, p_2 \geq 0$, (ii) $\lim_{p_2 \to \infty} D_1(p_1, p_2) = D(p_1)$ for all $p_1 \geq 0$ and (iii) $D_i(p_1, p_2) = D(p_1)/2$ if $p_1 = p_2$ for $i = 1,2$. The first assumption means that the duopoly demand is always lower than the pre-entry monopoly demand, the second assumption is that the post-entry demand is almost the same as the pre-entry demand if p_2 is extremely high, and the last assumption implies that if the firms charge the same prices, they split the monopoly quantity equally. Let t be a degree of product differentiation. We make an additional technical assumption that $\lim_{t \to 0} D_1(p_1, p_2; t)$ is continuous in t, is equal to $D(p_1)$ if $p_1 < p_2$ and is zero if $p_1 > p_2$, where $t = 0$ means no product differentiation.[3]

The firms play the following game. In the first stage, firm 2 proposes an input price w to firm 1 on a take-it-or-leave-it basis. If firm 1 rejects the proposal, entry is deterred and firm 1 remains as a monopolist. If firm 1 accepts the proposal, in the second stage, they engage in price competition.

Entry into the downstream sector affects the profits of the integrated firm as well as the entrant, thus the overall industry profit. If both can be made better off, it will be called feasible entry. Insofar as entry is feasible, there would be some wholesale price which allocates the increased joint profit to the incumbent and the entrant so that both of them could be made better off.

The feasibility (or efficiency) of entry depends on whether the increase in the joint profit exceeds the entry cost.[4] Let the pre-entry profit be $\pi_1^M \equiv \max_{p_1} (p_1 - c_0 - c_1) D(p_1)$. Feasible entry requires

$$\max_{p_1, p_2} \Pi(p_1, p_2) \equiv \pi_1(p_1, p_2) + \pi_2(p_1, p_2) \geq \pi_1^M + K. \tag{3}$$

Let the left-hand side of equation (3) be Π^J. Then, since $\Pi^J = (p_1^J - c_0 - c_1) D_1 + (p_2^J - c_0 - c_2) D_2$, we have $\partial \Pi^J / \partial c_2 = -D_2 < 0$ by Envelope Theorem. Therefore, we have the following proposition.

Proposition 1 *For some* $\bar{K}(>0)$, *if* $K \leq \bar{K}$, *there exists* $c^f(K)$ *such that entry is feasible for* $c_2 < c^f$ *and is infeasible for* $c_2 > c^f$. *If* $K > \bar{K}$, *entry is infeasible for any* c_2.

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[3] Assumption (iii) implies that $\lim_{t \to 0} D_1(p_1, p_2; t) = D(p_1)/2$ if $p_1 = p_2$.

[4] By "efficiency", we mean technical efficiency, not allocative efficiency. So, consumer welfare is not taken into consideration.

Two things are noteworthy. First, c_1 is critical for feasible entry. If $K=0$, $c^f(0)=c_1$ by assumption (iii),[5] but since $K>0$, $c^f(K)<c_1$. In other words, $c_2<c_1$ is necessary for feasible entry but not sufficient. Due to the entry cost, efficiency of entry requires that the marginal cost of the entrant be much lower than the marginal cost of the incumbent. Second, once entry occurs, the industry profit is maximized when the products are produced only by the more cost-efficient firm. So, if $c_1\le c_2$, the integrated firm produces all, and if $c_1>c_2$, the integrated firm only produces inputs while all the final goods are produced by the entrant.[6] As a result, the industry profit will be $\Pi=\pi_1^M$ if $c_1\le c_2$, and $\Pi>\pi_1^M$ if $c_1>c_2$, although entry does not actually occur when $c_1\le c_2$ or $c^f<c_2<c_1$.

1. The Second Stage of the Game: Post-Entry Competition

To solve the two-stage sequential game, we resort to the subgame perfect equilibrium as a solution concept which can be found by backward induction. Given w, the equilibrium prices in the second stage are characterized by the following implicit reaction functions;

$$\frac{\partial\pi_1}{\partial p_1}=[D_1+(p_1^*-c_0-c_1)D_{1,1}]+(w-c_0)D_{2,1}=0, \tag{4}$$

$$\frac{\partial\pi_2}{\partial p_2}=D_2+(p_2^*-w-c_2)D_{2,2}=0, \tag{5}$$

where $D_{i,j}=\partial D_i/\partial p_j$. The first term and the second term in equation (4) indicate the increase in the profit from the downstream sector and the increase in the revenue from the upstream sector due to an increase in the demand for the rival good respectively.

By differentiating equations (4) and (5), we obtain upward sloping best-response curves, $\partial p_1^{BR}(p_2)/\partial p_2, \partial p_2^{BR}(p_1)/\partial p_1>0$. This implies that p_1 and p_2 are strategic complements. In addition, differentiating equations (4) and (5) with respect to w and c_2 yield following important comparative static results.

[5] This comes directly from symmetric demands. If $c_1=c_2=c$, the joint-profit maximizing prices are also symmetric, and the optimal symmetric price pair is $p_1=p_2=\arg\max_p \Pi(p,p)=2(p-c_0-c)D(p,p)=(p-c_0-c)D(p)$ and the maximized joint profit is π_1^M. Thus, the inequality (3) is binding if $K=0$, implying that $c^f(0)=c_1$.

[6] When $c_1<c_2$, the joint profit from producing both of the downstream products is $\psi(p_1,p_2)\equiv(p_1-c_0-c_1)D_1(p_1,p_2)+(p_2-c_0-c_2)D_2(p_1,p_2)<(p_1-c_0-c_1)D_1(p_1,p_2)+(p_2-c_0-c_1)D_2(p_1,p_2)$ for all p_1,p_2. Hence, $\max_{p_1,p_2}\psi(p_1,p_2)=\max_p(p-c_0-c_1)D(p)$ by the assumption of symmetric demands, meaning that the joint profit from producing both products cannot be higher than when only the product with the lower cost is produced.

Proposition 2 *(i)* $dp_i^* / dw > 0$ *and (ii)* $dp_i^* / dc_2 > 0$.

A rise in the input price shifts both reaction curves upwards, while a rise in c_2 shifts only the reaction curve of firm 2. As a result, both prices increase. Intuitively, if the input price rises, firm 1 prefers a larger p_2 and so increases its price $p_1 (dp_1^* / dw > 0)$. Consequently, it increases the revenue from the upstream sector with decreasing the profit from the downstream sector. Similarly, firm 2 also increases its price in order to reduce its sales if the input price rises.

Also, if c_2 increases, firm 2 raises p_2 by markup. Then, firm 1 also raises p_1 because p_1 and p_2 are strategic complements.

We will say that entry is competitively feasible if $\pi_1(p_1^*, p_2^*) + \pi_2(p_1^*, p_2^*) \geq \pi_1^M + K$. Clearly, competitive feasibility of entry implies feasibility of entry but not conversely.

2. The First Stage of the Game: Determining the Input Price

We consider the first stage to set the input price. Unlike in most literature, the entrant, not the incumbent, proposes the price w.

Since firms do not charge cooperative prices but Nash prices when entry actually occurs, feasibility of entry does not guarantee positive net profits of both firms. If $c_2 > c^f$, entry is not competitively feasible. Any offer which is profitable to the entrant will be rejected by the incumbent. For otherwise it implies that the offer would be profitable to both of them, which is contradictory to infeasible entry. If $c_2 \leq c^f$, however, entry could be feasible. Then, the entrant will offer w which is best to him among the offers the incumbent will be willing to accept. We have

Proposition 3 *For large* c_1*, there exists* $\hat{K}(>0)$ *such that if* $K \leq \hat{K}$*, entry is competitively feasible for all* $c_2 \leq c_2(K)$ *for some* $c_2(K)$.

This proposition says that there exists w making both firms better off if K is low and c_2 is low, clearly suggesting that such a price offer may not exist if K is large or $c_2 \approx c_1$.

The choice of w affects π_1 and π_2 directly and indirectly through the equilibrium retail prices p_1^* and p_2^*. Assuming interior optima, let w_1^* and w_2^* be the optima of firm 1 and firm 2 respectively. Figure 1 illustrates the optima. It is usual that the input seller wants a higher price than the input buyer, i.e., $w_1^* > w_2^*$, as in Figure 1.

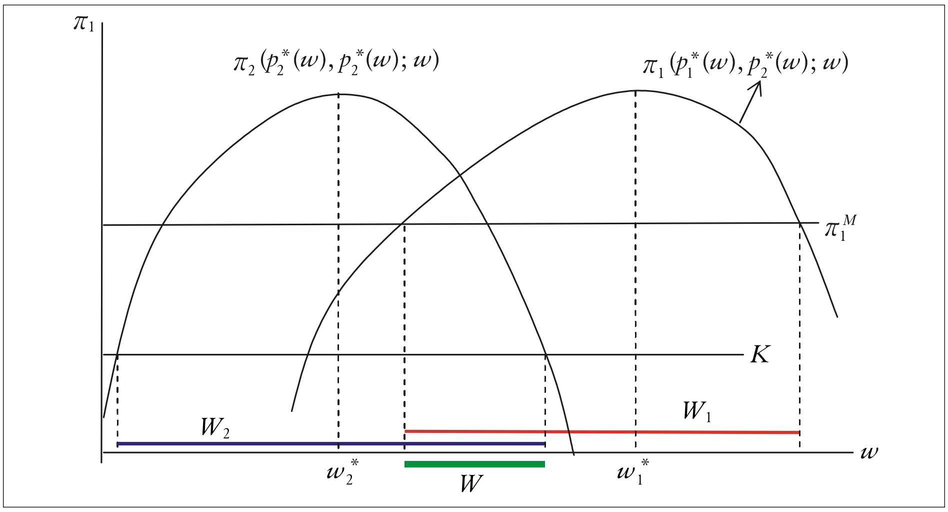
The participation constraints of the two firms require that

$$\pi_1^*(w; c_2) \geq \pi_1^M, \qquad \text{[PC1]}$$

$$\pi_2^*(w;c_2) \geq K . \qquad \text{[PC2]}$$

Let the set of w satisfying [PC1] and [PC2] be $\mathbb{W}_1$ and $\mathbb{W}_2$. Then, $\mathbb{W} = \mathbb{W}_1 \cap \mathbb{W}_2$ is called the bargaining range. Note that $\mathbb{W}$ depends on K and that as K is larger, it gets smaller, until the area becomes extinct if entry is infeasible. However, if K is so small that entry is competitively feasible, it is possible that $\mathbb{W} \neq \emptyset$. So, let us use the notation of $\mathbb{W}(K)$.

[Figure 1] Bargaining Range



We restrict our attention to the case in which the unconstrained optimum w_1^* and w_2^* differ very much as in Figure 1.[7] Then, it must be that $w_2^* \notin \mathbb{W}(K)$ regardless of K. This implies that the unconstrained optimum w_2^* cannot be the bargaining solution. Since firm 2 wants the lowest possible price w within the bargaining range, i.e., $\underline{w} = \min \mathbb{W} \equiv \mathbb{W}_1 \cap \mathbb{W}_2$, the constrained optimum must be the minimum value of w in $\mathbb{W}_1$. To elaborate, let $w_1(c_2)$ and $w_2(c_2)$ be the minimum input price which makes [PC1] binding and the maximum input price which makes [PC2] binding respectively given c_2, since firm 1 wants as high w as possible among the input prices within the bargaining range. Then, firm 2 proposes the minimum input price $\underline{w}$ which makes [PC1] binding, that is,

$$\pi_1^*(\underline{w};c_2) = \pi_1^M . \qquad (6)$$

[7] In the alternative case in which the unconstrained optima are not far apart, $w_2^* \in \mathbb{W}$, so firm 2 can always propose its favorite price w_2^*.

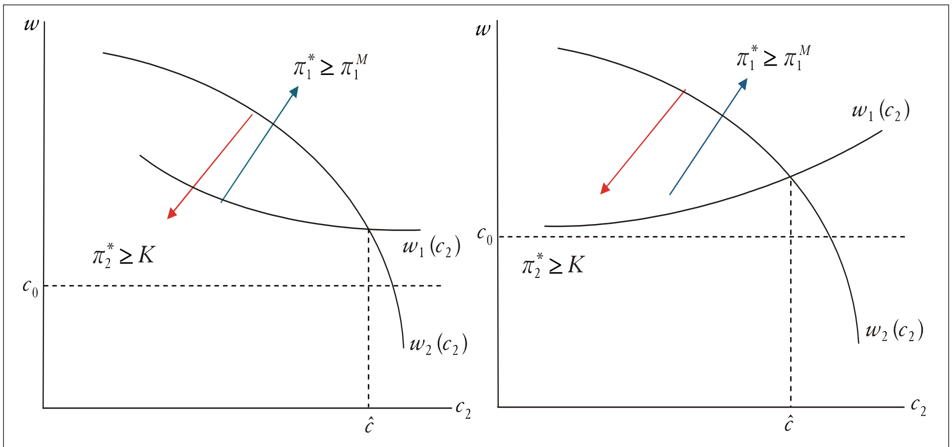
If we denote it by $\underline{w}(c_2)$, it is clear that $\underline{w}(c_2) = w_1(c_2)$. This will be called the input price schedule. Note that $\underline{w}(c_2) > c_0$ for any c_2; otherwise, the duopoly profit of firm 1 should fall below the monopoly profit.

The input price schedule is essential to our analysis. Let $\hat{c}$ be the value of c at the intersection point of the two curves $w_1(c_2)$ and $w_2(c_2)$ in Figure 2. Now, consider the maximum input price which makes [PC2] binding, that is,

$$\pi_2^*(\overline{w}; c_2) = K .$$

We will denote it by $w_2(c_2)$. Note that the less efficient the entrant is, the lower input price is needed for its survival (break-even). Thus, this curve is downward sloping. If $c_2 > \hat{c}$ and $w \geq w_2(c_2)$, the entrant will not enter the market, so firm 1 can make the monopoly profit. Thus, if $c_2 > \hat{c}$, the input price schedule will be identical to $w_2(c_2)$.

[Figure 2] Input Price Schedule



(a) Downward Sloping Case (b) Upward Sloping Case

Now, our main interest lies in the shape of $\underline{w}(c_2)$. Total differentiation of equation (6) yields

$$\frac{d\pi_1^*}{dw} dw + \frac{d\pi_1^*}{dc_2} dc_2 = 0 . \tag{7}$$

Figure 1 shows that

$$\frac{d\pi_1^*}{dw} = \underbrace{\frac{\partial \pi_1^*}{\partial w}}_{+} + \underbrace{\frac{\partial \pi_1^*}{\partial p_2}}_{?} \underbrace{\frac{\partial p_2^*}{\partial w}}_{+} > 0 \tag{8}$$

for $w \in \mathbb{W}$.[8] By the Envelope Theorem, the effect of p_1^* on π_1^* is ignored in (8). The intuition for this derivative is quite straightforward. An increase in w affects the profit of firm 1 in two ways. First, it directly increases its revenue in the upstream sector by $q_2 = D_2$. Second, it increases the price for good 2 which indirectly affects the profit of firm 1. Although $\frac{\partial \pi_1^*}{\partial w} = D_2 > 0$ and $\frac{\partial \pi_2^*}{\partial w} > 0$ by Proposition 2, we cannot determine the sign of $\frac{\partial \pi_1^*}{\partial p_2}$. Also, we have

$$\frac{d\pi_1^*}{dc_2} = \frac{\partial \pi_1^*}{\partial p_2}\frac{dp_2^*}{dc_2}. \tag{9}$$

Similarly, an increase in c_2 affects the profit of firm 1 via a change in p_2^*. There is no direct effect in this case, because c_2 does not enter π_1 directly. However, since $\frac{dp_2^*}{dc_2} > 0$ by Proposition 2, we know that $\frac{dw^*}{dc_2} < 0$ if $\frac{d\pi_1^*}{dp_2} > 0$, while not vice versa. In this case, $\underline{w}(c_2)$ is downward sloping, while it is upward sloping if $\frac{d\pi_1^*}{dc_2} < 0$ due to $\frac{d\pi_1^*}{dp_2} < 0$.

The intuition is clear. Consider the expression for the derivative

$$\frac{d\pi_1^*}{dp_2} = \underbrace{(p_1^* - c_0 - c_1)D_{1,2}}_{\text{substitution effect}} + \underbrace{(w - c_0)D_{2,2}}_{\text{revenue effect}}. \tag{10}$$

An increase in the rival product's price influences the integrated firm 1's profit in two channels. On one hand, it increases the demand for firm 1's product in the downstream sector, which in turn increases its profit. On the other hand, it decreases the firm 2's own demand, which reduces firm 1's revenue in the upstream firm. We will call the first effect the substitution effect and the second effect the revenue effect.[9] The first term in the formula (10) indicates the downstream substitution effect and the second term indicates the upstream revenue effect. If the two products are highly substitutable, the first term dominates the second term, so an increase in p_2 increases the profit of firm 1. In this case, both w and c_2 increase the profit of firm 1, therefore, the input price schedule, which is a sort of indifference curve of firm 1, must be downward sloping. On the other hand, if $D_{1,2}$ is small, i.e., the substitutability between the two product are low, an increase in p_2 only reduces the revenue of firm 1 without affecting the boost of its demand considerably. In this case, the input price schedule will be upward sloping. Intuitively, the economics behind the downward input price curve is that a low cost

[8] This sign comes from the fact that $\underline{w}$ is the minimum of $\mathbb{W}_1$, that is, $\underline{w}$ is in a range in which π_1^* is increasing in w.

[9] Dewenter and Haucap (2007) use the term of the competition effect or the cannibalization effect for the first effect.

of the entrant implies a low profit of the incumbent so that the input price offer should be high for the incumbent to accept it. On the other hand, the economics behind the upward input price curve is that a low cost of the entrant yields a high profit of the incumbent so that the incumbent will be more likely to accept an offer, thus the entrant makes a low offer.

The upshot is that the upward sloping $\underline{w}(c_2)$ curve is possible mainly because of a low substitution effect due to high product differentiation. Without it, the curve will be usually downward sloping.

Is it necessary for the government to regulate the input price? Under full information, the efficient entrant enters and the inefficient entrant does not, provided that the two firms can voluntarily bargain over the access price in a way that the entrant makes the offer on a take-it-leave-it basis. This implies that the access price regulation is not necessary for efficient entry if the firms can enter into voluntary negotiation and the entrant has the bargaining power.

III. Model of Incomplete Information

In this section, we depart from the assumption of full information. Firm 2 has private information about its own cost c_2, while firm 1 is not informed of the value. The value of c_2 is either c_L or c_H where $c_L < c_H$. The prior probability that $c_2 = c_L$ is denoted by $\lambda \in (0,1)$. It is assumed that λ is common knowledge. This information is perfectly revealed after the entry.[10] Since this is a sequential game of incomplete information, it is reasonable to use the Perfect Bayesian Equilibrium as a solution concept.

In this sequential game, the informed player, firm 2, first makes a take-it-or-leave-it offer to firm 1. The uninformed player, firm 1, forms the posterior belief after observing the price offer of the informed entrant. Let the posterior belief that the marginal cost of firm 2 is c_L be $\hat{\lambda} \in [0,1]$. The notation $\hat{\lambda}(w)$ means that the incumbent believes that the entrant's cost is c_L with probability $\hat{\lambda}$ after observing w.

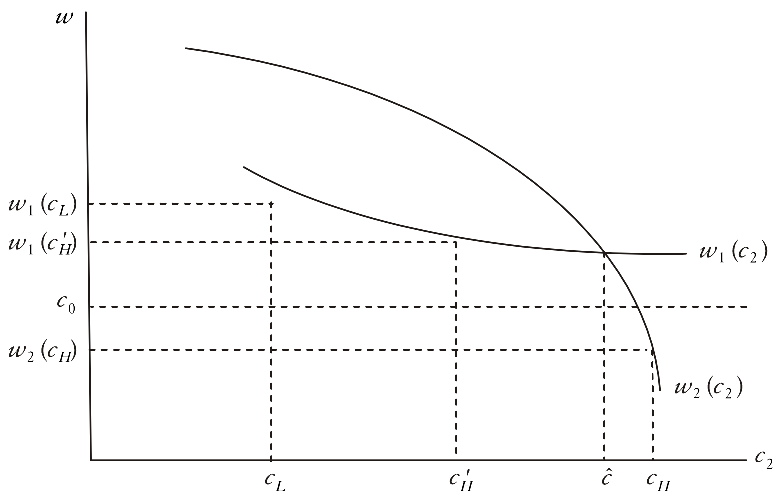
We define $\mathbb{C}_1$ and $\mathbb{C}_2$ by a set of pairs of (c_2, w) satisfying [PC1] and [PC2] respectively. Then, $\mathbb{C} = \mathbb{C}_1 \cap \mathbb{C}_2$ is a feasible set of input prices associated with costs.

[10] This can be justified by the long-term nature of the interactions between the firms. If we interpret the post-entry profit of each firm as the long-run average profit, it is more natural to assume that firms know each other's cost over time.

1. When $\underline{w}(c_2)$ is Negatively Sloped

Consider c_L and c_H which are pointed in Figure 3. If firm 1 has full information, firm 2 with a low production cost would choose $w_L = w_1(c_L)$ and firm 2 with a high production cost would choose w_H which is any offer less than $w_1(c_H)$ as input prices,[11] and only the high offer w_L will be accepted. A high-cost entrant cannot find any profitable input price which can be willingly accepted by the incumbent. So, he is indifferent among any offer as long as it is rejected. In fact, this is the only separating equilibrium outcome.[12]

[Figure 3] Separating Equilibria with Downward Sloping Input Price Schedule



$w_L = w_1(c_L)$, $w_H > w_1(c_H)$, *when* $c_2 = c_H > \hat{c}$
No Separating Equilibrium when $c_2 = c_H > \hat{c}$

To see why this is an equilibrium, assign the most pessimistic off-the-equilibrium belief, that is, assume that any off-the-equilibrium offer is made by a low-type entrant.[13] If high-type firm 2 increases the offer so as to be accepted, he will lose money because $(w, c_H) \notin \mathbb{C}_2$. So, he will not deviate. If his offer is rejected, he is indifferent between deviating and not. Therefore, a high-type firm 2 has no incentive to deviate from the equilibrium offer. A low-type firm 2 clearly has no

[11] If $w_H = w_1(c_H)$ and this is always accepted, it could be an equilibrium as well.

[12] Although high-type equilibrium offers are not unique, the equilibrium outcome is unique, since they are rejected in equilibrium.

[13] The most pessimistic belief implies that $\hat{\lambda} = 1$ if $\underline{w}'(c_2) < 0$ because an offer is more likely to be rejected when the entrant is perceived to be low type, but that $\hat{\lambda} = 0$ if $\underline{w}'(c_2) > 0$, because the opposite is true.

incentive to increase his offer. If he lowers the offer, he will be perceived as a low type under the pessimistic belief and this will be rejected. Hence, in this case, the undistorted outcome is an equilibrium and no costly signal is necessary. In this separating equilibrium, the low type successfully enters the downstream market and the high type stays out of the market. A high price signals the low cost (superior technology), and invokes entry. We will call this "entry-invoking behavior". In other words, entry-invoking refers to signalling by high price to be invited to enter. However, costly entry invoking behavior by an excessively high price is unnecessary. Thus, there is no efficiency loss, and neither excessive foreclosure nor excessive entry occurs.

Consider an alternative situation in which entry would be efficient regardless of the cost type, i.e., c_L, $c_H < \hat{c}$, as (c_L, c'_H) pair in Figure 3. In this case, both offers which are made according to $w_1(c)$ would be accepted under full information. However, this cannot be an equilibrium under incomplete information, because the low type would imitate the high type insofar as the high type's offer is lower and this will be accepted as well. Therefore, in a separating equilibrium, the high type's offer must be distorted so as for the low type not to imitate it. This requires that $w_L < w_H$. However, the high type would imitate the low type. Thus, generally, there is no separating equilibrium in which both offers are accepted with probability one, because one type (bad type) would imitate the other (good type).[14]

Proposition 4 *When the fee schedule is downward sloping, (i) the undistorted outcome is the unique separating equilibrium, if and only if only entry by the low type is feasible. (ii) If entry by both types is feasible, there is no (pure strategy) separating equilibrium.*

The intuition is clear. First, why is high price a signal of low cost? This is because a low cost of the entrant implies a low profit of the incumbent which in turn implies that only a high price will be accepted by the incumbent. Second, why is it unnecessary for a low-cost type to engage in costly signal in spite of the high-cost type's imitation possibility? It is too costly for a high-cost type to imitate, because he has to pay a higher price than the price he can barely afford $w_1(c_H)$ in order to pretend as if he were a low-cost entrant. This feature is mainly due to a downward-sloping input price schedule.

Now, consider the possibility of a pooling equilibrium. Let the pooling offer be

[14] This is the case to the extent that we allow only pure strategies. If we allow mixed strategies, a separating equilibrium can exist. Let $r(w)$ be the probability that w is accepted. If $r(w_L)=1$ and $r(w_H)\in(0,1)$, a low type must be indifferent between w_L and w_H. Therefore, it is required that $\pi_2^*(w_L,c_L)-K=r(w_H)[\pi_2^*(w_H,c_L)-K]$, that is $r(w_H)=\frac{\pi_2^*(w_L,c_L)-K}{\pi_2^*(w_H,c_L)-K}<1$. It is clear that a high type has no incentive to mimic a low type.

w^p and assign the most pessimistic belief so that any off-the-equilibrium offer comes from a low type. In equilibrium, this pooling offer must be accepted. If a pooling offer were rejected, a low type would profitably deviate to $w_1(c_L)$ which would be always accepted under the pessimistic belief. The condition for firm 1 to accept a pooling offer is that

$$\lambda\pi_1^*(w^p, c_L) + (1-\lambda)\pi_1^*(w^p, c_H) \geq \pi_1^M, \tag{11}$$

more specifically, $w^p > w_1(c_H)$, since $\pi_1(w_1(c_H), c_L) < \pi_1^M$ and $\pi_1(w_1(c_H), c_H) = \pi_1^M$. Then, a high-type firm 2 will not find it in his interest to make such a high offer $(w^p > w_1(c_H))$ if $\hat{c} < c_H$ so that $w_1(c_H) > w_2(c_H)$. Hence, we have the following proposition.

Proposition 5 *When the fee schedule is downward sloping, (i) there is no pooling equilibrium, if* $\hat{c} < c_H$. *(ii) If entry by both types is feasible, i.e.,* $c_H < \hat{c}$, *there exist a continuum of pooling equilibria in which firm 2 offers* $[w \in (w_1(c_H),\ \min\{w_1(c_L), w_2(c_H)\}]$ *and it is accepted by firm 1 for* $\lambda \leq \frac{\pi_1^*(w^p, c_H) - \pi_1^M}{\pi_1^*(w^p, c_H) - \pi_1^*(w^p, c_L)}$.

Since the downward sloping price schedule corresponds to the case that $\partial\pi_1^* / \partial c_2 > 0$, we have $\pi_1^*(w, c_H) > \pi_1^*(w, c_L)$ for all w. Thus, if λ is too high, the profit of firm 1 when he accepts the pooling offer is expected to be lower than the monopoly profit. Therefore, λ must be small enough. Also, note that no excessive entry occurs in this pooling equilibrium. Entry occurs in a pooling equilibrium if and only if entry occurs under complete information.

2. When $\underline{w}(c_2)$ is Positively Sloped

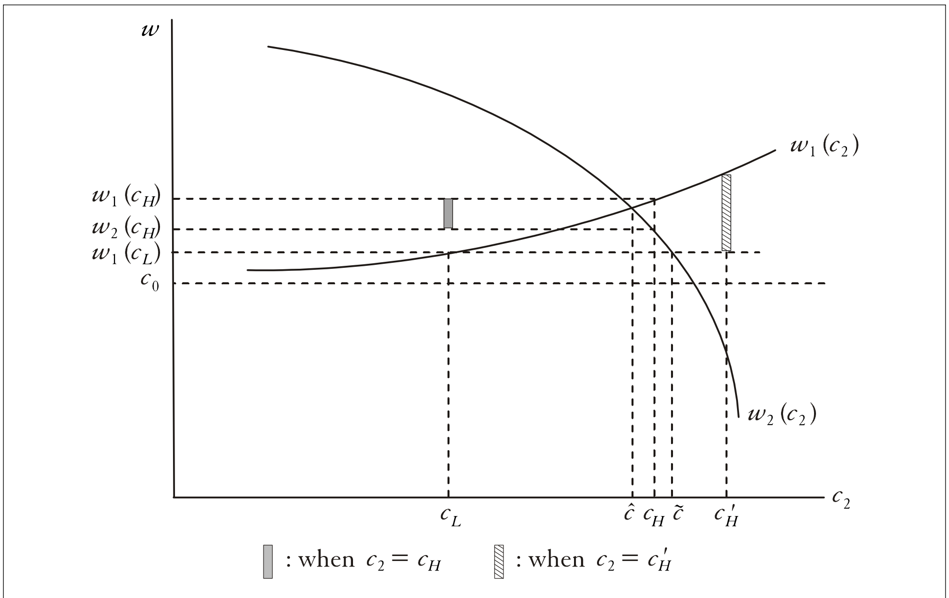
Figure 4 illustrates the case in which the input price schedule is upward-sloping, i.e., $w_1(c_L) < w_1(c_H)$ where $c_L < \hat{c} < c_H$. Under full information, a low type firm 2 offers $w_1(c_L)$ which is accepted, and a high type offers any w less than $w_1(c_H)$ which is rejected.[15]

However, it can be shown that under incomplete information, this is, in general, not a separating equilibrium. If $w_1(c_L) < w_2(c_H)$, this is clearly not an equilibrium, because firm 2 always wants to lower the input price. So, if the high type mimics the low type, it is always successful because the offer is accepted. Therefore, for a separating equilibrium, a low type's offer must be distorted upward so that a low

[15] A high-type entrant cannot offer a price which can be accepted by the incumbent, because he will then lose money. Thus, he will offer any price $w \notin \mathbb{W}_1$. However, considering a small perturbation by assuming that firm 1 accepts any offer with some small probability $\varepsilon > 0$, offering $w \notin \mathbb{W}_2$ is not (trembling-hand) perfect.

type offers a higher price than a high type in equilibrium. The high price is accepted because it is a signal of a low cost, while the low price is rejected. Thus, in this separating equilibrium, only the efficient firm successfully enters. Successful entry by the low type is due to his costly entry invoking behavior by an excessively high input price offer.

[Figure 4] Separating Equilibria with Upward Sloping Input Price Schedule



If $w_1(c_L) > w_2(c_H)$ as in the case of c'_H in Figure 4, a high type has no incentive to imitate the higher price of the low type. So, it is easy to see that the undistorted outcome can be a separating equilibrium, just as we saw in the case of negatively sloping $\underline{w}(c_2)$.

Let w_L and w_H be the separating equilibrium offers by a low type and a high type respectively. Defining $\tilde{c}$ by $w_1(c_L) = w_2(\tilde{c})$, we have

Proposition 6 *When the fee schedule is upward sloping, (i) if $c_H < \hat{c}$, there exists no separating equilibrium, (ii) if $\hat{c} < c_H < \tilde{c}$, there is a continuum of separating equilibria in which $w_H < w_L$ and an offer w is accepted if and only if $w \geq w_L$, where $w_L \in [\max\{w_1(c_L), w_2(c_H)\}, \min\{w_1(c_H), w_2(c_L)\}]$,* [16] *and (iii) if $c_H > \tilde{c}$, the undistorted equilibrium is the unique separating equilibrium.*

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[16] This equilibrium strategy of firm 1 is supported by the most pessimistic belief that $\hat{\lambda}(w) = 0$ for all $w \neq w_L$.

The range of w_L is $[w_2(c_H), \underline{w}_{12}]$ if $w_1(c_L) < w_2(c_H)$ and $[w_1(c_L) < \underline{w}_{12}]$ if $w_1(c_L) > w_2(c_H)$ where $\underline{w}_{12} \equiv \min\{w_1(c_H), w_2(c_L)\}$. Note that $\max\{w_1(c_L), w_2(c_H)\} < \min\{w_1(c_H), w_2(c_L)\}$ since $w_2(c) > w_1(c)$ for $c = c_L$ and $w_1(c) > w_2(c)$ for $c = c_H$.

If $w_L > w_2(c_H)$, the high type cannot imitate w_L, because no offer higher than $w_2(c_H)$ would be profitable to him. The low type will not deviate from the offer, because a deviation to any other offer, say $w_1(c_L)$, would be perceived to come from a high type and would be rejected. Also, it must be in the interest of a low-type entrant to accept w_L. Therefore, $w_L \le w_2(c_L)$. Moreover, w_L cannot be higher than $w_1(c_H)$, either. If the offer is so high that $w_L > w_1(c_H)$, a low type would profitably offer a slightly lower price $w' = w_L - \varepsilon > w_1(c_H)$ which would be accepted. The set of separating equilibrium price is drawn in Figure 4 in this case. The set of separating equilibrium in the case that $w_1(c_L) < w_2(c_H)$ can be characterized similarly.

If a low type finds it too costly to distort its input price, they may end up with a pooling equilibrium by giving up offering such a high price. The next proposition characterizes pooling equilibria.

Proposition 7 *When the fee schedule is upward sloping, if* $c_H < \tilde{c}$*, there is a continuum of pooling equilibria in which the pooling price* $w \in [w_1(c_L), \min\{w_1(c_H), w_2(c_H)\}]$ *if* $\lambda \ge \frac{\pi_1^M - \pi_1^*(w^p, c_H)}{\pi_1^*(w^p, c_L) - \pi_1^*(w^p, c_H)}$.

If $w_2(c_2)$ is decreasing in c_2, $\hat{c} < \tilde{c}$. This implies that in this pooling equilibrium, some inefficiency results in the sense that excessive entry can occur when $\hat{c} < c_H < \tilde{c}$.

Signaling along the input price schedule is not possible, as far as the schedule is upward-sloping, because the high type (bad type) can easily imitate the low type by a lower price offer. To prevent the incentive to mimic, the offer of the low type must be higher. This involves a costly signal. There will be efficient entry, but it could be obtained only by an inefficiently costly signal. This is the main difference from the case of the downward sloping price schedule.

Although this game has a plethora of separating (Perfect Bayesian) equilibria, Intuitive Criterion by Cho and Kreps (1987) can refine the equilibrium set significantly. In fact, it turns out that $w_L = w_2(c_H)$ is the unique equilibrium offer that survives Intuitive Criterion when $w_1(c_L) < w_2(c_H)$. To see this, for an equilibrium offer which is strictly higher than $w_2(c_H)$, consider an off-the-equilibrium offer $w' = w_L - \varepsilon > w_2(c_H)$. If it is accepted, a high type is made worse off than in the equilibrium, whereas a low type is made better off. Since w' is equilibrium (weakly) dominated for a high type, Intuitive Criterion requires that $\hat{\lambda}(w') = 0$. Then, low-type firm 2 would have an incentive to deviate to w', which overturns the equilibrium involving any $w_L > w_2(c_H)$. This implies that $w_L =$

$w_2(c_H)$ is the unique separating equilibrium outcome which passes the Intuitive Criterion. When $w_1(c_L) > w_2(c_H)$, a similar argument can be applied. Suppose $w_L > w_1(c_L)$. Consider an off-the-equilibrium price $w = w_L - \varepsilon > w_1(c_L)$. When this offer is accepted, a low type would gain, whereas a high type would lose. This means that the offer of w is equilibrium dominated to a high type and the Intuitive Criterion requires that $\hat{\lambda}(w) = 0$. Under this belief, a low type would have an incentive to lower the offer. Hence, no separating equilibrium involving $w_L > w_1(c_L)$ passes the Intuitive Criterion. On the other hand, all the pooling equilibria survive the Intuitive Criterion. It is clear that no type is benefited from making a higher offer than the equilibrium offer. If firm 2 lowers the offer slightly, both types get benefited given that firm 1 accepts it. Thus, $w - w^p - \varepsilon(\varepsilon > 0)$ is equilibrium dominated for neither type, implying that the Intuitive Criterion cannot subvert any pooling equilibrium.[17]

3. Discussion on a Continuum Type

If the value of the entrant's cost is drawn from a continuum space $\Theta \equiv [\underline{c}, \overline{c}]$ where $\hat{c} \in \Theta$ according to a probability density function $f(c_2)$, the qualitative nature of the separating equilibrium remains unaffected. The preceding subsection indicates that there is no pure strategy separating equilibrium when the price schedule is negatively sloped and entry is always efficient. Thus, in this section, we focus on this case of downward sloping price schedule and we see whether the existence of a separating equilibrium is recovered by allowing mixed strategies of the incumbent.

Let $(w^*(c_2), r^*(w))$ the equilibrium pair of strategies where $r^*(w)$ is a probability that w is accepted. If $w^*(c_2)$ is a separating equilibrium strategy, it must be that $w^*(c_2) \neq w^*(c_2')$ for any $c_2' \neq c_2$, i.e., $w^{*\prime}(c_2) \neq 0$. As such, firm 1 can perfectly infer the true type of firm 2 from the equilibrium offer w by the inverse function inference rule $c_2 = \rho(w) \equiv (w^*)^{-1}(w)$.

We will characterize the equilibrium strategies. From $r^*(w) \in (0,1)$, it is clear that $w^*(c_2) = w_1(c_2)$ from the indifference condition. Using $c_2 = \rho(w)$, the incentive compatibility condition of firm 2 requires that

[17] Some may conjecture that a stronger refinement, for example, D1 Criterion by Cho and Kreps (1987) or Universal Divinity by Banks and Sobel (1987) can eliminate all or some pooling equilibria. However, it can be shown that it is not possible unless we make additional assumptions on the profit function of firm 2. Define $r_0(w, c_2)$ be firm 1's mixed strategy (probability) of accepting the off-the-equilibrium offer w that makes firm 2 of type c_2 indifferent between w^p and w. If $r_0(w, c_H) < r_0(w, c_L)$, a high type is more likely to deviate to w, so D1 Criterion requires that $\hat{\lambda}(w) = 0$. Let $w' = w - \varepsilon$ for an equilibrium offer w. In this model, $r_0(w', c_L) = \frac{\pi_2^*(c_L)}{\pi_2^*(w', c_L)}$ and $r_0(w', c_H) = \frac{\pi_2^*(c_H)}{\pi_2^*(w', c_H)}$. If $\frac{\pi_2^*(c_L)}{\pi_2^*(c_H)} > \frac{\pi_2^*(w', c_L)}{\pi_2^*(w', c_H)}$ for $w' > w$, D1 Criterion eliminates pooling equilibria by pinning down the posterior belief to $\hat{\lambda} = 0$, but otherwise it does not.

$$w^*(c_2) = \arg\max_{w} r^*(w)[\pi_2(p_1^*(w), p_2^*(w), w, \rho(w)) - K]. \tag{12}$$

The first-order condition implies that

$$r'(w)[\pi_2^* - K] + r\frac{d\pi_2^*}{dw} = 0\ , \tag{13}$$

or equivalently,

$$\frac{r'(w)}{r(w)} = -\frac{\frac{d\pi_2^*}{dw}}{\pi_2^* - K} \equiv \phi(w)\ . \tag{14}$$

Since $\frac{d\pi_2^*}{dw} < 0$ and $\pi_2^* > K$, we have $r'(w) > 0$, that is, a higher offer is accepted with a higher probability. Solving the differential equation, we obtain

$$r(w) = A(w)e^{\Phi(w)}\ , \tag{15}$$

where $\Phi(w) = \int_{\overline{w}}^{w} \phi(x)dx$. Let $w_1(\underline{c}) \equiv \overline{w}$ and $w_1(\hat{c}) \equiv \hat{w}$. Then, it is clear that $r^*(w) = 1$ for all $w > \overline{w}$ and $r^*(w) = 0$ for all $w < \underline{w}$. Also, note that $r^*(w)$ must be left continuous; otherwise, a slight increase in w at the discontinuous point induces a significant jump in the probability of acceptance, implying that such w cannot be an equilibrium offer. Therefore, by the boundary condition $r^*(\overline{w}) = 1$, we have

$$r(\overline{w}) = A(\overline{w})e^{\Phi(\overline{w})} = 1\ .$$

Thus, we get $A(\overline{w}) = e^{-\Phi(\overline{w})}$, meaning that $r(w) = e^{\Phi(w) - \Phi(\overline{w})}$.

Our main concern is the possibility of two kinds of inefficiency due to incomplete information. First, excessive foreclosure may occur when an efficient entrant cannot enter the market. Second, excessive entry may occur when an inefficient entrant enters the market. Recall that neither type of inefficiency occurs in a separating equilibrium if we allow only pure strategies of the incumbent. However, if we allow mixed strategies, excessive foreclosure can occur in this separating equilibrium. In this equilibrium, the incumbent uses a mixed strategy to prevent a lower-cost entrant from mimicking a higher-cost entrant thereby paying a lower fee in the case of downward fee schedule. On the other hand, excessive entry can occur in a pooling equilibrium. A lower offer by a higher-cost type must be rejected with higher probability to prevent the incentive of a lower-cost type to make a lower offer. As such, excessive foreclosure may occur in the separating equilibrium to prevent such an incentive of the lower-cost type, while no excessive entry occurs.

IV. Regulation

In this section, we consider the effect of the access price regulation, mainly the retail-minus regulation. Under the retail-minus regulation, the wholesale price cannot exceed the retail price minus the retail cost. The purpose of the retail-minus regulation is two-fold; to lower the final good prices and to induce only efficient firms to enter the downstream market. The first effect was already challenged by Höffler and Schmidt (2007). They argued that the integrated firm may increase its retail price under the retail-minus regulation in order to meet the regulation standard. In this section, we reexamine the argument by Höffler and Schmidt (2007) and address the second issue.

The retail-minus regulation requires that

$$w \leq p_1^*(c_2) - c_1 \tag{16}$$

in our model. In fact, it corresponds to a simple form of ECPR. Laffont and Tirole (1994) asserted that this form of ECPR rule ensures the optimal entry decision under following five assumptions; (i) downstream firms produce perfect substitutes, (ii) the regulator observes firm 1's cost, (iii) the entrant has no monopoly power, (iv) technologies exhibit constat returns to scale, and (v) the benchmark pricing rule is MC pricing. Since the products that are produced by downstream firms are not perfect substitutes and the entrant has a monopoly power in our model, efficient entry will not be generally guaranteed. Furthermore, under this regulation, the second-stage price competition of the firms given w is affected. The new best-response of firm 1 is $\overline{p}_1^{BR}(p_2;w) = \max\{w + c_1, p_1^{BR}(p_2;w)\}$. Therefore, if the regulation is binding, it must be that $\overline{p}_1^{BR}(p_2;w) > p_1^{BR}(p_2;w)$. Then, the new equilibrium prices must be that $\overline{p}_i^*(w) > p_i^*(w)$ for $i = 1,2$. However, the effect of the regulation on the retail prices can be completed only after we take the effect on the wholesale price into consideration. Note that the retail-minus regulation is a device to maintain higher prices given w. That is, the regulation is not to lower the wholesale price but to increase the retail prices. If the profits of both firms are increased as a result of the collusion-facilitation effect of the retail-minus regulation, the bargaining range becomes enlarged. Therefore, the new fee schedule is $w_1^R(c_2) < w_1(c_2)$. Thus, as long as the entrant has the bargaining power by making a take-it-or-leave-it offer, there is a good potential that the wholesale price is lowered due to the retail-minus regulation. If we consider this effect as well, the effect on the final goods prices is ambiguous.

Moreover, the incomplete information assumed in this model has further implications on the efficiency of entry. Consider the regulation constraint given by (16). Since $\partial \overline{p}_1^*(c_2)/\partial c_2 > 0$, the boundary has an upward slope as in Figure 4. Since it imposes an extra restriction, the possibility of signaling the efficiency is further limited. For example, in Figure 4, a low-cost type cannot signal its cost by a higher wholesale price with the regulation, while it could without the regulation. To see this, consider a separating offer by a low type w^s. If $w^s > p_1^*(w^s) - c_1$, it does not satisfy the retail-minus regulation. Then, firm 1 might raise its price to meet the regulation standard so that $w^s = \overline{p}_1^*(w^s)$, and correspondingly firm 2 raises the price due to strategic complementarity. This clearly increases the profit of firm 2 but the effect on the profit of firm 1 is ambiguous. Firm 1's profit can be either increased or decreased. Let $\hat{c}'$ be the counterpart for $\hat{c}$ under the regulation. In the former case, $\hat{c} < \hat{c}'$ but it is still maintained that $c_L < \hat{c}' < c_H$ due to the assumption that $c^f < c_H$ and the relation of $\hat{c}' < c^f$. In the latter case, however, it is possible that $\hat{c}' < c_L < c_H$. In this case, the only possible equilibrium is the pooling equilibrium in which all types of the entrant choose the same price, implying that inefficient firms can enter the market.

Laffont and Tirole (1994) and Economides and White (1995) both criticize ECPR rule for paying little attention to the effect on the final good prices. Especially, Economides and White (1995) argued that ECPR does not necessarily ensure efficient entry but is socially harmful. Their main argument is that it may be socially desirable for even inefficient entry to occur because it triggers competition and thus this allocative efficiency may exceed the welfare loss by the inefficient entry. This paper provides a new argument against ECPR regulation other than the allocative efficiency.

V. Conclusion

In this paper, we analyzed the model of entry invoking under incomplete information. An informed entrant may engage in entry invoking behavior by offering a high input price to convince the incumbent that he is a low-cost type. In a screening model in which the incumbent offers the input price, entry invoking cannot occur and no useful information is revealed. Thus, if the information about the entrant's cost is really valuable and can make both firms better off, it will be in their common interests to wait for the entrant to offer the input price, thereby making it possible for them to coordinate on a more efficient signaling outcome.

This paper also has an interesting policy implication on the retail-minus regulation. It says that if the vertically integrated incumbent firm voluntarily bargains for the access charge with a potential entrant into the downstream industry who has a bargaining power, such a voluntary bargaining process leads to the efficient entry under complete information; hence, no regulation is necessary. Furthermore, under incomplete information about the entrant's cost, ECPR regulation cannot be even applicable, because $w_1(c_2)$ is unknown to the government. The retail-minus regulation can be applied under incomplete information, but it may reduce the signaling effect, possibly causing inefficient entry under incomplete information, which is even worse. Thus, it urges us to reexamine the effect of regulation policies which are widely used in access pricing.

Appendix

Proof of Proposition 1: As $c_2 \to \infty$, either $p_2 \to \infty$ or $D = 0$; otherwise, $(p_2^J - c_0 - c_2)D_2 = -\infty$. If $p_2 \to \infty$, $D_1 \to D$ by assumption (ii) Thus, $\Pi \to \pi_1^M < \pi_1^M + K$. If $D = 0$, $\Pi^J = (p_1^J - c_0 - c_1)D_1 < (p_1^J - c_0 - c_1)D \leq \pi_1^M < \pi_1^M + K$ by assumption (i). In either case, $\lim_{c_2 \to \infty} \Pi^J(c_2) < \pi_1^M + K$. On the other hand, if $c_2 = c_1$, $\Pi^J(c_2) \geq \max_{p_1}[(p_1 - c_0 - c_1)D_1 + (p_1 - c_0 - c_1)D_2] = \max_{p_1}(p_1 - c_0 - c_1)D = \pi_1^M$ by assumption (i) if $p_1 = p_2$. Since $\partial \Pi^J(c_2)/\partial c_2 < 0$, $\Pi^J(c_2) > \pi_1^M$ for all $c_2 < c_1$. Let $\bar{K} = \Pi^J(0)$. Since $\Pi^J(c_2)$ is continuous with respect to c_2, for any $K \leq \bar{K}$, there exists $c^f(K)$ such that $\Pi^J(c_2) \geq \pi_1^M + K$ for all $c_2 \leq c^f(K)$ and $\Pi^J(c_2) < \pi_1^M + K$ for all $c_2 > c^f(K)$.

Proof of Proposition 2: Differentiating equations (4) and (5) with respect to w yield

$$\begin{bmatrix} \pi_{11} & \pi_{12} \\ \pi_{21} & \pi_{22} \end{bmatrix} \begin{bmatrix} dp_1^* \\ dp_2^* \end{bmatrix} = -\begin{bmatrix} \pi_{1w} \\ \pi_{2w} \end{bmatrix} dw, \tag{17}$$

where $\pi_{11} = 2D_{1,1} + (p_1 - c_0 - c_1)D_{1,11} + (w - c_0)D_{2,11}$, $\pi_{12} = D_{1,2} + (p_1 - c_0 - c_1)D_{1,12} + (w - c_0)D_{2,12}$, $\pi_{21} = D_{2,1} + (p_2 - w - c_2)D_{2,21}$, $\pi_{22} = 2D_{2,2} + (p_2 - w - c_2)D_{2,22}$, $\pi_{1w} = D_{2,1}$ and $\pi_{2w} = -D_{2,2}$. Note that $\pi_{ii} < 0$ for $i = 1,2$, $\pi_{ij} > 0$ for $i \neq j$ and $\pi_{iw} > 0$. Let

$$\Delta = \begin{bmatrix} \pi_{11} & \pi_{12} \\ \pi_{21} & \pi_{22} \end{bmatrix}.$$

Applying Cramer's rule, we obtain

$$\frac{\partial p_1^*}{\partial w} = -\frac{|\Delta_1|}{|\Delta|} > 0, \tag{18}$$

since $|\Delta| > 0$ by the second-order condition and $|\Delta_1| = \pi_{1w}\pi_{22} - \pi_{2w}\pi_{12} < 0$. Similarly, we have

$$\frac{\partial p_2^*}{\partial w} = -\frac{|\Delta_2|}{|\Delta|} > 0, \tag{19}$$

since $|\Delta_2| = \pi_{2w}\pi_{11} - \pi_{1w}\pi_{21} < 0$.

Also, differentiating equations (4) and (5) with respect to c_2 yield

$$\begin{bmatrix} \pi_{11} & \pi_{12} \\ \pi_{21} & \pi_{22} \end{bmatrix} \begin{bmatrix} dp_1^* \\ dp_2^* \end{bmatrix} = - \begin{bmatrix} \pi_{1c_2} \\ \pi_{2c_2} \end{bmatrix} dw , \tag{20}$$

where $\pi_{1c_2} = 0$ and $\pi_{2c_2} = -D_{2,2} > 0$. Therefore, by applying Cramer's Rule, we obtain $\partial p_i^* / \partial c_2 > 0$ for $i = 1,2$.

Proof of Proposition 3: First, $K = 0$, $t = 0$ and $w = c_0$. If $c_2 < c_1$, the equilibrium prices are $p_1^* = c_1$ and $p_2^* = c_1 - \varepsilon$, and thus $\pi_2^*(c_2) = (p_2^* - c_2)D(p_2^*)$ $\approx (c_1 - c_2)D(c_1)$. Since $c_2 < c_1$, we have $\pi_1^M(c_1) = (p^M(c_1) - c_1)D(p^M(c_1)) < (p^M(c_2)$ $-c_2)D(p^M(c_2)) \equiv \pi_2^M(c_2)$. Note that $\pi_2^*(c_2) = \pi_2^M(c_2) > \pi_1^M(c_1)$ if $c_1 = p^M(c_2)$, i.e., $c_2 = (p^M)^{-1}(c_1)$. Therefore, $\pi_2^*(c_2) > \pi_1^M(c_1)$ for all $c_2 \le (p^M)^{-1}(c_1)$. Let $(p^M)^{-1}$ $(c_1) = c_2(K = 0)$. Then, for all $c_2 \le c_2(K = 0)$ and for all c_2 such that $w \le c_0$ $+ c_1 - c_2$, only firm 2 will produce and as w is increased up to $c_0 + c_1 - c_2$, $\pi_1^*(w; c_2)$ is continuously increasing in w and $\pi_2^*(w; c_2)$ is continuously decreasing, while Π^I is constant. We will show that there exist large c_1 and w satisfying the following two conditions;

$$w \le c_0 + c_1 - c_2 , \tag{21}$$

$$\pi_1^*(w; c_2) \equiv (w - c_0)D(p_2^*(c_2)) \ge \pi_1^M(c_0, c_1) . \tag{22}$$

Fix $c_1 = c_1^0$ and let $w_0(c_1^0)$ such that $\pi_1^*(w; c_2) = \pi_1^M(c_0, c_1^0)$. Note that $d\pi_1^M / dc_1 < 0$ in inequality (22) and $dw_0(c_1) / dc_1 < 0$, both inequalities (21) and (22) hold for all $c_1 \ge c_1^0$ and for all $w \ge w_0(c_1^0)$. Therefore, there exists large c_1 and w such that $\pi^*(w; c_2) > \pi_1^M$ and $\pi_2^*(w; c_2) > K = 0$ for all $c_2 \le c_2(K = 0)$. By continuity of $\pi_2^*(w; c_2)$ with respect to c_2, there exists $\hat{K} > 0$ such that for all $K \le \overline{K}$, entry is competitively feasible if $c_2 \le c_2(K)$. Finally, for all $t \le \overline{t}(> 0)$, entry is competitively feasible if $c_2 \le c_2(K)$ by continuity of D as $t \to 0$.

Proof of Proposition 4: It is already proved that the undistorted outcome is a separating equilibrium, if only the low type's entry is feasible. So, what remains is the uniqueness part. Since both offers cannot be accepted in a separating equilibrium, the offer from a high type must be rejected. Suppose the offer from a low type w_L is not $w_1(c_L)$. Then, he always has an incentive to deviate to $w_1(c_L)$ from the pessimistic belief. The converse part is also trivial. We showed that if both types of entry are feasible, neither a separating equilibrium nor a pooling equilibrium exists. This completes the proof.

Proof of Proposition 5: It is clear that there is no pooling equilibrium if $\hat{c} < c_H$ as we already argued. When $c_H < \hat{c}$, the incentive compatibility (IC) conditions of firms lead the range of the pooling equilibrium offer. First, consider (IC) condition of firm 1. It is profitable for him to accept w^p if (11) holds. For this to hold for some $\lambda \in (0,1)$, it must be that $\pi_1(w^p, c_H) > \pi_1^M$, hence, $w^p > w_1(c_H)$. Also, note that (11) holds if $\lambda \le \frac{\pi_1^*(w^p, c_H) - \pi_1^M}{\pi_1^*(w^p, c_H) - \pi_1^*(w^p, c_L)}$. Second, consider (IC) condition of firm 2. Regardless of his type, his deviant offer w will be accepted if and only if $w \ge w_1(c_L)$, because his deviation would be perceived as L. Thus, his best offer that will be accepted is $w_1(c_L)$. This implies that he has no incentive to deviate if $w^p \ge w_1(c_L)$. Finally, the participation condition of firm 2 is that $w^p \le w_2(c_2)$. Therefore, $w^p \le w_2(c_H)$ since $w_2(c_L) > w_2(c_H)$. This completes the proof.

Proof of Proposition 6: Due to the arguments provided below Proposition 6, it remains to show that $w_L = [w_1(c_L), \min\{w_1(c_H), w_2(c_L)\}]$ if $w_1(c_L) > w_2(c_H)$. Suppose $w_L > w_1(c_H)$. A low type will deviate to $w' = w_L - \varepsilon > w_1(c_H)$, since it will be accepted. So, it must be that $w_L \le w_1(c_H)$. Also, if $w_L \le w_2(c_L)$, a low type prefers w_L being accepted to being rejected.

Proof of Proposition 7: The incentive compatibility (IC) condition of firm 1 implies that

$$\lambda \pi_1^*(w^p, c_L) + (1-\lambda)\pi_1^*(w^p, c_H) \ge \pi_1^M, \tag{23}$$

requiring that $\lambda \ge \frac{\pi_1^M - \pi_1^*(w^p, c_H)}{\pi_1^*(w^p, c_L) - \pi_1^*(w^p, c_H)}$. Also, inequality (21) implies that $w^p > w_1(c_L)$. The participation condition of the high type is that $w^p \le w_2(c_H)$. The nonemptiness of w^p satisfying above two inequalities requires that $c_H < \tilde{c}$. Finally, (IC) condition of firm 2 requires that $w \le w_1(c_H)$ under the most pessimistic belief $\hat{\lambda}(w) = 0$ for any $w \ne w^p$. This completes the proof.

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