# Strategic Investment and Market Structure under Access Price Regulation*


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**Abstract**

This paper examines a relationship between infrastructure investment and market structure in an open access environment. In our model, an entrant is allowed to vertically merge with an upstream firm that has a bypass technology (i.e., an alternative technology to an incumbent's infrastructure), and the (horizontal and vertical) market structures are endogenously determined by the incumbent's investment in infrastructure. Then, we show that in equilibrium, the incumbent strategically gives birth to excessive vertical merger and insufficient access to its infrastructure from a welfare viewpoint. In addition, two types of excess entry (i.e., "excess entry with access" and "excess entry with vertical merger") can occur in equilibrium. We also show the prevalence of underinvestment in infrastructure with the equilibrium market structures, irrespective of the incumbent's technology for infrastructure investment.



**Keywords**: access pricing, infrastructure investment, bypass, vertical merger.

**JEL classification**: L43, L51, L96.


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# 1 Introduction

Introducing competition has been an effective method to enlarge an allocative efficiency in network industries.[1] We are, however, still wondering if a new type of infrastructure such as broadband networks can be built smoothly in a competitive environment. The purpose of this paper is to investigate a firm's incentive for infrastructure investment in a symbolic competitive environment of network industries, called an "open access" environment.[2]

Valletti (2003) and Guthrie (2006) dealt with a firm's incentive for infrastructure investment in an open access environment.[3] However, most related researches to this paper are Foros (2004) and Kotakorpi (2006). Foros (2004) examined the effect of access price regulation when a network owner has a strategic opportunity to invest in infrastructure. Comparing the environments with and without access price regulation, he found the possibility of welfare-reducing regulation in the sense that it may lower consumer welfare if an incumbent and an entrant provides the same quality service. Kotakorpi (2006) also insisted that an incentive for infrastructure investment is reduced more with access price regulation than without it.

This paper is similar to theirs in the sense that it features a strategic aspect of a network owner's incentive in infrastructure investment. However, our approach differs from these two papers in the following way. We suppose that access price regulation is a necessary tool to enhance an allocative efficiency in a retail market. Given access price regulation, however, we allow an entrant to vertically merge with an upstream firm that has a bypass technology (i.e., an alternative technology to an incumbent's infrastructure).[4]

[1] See Armstrong and Sappington (2006) for the summary on the theoretical justification of several policy tools adopted in network industries, including the introduction of competition.

[2] In its broad meaning, an open access environment can be found even in other kind of industries, as long as some fims use the other firm's facility upstream (or downstream) in an identical industry.

[3] Needless to say, access pricing literature is related to our paper. See Armstrong (2002) and Vogelsang (2003) for its survey.

[4] Laffont and Tirole (1990) also dealt with the case where a bypass technology is available. However, they focused on the issue of cream-skimming by assuming multiple types of consumers. Armstrong (2001) examined the appropriability of universal fund policy when there exists a bypass technology. These two papers did not deal with the issue on infrastructure investment.

Then, an incumbent makes a strategic investment in infrastructure, which affects the entrant's choice of strategy to enter the market; access strategy or vertical-merger strategy. This implies that horizontal and vertical market structures are endogenously determined by the incumbent's strategic investment, the entrant's strategy, and access price regulation. In other words, our focus is the relationship between infrastructure investment and a market structure in an open access environment.

In our model, infrastructure investment has demand-enhancing effect, and there exists spillover of this effect when an entrant accesses an incumbent's infrastructure. Then, two main findings are obtained from the analysis in this paper. First, we show that in equilibrium, the incumbent strategically gives birth to excessive vertical merger and insufficient access to its infrastructure, when the spillover is large and the incumbent's investment technology is inefficient. This finding is concerning the vertical side of equilibrium market structure. Second, two types of excess entry occurs in equilibrium.[5] In particular, when the incumbent's access cost is lower than the production cost of bypass technology, the "excess entry with access" occurs in the equilibrium market structure. Otherwise, the "excess entry with vertical merger" occurs in equilibrium. This is concerning the horizontal side of equilibrium market structure.

The driving force that generates these two findings is an incumbent's weaker incentive in infrastructure investment than the one desired from a welfare viewpoint. In fact, we also show the prevalence of underinvestment in infrastructure with the equilibrium market structures, irrespective of the incumbent's technology for infrastructure investment. Hence, we assert that a policy suggestion be made concerning how to give an appropriate incentive for infrastructure investment to a network owner.

The next section explains the framework of the model. Then, the analysis in Section 3 provides a preliminary analysis that deals with the case where an entrant has only the

[5] In this respect, our paper is also related to the "excess entry" literature such as Mankiw and Whinston (1986) and Suzumura and Kiyono (1987). However, the driving force that generates the excess entry phenomenon is totally different from theirs. See the discussion in Section III.

strategy of the access to an incumbent's infrastructure, Section 4 gives the analysis of the model. Some policy implications of the analytical results are discussed in Section 5. Section 6 concludes the paper.

# 2 The Model

Let us consider a vertically related sectors, called an *upstream* sector and a *downstream* sector, and the two sectors are required to supply goods to consumers in a market. There are three firms; firm $m$, firm $e$, and firm $u$. Firm $m$ has an infrastructure upstream and a production facility downstream (i.e., a vertically integrated firm). Firm $e$ has only a production facility downstream, while firm $u$ has a *bypass* upstream. The bypass can be used to provide an input for the production downstream, as is the same as firm $m$'s infrastructure. However, its characteristic is inferior to that of infrastructure in the sense that it is too costly to expand its capacity size, so that only one firm can use it.[6] On the other hand, the expansion of firm $m$'s infrastructure can be achieved with some investment cost, and its expansion has a demand-enhancing effect through the improvement of the quality of goods.

To serve its consumers, firm $e$ needs an upstream technology. In this paper, firm $e$ is allowed to vertically merge firm $u$ that has a bypass. This means that firm $e$ has two alternative strategies to enter the market. The first is called an *access strategy*; it can access firm $m$'s infrastructure by paying access charge $a$ set by a regulator. The second is called a *vertical merger strategy*; it can propose a vertical merger to firm $u$. Note that there exists a third (potential) strategy, called a *bypass strategy*; firm $e$ may use firm $u$'s bypass by paying a wholesale price $w$ set by firm $u$ without vertical merger. This would occur when the access charge is extremely high and the proposal of vertical merger were rejected by firm $u$. Then, using one of the three strategies, firm $e$ can compete with firm

[6] The treatment of bypass technology in this paper is standard in the access pricing literature. See Armstrong (2001), for example.

$m$ in the market.

Let us formulate the situation specifically. For analytical tractability, we deal with the case where a representative consumer's utility in the market is described by the following quadratic function. A representative consumer's utility is

$$U(q^m, q^e) = (V + x^m) q^m + (V + sx^m) q^e - \frac{1}{2}(q^m + q^e)^2$$

if firm $e$ accesses firm $m$'s infrastructure. Here, $q^i$ $(i = m,\ e)$ is the quantity of goods supplied by firm $i$, $x^m$ is the level of firm $m$'s infrastructure investment, and $s\,(\in [0,1])$ represents a *spillover* to firm $e$ generated by the infrastructure investment.

On the other hand, if firm $e$ uses firm $u$'s bypass with (or without) vertical merger, a consumer's utility is described by

$$U(q^m, q^e) = (V + x^m) q^m + V q^e - \frac{1}{2}(q^m + q^e)^2$$

That is, the spillover occurs only when firm $e$ accesses firm $m$'s infrastructure.

As is well known, this utility function yields the linear inverse demand system as follows.

$$p^m = (V + x^m) - (q^m + q^e) \text{ and } p^e = (V + sx^m) - (q^e + q^m),$$

if firm $e$ accesses firm $m$'s infrastructure, and

$$p^m = (V + x^m) - (q^m + q^e) \text{ and } p^e = V - (q^e + q^m),$$

if firm $e$ uses firm $u$'s bypass with (or without) vertical merger.[7]

One unit of input (i.e., the output produced upstream) produces one unit of output downstream. For simplicity, we assume that the (constant) marginal access cost $c$ that firm

[7] Foros (2004) provides the derivation of this type of linear inverse demand with a reference to a broadband interenet demand.

$m$ owes for firm $e$'s access is the same as its marginal production cost upstream, and the production cost downstream for each firm is zero. Firm $u$'s (constant) marginal production cost is denoted by $c^u$. The production cost of bypass technology can be better or worse than that of an incumbent's technology; $c \lesseqgtr c^u$. The expansion of infrastructure can be achieved with some investment cost incurred by firm $m$, and its expansion has a demand-enhancing effect. On the other hand, the expansion of bypass technology is impossible and only one firm (i.e., firm $e$) can use it. Here, we suppose that the investment cost is represented by a quadratic function; $I(x^m) = \frac{1}{2}\gamma (x^m)^2$ with an investment technology parameter $\gamma\,(> 0)$.

A regulator determines the level of access charge $a$, and we assume that it is the only policy instrument available for the regulator. We assume Cournot competition between firm $m$ and firm $e$ in the downstream market.[8]

Then, firm $m$'s profit is formulated by

$$\pi^m = [p^m - c]\, q^m + [a - c]\, q^e - \frac{1}{2}\gamma (x^m)^2,$$

if firm $e$ accesses its infrastructure, and

$$\pi^m = [p^m - c]\, q^m - \frac{1}{2}\gamma (x^m)^2,$$

if firm $e$ uses firm $u$'s bypass with (or without) vertical merger.

Firm $e$'s profit is

$$\pi^e = [p^e - a]\, q^e,$$

if it accesses firm $m$'s infrastructure.

[8] In a broadband internet market, Cournot competition is justified by the fact that each of retail ISPs needs regional and global backbone (i.e., it faces a capacity constraint). See the discussion in Faulhaber and Hogendorn (2000) and Foros (2004).

In the case of vertical merger, the joint profit is defined by

$$\pi \equiv \pi^e + \pi^u = [p^e - c^u]\, q^e$$

As mentioned before, if access charge is extremely high and firm $e$'s proposal of vertical merger were rejected by firm $u$, firm $e$ would use firm $u$'s bypass by paying a wholesale price $w$ set by firm $u$.[9] In that case, firm $e$'s profit is

$$\pi^e = [p^e - w]\, q^e,$$

and firm $u$'s profit is

$$\pi^u = [w - c^u]\, q^e.$$

Since most infrastructure investments are irreversible and the regulator's ability of commitment to an access charge is limited, we assume that firm $m$ invests in infrastructure prior to the regulator's setting of access charge. Hence, the timing of the game is summarized as follows. First, firm $m$ determines the level of investment $x^m$. Second, given $x^m$, the regulator determines the level of access charge $a$. Third, given $x^m$ and $a$, firm $e$ chooses one of the two alternative strategies to enter the market. That is, it decides whether it accesses firm $m$'s infrastructure or offers the proposal of vertical merger to firm $u$ by anticipating firm $u$'s response to its proposal. If firm $u$ rejected firm $e$'s proposal of vertical merger, it would set the wholesale price $w$ and firm $e$ would use its bypass by paying $w$. Moreover, firm $u$ and firm $e$ would do so when firm $e$ neither accesses nor offer a proposal of the vertical merger. Fourth, firm $m$ and firm $e$ competes downstream in a Cournot fashion.

[9] In this paper, we assume that firm $u$ can unilaterally set the wholesale price $w$. Other formulation of the setting $w$ changes the profit distribution under a vertical-merger proposal, whereas the main message of this paper does not change.

# 3 A Preliminary Analysis: The Equilibrium Market Structure with Access

Before analyzing the model described in section 2, it is useful to examine as a benchmark the equilibrium of the case where firm $e$ has only the access strategy. Indeed, this benchmark corresponds to the analyses of Foros (2004) and Kotakorpi (2006).

For analytical tractability, we prepare the following assumptions.

$$\textbf{Assumptions (i) } Y \equiv V - c > 2\Delta c \equiv 2\left(c - c^u\right), \text{ (ii) } a \geq c, \text{ (iii) } \gamma > \frac{11}{9}.$$

Assumption (i) states that the demand size is sufficiently large relative to the cost difference between firm $m$ and firm $e$.[10] For practical reason, we put Assumption (ii). Indeed, it is rare for access charge to be set below the marginal access cost in the real policy arena.[11] Assumption (iii) guarantees the interior solutions for not only firm $m$'s profit-maximizing but also welfare-maximizing investment problems without any restrictions in the following analysis.

When access is the only available strategy for firm $e$ to enter the market, the level of access charge $a$ determines firm $e$'s decision of whether it enters the market by access or it remains outside the market (i.e., the case of foreclosure), given the level of infrastructure investment $x^m$. This situation corresponds to the case of "regulated access charge" analyzed in Foros (2004).[12]

In the fourth stage of the model, firm $m$ and firm $e$ competes in a Cournot fashion if firm $e$ enters the market. Table 1 reports the equilibrium productions and their associated profits in all the market structures realized in equilibrium, including the case where firm

[10] Remember that we allow the case where $\Delta c \equiv c - c^u > 0$. When the bypass technology is not available, (i) becomes $V > 3c$.

[11] Foros (2004) also constrained his analysis to the case where access charge is at least greater than access cost.

[12] Kotakorpi (2006) also deals with this case, except that the entrants are competitive fringe in his model.

$e$ has only the access strategy. See the first row named "Access" and the last row named "Foreclosure". When firm $e$ has only the access strategy, these two market structures are possible in equilibrium. Of course, when the profit with access strategy is positive (i.e., $\pi^{e*A} > 0$), firm $e$ enters the market.

[Insert Table 1 around here.]

[Insert Figure 1 around here.]

Figure 1 illustrates firm $e$'s decision in terms of the level of access charge $a$ and that of infrastructure investment $x^m$ for $s > 1/2$. From a simple calculation, we derive the critical hyperplane whose equation is given by

$$a = \left(\frac{V+c}{2}\right) + \left(\frac{2s-1}{2}\right) x^m \tag{1}$$

Below (above) the hyperplane (1), firm $e$ enters (does not enter) the market by accessing firm $m$'s infrastructure. That is, when access charge is low (high), firm $e$ enters (does not enter) the market. This is an obvious result, because the access charge is the production cost for firm $e$ when accessing firm $m$'s infrastructure.

The effect of infrastructure investment $x^m$ needs some attention for its interpretation. In the case where $s > 1/2$, as in Figure 1, firm $e$ enters the market with access strategy as long as $a < (V + c)/2$. However, when $s < 1/2$, it does not enter the market even for a low access charge if the level of infrastructure investment $x^m$ is large. In fact, when $s < 1/2$, the critical hyperplane in Figure 1 becomes a downward sloping line. This means that when the spillover effect is small and the level of $x^m$ is large, firm $e$ does not have an incentive to enter the market. The reason is explained as follows. In our model, the infrastructure investment has a demand-enhancing effect through the improvement of quality of goods. Then, when the spillover effect is small, the difference of the benefit to consumers between firm $m$'s goods and firm $e$'s goods expands, so that firm $e$ cannot sell its goods to obtain positive profit by entering the market. Hence, the foreclosure occurs in that case.[13]

Next, we turn to the second stage. In the second stage, the regulator determines the level of access charge $a$, given the level of infrastructure investment $x^m$ with the anticipation of the market structure downstream. Since competition in the downstream sector is imperfect (i.e., duopoly or monopoly) in our model, access charge should be set as low as possible in order to correct the distortion of underproduction. Hence, with Assumption (ii), the regulator sets the socially optimal access charge $a^{**}$ such that the access charge is equal to the marginal access cost, i.e., $a^{**} = c$.

Finally, in the first stage, firm $m$ decides the level of infrastructure investment $x^m$. Firm $m$ decides its profit-maximizing level of infrastructure investment with the anticipation of $a^{**} = c$ and the market structure realized in the downstream sector. Appendix A gives the procedure of the derivation of the solution of firm $m$'s profit-maximizing investment problem.

[Insert Figure 2 around here.]

Figure 2 illustrates the equilibrium market structures that occur through firm $m$'s infrastructure investment in $(s,\ \gamma)$ plane. According to Figure 2, a "duopoly with access" market structure is achieved under the regulated access charge $a^{**} = c$ in all the regions except the one where both $s$ and $\gamma$ are small.

How can we evaluate the equilibrium market structure from a welfare viewpoint? To do so, it is useful to derive the socially desirable level of investment and its associated market structure as a benchmark. Let us define *the second-best investment* as the investment that the regulator sets in addition to the regulated access charge $a^{**} = c$. Also, let us define

[13] Notice that when both the spillover effect and the level of infrastructure investment are large (i.e., when $s > 1/2$ and $x^m$ is large), this reasoning can be applied to explain why firm $e$ enters the market even if the access charge $a$ is high.

*the second-best market structure* as the market structure associated with that investment. The sketch of the procedure to derive them is given in Appendix B.

Then, the comparison of second-best and equilibrium market structures are drawn in Figure 3.

[Insert Figure 3 around here.]

In Figure 3, we have the region where firm $e$ enters with access in equilibrium whereas it does not enter the market in the second best (region III).[14] That is, when firm $m$'s infrastructure investment technology is efficient (i.e., $\gamma$ is small) and the infrastructure's spillover effect is small (i.e., $s$ is small), excess entry with access occurs in equilibrium. We summarize this finding as a proposition.

**Proposition 1** *Suppose an entrant has only the access strategy to enter a market. Then, the excess entry with access occurs when an incumbent has an efficient technology for infrastructure investment and its spillover effect is small.*

The intuitive reason for the occurrence of the *excess entry with access* is explained as follows. In our model, the improvement of the allocative efficiency is achieved by two routes: one route is to increase the production level by introducing competition in the downstream sector, while the other is to enlarge consumer's willingness-to-pay by investing in infrastructure. When firm $m$ (an incumbent) has an efficient technology for infrastructure investment and its spillover effect is small, it is better to invest in infrastructure and foreclose firm $e$ (an entrant) than introducing competition from an efficiency point of view. However, since firm $m$ does not fully care about consumer's willingness-to-pay, its investment incentive is less than that in the second best. Therefore, there exists a room where firm $e$ can enter the market by accessing firm $m$'s infrastructure.

[14] Region IV also has the same result as that of region III, except that firm $m$'s decision is indifferent between allowing firm $e$'s entry with access and foreclosure.

Notice that a crucial factor that induces the excess entry with access is not an entrant's (firm $e$'s) decision, but an incumbent's (firm $m$'s) weak incentive for infrastructure investment. In fact, as observed by Sappington (2005), given an input price, an entrant's make-or-buy decision, which corresponds to its choice of entry strategy in our model, can be always efficient from a welfare viewpoint, irrespective of the level of access charge. Hence, a suggestion for competition policy should be made concerning how to give an appropriate incentive for infrastructure investment to an incumbent.

As mentioned in section 1, Foros (2004) dealt with the case where an entrant has only the access strategy under the regulated access price. However, he did not examine how the equilibrium market structure is evaluated from a welfare viewpoint, since his main interest is the comparison of the environments with and without access price regulation. Hence, Proposition 1 has a complementary role concerning the effect of an incumbent's strategic investment upon the equilibrium market structure in an open access environment.

From the intuitive reason of Proposition 1, it seems to be obvious that the level of infrastructure investment in equilibrium is less than that in the second best. Indeed, the next proposition shows that in equilibrium, the underinvestment result occurs irrespective of the incumbent's technology for infrastructure investment.

**Proposition 2** *When an entrant has only the access strategy to enter a market, an incumbent has less incentive to invest in infrastructure in equilibrium than in the second-best optimum, irrespective of the incumbent's technology for infrastructure investment.*

**Proof.** See Appendix C. ∎

The underinvestment in equilibrium when an entrant has only the access strategy was also shown in Kotakorpi (2006). As seen in the next section, we will extend the underinvestment result to the case where the entrant has an opportunity to use the other alternative strategy for entry.

The reason why the underinvestment prevails in equilibrium deserves to be clarified. Remember that we define the "second-best" as the situation where the regulator sets not only the access charge $a^{**}$ $(= c)$ but also the level of investment $x^m$. In other words, firm $e$'s strategic behavior *given* $a^{**}$ *and* $x^m$ still remains in the second-best. From this viewpoint, the underinvesment result in equilibrium when compared with the second-best is not due to the strategic interaction between firm $m$ and firm $e$. Rather, the main driving force that gives birth to the result of underinvestment in infrastructure is the fact that firm $m$ does not fully care about the enlargement of consumer's willingness-to-pay generated by infrastructure investment.

Needless to say, when compared with the first-best where the regulator sets not only the level of investment but also that of production downstream, the strategic interaction between firm $m$ and firm $e$ needs to be mentioned as a main force for underinvestment. In particular, Kotarkorpi (2006) showed that the spillover effect has a negative impact on infrastructure investment because of their strategic interaction (see Proposition 3 in his paper). This point is easily ensured in our framework as well.[15]

# 4 The Equilibria with Access and Vertical Merger

## 4.1 Firm $e$'s strategies for entry

Let us turn to the model described in section 2. In the model, firm $e$ has three alternative strategies for entry; access, vertical merger, and bypass. That is, firm $e$ has an opportunity to use firm $u$'s bypass technology through an agreement of a vertical merger with firm $u$, when it refuses the access to firm $m$'s infrastructure. In addition, as mentioned in section 2, when $a$ is extremely high and firm $e$'s proposal of vertical merger is rejected by firm $u$, firm $e$ may use firm $u$'s bypass by paying a wholesale price $w$ set by firm $u$. Hence, we need to carefully examine firm $e$'s decision on the choice of entry strategy.

[15] The details of this point will be sent upon request.

In the third stage, firm $e$ determines its entry strategy, given the level of infrastructure investment $x^m$ and the regulated access charge $a$. When proposing a vertical merger to firm $u$, firm $e$ needs to anticipate the wholesale price $w$ set by firm $u$ that would be offered if the vertical-merger proposal were rejected. Here, we should notice that the regulated access charge $a$ can put some restriction on $w$. In Appendix D, we provide the sketch of the procedure to derive firm $e$'s entry decision under the level of infrastructure investment $x^m$ and the regulated access charge $a$. (See Appendix D.) Figure 4-1 summarizes firm $e$'s choice of entry strategy in the third stage when $s > 1/2$.

[Insert Figure 4-1 around here.]

In the figure, the three upward-sloping straight lines and a vertical line are drawn in addition to (1).

$$a = \left(\frac{V + c + c^u}{4}\right) + \left(\frac{4s - 1}{4}\right) x^m. \tag{2}$$

$$a = c^u + sx^m. \tag{3}$$

$$a = -\left(\frac{V + c - 4c^u}{2}\right) + \left(\frac{2s + 1}{2}\right) x^m \tag{4}$$

$$x^m = \overline{x}^m \left(\equiv V + c - 2c^u\right) \tag{5}$$

Equation (2) indicates whether or not firm $u$ can obtain a nonnegative profit (i.e., it has an incentive to actually offers the wholesale price $w$) when the access price regulation is binding for firm $u$'s setting its profit-maximizing wholesale price $w^*$. In fact, when the regulated access charge is low, firm $u$ cannot set $w^*$ given by

$$w^* = \frac{1}{4}\left(V - x^m + c + 2c^u\right) \tag{6}$$

Instead, it has to set the binding wholesale price $\overline{w}$ given by[16]

$$\overline{w} = a - sx^m. \tag{7}$$

The right hand side of $\overline{w}$ is interpreted as an "effective" access charge. Indeed, the access to firm $m$'s infrastructure makes the quality of firm $e$'s goods upgrade (i.e., the existence of a spillover effect), so that the wholesale price $w$ firm $u$ offers needs to be lower than the nominal access charge $a$. Then, only when $\overline{w} \geq c^u$, firm $u$ can obtain a nonnegative profit.

Similarly, equation (3) represents whether firm $u$ has an incentive to offer the binding wholesale price $\overline{w}$ (i.e., whether its profit with $\overline{w}$ is positive or not). Hence, the region enclosed by (2) and (3) means that firm $u$ would like to offer $\overline{w}$, since it can gain a positive profit and firm $e$ accepts it if there is not a vertical-merger proposal.

Equation (4) represents whether firm $e$ prefers vertical merger to the other two entry strategies. In addition, the vertical line (5) $x^m = \overline{x}^m$ ($\equiv V + c - 2c^u$) represents whether firm $e$ accepts the wholesale price $w^*$ firm $u$ offers when the access price regulation is not binding.

Now, we ensure several remarkable findings in Figure 4-1 when compared to Figure 1. First, the vertical-merger strategy prevails when the level of access charge $a$ is high and the level of infrastructure $x^m$ is small. In particular, there is no room where the bypass strategy is used instead of the vertical-merger strategy. Remember that this finding depends on the competition mode downstream and how to determine the wholesale price. In fact, as in the setting of Ordover et al. (1990), when firm $m$ and firm $e$ competes in price downstream and firm $u$ can communicate with firm $e$, it is possible for the bypass strategy to overcome the vertical-merger strategy in the sense that both firm $u$ and firm $e$

[16] Under access price regulation, firm $u$'s problem is stated as

$$\underset{w}{Max}\pi^u \quad s.t.\ \pi^{e*B} \geq \pi^{e*A}$$

$\overline{w}$ is derived when the constraint is binding, i.e., $\pi^{e*B} = \pi^{e*A}$.

can be better off. In that case, the bypass strategy can appear in some part of the region of vertical merger in Figure 4-1.

Second, the region of the access strategy shrinks when compared to Figure 1. In particular, in the region enclosed by (1) and (3) for $x^m \leq \overline{x}^m$, firm $e$ takes the vertical-merger strategy instead of the access strategy. As discussed in section 5, the vertical-merger strategy taken by firm $e$ contributes to the enhancement of production efficiency.

Third, the region of foreclosure becomes smaller than in Figure 1. In fact, when the level of infrastructure $x^m$ is small, firm $e$ has an incentive to enter with the vertical-merger strategy even when access charge is high. In this sense, the existence of the bypass technology actually contributes to the achievement of competitive environment in network industries. When $x^m$ is large, however, firm $e$ gives up entry. This is because the difference of the quality of goods between firm $m$'s and firm $e$'s is large, so that firm $e$ cannot fascinate consumers.

We mention a final remark in this subsection. The qualitative features of firm $e$'s entry decision does not change even for $s \leq 1/2$. However, when firm $m$'s strategic opportunity for infrastructure investment is introduced, firm $e$'s choice of entry strategy in equilibrium may dramatically change according to the level of $s$. Hence, we show the figures for the cases where $(1/4) < s \leq (1/2)$ and where $0 \leq s \leq (1/4)$.

[Insert Figures 4-2 and 4-3]

## 4.2 Firm $m$'s strategic infrastructure investment and the equilibrium market structure

In the second stage, the regulator would like to set $a^{**} = c$, because the imperfection in the retail market is prevalent, irrespective of the level of $x^m$.

Then, given $a^{**} = c$ and firm $e$'s choice of entry strategy, firm $m$ invests in infrastructure in order to maximize its profit in the first stage. The procedure to derive the optimal investment is the same as in section 3, except that the classification of the cases we need to check does not depend only on the level of $s$. We also need to check the sign of cost difference $\Delta c \equiv c - c^u$ and the relationship between the level of firm $m$'s marginal cost and the demand size. (See Appendix E for the sketch of the derivation.) In fact, the classification of the equilibrium market structure according to these parameters is as follows.

[Insert Figures 5 and 6 around here.]

*Case 1:* When $1/2 \leq s \leq 1$ and $\Delta c \leq 0$.

From Figure 4-1, we ensure that firm $e$ takes only the access strategy for entry. Hence, the analysis is the same as in section 3. That is, a duopoly with access is realized in equilibrium. (See Figure 2.)

*Case 2:* When $1/2 \leq s \leq 1$ and $\Delta c > 0$.

From Figure 4-1, we ensure that the access and the vertical-merger strategies are taken by firm $e$. The part of $s \in [1/2,\ 1]$ in Figure 5 (or Figure 6) applies to this case. (See Appendix E for the derivation of Figure 5.)

*Case 3:* When $1/4 \leq s < 1/2$ and $\Delta c \leq 0$.

From Figure 4-2, we ensure that firm $e$ takes only the access strategy for entry. Hence, the analysis is the same as in section 3. That is, a duopoly with access is realized in equilibrium. (See Figure 2.)

*Case 4:* When $1/4 \leq s < 1/2$ and $\Delta c > 0$.

From Figure 4-2 and the assumption that $Y \equiv V - c > 2\Delta c$, we ensure that firm $e$ takes not only the access strategy but also the vertical-merger strategy, which depends on the level of $x^m$. The equilibrium market structure is given in the part of $s \in [1/4,\ 1/2)$ in Figure 5.

*Case 5:* When $0 \leq s \leq 1/4$ and $\Delta c \leq 0$.

From Figure 4-3, we ensure that firm $e$ takes only the access strategy for entry. Hence, the analysis is the same as in Section 3. That is, the "duopoly with access" and the foreclosure are possible in equilibrium. (See Figure 2.)

*Case 6:* When $0 \leq s \leq 1/4$ and $\Delta c > 0$.

Note that when $0 \leq s \leq 1/4$, we have $2 \leq (1-2s)/s$. In this case, we have several cases according to the market size $V$. Here, we restrict our attention to two illustrative cases, i.e., $0 < \Delta c \leq (1/10)\,Y$ and $(1/10)\,Y < \Delta c \leq (4/17)\,Y$, which give a clear contrast between the equilibrium market structure and the second-best market structure.

The above six cases can be summarized as follows.

(i) When $\Delta c \leq 0$, the equilibrium market structure is the same as in Figure 2.

(ii) When $0 < \Delta c \leq (1/10)\,Y$, the equilibrium market structure is drawn in Figure 5.

(iii) When $(1/10)\,Y < \Delta c \leq (4/17)\,Y$, the equilibrium market structure is drawn in Figure 6.

[Insert Figure 7 around here.]

According to the parameter range adopted in the classification of the equilibrium market structures, the second-best market structures are drawn in Figure 7. Then, comparing Figures 5 and 6 with Figure 7 (in addition to the result of Figure 3), we obtain the following proposition.

**Proposition 3** *Suppose that an entrant has not only the access strategy but also the vertical-merger strategy and an incumbent's access cost is higher than the production cost of bypass technology(i.e.,* $\Delta c \equiv c - c^u > 0$*). Then, when the spillover effect of infrastructure investment is large and the incumbent's investment technology is inefficient, excessive vertical merger and insufficient access to infrastructure occurs from a welfare viewpoint.*

**Proposition 4** *Suppose that an entrant has not only the access strategy but also the vertical merger strategy. Then, if an incumbent's access cost is higher (lower) than the production cost of bypass technology(i.e.,* $\Delta c \equiv c - c^u > (<)\, 0$*). Then, the excess entry* *with vertical merger (with access) occurs in equilibrium when the spillover effect is small and the incumbent's investment technology is efficient.*

Proposition 3 states that in equilibrium, firm $e$ adopts the excessive vertical merger strategy when the spillover effect of infrastructure investment is large. At first glance, this seems to be counterintuitive. The reason for the occurrence of excessive vertical merger is explained by firm $m$'s incentive for underinvestment in infrastructure. Since firm $m$ does not fully care about the benefit to consumers generated by infrastructure investment, its investment incentive is weak. This gives birth to firm $e$'s incentive for vertical merger, since it cannot enjoy the benefit of access because of underinvestment in infrastructure. Proposition 4 has a similar flavor of Proposition 1.

The underinvestment in the equilibrium for any technological environment is also obtained as in sections 3.1 and 3.2.

**Proposition 5** *When an entrant has not only the access strategy but also vertical-merger strategy to enter a market, an incumbent has less incentive to invest in infrastructure in the equilibrium than in the second-best optimum, irrespective of the incumbent's technology for infrastructure investment.*

# 5 Discussion: Policy Implications

From the propositions derived in the previous section, we can obtain a general message. Since firm $m$'s (i.e., an incumbent's or a network owner's) incentive for infrastructure investment is weak from a welfare viewpoint, a market structure that results from the relationship between the infrastructure expansion and firm $e$'s (i.e., an entrant's) entry decision can be also distorted.

Notice that if the infrastructure coverage is taken as given, an entrant's make-or-buy decision generates no distortion in production efficiency, irrespective of the level of the regulated access charge (see Sappington (2005)). This point is easy to be verified in our model. Indeed, when there is no infrastructure investment, the vertical-merger strategy is taken by firm $e$, as long as $c^u < c$ (i.e., the vertical intercept of $a = c^u + sx^m$ in Figure 4-1). Furthermore, even when there is a positive level of infrastructure investment, the vertical-merger strategy is taken by firm $e$, as long as $c^u < c - sx^m$ (i.e., the unit production cost of bypass is less than the "effective" unit access cost that includes the benefit of spillover effect on the demand). Hence, the driving force that generates a distortion in the equilibrium market structure is an incumbent's weak incentive for infrastructure investment.

For example, when the bypass technology is not available for firm $e$, the excess entry with access occurs in the equilibrium. At a first glance, the access is desirable from a welfare viewpoint. However, remember that in our model, the improvement of the allocative efficiency can be achieved by not only increasing the production level through competition downstream, but also enlarging consumer's willingness-to-pay through the infrastructure investment. Then, when firm $m$ has an efficient technology for infrastructure investment and its spillover effect is small, it is better to invest more in infrastructure and foreclose firm $e$ from an efficiency viewpoint than introducing competition. However, since firm $m$ does not fully care about consumer's willingness-to-pay, its investment incentive is weak, and firm $e$ can enter the market with access.

Similarly, when the bypass technology is available through a vertical merger with firm $u$, the excess entry with vertical merger can occur in equilibrium. When the spillover effect $s$ is small, the entrant desires the use of bypass or wants to propose a vertical merger with a firm that has the bypass. However, from an efficiency viewpoint, the foreclosure is better especially when firm $m$'s investment technology is good. Again, this is because the infrastructure investment can enlarge consumer's willingness-to-pay.

The recent policy stance in network industries has been an introduction of competition, and the regulators in many countries concern about the existence of an incumbent's market power that is used for the exclusion of potential entrants. Hence, the message we obtain seems to go into the opposite direction to the instruction of competition policy in reality. However, this is not the case. Our message is crucially based on the appropriate setting of access charge and nonexistence of nonprice exclusionary tools other than the infrastructure investment. If an incumbent has a private information on access cost or the other kinds of nonprice exclusionary tool such as tying, advertisement, etc., the foreclosure should be carefully monitored. On the other hand, if these issues are appropriately solved in the policy area, our message can give a suggestion on the relationship between the level of infrastructure investment and its associated market structure. In this sense, the message derived from our analysis should be considered to be a complement to the policy instruction in reality.

Then, the question is: how to induce a sufficient incentive for infrastructure investment? One effective way to do this is to allow a regulator to obtain an initiative for infrastructure investment, as long as she understands the degree of demand-enhancing effect of infrastructure investment.[17] In that case, there may be a trade-off between a regulator's ability to commit an appropriate vision of infrastructure projects and the loss generated from the deterrence of introducing competition in network industries.

# 6 Concluding Remarks

This paper investigated a firm's incentive for infrastructure investment in a competitive environment with open access. In the model, we supposed that access price regulation is a necessary tool to enhance an allocative efficiency in a retail market. Given access price regulation, we allowed an entrant to has an opportunity to use a bypass technology through a vertical merger with an upstream firm.

[17] In the framework of coalition formation to build an infrastructure, Mizuno and Shinkai (2006) also propose the delegation of the initiative for infrastructure building to a regulator, when the cost-reducing effect of infrastructure is large. They, however, insist that, when the effect is small, a network owner has an appropriate incentive for infrastructure investment from a welfare viewpoint, so that the regulator should not intervene the market.

Three main findings were obtained from the analysis in this paper. First, we showed that in equilibrium, the incumbent strategically gives birth to excessive vertical merger and insufficient access to its infrastructure from a welfare viewpoint. Second, two types of excess entry occur in equilibrium. In particular, when the incumbent's access cost is lower than the production cost of bypass technology, the "excess entry with access" occurs in the equilibrium market structure. Otherwise, the "excess entry with vertical merger" occurs in equilibrium. We also showed the prevalence of underinvestment in infrastructure with the equilibrium market structures, irrespective of the incumbent's technology for infrastructure investment.

In an open access environment, several concrete policy ideas other than the delegation of the initiative for infrastructure projects to a regulator can be considered for promoting infrastructure investment. Their effects may depend on the characteristics of different network industries. Hence, an important research area from now on is to investigate the effects of different concrete policies for the promotion of infrastructure investment by taking the characteristics of different network industries into consideration.

# Appendix

## A. Firm $m$'s profit-maximizing investment problem with firm $e$'s access strategy

When $s \geq 1/2$, it is apparent that firm $e$ accesses firm $m$'s infrastructure for any $x^m$ under the regulated access charge $a^{**} = c$. Hence, the profit-maximizing investment is

$$x^{m*A} = \frac{2(2-s)Y}{9\gamma - 2(2-s)^2}, \tag{8}$$

where $Y \equiv V - c$.

When $s < 1/2$ and $a^{**} = c$, there exists a critical level of $x^m$, denoted by $\overline{x}^{mA}$, below (above) which firm $e$ enters (does not enter) the market. In fact, we have

$$\overline{x}^{mA} = \frac{Y}{1-2s}. \tag{9}$$

Then, firm $m$'s problem can be analyzed by solving the two subproblems; one subproblem is to choose the optimal investment under firm $e$'s access strategy, while the other is to choose the optimal investment with foreclosure. When allowing firm $e$'s access, firm $m$'s problem is

$$\underset{x^m}{Max}\ \pi^{m*A} = \widetilde{\pi}^{m*A} - \frac{1}{2}\gamma\left(x^m\right)^2 \qquad s.t.\ 0 \leq x^m \leq \overline{x}^{mA}$$

Then, firm $m$'s maximized profit is represented as follows.

$$\pi^{m*A}\left(x^{m*A}\right) \quad \text{if} \ \ x^{m*A} \ \leq \ \overline{x}^{mA}, \tag{10}$$

$$\pi^{m*A}\left(\overline{x}^{mA}\right) \quad \text{if} \ \ x^{m*A} \ > \ \overline{x}^{mA} \tag{11}$$

Substituting (14) and (15) into $x^{m*A}$ and $\overline{x}^{mA}$ in the "if" condition of (16) or (17), we have the critical hyperplane $x^{m*A} = \overline{x}^{mA}$. That is,

$$\gamma = \frac{2}{3}\left(2-s\right)\left(1-s\right), \tag{12}$$

which is drawn in Figure 2. Then, we ensure that $\pi^{m*A}\left(x^{m*A}\right)$ $(\pi^{m*A}\left(\overline{x}^{mA}\right))$ is obtained above (below) the hyperplane (1).

Similarly, when foreclosing firm $e$, firm $m$'s program is

$$\underset{x^m}{Max}\ \pi^{m*F} = \widetilde{\pi}^{m*F} - \frac{1}{2}\gamma\left(x^m\right)^2 \qquad s.t.\ \overline{x}^{mA} \leq x^m$$

Then, firm $m$'s maximized profit is represented as follows.

$$\pi^{m*F}\left(x^{m*F}\right) \quad \text{if} \quad x^{m*F} > \overline{x}^{mA}, \tag{13}$$

$$\pi^{m*F}\left(\overline{x}^{mA}\right) \quad \text{if} \quad x^{m*F} \leq \overline{x}^{mA}, \tag{14}$$

where

$$x^{m*F} = \frac{Y}{2\gamma - 1} \tag{15}$$

Substituting (21) and (15) into $x^{m*F}$ and $\overline{x}^{mA}$ in the "if" condition of (19) or (20), we have the critical hyperplane $x^{m*F} = \overline{x}^{mA}$. That is,

$$\gamma = 1 - s, \tag{16}$$

which is also drawn in Figure 2. We ensure that $\pi^{m*F}\left(\overline{x}^{mA}\right)$ $\left(\pi^{m*F}\left(x^{m*F}\right)\right)$ is obtained above (below) the hyperplane (1).

Now, we can derive the solution of firm $m$'s investment by combining the two subproblems for the case where $s < 1/2$. Note that the solution implies the determination of the equilibrium market structure in each region. For example, consider the region where

$$\gamma > \frac{2}{3}(2-s)(1-s) \text{ and } \gamma > 1-s.$$

This region corresponds to the case where $x^{m*A} \leq \overline{x}^{mA}$ and $x^{m*F} \leq \overline{x}^{mA}$. Since $\pi^{m*A}\left(\overline{x}^{mA}\right) = \pi^{m*F}\left(\overline{x}^{mA}\right)$ and $\pi^{m*A}\left(x^{m*A}\right) > \pi^{m*A}\left(\overline{x}^{mA}\right)$. firm $m$'s profit-maximizing investment is $x^{m*A}$, and the equilibrium market structure in this region becomes duopoly with access.

The profit-maximizing investment and the equilibrium market structure in other regions are similarly derived, as is shown in Figure 2.

## B. The sketch of the derivation of second-best investment and its associated market structure with firm $e$'s access strategy

Notice that the difference between the second-best investment problem and firm $m$'s profit-maximization problem exists only on the objective function. Hence, the procedure to derive the second-best investment is exactly the same as that of firm $m$'s profit-maximization problem.

The social welfare is represented by

$$W^A = (V + x^m) q^{m*A} + (V + sx^m) q^{m*A} - \frac{1}{2} \left(q^{m*A} + q^{e*A}\right)^2 - c \left(q^{m*A} + q^{e*A}\right) - \frac{1}{2}\gamma (x^m)^2 , \tag{17}$$

when firm $e$ accesses firm $m$'s infrastructure. Similarly, the social welfare when firm $m$ forecloses firm $e$ is represented by

$$W^F = (V + x^m) q^{m*F} - \frac{1}{2} \left(q^{m*F}\right)^2 - cq^{m*F} - \frac{1}{2}\gamma (x^m)^2 . \tag{18}$$

When $s \geq 1/2$, firm $e$ accesses firm $m$'s infrastructure for any $x^m$ under $a^{**} = c$, so that we have

$$x^{m**A} = \frac{4(s+1)Y}{9\gamma - (11s^2 - 14s + 11)}. \tag{19}$$

When $s < 1/2$ and $a^{**} = c$, the critical level of $\overline{x}^{mA}$ also applies to the second-best problem. Hence, the problem is analyzed by the subproblems of the cases of access and foreclosure, as is firm $m$'s profit-maximization problem. In fact, the critical hyperplane when firm $e$ accesses is given by

$$\gamma = \frac{1}{3}(5 - s)(1 - s). \tag{20}$$

That is, in the region above (below) (26), the condition that $x^{m**A} < (>) \, \overline{x}^{mA}$ holds, which gives $W^A \left(x^{m**A}\right)$ $\left(W^A \left(\overline{x}^{mA}\right)\right)$ in that region.

Similarly, we obtain the critical hyperplane when firm $e$ is foreclosed is given by

$$\gamma = \frac{3}{2}(1-s). \tag{21}$$

Below (27), we have the unconstrained second-best investment under the foreclosure, which is given by

$$x^{m**F} = \frac{3Y}{4\gamma - 3}, \tag{22}$$

and the associated social welfare is $W^F\left(x^{m**F}\right)$. The social welfare in the above region is $W^F\left(\overline{x}^{mA}\right)$.

Comparing $W^A(.)$ and $W^F(.)$, both of which are evaluated at the associated investment levels, we can derive the second-best market structure in each region when $s < 1/2$. Then, combining the second-best market structure and that in the equilibrium, we obtain Figure 3.

## C. The proof of Proposition 2

From (14) and (25), it is easy to verify that $x^{m*A} < x^{m**A}$. Then, the claim in the text is obtained from the comparison of the regions in the second-best and equilibrium market structures and the fact that $x^{m*A} < \overline{x}^{mA} < x^{m**F}$. ■

## D. Firm $e$'s entry decision in the third stage

In this appendix, we provide the sketch of the procedure to derive firm $e$'s entry decision in the third stage.

First of all, we need to prepare firm $u$'s setting of the wholesale price $w$ under a regulated access charge $a$. Given $a$, the wholesale price $w$ should be accepted by firm $e$. This constraint requires $\pi^{e*B}(w) \geq \pi^{e*A}(a)$, where $\pi^{e*B}(w)$ is firm $e$'s profit under a bypass strategy with $w$, whereas $\pi^{e*A}(a)$ is its profit under access strategy with $a$. The condition $\pi^{e*B}(w) \gtreqless \pi^{e*A}(a)$ is rewritten as

$$w \lesseqgtr a - sx^m \equiv \overline{w} \tag{23}$$

Furthermore, under $\overline{w}$, firm $u$'s profit should be nonnegative; $\pi^{u*B}(\overline{w}) \geq 0$. Hence, we need to examine four cases, depending on whether or not firm $u$'s profit-maximizing wholesale price is lower than $\overline{w}$ (i.e., $w^* \gtreqless \overline{w}$ where $w^*$ is the profit-maximizing wholesale price given by (6)) and whether firm $u$'s profit is nonnegative or not (i.e.,$\pi^{u*B}(\overline{w}) \gtreqless 0$). The condition that $\pi^{u*B}(\overline{w}) \geq (<) \, 0$ is rewritten as

$$a \geq (<) \, c^u + sx^m \tag{24}$$

Using these conditions, we need to examine firm $e$'s entry decision in all the four cases.

Let us turn to firm $e$'s entry decision in the third stage.

First, consider the case where $w^* \geq \overline{w}$. The condition that $w^* \geq \overline{w}$ is rewritten as

$$a \leq \left(\frac{V + c + c^u}{4}\right) + \left(\frac{4s - 1}{4}\right) x^m. \tag{25}$$

In this case, firm $u$ needs to offer $\overline{w}$ if it rejects the proposal of vertical merger. When firm $e$ proposes a vertical merger, the following condition must be held.

$$\pi^{*M} - \pi^{u*B}(\overline{w}) \geq \pi^{e*B}(\overline{w}) \left(= \pi^{e*A}(a)\right) \tag{26}$$

Then, let us examine the case where $\pi^{u*B}(\overline{w}) < 0$. The condition that $\pi^{u*B}(\overline{w}) < 0$ is rewritten as $a - sx^m < c^u$. In this case, firm $u$ does not have an incentive to offer $\overline{w}$. Then, firm $e$'s alternatives are vertical-merger strategy and access strategy. The condition that $\pi^{*M} \geq \pi^{e*A}(a)$ is rewritten as $a - sx^m \geq c^u$, which contradicts the premise that $\pi^{u*B}(\overline{w}) < 0$. Hence, when $\pi^{u*B}(\overline{w}) < 0$, firm $e$ always has an incentive to use the access strategy.

In the case where $\pi^{u*B}(\overline{w}) \geq 0$, firm $e$ offers a vertical merger if and only if

$$a \leq -\left(\frac{V + c - 4c^u}{2}\right) + \left(\frac{2s+1}{2}\right) x^m \tag{27}$$

Second, consider the case where the regulated access charge does not bind firm $u$'s profit-maximizing wholesale price; $w^* < \overline{w}$. When firm $e$ proposes a vertical merger, the following condition must be held.

$$\pi^{*M} - \pi^{u*B}(w^*) \geq \pi^{e*B}(w^*) > \pi^{e*A}(a) \tag{28}$$

In fact, under Cournot competition in the resale market, we ensure that $\pi^{*M} > \pi^{u*B}(w^*) + \pi^{e*B}(w^*)$. Hence, (13) holds as long as $q^{e*B}(w^*) > 0$.

Summarizing these results, we obtain Figure 4.

## E. The derivation of Figures 5 and 6: the equilibrium investment and market structure with access and vertical-merger strategies

As in Figures 4-1 to 4-3, firm $e$'s entry decision depends on the level of $s$, the sign of cost difference $\Delta c \equiv c - c^u$, and the relationship between the level of firm $m$'s marginal cost and the demand size. Hence, firm $m$'s investment problem should be examined in all the seven cases stated in the text.

Here, the equilibrium investment in the vertical-merger market without any restriction on $x^m$ is given by

$$x^{m*M} = \frac{4(Y - \Delta c)}{9\gamma - 8} \tag{29}$$

The procedure to derive the equilibrium investment and market structure is the same as in Section 3. Hence, we give the analysis of one case as an example. Consider the case where $1/2 \leq s \leq 1$ and $\Delta c > 0$. See Figure 4-1. In this case, under $a^{**} = c$, firm $e$

takes vertical-merger strategy if $x^m \leq \overline{x}^{mM}$ where $\overline{x}^{mM}$ is defined by $c = s\overline{x}^{mM} + c^u$, i,e., $\overline{x}^{mM} = \Delta c/s$. Hence, when allowing firm $e$'s vertical merger, firm $m$'s problem is

$$\underset{x^m}{Max}\ \pi^{m*M} = \widetilde{\pi}^{m*M} - \frac{1}{2}\gamma\left(x^m\right)^2 \qquad s.t.\ 0 \leq x^m \leq \overline{x}^{mM}$$

On the other hand, when allowing firm $e$'s access, firm $m$'s problem is

$$\underset{x^m}{Max}\ \pi^{m*A} = \widetilde{\pi}^{m*A} - \frac{1}{2}\gamma\left(x^m\right)^2 \qquad s.t.\ \overline{x}^{mM} \leq x^m$$

Analyzing these two subproblems, we can draw the region of the equilibrium market structure for $s \in [1/2,\ 1]$ in Figures 5 and 6. The equations of critical hyperplanes are

$$\gamma = \frac{8}{9} + \frac{4\left(Y - \Delta c\right)}{9\Delta c}s, \tag{30}$$

$$\gamma = \frac{2}{9}\Delta c\left[-\left(Y - \Delta c\right)s^2 + 2\left(Y - 2\Delta c\right)s + 4\Delta c\right]. \tag{31}$$

All the other cases are similarly examined. One caveat: for $s \in [0,\ 1/4)$, we need to classify several cases according to the market size $V$. As mentioned in the text, we restrict our attention to two illustrative cases, i.e., $0 < \Delta c \leq (1/10)\,Y$ and $(1/10)\,Y < \Delta c \leq (4/17)\,Y$.

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| | | Firm *m* | | Firm *e* | | Firm *u* | |
|---|---|---|---|---|---|---|---|
| | | $q^{m*}$ | $\tilde{\pi}^{m*}$ | $q^{e*}$ | $\pi^{e*}$ | $q^{u*}$ | $\pi^{u*}$ |
| **Access** | | $q^{m*A} = \frac{1}{3}\left(V+(2-s)x^m+a-2c\right)$ | $\tilde{\pi}^{m*A} = \left(q^{m*A}\right)^2 + (a-c)q^{e*A}$ | $q^{e*A} = \frac{1}{3}\left(V+(2s-1)x^m+c-2a\right)$ | $\pi^{e*A} = \left(q^{e*A}\right)^2$ | 0 | 0 |
| **Bypass** | **Non-Binding APR** | $q^{m*B} = \frac{1}{12}\left(5V+7x^m+2c^u-7c\right)$ | $\tilde{\pi}^{m*B} = \left(q^{m*B}\right)^2$ | $q^{e*B} = \frac{1}{6}\left(V-x^m+c-2c^u\right)$ | $\pi^{e*B} = \left(q^{e*B}\right)^2$ | $q^{u*B} = q^{e*B}$ | $\pi^{u*B} = \frac{1}{24}\left(V-x^m+c-2c^u\right)^2$ |
| | **Binding APR** | $\bar{q}^{m*B}\left(=q^{m*A}\right) = \frac{1}{3}\left(V+(2-s)x^m+a-2c\right)$ | $\tilde{\bar{\pi}}^{m*B} = \left(\bar{q}^{m*B}\right)^2$ | $\bar{q}^{e*B}\left(=q^{e*A}\right) = \frac{1}{3}\left(V+(2s-1)x^m+c-2a\right)$ | $\bar{\pi}^{e*B} = \left(\bar{q}^{e*B}\right)^2$ | $\bar{q}^{u*B} = \bar{q}^{e*B}$ | $\bar{\pi}^{u*B} = \frac{1}{3}\left(a-sx^m-c^u\right)\bar{q}^{e*B}$ |

**Table 1 Equilibrium Production and the Associated Profits**

Notes:

(i) $\tilde{\pi}^{m*}$ represents firm *m*'s profit excluding the infrastructure investment cost.

(ii) "(Non-)Binding APR" represents the case where access price regulation is (not) binding.

| | Firm $m$ | | Firm $e$ | | Firm $u$ | |
|---|---|---|---|---|---|---|
| | $q^{m*}$ | $\tilde{\pi}^{m*}$ | $q^{e*}$ | $\pi^{e*}$ | $q^{u*}$ | $\pi^{u*}$ |
| **Vertical Merger** | $q^{m*M} = \frac{1}{3}\left(V + 2x^m + c^u - 2c\right)$ | $\tilde{\pi}^{m*M} = \left(q^{m*M}\right)^2$ | $q^{e*}\left(= q^{u*}\right)$<br>$q^{e*M} = \frac{1}{3}\left(V - x^m + c - 2c^u\right)$ | | $\pi^* \equiv \pi^{e*} + \pi^{u*}$<br>$\pi^{*M} = \left(q^{e*M}\right)^2$ | |
| **Foreclosure** | $q^{m*F} = \frac{1}{2}\left(V + x^m - c\right)$ | $\tilde{\pi}^{m*F} = \left(q^{m*F}\right)^2$ | 0 | 0 | 0 | 0 |

**Table 1**(Continued) **Equilibrium Production and the Associated Profits**

Notes:

(i) $\tilde{\pi}^{m*}$ represents firm $m$'s profit excluding the infrastructure investment cost.

(ii) The joint production and its associated profit are reported in the vertical merger case.

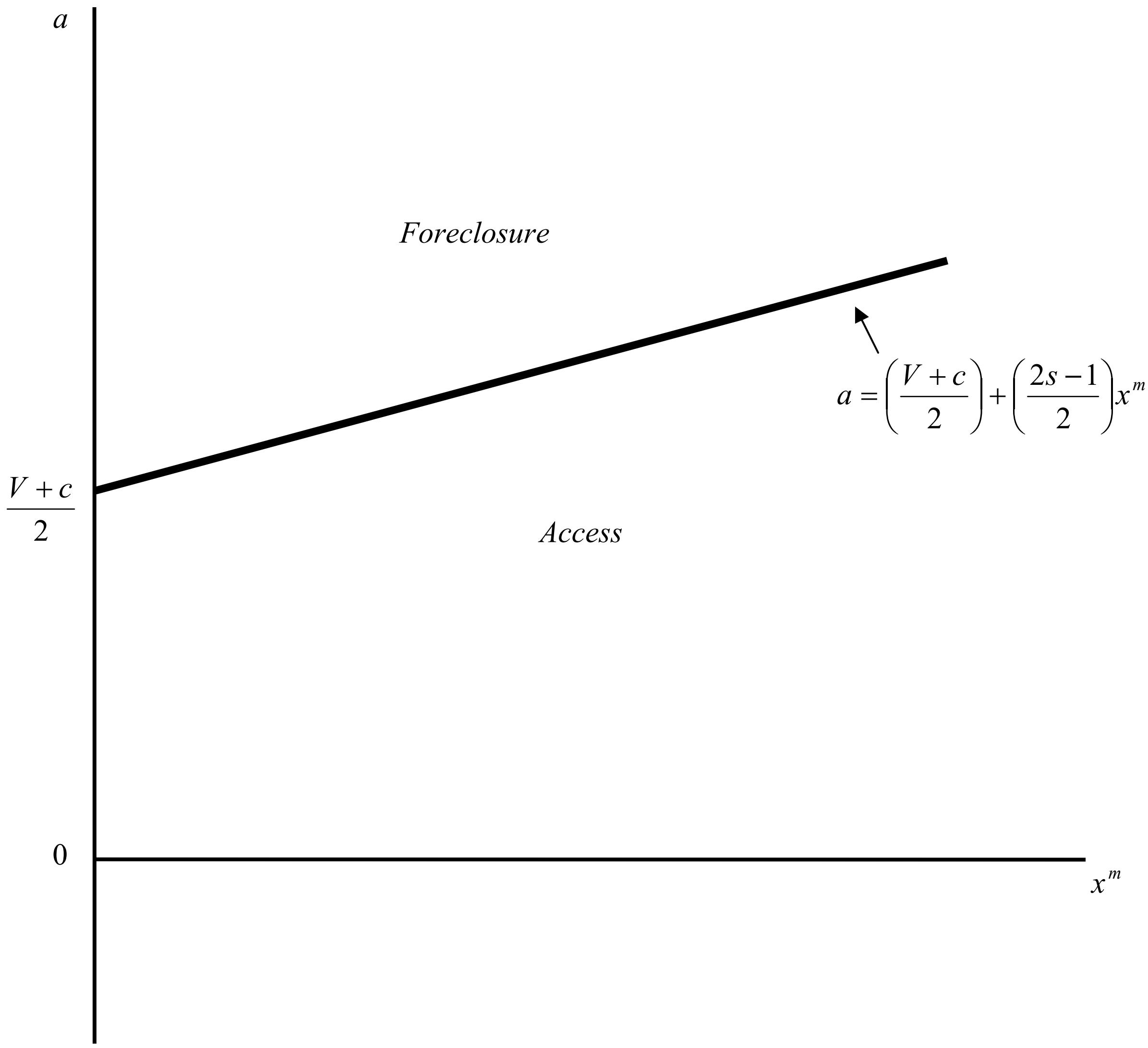


**Figure 1 Firm *e*'s Entry Decision with Access: The case where $\frac{1}{2} < s \leq 1$**

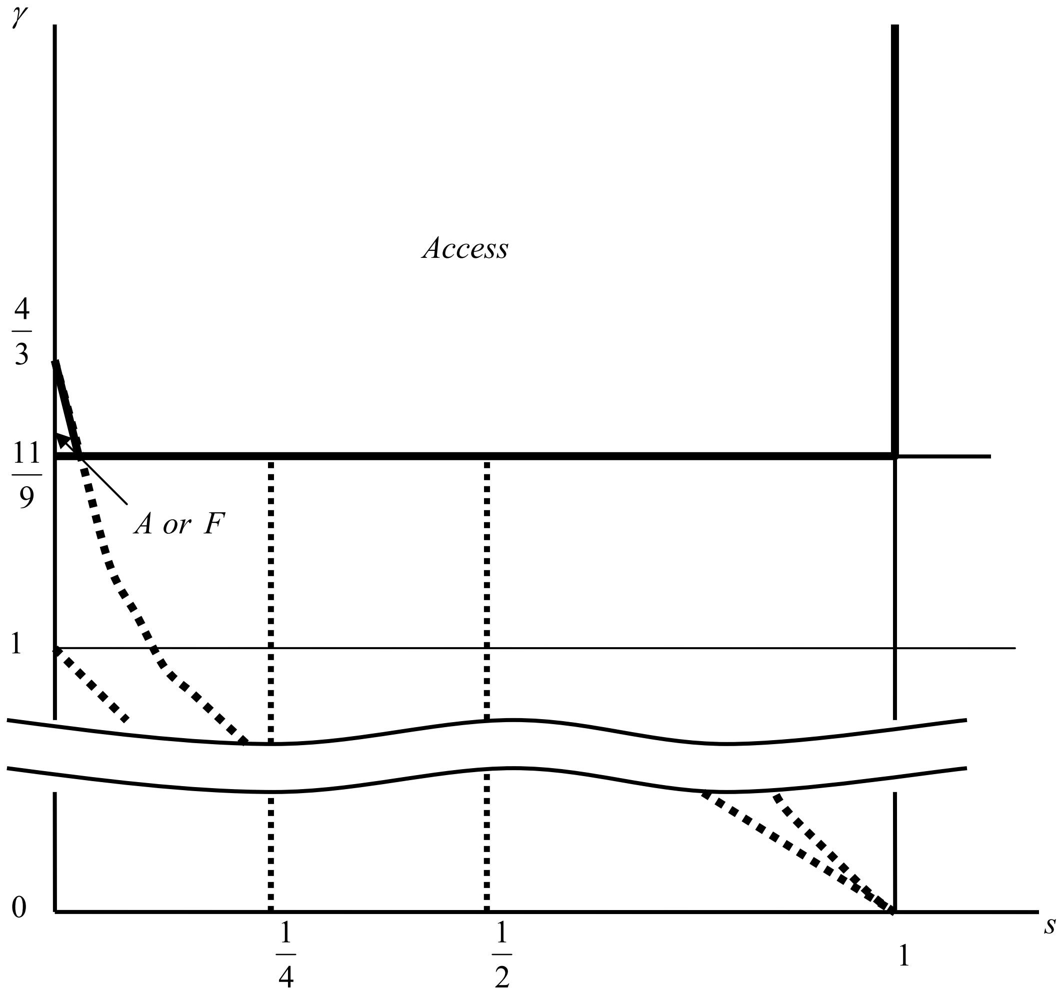


**Figure 2 Equilibrium Market Structure with Access**

Note: "*A or F*" represents "Access or Foreclosure".

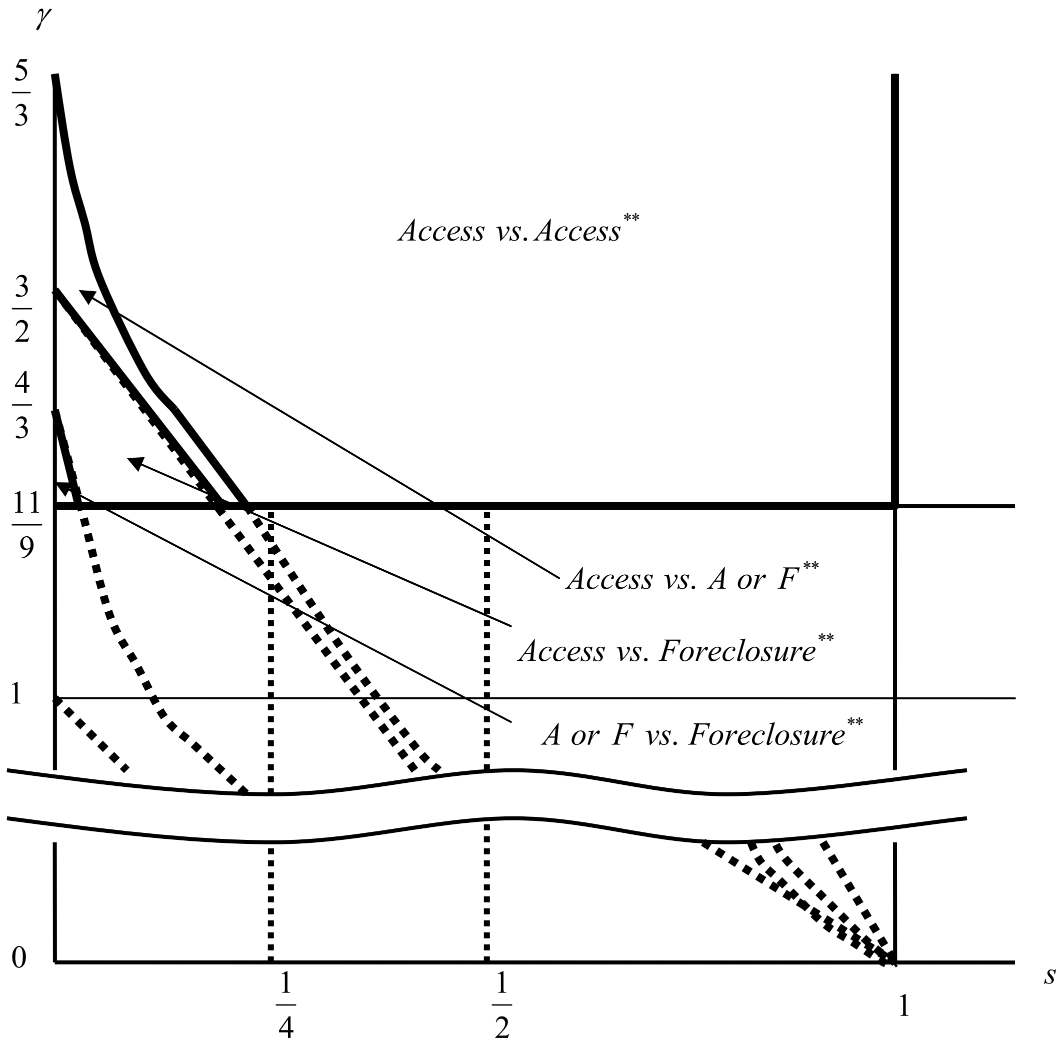


**Figure 3 Comparison of Second-Best and Equilibrium Market Structures with Access**

Notes:

(i) "*A or F*" represents "Access or Foreclosure".

(ii) Double asterisk (**) represents the second-best.

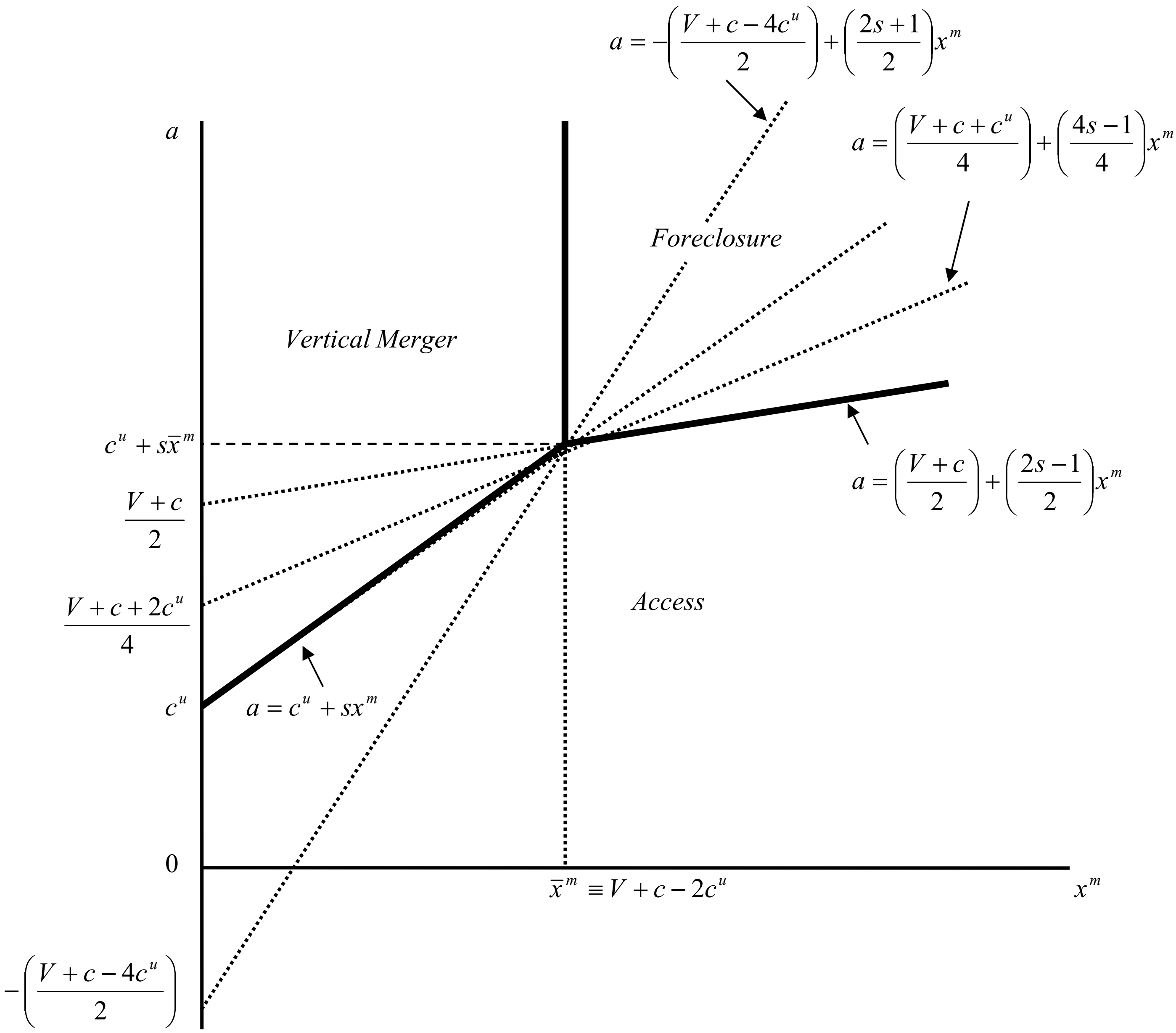


**Figure 4-1 Firm *e*'s Entry Decision with Access and Vertical Merger: The Case where $\frac{1}{2} < s \leq 1$**

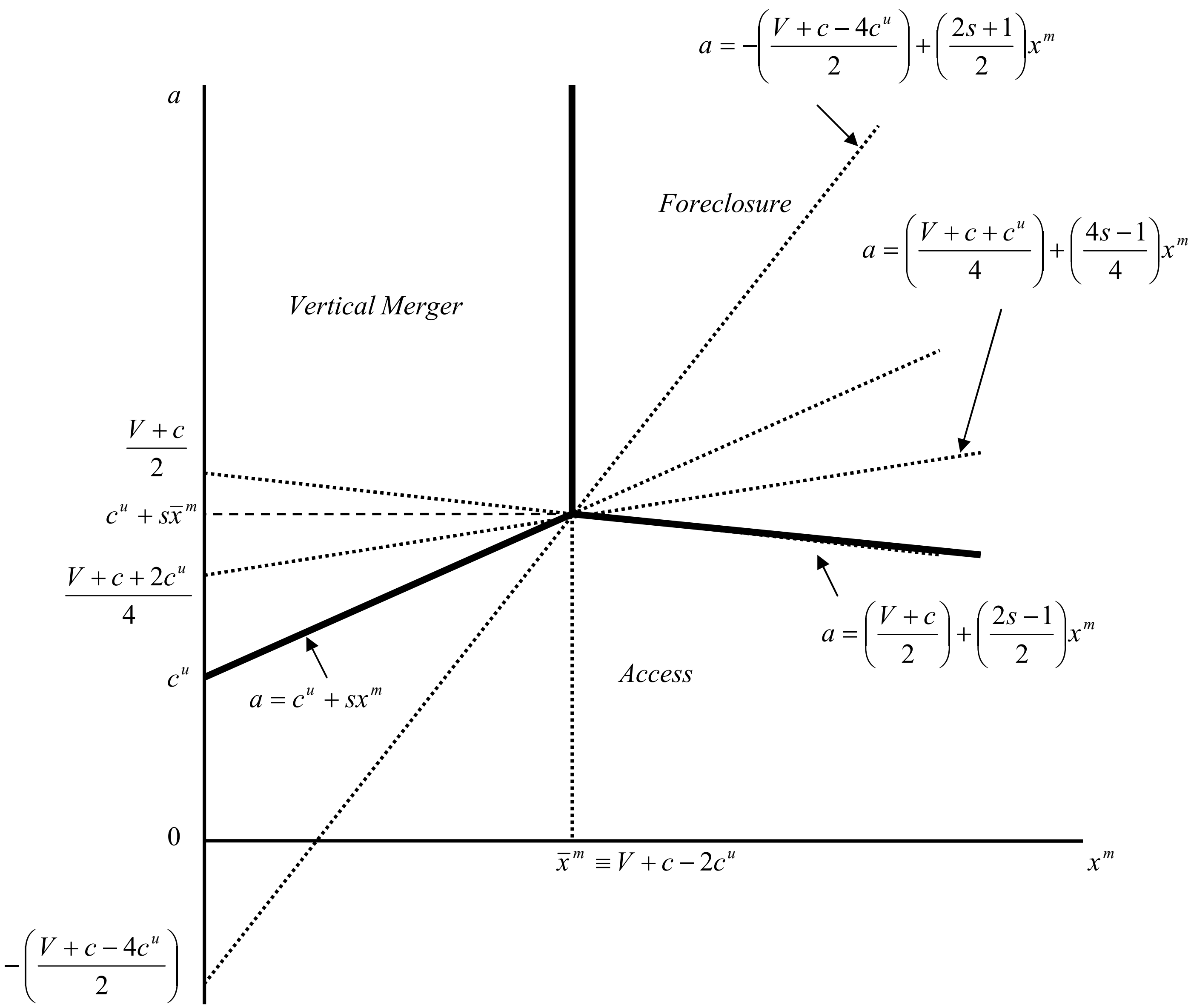


**Figure 4-2 Firm *e*'s Entry Decision with Access and Vertical Merger: The Case where $\frac{1}{4} < s \leq \frac{1}{2}$**

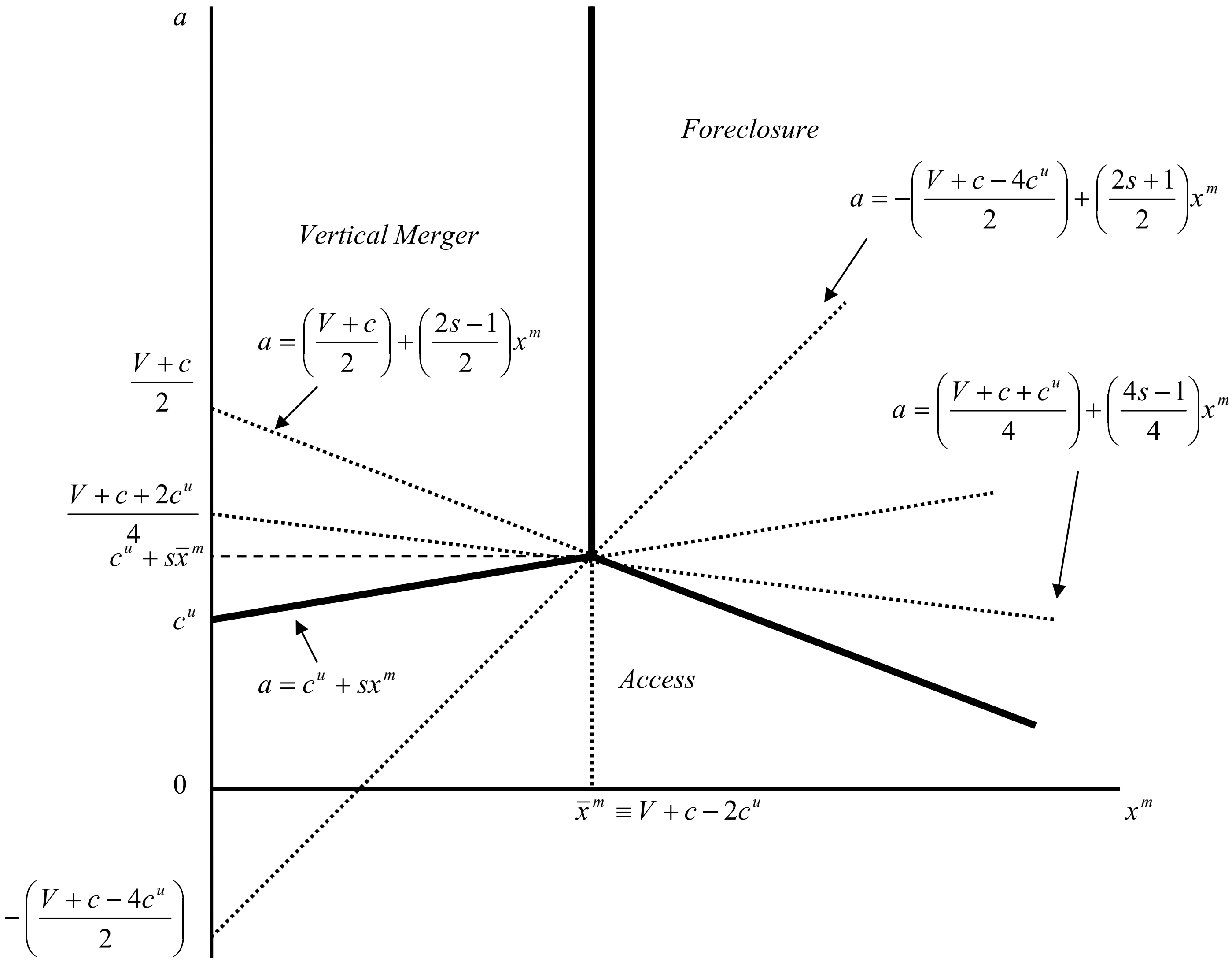


**Figure 4-3 Firm *e*'s Entry Decision with Access and Vertical Merger: The Case where $0 \le s \le \frac{1}{4}$**

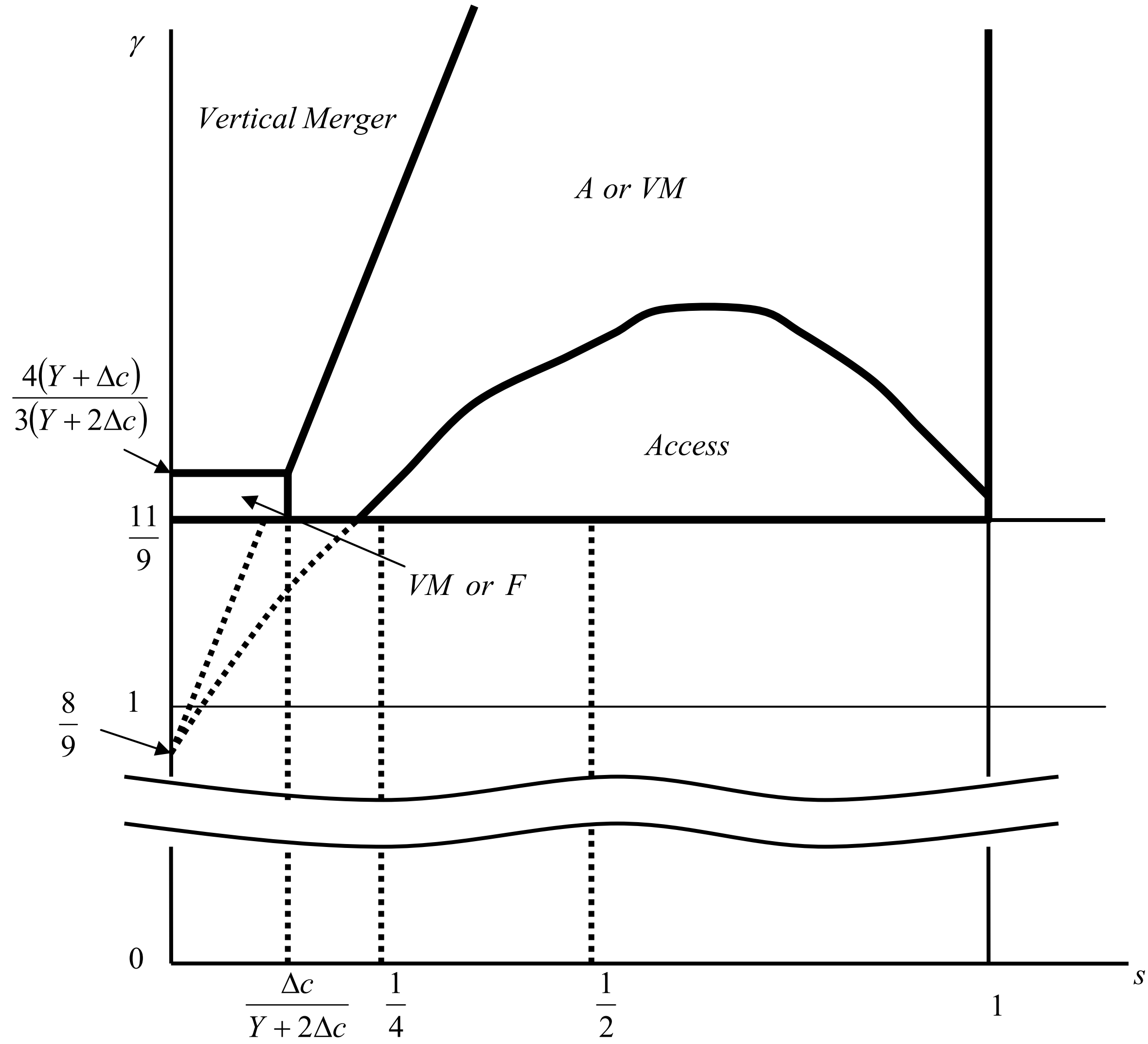


**Figure 5 Equilibrium Market Structure with Access and Vertical Merger: The Case where** $0 < \Delta c \leq \frac{1}{10} Y$

Notes:

(i) $Y \equiv V - c$, and $\Delta c \equiv c - c^u$.

(ii) "*A or VM*" represents "Access or Vertical Merger".

(iii) "*VM or F*" represents "Vertical Merger or Foreclosure".

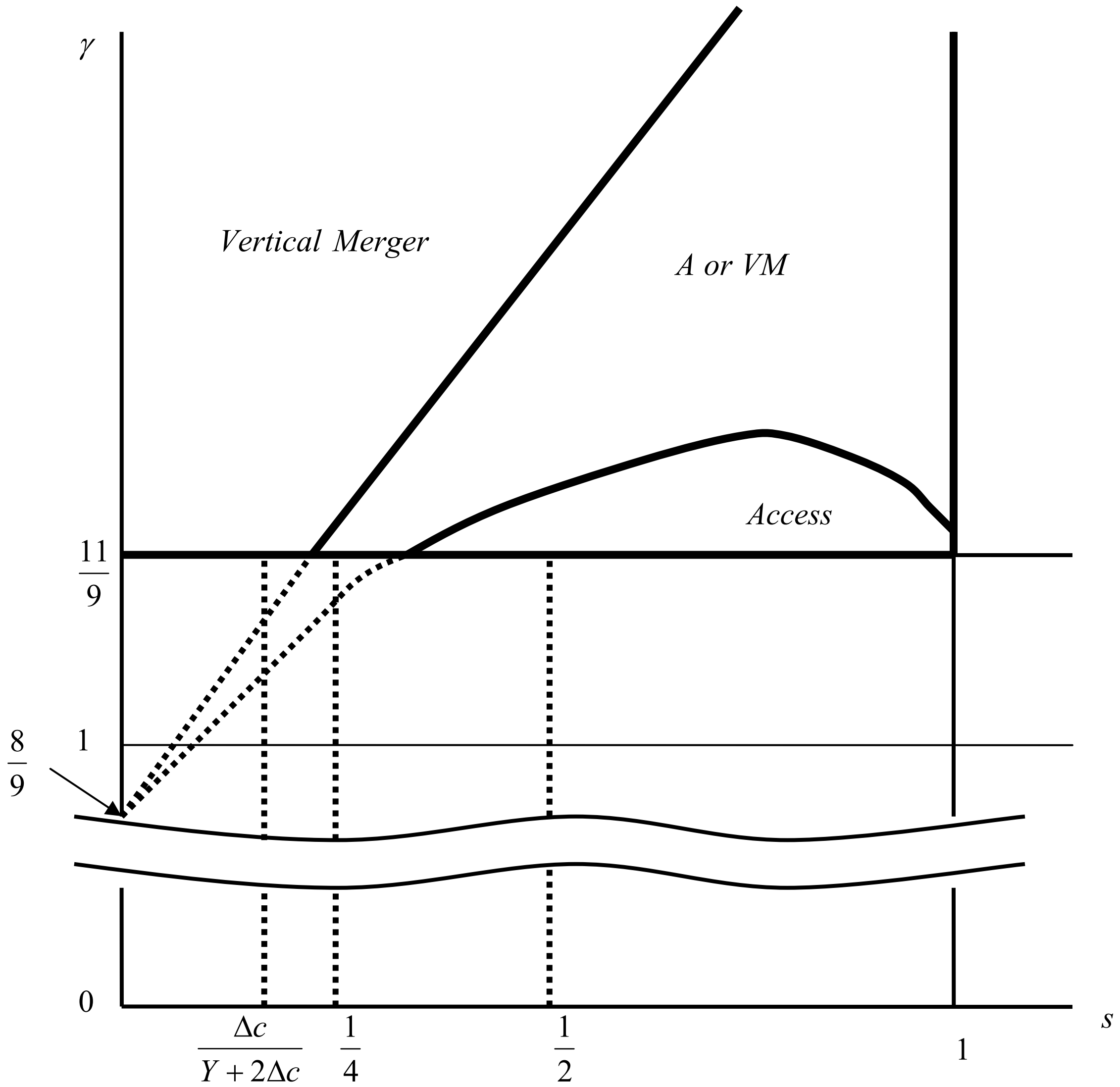


**Figure 6　Equilibrium Market Structure with Access and Vertical Merger:**
**The Case where** $\frac{1}{10}Y < \Delta c \leq \frac{4}{17}Y$

Notes:

(i) $Y \equiv V - c$, and $\Delta c \equiv c - c^u$.

(ii) "*A or VM*" represents "Access or Vertical Merger".

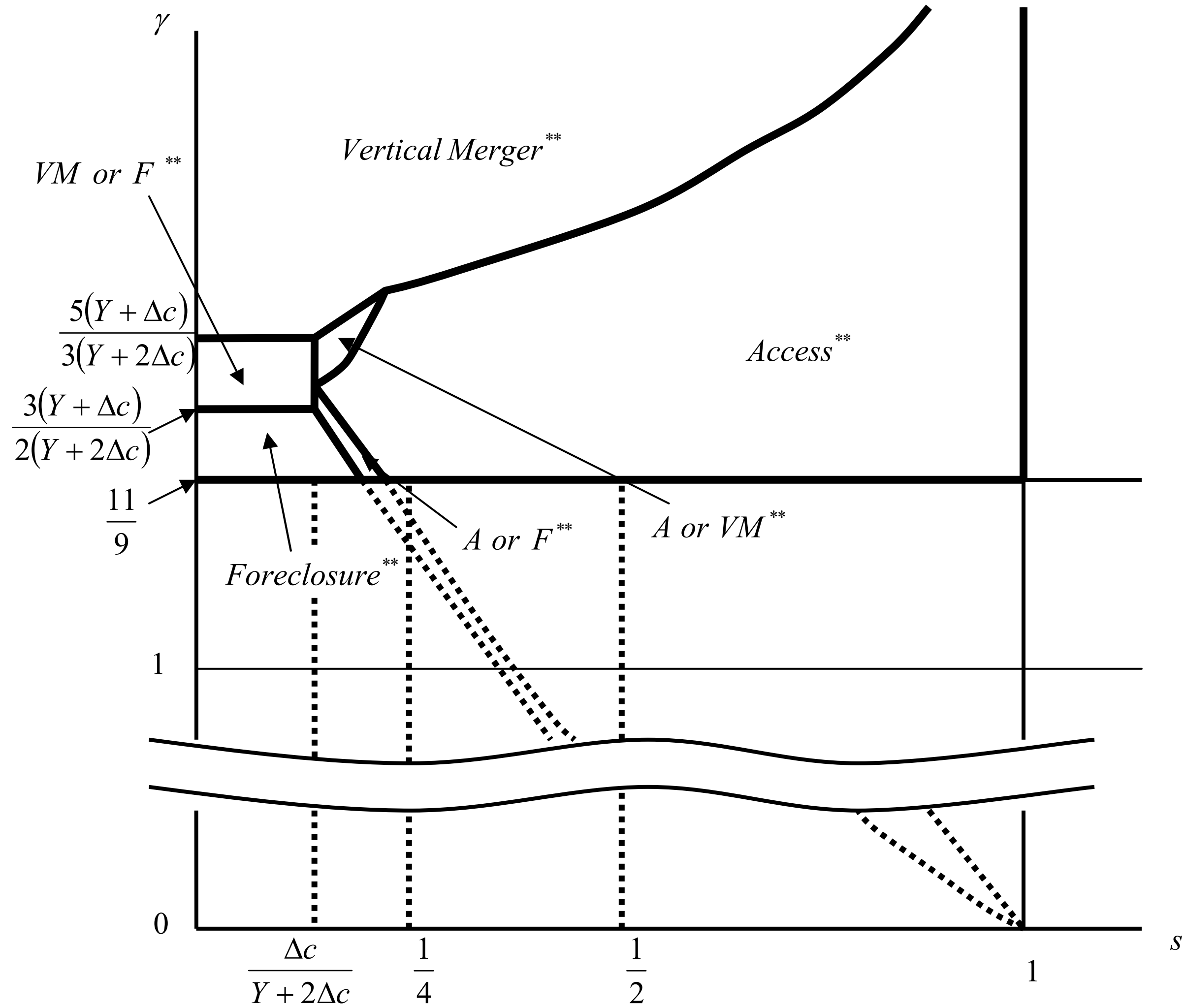


**Figure 7 Second-Best Market Structure with Access and Vertical Merger: The Case where $0 < \Delta c \leq \frac{4}{17}Y$**

Notes:

(i) $Y \equiv V - c$, and $\Delta c \equiv c - c^u$.

(ii) "*A or VM*" represents "Access or Vertical Merger".

(iii) "*A or F*" represents "Access or Foreclosure".

(iv) Double asterisk (**) represents the second best.