Topics

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The Effect of Vertically Differentiated Entry Under Retail-Minus Access Pricing

Abstract: We examine the effect of vertically differentiated entry under retail-minus access pricing. Unlike the existing studies, we show that retail-minus regulation could obtain the intended result of reducing the retail price. This concurs to a great extent with conventional wisdom, which has been criticized, but not entirely, because the price-reducing effect in our model is not driven by competition. Such an effect is more obvious in the case of inferior-quality entry, where the lower incumbent price can help the entrant expand the market. The key is that the retail-minus rule offers the incumbent an incentive to reduce its price in order to utilize the value created by the entrant. The outcome relies on the combination of a differentiated entry and the retail-minus rule. Differentiated entry under the retail-minus rule could benefit both the incumbent and consumers because the rule protects the incumbent from business stealing while allowing value creation by the entrant.

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1 Introduction

A firm can have market dominance when it owns and has exclusive access to an essential input. Local loops and spectrums in the telecommunications industry, transmission grids in the electricity industry, and rail tracks in the railway industry are examples of essential inputs. In response to the lack of competition in such markets needing essential inputs, public regulators often require

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incumbent firms to provide access to the inputs for potential entrants. A critical issue is then the pricing of such access, which is known as one-way access pricing problem. The retail-minus rule, the main subject of this paper, has been popular in reality as a one-way access pricing approach.[1] For instance, the British regulator, Ofcom (Office of Communications), implemented retail-minus regulation to allow access to BT's wholesale IPstream and Datastream services in the broadband Internet access market (Sarmento and Brandao 2007). In Korea, Telecommunications Business Act was revised in 2010 to require a significant market power (SMP) mobile network operator (MNO) to offer wholesale service to mobile virtual network operators (MVNOs) at the rate determined by the retail-minus rule.

The retail-minus rule requires that the access charge be the incumbent's retail price minus the incumbent's retail cost. It is also known as margin rule that is a special case of the efficient component pricing rule, or ECPR (Armstrong 2002). The idea of ECPR is basically such that the incumbent is permitted to price access at a level sufficient to compensate it for the sacrifice in profit owing to the supply to the entrant.

Regulators tend to expect the retail-minus rule to reduce the ability of the incumbent firms to pursue market foreclosure through margin squeeze and facilitate efficient entries into the retail markets (IRG 2005). Armstrong (2002) observed that it has the virtue of being simple and informationally undemanding as an access pricing rule. And Laffont and Tirole (2000) noted two social benefits expected from the rule. First, it sends an efficient signal to potential entrants. Second, entry has no effect on the incumbent's profit or revenue. They explained that such revenue neutrality is important because it reduces the incumbent's incentive to destroy the level playing field by skimping on the quality of access. It will also prevent interference with the historical cross-subsidization of the bottleneck segment by the competitive segment. However, access pricing under the retail-minus rule is not optimal except in a few special cases (Armstrong 2002). In this paper, we do not consider the optimality of retail-minus access pricing, but rather its effect, which is worth knowing because it is prevalent regardless of its optimality.

1 Cost-based pricing with the long-run incremental cost (LRIC) method may be preferred by the regulators themselves, as it makes their policies more effective and visible. However, Laffont and Tirole (2000) pointed out that it is not easily justified in an economic sense, unlike the broad regulatory consensus. Sarmento and Brandao (2007) explained in detail the problems with cost-based regulation relative to retail-minus regulation. Yoon (2010) found from an analysis of a Hotelling model that retail-minus regulation is likely to increase social welfare more than cost-plus regulation.

It is a conventional wisdom, especially among regulators, that the use of retail-minus access pricing introduces competition to the concentrated retail market and contributes to reducing consumer prices. As Armstrong (2002) explained, however, this does not hold true in a simple model with a perfectly competitive downstream market, where the retail-minus rule simply replicates the totally unregulated outcome. Hoffler and Schmidt (2008) examined more realistic models with differentiated entry to show that the retail-minus rule cannot be relied upon to reduce retail prices. Consistent with these theoretical findings, Dewenter and Haucap (2007) explained that the rule's major drawback is its allocative inefficiency if retail prices are left unregulated, citing the European Regulators Group's (ERG 2004) concern that, under the retail-minus rule, an excessive retail price will automatically feed into an excessive wholesale price or vice versa.

We consider the validity of the conventional wisdom again, but in a slightly different manner, reaching a quite different conclusion. While Hoffler and Schmidt (2008) assumed a horizontally differentiated oligopoly without cost difference, the effect of entry in our model depends on quality difference and cost difference. Laffont and Tirole (2000) pointed out that the presence of entrants induced by access regulation may be desirable because they create value through product differentiation or cost efficiency,[2] both of which are central to our model. Showing that the incumbent can often choose to lower its price, our results concur with the conventional wisdom, which has been criticized, but not entirely, because the price-reducing effect is not driven by competition. In other words, retail-minus regulation is useful, as it can obtain the intended result of reducing retail prices, but this is done primarily through constraining the choice set of the incumbent facing a value-creating entrant, not through competition.

The equilibrium of our model takes quite different forms depending on whether the entrant is of superior quality (and higher cost) or of inferior quality (and lower cost). In the case of superior-quality entry, the incumbent's price and profit are simply maintained at the monopoly level, which is consistent with the already-known revenue neutrality. Although it may appear as if regulation does not work here, we will explain that this monopoly price is still under the desirable effect of the retail-minus rule, constraining the price while superior-quality outputs are supplied. The price-reducing effect is more pronounced in the case of inferior-quality entry. Interestingly, we will show that revenue

2 They also mentioned another important possibility: entrants forcing the incumbent to produce more efficiently. However, the present work does not address this issue.

neutrality no longer holds and the incumbent can increase its profit quite often.[3] This profit improvement is often achieved by reducing the price. The key is that, in this case, the incumbent firm can increase its profit because of the entrant's capability to expand the market; its own retail pricing is the only instrument available to help the entrant expand the market under the retail-minus rule. The incumbent should consider whether it will lower its price to help market expansion or raise it (and hence, raise the input price) to exploit the expanded market.

For both superior-quality and inferior-quality entries, we can show that social welfare increases. This welfare result implies that imposing the retail-minus rule would not induce inefficient entry at the very least, which contrasts with Banerjee and Dippon's (2009) concern about access regulation in general. Furthermore, we will demonstrate that a duopoly under the retail-minus rule tends to perform better than under a voluntary relationship. A differentiated entry under the retail-minus rule could benefit both the incumbent and consumers because the rule protects the incumbent from business stealing while allowing value creation by the entrant with a differentiated product or cost efficiency.

The paper proceeds as follows: Section 2 presents the basic model. Sections 3 and 4 analyze the equilibria of the cases of superior-quality entry and inferior-quality entry, respectively. Section 5 discusses the merit of the retail-minus rule as compared to the voluntary relationship. Section 6 attempts to draw insights into the results and concludes the paper.

2 Model

Let us start from a simple standard model of vertical differentiation. A consumer in our model is assumed to purchase at most a single unit of a product (or service), and thereby, obtain the utility that depends on individual preference for quality (θ), product quality level (s), and price (p). The utility function is given by

$$U(p, s|\theta) = s\theta - p, \quad \theta \sim \text{uniform}[0, 1]. \tag{1}$$

The size of the consumer population is assumed to be 1.

Before access regulation enables an entry, firm 1 is a vertically integrated monopolist with an essential input upstream, the bypassing of which is not

3 Since this non-neutrality of revenue still guarantees positive incumbent profit in our equilibrium, we do not lose the benefits of revenue neutrality explained by Laffont and Tirole (2000).

possible for any other firm. One unit of access to the essential input is needed to supply one unit of final output. Firm 1's cost occurs only downstream, with its marginal cost being positive and constant at c_1. This simplifying assumption of zero upstream cost may represent the situation where most past essential input costs are considered as sunk. As the regulation forces firm 1 to provide access, firm 2 pays firm 1 the access charge, w, per unit produced and competes with firm 1 downstream. Its downstream marginal cost is c_2.

We impose four restrictions on the parameters: s_1, s_2, c_1, and c_2 as well as the variable w; these are summarized in Assumption 1. First, fixing firm 1's product quality level to 1, without loss of generality, we assume firm 2's product quality level ($\hat{s}$) is given to be different from 1. With these differentiated qualities fixed, the two firms compete by choosing their prices, p_1 and p_2.

Second, we need to ensure that downstream costs are not too expensive to frustrate the two firms' businesses by assuming $0 < c_1 < 1$ and $0 < c_2 < \hat{s}$. Then, there would exist at least a consumer (e.g. $\theta = 1$) willing to pay more than marginal cost for each firm's product.

Third, the entrant's efficiency, which can be measured by $\hat{s} - c_2$, should not be too high relative to that of the incumbent, $1 - c_1$. If an entrant has a very high quality or very low cost, it would be rational for the incumbent to choose to become a vertically separated input supplier. This case, however, is not very interesting to us, because retail-minus access pricing is based on the effective existence of the retail price of the incumbent, and regulators will not seriously consider access regulation in such markets. Assuming that $\frac{(\hat{s}-c_2)^2}{2\hat{s}} \leq (1-c_1)^2$ will eliminate such concern in all the equilibria we will consider in this paper.[4]

The last and most important restriction is the regulator's access pricing rule $w = p_1 - c_1$, where p_1 and c_1 are observed correctly.[5] We assume that the final output pricing of the incumbent is unregulated, and hence, the only instrument of regulation is the margin, which amounts to the case that Armstrong and Vickers (1998) called the access pricing problem with deregulation.

This equational definition of the retail-minus rule or margin rule has been widely used by the economists (e.g. Armstrong 2002) as well as the regulators

4 If firm 1 specializes in selling input, the retail-minus rule is no longer an effective constraint, and firm 1 will choose w freely to maximize its upstream profit. Then, the solution of the model becomes $w = \frac{\hat{s}-c_2}{2}$, $p_2 = \frac{3\hat{s}+c_2}{4}$, and $\pi_1 = \frac{(\hat{s}-c_2)^2}{8\hat{s}}$. As will be shown in Sections 3 and 4, the incumbent profits are at least equal to the monopoly profit in the equilibria we found. Since the condition $\frac{(\hat{s}-c_2)^2}{2\hat{s}} \leq (1-c_1)^2$ is equivalent to $\pi_1 = \frac{(\hat{s}-c_2)^2}{8\hat{s}} \leq (\frac{1-c_1}{2})^2 =$ monopoly profit, it guarantees that the incumbent firm in equilibrium has the incentive to be active downstream.

5 Although how the regulator estimates c_1 while preventing incentives for moral hazard is a critical issue in practice, we ignore this policy issue in this paper. Beard, Kaserman, and Mayo's (1998) study examines the issue.

(e.g. IRG 2005). An alternative definition used by the economists (e.g. Hoffler and Schmidt 2008) is $w \leq p_1 - c_1$. Our choice of the definition relies on the regulatory practice in which a firm is not supposed to lower the access price voluntarily unless it is under price cap. By fixing the access price to a certain level, the regulator can avoid the risk of anticompetitive issue of input price discrimination being raised. It is supposed to be one of the reasons why the Korean Telecommunications Business Act and its sub-rules describe the access charge for MVNOs as determined by the equational retail-minus rule and in fact are being executed as such. We will come back to this issue in Section 6 and argue further that the rule of $w = p_1 - c_1$ should be preferred to $w \leq p_1 - c_1$, no matter which definition represents the current practice better.

Assumption 1

(a) [vertical differentiation] $s_1 = 1$, $s_2 = \hat{s} \neq 1$

(b) [downstream cost] $0 < c_1 < 1$, $0 < c_2 < \hat{s}$

(c) [limited efficiency of entrant] $\frac{(\hat{s}-c_2)^2}{2\hat{s}} \leq (1-c_1)^2$

(d) [retail-minus rule] $w = p_1 - c_1$, where p_1 is chosen by firm 1.

Under these assumptions, we will consider a two-stage game where firm 1 sets p_1 at the first stage, and then, firm 2 sets p_2, taking p_1 and w as given.[6] Before analyzing the duopoly models of interest in the following sections, it is useful to consider the before-entry monopoly case as a benchmark. Suppose firm 1 is a monopolist. Since demand for firm 1 is then $D_1(p_1) = 1 - p_1$, firm 1's profit function and profit-maximizing price and quantity are

$$\pi_1(p_1) = (p_1 - c_1)(1 - p_1), \quad [2]$$

$$p_{1m} = \frac{1 + c_1}{2}, \quad D_1(p_{1m}) = \frac{1 - c_1}{2} > 0. \quad [3]$$

In using this monopoly equilibrium as benchmark, we are in fact assuming that a voluntary relationship between the incumbent and the entrant is not possible.[7]

6 With this two-stage price leadership model, the entrants can be offered a certain access rate by the incumbent under the retail-minus regulation as they are in practice. An alternative one-stage model may also be considered to reflect how the downstream competition feeds back into the access rate. We suppose, however, that the price leadership model describes better the market conditions the retail-minus regulation is usually chosen to apply to, where the incumbent is an established SMP firm and an entrant as reseller is not expected to have all-out competition against the incumbent.

7 Otherwise, a better benchmark might be the case of no regulation. In Section 5, we will complement the analysis by comparing our equilibrium with the hypothetical voluntary relationship equilibrium.

One way of justifying this additional assumption is to consider fixed costs in entering a voluntary relationship, high enough to make it ex ante unprofitable. For instance, the incumbent and the entrant could face some uncertainty as to the reliability of such relationship as well as transaction costs for negotiating for and maintaining it, and hence, they could be reluctant to have a vertical transaction without regulation. The stepping-stone hypothesis (Hausman and Sidak 2005) may present another justification. If the incumbent firm is concerned that accommodating an entrant downstream could give the entrant a stepping stone to reach upstream production and become a vertically integrated competitor in the future, it would be reluctant to have a vertical relationship with the entrant. In practice, the regulator would more likely intervene when a meaningful voluntary relationship is hardly expected, the reason of which could be fixed costs or the incumbent's concern about potential competition.

In the next section, we consider the case of superior-quality entry ($\hat{s}>1$) first. As will be shown, an entrant of superior quality under the retail-minus rule is supposed to take away quality-sensitive consumers from the incumbent without changing the market size, and hence the incumbent is almost unaffected by the entry. This simplicity, however, will not be maintained in the case of inferior-quality entry ($\hat{s}<1$) in Section 4.

3 Duopoly with an entrant of superior quality ($\hat{s}>1$)

In considering the case of $\hat{s}>1$, first note that our vertical differentiation setup requires p_1 to be sufficiently low relative to p_2 that

$$p_1 < \frac{p_2}{\hat{s}} \qquad [4]$$

for any meaningful equilibrium because there would be no demand for firm 1 otherwise. Condition [4] implies that, in the equilibrium of interest, the consumer who chooses firm 2's product ($\theta > \frac{p_2}{\hat{s}}$) could have purchased firm 1's product ($\theta > p_1$) if without an option for firm 2, while the opposite is not always true. In other words, there is no market expansion possible by a superior-quality entry.

Assuming eq. [4], a threshold consumer, if any, who is indifferent between the products of firm 1 and firm 2 must have the quality preference parameter $\tilde{\theta} = \frac{p_2 - p_1}{\hat{s}-1}$. This implies that a consumer with $\theta > \tilde{\theta}(\theta < \tilde{\theta})$ prefers firm 2's (firm 1's) product provided that $0 < \tilde{\theta} < 1$. If $p_1 < \frac{p_2}{\hat{s}}$ (or, equivalently, $\frac{p_2 - p_1}{\hat{s}-1} > p_1$), therefore, we can consider three cases of demand functions according to p_1 and p_2.

(a) If $p_1 \geq 1$, then $D_1(p_1, p_2) = 0$, $D_2(p_1, p_2) = 0$.
(b) If $\frac{p_2 - p_1}{\hat{s}-1} \geq 1 > p_1$, then $D_1(p_1, p_2) = 1 - p_1 > 0$, $D_2(p_1, p_2) = 0$.
(c) If $\frac{p_2 - p_1}{\hat{s}-1} < 1$, then $D_1(p_1, p_2) = \frac{p_2 - p_1}{\hat{s}-1} - p_1 > 0$, $D_2(p_1, p_2) = 1 - \frac{p_2 - p_1}{\hat{s}-1} > 0$.

We will focus mainly on case (c) in the remainder of this section because the regulation of retail-minus access pricing is intended to introduce (or at least demonstrate something similar to) downstream competition. Note that assumption [4] and the condition $\frac{p_2 - p_1}{\hat{s}-1} < 1$ are necessary for the case of downstream duopoly where demand for each firm is positive. The two inequalities, $p_1 < \frac{p_2}{\hat{s}}$ and $\frac{p_2 - p_1}{\hat{s}-1} < 1$, can be combined into $\hat{s}p_1 < p_2 < p_1 + (\hat{s} - 1)$.

Lemma 1 [downstream duopoly] $\hat{s}p_1 < p_2 < p_1 + (\hat{s} - 1)$ *is necessary for both firms to have positive downstream demand.*

By focusing on the case of a downstream duopoly, we intend to ignore incumbent pricing that excludes the entrant, although this possibility will be considered again for the validity of the downstream-duopoly equilibrium in the proof of Proposition 1.

Assuming downstream duopoly, the two firms' profit functions are

$$\pi_1(p_1, p_2) = (p_1 - c_1)\left(\frac{p_2 - p_1}{\hat{s} - 1} - p_1\right) + w\left(1 - \frac{p_2 - p_1}{\hat{s} - 1}\right) = (p_1 - c_1)(1 - p_1), \quad [5]$$

$$\pi_2(p_1, p_2) = (p_2 - p_1 + c_1 - c_2)\left(1 - \frac{p_2 - p_1}{\hat{s} - 1}\right). \quad [6]$$

They let us recognize another restriction required for the justification of equilibrium: the nonnegativeness of profits:

$$p_1 - c_1 \geq 0, \quad [7]$$

$$p_2 - p_1 + c_1 - c_2 \geq 0. \quad [8]$$

Firm 1's profit in eq. [5] does not depend on p_2, and its profit-maximizing price is determined without consideration of firm 2's reaction, which is the same as the monopoly price,

$$p_{1r} = \frac{1 + c_1}{2} = p_{1m}. \quad [9]$$

Given $p_1 = \frac{1+c_1}{2}$, firm 2's profit-maximizing price is

$$p_{2r} = \frac{\hat{s} + c_2}{2}. \quad [10]$$

In order to have these as equilibrium prices, the condition of Lemma 1 and inequalities [7] and [8] must be satisfied.

Proposition 1 *Given Assumption 1 and with an entrant of superior quality, a downstream-duopoly equilibrium with eqs [9] and [10] as equilibrium prices is valid if and only if* $\hat{s}c_1 < c_2 < c_1 + \hat{s} - 1$.

Proof. Substituting eqs [9] and [10] into the inequalities of Lemma 1, we obtain $\hat{s}c_1 < c_2 < c_1 + \hat{s} - 1$. Inequality [7] is easily shown to be satisfied given Assumption 1(b). Substituting eqs [9] and [10] in eq. [8] gives us $c_2 \leq c_1 + \hat{s} - 1$. Combining the conditions, we get $\hat{s}c_1 < c_2 < c_1 + \hat{s} - 1$, which is merely a necessary condition for equilibrium. To check whether the condition is sufficient as well, note that the downstream duopoly might be less profitable to the incumbent than a case when the incumbent is allowed to deter the entrant. As we will see in (c) of Proposition 2, however, we need not be concerned about this, because the incumbent's profit in the downstream-duopoly equilibrium is always the same as the monopoly profit, and deviating from the monopoly price to deter the entrant would only lower the incumbent's profit. ■

The condition of Proposition 1 says that entrant efficiency should be neither too high nor too low for the existence of the downstream-duopoly equilibrium. More specifically, one can easily see from the condition that the superior-quality entrant should have a higher cost ($c_1 < c_2$) but remain more efficient than the incumbent ($\hat{s} - c_2 > 1 - c_1$).

The effect of the entry enabled by retail-minus regulation on prices, market demand, and profits can be summarized as follows in comparison with the benchmark case of a monopoly.

Proposition 2 *In a downstream-duopoly equilibrium with an entrant of superior quality, the following properties hold.*
(a) $p_{2r} > p_{1m} = p_{1r}$;
(b) $D_1(p_{1r}, p_{2r}) + D_2(p_{1r}, p_{2r}) = D_1(p_{1m})$;
(c) $\pi_1(p_{1r}, p_{2r}) = \pi_1(p_{1m})$.

Proof. (a) $p_{2r} - p_{1m} = \frac{\hat{s}+c_2}{2} - \frac{1+c_1}{2} > 0$ because $c_1 < c_2$. (b) $D_1(p_{1r}, p_{2r}) + D_2(p_{1r}, p_{2r}) = (\frac{p_{2r}-p_{1r}}{\hat{s}-1} - p_{1r}) + (1 - \frac{p_{2r}-p_{1r}}{\hat{s}-1}) = 1 - p_{1r} = 1 - p_{1m} = D_1(p_{1m})$. (c) $\pi_1(p_{1r}, p_{2r}) = (p_{1r} - c_1)(1 - p_{1r}) = (p_{1m} - c_1)(1 - p_{1m}) = \pi_1(p_{1m})$. ■

The result is simple and clear. The incumbent does not change its monopoly price, the entrant takes some portion of the market but the market size

remains the same, and the incumbent's profit is not affected at all; thus, revenue neutrality holds true in this case. This somewhat extreme result is because the superior-quality entry cannot expand the market by the design of this vertical differentiation model. Consumers with high preference for quality were already users of the incumbent's product; the superior-quality entrant can take away consumers, but cannot create new consumers. Without any market expansion, the incumbent's strategy under retail-minus regulation is simply to maintain its pricing, which would continue to guarantee the monopoly profit.

It must be emphasized that the incumbent maintaining the monopoly price does not mean that retail-minus regulation is ineffective. Regulation facilitates entry with superior quality while constraining the price. Without the retail-minus rule, entry must have increased prices, as will be shown in Section 5. Thus, while simple, the downstream-duopoly equilibrium obtained is an interesting outcome achieved by the combination of a superior-quality entrant and the retail-minus rule. It lets us expect the increase in social welfare.

The social welfare of this downstream-duopoly equilibrium can be measured as

$$SW(p_{1r}, p_{2r}) = \int_{\tilde{\theta}_r}^{1} \hat{s}\theta d\theta + \int_{p_{1r}}^{\tilde{\theta}_r} \theta d\theta - c_1 D_1(p_{1r}, p_{2r}) - c_2 D_2(p_{1r}, p_{2r}). \quad [11]$$

In comparison to the monopoly equilibrium, the welfare gain of the downstream-duopoly equilibrium is brought by the higher quality of firm 2, whereas the welfare loss is owing to the higher cost of firm 2. If the former is greater than the latter, social welfare is increased in our equilibrium.

Proposition 3 *In an equilibrium of a downstream duopoly with an entrant of superior quality, social welfare is improved over that of a monopoly.*

Proof. Welfare change arises only with switchers from firm 1 to firm 2. Among those switchers, the threshold consumer ($\tilde{\theta}_r = \frac{p_{2r} - p_{1r}}{\hat{s}-1}$) gains the least by the quality improvement. When she gains the surplus proportional to $(\hat{s} - 1)\tilde{\theta}_r = p_{2r} - p_{1r}$ (ignoring the private loss from the higher price from the perspectives of social welfare), society loses the surplus proportional to $c_2 - c_1$. From eq. [8], we know that $p_{2r} - p_{1r} \geq c_2 - c_1$, which means that the threshold loss of the cost increase is sufficiently compensated for by quality improvement. All other consumers of firm 2 gain more than she does from quality improvement, but the cost increase applies uniformly. This proves the proposition. ■

4 Duopoly with an entrant of inferior quality ($\hat{s} < 1$)

While the condition of $p_1 < \frac{p_2}{\hat{s}}$ was necessary to provide positive demand for firm 1 in the case of $\hat{s} > 1$, we need the opposite condition of

$$p_1 > \frac{p_2}{\hat{s}} \quad [12]$$

to provide positive demand for firm 2 in the case of $\hat{s} < 1$. The condition $p_1 > \frac{p_2}{\hat{s}}$ implies that, in the equilibrium of interest, the consumer who chooses firm 1's product ($\theta > p_1$) could have purchased firm 2's product ($\theta > \frac{p_2}{\hat{s}}$) if without an option for firm 1. And, there exist some consumers ($p_1 > \theta > \frac{p_2}{\hat{s}}$) who choose the entrant firm 2's product, but who would not buy from firm 1. This means that market expansion is allowed here, unlike in the case of superior-quality entry.

Assuming eq. [12], a threshold consumer, if any, who is indifferent between the products of firm 1 and firm 2 must have the quality preference parameter $\tilde{\theta} = \frac{p_1 - p_2}{1 - \hat{s}}$. If $p_1 > \frac{p_2}{\hat{s}}$ (or, equivalently, $\frac{p_1 - p_2}{1 - \hat{s}} > \frac{p_2}{\hat{s}}$), we can consider three cases of demand functions according to p_1 and p_2.

(a) If $\frac{p_2}{\hat{s}} \geq 1$, then $D_1(p_1, p_2) = 0$, $D_2(p_1, p_2) = 0$.
(b) If $\frac{p_1 - p_2}{1 - \hat{s}} \geq 1 > \frac{p_2}{\hat{s}}$, then $D_1(p_1, p_2) = 0$, $D_2(p_1, p_2) = 1 - \frac{p_2}{\hat{s}} > 0$.
(c) If $\frac{p_1 - p_2}{1 - \hat{s}} < 1$, then $D_1(p_1, p_2) = 1 - \frac{p_1 - p_2}{1 - \hat{s}} > 0$, $D_2(p_1, p_2) = \frac{p_1 - p_2}{1 - \hat{s}} - \frac{p_2}{\hat{s}} > 0$.

Again, we will focus mainly on case (c). Assumption [12] and the condition $\frac{p_1 - p_2}{1 - \hat{s}} < 1$ are necessary for the downstream duopoly where demand for each firm is positive. The two inequalities can be combined into $\frac{p_2}{\hat{s}} < p_1 < p_2 + (1 - \hat{s})$.

Lemma 2 [downstream duopoly] $\frac{p_2}{\hat{s}} < p_1 < p_2 + (1 - \hat{s})$ *is necessary for both firms to have positive downstream demand.*

Assuming a downstream duopoly, the two firms' profit functions are

$$\pi_1(p_1, p_2) = (p_1 - c_1)\left(1 - \frac{p_1 - p_2}{1 - \hat{s}}\right) + w\left(\frac{p_1 - p_2}{1 - \hat{s}} - \frac{p_2}{\hat{s}}\right) = (p_1 - c_1)\left(1 - \frac{p_2}{\hat{s}}\right), \quad [13]$$

$$\pi_2(p_1, p_2) = (p_2 - p_1 + c_1 - c_2)\left(\frac{p_1 - p_2}{1 - \hat{s}} - \frac{p_2}{\hat{s}}\right). \quad [14]$$

Here, the same restrictions as eqs [7] and [8] are required to ensure the non-negativeness of profits.

Given p_1, firm 2's profit-maximizing price is

$$p_2 = \frac{(1+\hat{s})p_1 - c_1 + c_2}{2}. \quad [15]$$

Substituting eq. [15] for p_2 in eq. [13], firm 1's profit as a function of p_1 is

$$\pi_1(p_1) = (p_1 - c_1)\left(1 - \frac{(1+\hat{s})p_1 - c_1 + c_2}{2\hat{s}}\right), \quad [16]$$

from which firm 1's profit-maximizing price is

$$p_{1r} = \frac{(2+\hat{s})c_1 - c_2 + 2\hat{s}}{2(1+\hat{s})}. \quad [17]$$

Putting eq. [17] into eq. [15], we get

$$p_{2r} = \frac{\hat{s}c_1 + c_2 + 2\hat{s}}{4}. \quad [18]$$

In order to have these as equilibrium prices, the condition of Lemma 2 and inequalities [7] and [8] must be satisfied.

Proposition 4 *Given Assumption 1 and with an entrant of inferior quality, the downstream-duopoly equilibrium with eqs [17] and [18] as equilibrium prices is valid only if* $\frac{(3\hat{s}+1)c_2+2\hat{s}(1-\hat{s})}{\hat{s}(\hat{s}+3)} < c_1 < \frac{(3+\hat{s})c_2-2\hat{s}(1+\hat{s})+4}{4+\hat{s}-\hat{s}^2}$.

Proof. Substituting eqs [17] and [18] in the inequalities of Lemma 2, $p_1 > \frac{p_2}{\hat{s}}$ becomes $\hat{s}(\hat{s}+3)c_1 - (3\hat{s}+1)c_2 - 2\hat{s}(1-\hat{s}) > 0$ and $\frac{p_1-p_2}{1-\hat{s}} < 1$ becomes $(4+\hat{s}-\hat{s}^2)c_1 - (3+\hat{s})c_2 + 2\hat{s}(1+\hat{s}) - 4 < 0$. We can rearrange the inequalities to obtain $\frac{(3\hat{s}+1)c_2+2\hat{s}(1-\hat{s})}{\hat{s}(\hat{s}+3)} < c_1 < \frac{(3+\hat{s})c_2-2\hat{s}(1+\hat{s})+4}{4+\hat{s}-\hat{s}^2}$. The nonnegative profit conditions [7] and [8] can also be shown to be satisfied as $p_{1r} - c_1 = \frac{(2+\hat{s})c_1-c_2+2\hat{s}}{2(1+\hat{s})} - c_1 = \frac{\hat{s}(1-c_1)+\hat{s}-c_2}{2(1+\hat{s})} > 0$ by Assumption 1 and $(c_1 - c_2) - (p_{1r} - p_{2r}) = (c_1 - c_2) - \frac{(4+\hat{s}-\hat{s}^2)c_1-(\hat{s}+3)c_2+2\hat{s}(1-\hat{s})}{4(1+\hat{s})} = \frac{1}{4(1+\hat{s})}[\hat{s}(\hat{s}+3)c_1 - (3\hat{s}+1)c_2 - 2\hat{s}(1-\hat{s})] > 0$. ■

Unlike Proposition 1, Proposition 4 states only a necessary condition. Even when the condition of Proposition 4 is satisfied, the potential equilibrium is subject to the condition of Lemma 2 and downstream exclusion might provide the incumbent higher profit. We will discuss this issue when we address the effect on the incumbent's profit below.

As in Proposition 1, the condition of Proposition 4 basically says that entrant efficiency should be neither too high nor too low for the existence of the downstream-duopoly equilibrium. More specifically, it requires $\hat{s}c_1 > c_2$, and hence,

$c_1 > c_2$[8]; that is, the inferior-quality entrant should have a lower cost, while the relative efficiency of either the incumbent or the entrant is not required this time.

The effects of entry enabled by retail-minus regulation on prices and market demand in comparison with the benchmark case of a monopoly are summarized in the following proposition.

Proposition 5 *In an equilibrium of a downstream duopoly with an entrant of inferior quality, the following properties hold.*
(a) $p_{2r} < p_{1m}$;
(b) $p_{1r} < p_{1m}$ *if and only if* $\hat{s} - c_2 < 1 - c_1$;
(c) $D_1(p_{1r}, p_{2r}) + D_2(p_{1r}, p_{2r}) > D_1(p_{1m})$.

Proof. (a) $p_{2r} = \frac{\hat{s}c_1 + c_2 + 2\hat{s}}{4} < \frac{c_1 + c_2 + 2}{4} < \frac{2c_1 + 2}{4} = p_{1m}$ since $c_1 > c_2$.
(b) $p_{1m} - p_{1r} = \frac{c_2 - c_1 + 1 - \hat{s}}{2(1+\hat{s})}$, which is greater than 0 if and only if $\hat{s} - c_2 < 1 - c_1$.
(c) As $D_1(p_{1r}, p_{2r}) + D_2(p_{1r}, p_{2r}) = 1 - \frac{p_{2r}}{\hat{s}} = \frac{2\hat{s} - \hat{s}c_1 - c_2}{4\hat{s}}$, $D_1(p_{1r}, p_{2r}) + D_2(p_{1r}, p_{2r}) - D_1(p_{1m}) = \frac{2\hat{s} - \hat{s}c_1 - c_2}{4\hat{s}} - \frac{1 - c_1}{2} = \frac{\hat{s}c_1 - c_2}{4\hat{s}}$, which is greater than 0 since $\hat{s}c_1 > c_2$. ■

The result of Proposition 5 implies that the regulation of retail-minus access pricing tends to have the desirable effects of lowering prices and expanding the market provided that it results in the equilibrium of a downstream duopoly. The retail price of the entrant is shown to be always lower than the original monopoly price, and the retail price of the incumbent could be lower than the original as well. While the lower price of inferior-quality entrant is not at all surprising, the possibility of a lower incumbent price is critical because it is often the goal of access regulation. Then, we can ask why the lower incumbent price could be induced by inferior-quality entry but not by superior-quality entry. Note that the effect of downstream competition cannot be a good answer because competition is not effective when the incumbent controls the prices in our model. The key is the market expansion effect of (c), which is due to condition [12]. Considering this market expansion effect of inferior-quality entry, the incumbent should consider whether it will lower its price to help market expansion or raise it to exploit the expanded market.[9] (b) of the Proposition 5 says that it will choose to lower its price when it is more

8 $\frac{(3\hat{s}+1)c_2 + 2\hat{s}(1-\hat{s})}{\hat{s}(\hat{s}+3)} < c_1$ can be rearranged as $\hat{s}c_1 > \frac{(3\hat{s}+1)c_2 + 2\hat{s}(1-\hat{s})}{(\hat{s}+3)} > \frac{(3\hat{s}+1)c_2 + 2(1-\hat{s})c_2}{(\hat{s}+3)} = c_2$.
9 This intuition is somewhat analogous to Weisman's (1995) finding that the vertically integrated firm faces a trade-off in which it could choose a low retail price to stimulate wholesale demand or a high retail price to generate higher retail profit (if the change in the vertically integrated firm's retail price is always matched by its rival).

efficient in terms of quality and cost relative to the entrant. This price effect is not simply an effect of entry, but is driven by the retail-minus rule in combination with inferior-quality entry. As will be shown in Section 5, an inferior-quality entry without regulation would only induce the incumbent firm to maintain its monopoly price.

The recent experience of the MVNO entries in Korean mobile telecommunications market may be an example of such market expansion driven by inferior-quality entries. Korea Information Society Development Institute (KISDI), a major telecom policy think tank in Korea, stated in its 2013 report on the assessment of competition that the Korean mobile market started to slow in growth in 2002 and is now in the stage of saturation. Looking at the official numbers from Ministry of Science, ICT and Future Planning (MSIP), however, the market is still growing mostly due to the success of MVNO helped by the retail-minus regulation introduced in 2010. The number of MVNO users increased from 0.3~0.4 million before the regulation to 2.8 million in 2014 while the users of the three major mobile operators have grown in number only 0.35% since 2011.

The effect on profits is too ambiguous and intractable to derive any meaningful related condition. Thus, we have chosen to use randomly generated parameter values to examine the effects. This simulation approach will also allow us to learn how likely the price of the incumbent is to be lowered; in other words, how likely the parameters consistent with such an equilibrium are to satisfy the condition of the incumbent being more efficient ($\hat{s} - c_2 < 1 - c_1$).

For the simulation, we first generate random values for each of $\hat{s}$, c_1, and c_2 subject to independent uniform distribution [0,1] and then discard the sets of parameters that violate the conditions of Assumption 1 and Proposition 4. Using the appropriate parameter sets left from the screening process, we can examine the properties of the downstream-duopoly equilibrium. The validity of this simulation should increase with the number of random parameter sets.

To illustrate our simulation approach, Table 1 records numerical examples of the downstream-duopoly equilibrium calculated using ten sets of parameter values randomly generated and satisfying the conditions of Assumption 1 and Proposition 4. One can observe that firm 1's profit does not always increase after entry. In fact, the cases of decreasing incumbent profit in the downstream-duopoly equilibrium need to be questioned because the incumbent always has the option to set the monopoly price. Even when it shares the market with the entrant, if it chooses the monopoly price, the incumbent can achieve at least the monopoly profit since the entrant cannot shrink the market (consumers who purchased under monopoly are always willing to buy the incumbent's product if the entrant product is not available), and the same profit margin is guaranteed to the incumbent. Then, why is the profit lower than the monopoly profit in a

Table 1: Numerical examples of the downstream-duopoly equilibrium

$\hat{s}$	c_1	c_2	p_{1m}	π_{1m}	p_{1r}	p_{2r}	π_1
0.834	0.131	0.018	0.565	0.189	0.551	0.449	0.194
0.974	0.380	0.359	0.690	0.096	0.688	0.669	0.097
0.572	0.327	0.039	0.663	0.113	0.619	0.342	0.117
0.277	0.508	0.022	0.754	0.061	0.661	0.179	0.054
0.642	0.622	0.317	0.811	0.036	0.795	0.500	0.038
0.719	0.309	0.019	0.654	0.119	0.657	0.420	0.145
0.726	0.883	0.621	0.942	0.003	0.938	0.678	0.004
0.477	0.545	0.144	0.773	0.052	0.732	0.340	0.054
0.874	0.496	0.367	0.748	0.064	0.749	0.637	0.069
0.658	0.608	0.268	0.804	0.038	0.803	0.496	0.048

case in Table 1? It is because we forced the downstream-duopoly equilibrium with the condition of Lemma 2. If the monopoly pricing of the incumbent would exclude the entrant, to satisfy the condition of Lemma 2, the incumbent is supposed to lower its price to make room for the entrant while sacrificing its own profit. Such a case may be too artificial to be included in our assessment of the downstream-duopoly equilibrium. On the other hand, each of all the cases where the incumbent's profit increases after the entry amount to a valid equilibrium, because the maximum profit possible by exclusion is the monopoly profit, and the incumbent would prefer a downstream duopoly in these cases.

Our discussion helped by this simulation leads to a conclusion: If we allow the monopoly pricing of the incumbent to exclude the entrant, the incumbent's profit never decreases and often increases in the downstream-duopoly equilibrium with an entrant of inferior quality.

To see how often our downstream-duopoly equilibrium is valid, we generated 1 million sets of random parameter values and obtained 41,254 sets satisfying Assumption 1 and the condition of Proposition 4. In 36,346 (88%) sets of these, firm 1's profit increases after entry, which means that our downstream-duopoly equilibrium tends to make sense. Interestingly, this simulation also indicates that firm 1's price is frequently lowered after entry. Out of 36,346 valid cases of numerical equilibrium with increasing incumbent profit, 26,687 (73%) cases show these price-reducing results.

In sum, revenue neutrality does not hold here, and profit improvement is often achieved by reducing the price. The key is that, in this case, the incumbent firm can increase its profit because of the entrant's ability to expand the market;

its own retail pricing is the only instrument available to help the entrant expand the market under the retail-minus rule.[10]

The social welfare of this downstream-duopoly equilibrium can be measured as

$$SW(p_{1r}, p_{2r}) = \int_{\tilde{\theta}_r}^{1} \theta d\theta + \int_{\frac{p_{2r}}{\hat{s}}}^{\tilde{\theta}_r} \hat{s}\theta d\theta - c_1 D_1(p_{1r}, p_{2r}) - c_2 D_2(p_{1r}, p_{2r}), \quad [19]$$

and we can show that this is always greater than the social welfare obtained in a monopoly.

Proposition 6 *In an equilibrium of a downstream duopoly with an entrant of inferior quality, social welfare is improved over that of a monopoly.*

Proof. Note that, compared to the monopoly equilibrium, the welfare gain of the downstream-duopoly equilibrium is from the expanded quantity (Proposition 5 (c)) and the lower cost of firm 2 (Proposition 4), whereas the welfare loss is from the lower quality of firm 2. If the former is greater than the latter, social welfare is increased in our equilibrium. Firm 1's demand in monopoly (D_{1m}) may be higher or lower than that ($D_1(p_{1r}, p_{2r})$) in the downstream-duopoly equilibrium depending on the parameters. If $D_{1m} < D_1(p_{1r}, p_{2r})$, it is obvious that social welfare is increasing since the expanded consumption of firm 1's goods without any quality reduction guarantees a higher surplus, with demand for firm 2 resulting only in an increase in the surplus. The case of $D_{1m} > D_1(p_{1r}, p_{2r})$ is more difficult because there exist some consumers who experience quality downshifting by switching from firm 1 to firm 2. Among those switchers, the one who loses most by quality downshifting is the threshold consumer with the highest preference ($\tilde{\theta}_r = \frac{p_{1r} - p_{2r}}{1 - \hat{s}}$). When she loses the surplus proportional to $(1 - \hat{s})\tilde{\theta}_r = p_{1r} - p_{2r}$ (ignoring the private gain from the lower price from the perspectives of social welfare), society gains the surplus proportional to $c_1 - c_2$, that is, the surplus from cost reduction. From eq. [8], we know that $p_{1r} - p_{2r} \leq c_1 - c_2$, which means that the threshold consumer's loss is sufficiently compensated for by cost saving. All other consumers of firm 2 lose less than she does from quality downshifting, but cost saving applies uniformly. This proves the proposition. ■

10 One might argue that the incumbent firm does not need an inferior-quality entry to expand the market as it can always downgrade its own product. It is possible but not always so. As has been already shown, the inferior-quality entrant needs to have lower cost to have meaningful presence in the market. If the actual entrant is one of the firms that are the most cost-competitive among the numerous potential entrants, the incumbent might find it difficult to mimic the entrant specialized in producing cheaply. It is the case that our analysis applies to.

5 Discussion: retail-minus rule vs voluntary relationship

In this section, we argue for the merit of applying the retail-minus rule, especially in comparison to relying on the possibility[11] of a voluntary relationship between the incumbent and the entrant. Our position will be in interesting contrast to that of Banerjee and Dippon (2009),[12] who recently investigated the equilibrium of a voluntary relationship and concluded that policies mandating access need to be avoided given the possibility of an efficient voluntary relationship. Even in certain industries with conditions favorable to the formation of voluntary relationships, implementing the retail-minus rule would not induce inefficient entry at the very least.[13] Banerjee and Dippon argued that any policy imperative that mandates a vertical relationship (i.e. access regulation) will only produce an inferior outcome (relative to no such relationship) from the standpoint of welfare. We have shown in Propositions 3 and 6, however, that social welfare is always increased in the downstream duopoly under the retail-minus rule, and hence, retail-minus regulation does not force inefficient entry. This provides a counter-example to Banerjee and Dippon's negative view on access regulation.

Not only does the retail-minus rule avert inefficient entry, a duopoly under it tends to perform better than under a voluntary relationship from the standpoint of consumer welfare. We can show this by briefly examining the downstream-duopoly equilibrium without regulation (i.e. voluntary duopoly equilibrium). The model to consider is then a two-stage game where firm 1 sets p_1 and w freely at the first stage, and then, firm 2 sets p_2 taking p_1 and w as given.[14]

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11 Thus far we have assumed away this possibility. See the explanation on the assumption in Section 2.

12 Their analysis is motivated by the widespread emergence of voluntary relationships among MNOs and MVNOs. However, the MNO–MVNO relationships observed thus far are not in strong conflict with our analysis, which concentrates on regulating the monopolist to induce a duopoly. As mentioned in their paper, the MNOs most likely to partner voluntarily with MVNOs are those that rank third or fourth in terms of retail market share.

13 Note that the retail-minus rule inducing no inefficient entry does not mean that it always guarantees efficient entry.

14 We keep the structure of the two-stage price leadership model here as it describes better the market conditions the retail-minus regulation is usually chosen to apply to (see Footnote 6). Except for the absence of regulation, the same type of competition should be considered to examine the effect of regulation. Notice that we suppose certain market conditions give price leadership to the incumbent as well as require a regulation, not that the regulation causes price leadership.

Assuming a downstream duopoly, the equilibrium prices without regulation, p_1^{nr} and p_2^{nr}, are compared to those of the previous sections as follows.

In the case of superior-quality entry,[15]

$$p_1^{nr} = \frac{\hat{s} - c_2 + 1 + c_1}{2} > p_{1r} = \frac{1 + c_1}{2}, \quad [20]$$

$$p_2^{nr} = \frac{5\hat{s} - 1 + c_1 - c_2}{4} > p_{2r} = \frac{\hat{s} + c_2}{2}. \quad [21]$$

The equilibrium prices of both the incumbent and the entrant are lower under the retail-minus rule. The lower price of the incumbent attracts more consumers to achieve the market size of the original monopoly.

In the case of inferior-quality entry,

$$p_1^{nr} = \frac{1 + c_1}{2} > p_{1r} = \frac{(2 + \hat{s})c_1 - c_2 + 2\hat{s}}{2(1 + \hat{s})}, \quad \text{if } \hat{s} - c_2 < 1 - c_1, \quad [22]$$

$$p_2^{nr} = \frac{\hat{s}c_1 + c_2 + 2\hat{s}}{4} = p_{2r}. \quad [23]$$

While the entrant price is the same under the retail-minus rule as under a voluntary relationship, which means the market size does not change, the incumbent price can be lower if the incumbent is more efficient. The condition for a lower price is the same as in Proposition 5 since the incumbent price under a voluntary relationship is simply equal to the monopoly price.

The above comparison of our equilibrium with the voluntary duopoly equilibrium could also help us understand the unique effect of the retail-minus rule distinguished from the effect of allowing efficient entry. Since the entrant has differentiated quality and cost, the effect of entry is critical in our model. Then, the question arises as to how significant the retail-minus rule itself is in inducing the outcome described in the previous sections. If the effect comes mostly from the entry itself, then our focus on the retail-minus rule would be misplaced. We can see that such concern is unwarranted by considering the above voluntary duopoly equilibrium as representing the pure effect of entry. The equilibrium is significantly affected by the presence of retail-minus regulation except for the price of the inferior-quality entrant. In the case of superior-quality entry without regulation, the incumbent uses

15 We know from Section 3 that the downstream-duopoly equilibrium in this case requires $\hat{s} - c_2 > 1 - c_1$, which makes inequality [21] true.

the input price to exploit the value of the superior quality of the entrant, leading to a higher entrant price, and raises its own price to induce more consumers to buy superior quality at a higher price, which makes the size of the market shrink. The retail-minus rule, however, removes the incumbent's ability to capitalize on the entrant's quality by regulating the margin. While still allowing value to be created by the entrant, the retail-minus rule functions to keep prices at the original monopoly level and the market size from shrinking. Even though the equilibrium with the retail-minus rule would seem trivial at first glance, this comparison reveals the unique and desirable effect of the retail-minus rule. In the case of inferior-quality entry without regulation, the incumbent's price is the same as the monopoly price in equilibrium. This is because the incumbent can use the input price freely to absorb the surplus from the cost efficiency of the entrant. With the retail-minus rule, however, the incumbent should raise or lower its own retail price to affect and utilize the low-end market served by the entrant.

6 Concluding remarks

We examined the effect of vertically differentiated entry under the retail-minus rule and showed that retail-minus regulation tends to have desirable outcomes. Above all, it can obtain the intended result of reducing the retail price provided that the entrant is of inferior quality and the incumbent is more efficient. To understand the results, one needs to note that the retail-minus rule has two main effects – to protect the original profit of the incumbent firm and to prevent the incumbent from freely using retail and input prices to increase its profit. Critics usually focus on the first effect and have tended to conclude that it is of little use to competition and consumers. Consideration of differentiated quality and cost as well as a variable market size, however, can generate an entirely different view by incorporating the second effect. The retail-minus rule facilitates value-adding entry, which is already somewhat known, and further makes the incumbent maintain (when the incumbent could have otherwise increased) or reduce its price in the process of utilizing the value created by the entrant. As shown clearly in this paper, this kind of outcome is not possible by either a differentiated entry or the retail-minus rule alone, but by the combination of the two.

Throughout this paper, we have defined the retail-minus rule as $w = p_1 - c_1$, which we justified in Section 2. If this definition were changed to be, for instance, $w \leq p_1 - c_1$, our key result, the price-reducing effect of the rule,

could disappear, because the incumbent would be able to maintain the retail price and profit while increasing the wholesale profit by lowering only the input price. As we can infer from the discussion in Section 5, it then implies that the rule of $w = p_1 - c_1$ should be preferred to $w \leq p_1 - c_1$. Although the latter rule might seem better as it could give a lower input price especially in the case of inferior-quality entry, it does not lower the entrant's retail price (eq. [23]). Final consumers would definitely prefer the regime of $w = p_1 - c_1$ as it could lower the incumbent's price as explained in our analysis. Though somewhat paradoxical, the lesson is that the incumbent firm should not be allowed to price the input lower than the access price given by the retail-minus rule.

The model of vertical differentiation used in this study may or may not be appropriate to describe the real industries that we encounter for debate on the effect of access pricing. In practice, most markets would potentially have both vertical and horizontal differentiation. Horizontally differentiated entry, which we did not examine in this paper, would have an effect similar to our inferior-quality entry case as long as it can expand the market. Therefore, we conjecture that retail-minus access pricing would be more effective the more horizontally differentiated the entrant is, with the sign and the amount of the effect depending on the sensitivity of the market expansion. This kind of effect was not thoroughly considered by the existing works that examined cases of horizontally differentiated entry, as they often assumed away market expansion. In contrast, our vertical differentiation model is very effective in emphasizing the role of market expansion.

We did not consider dynamic efficiency in our model. However, the result of increasing the incumbent's profit is important in the sense that entry could contribute to the dynamic efficiency of the incumbent's investment in essential input. The result provides a case against the common concern that forcing entry could undermine dynamic efficiency.

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