Overusing Bypass under Asymmetric Access Regulation: The Effect of Strategic Investment*

Keizo Mizuno†
School of Business Administration
Kwansei Gakuin University

Ichiro Yoshino
School of Economics
Nagoya University of Commerce and Business Administration

April 2013

Abstract

This paper examines the welfare implications of an incumbent's strategic infrastructure investment when bypass technology (i.e., a substitute for infrastructure) exists. We show that unexpectedly, an incumbent's strategic investment generates excess entry and encourages an entrant to overuse bypass technology from a welfare perspective. Moreover, a vertical merger between an entrant and an upstream firm that owns bypass technology can occur excessively in equilibrium.

Keywords: bypass, access charge, infrastructure investment, market structure.

JEL classification: L43, L51, L96.

---

*The authors would like to thank Carlo Cambini, Ikuo Ishibashi, Akira Ishii, Noriaki Matsushima, Kazuhiko Mikami, Dan Sasaki, and participants in seminars at Florence School of Regulation, Niigata University, Sapporo Gakuin University, Seinan Gakuin University, the University of Hyogo, and the University of Tokyo for their helpful comments on an earlier version of this paper. The authors gratefully acknowledge the financial support of the Japanese Ministry of Education, Culture, Sports, Science, and Technology (MEXT) (Grant No.19530226) and the Telecommunications Advancement Foundation (TAF).

†Corresponding to: Keizo Mizuno, School of Business Administration, Kwansei Gakuin University, 1-1-155 Uegahara, Nishinomiya, Hyogo, 662-8501, Japan; tel: +81-798-54-6181; fax: +81-798-51-0903; e-mail: kmizuno@kwansei.ac.jp

1 Introduction

Infrastructure penetration is a crucial factor in long-run economic welfare via changes in the market structure of network industries. However, the existence of *bypass technology* (i.e., a substitute for an incumbent's infrastructure) can make it difficult to evaluate investment in infrastructure penetration from a welfare perspective. This result occurs because the effects of bypass technology are ambiguous: such technology may cause a dual capacity problem or may function as a complement to the existing infrastructure that introduces new services.

The purpose of this paper is to examine the welfare implications of infrastructure investment when bypass technology exists. Toward this end, we focus on an entrant's incentive to use bypass technology when an incumbent can strategically invest in infrastructure under access price regulation.[1] In fact, vertical (access vs. bypass) and horizontal (competition vs. foreclosure) market structures are endogenously determined by the combined effects of the incumbent's strategic investment, the entrant's strategy, and access price regulation. We evaluate the equilibrium market structure from a welfare perspective.

This research relates to those of Sappington (2005), Laffont and Tirole (1990), and Armstrong (2001), who also examine the policy implications of bypass in network industries. Sappington (2005) provides a valuable benchmark for the role of a regulated access charge when bypass technology exists. According to Sappington (2005), given an access charge and the opportunity for entry followed by retail competition, an entrant's make-or-buy decision (i.e., the entrant's decision to access an incumbent's infrastructure or to use its own bypass technology) can always be efficient from a welfare perspective, irrespective of the level of the access charge. That is, if retail competition is anticipated, the access charge does not have any impact on productive efficiency.[2] However, Sappington's argument excludes the possibility that an incumbent may be able to strategically invest in infrastructure. In this paper, we show that an incumbent's strategic investment in infrastructure will affect the opportunities for entry under access regulation, distorting entrants' make-or-buy decision from a welfare perspective.

Laffont and Tirole (1990) and Armstrong (2001) also examine the case in which bypass technology is available. Laffont and Tirole (1990) focus on the issue of cream skimming

[1] The studies by Foros (2004) and Kotakorpi (2006) relate to our paper in that they focus on an incumbent's strategic opportunity to invest in infrastructure.

[2] Following Sappington (2005), Gayle and Weisman (2007), Mandy (2009), Bloch and Gautier (2012) examine the robustness of this result regarding access charges by generalizing the model of retail price competition. See the discussion in Section 3.

by assuming that there are multiple types of consumers; Armstrong (2001) examines the effectiveness of a universal fund policy when bypass technology is available. However, neither author addresses the investment issues.

In addition, our paper differs from the existing literature in that we introduce an upstream firm that provides bypass technology as an outside option for entrants. Earlier studies, such as Laffont and Tirole (1990), Armstrong (2001), and Sappington (2005), implicitly assume that entrants themselves own bypass technology. However, the Japanese Internet (or broadband) market gives a representative example of a bypass environment in which an upstream firm provides bypass technology to entrants. In Japan, at the end of June 2006, 64.6% of optical fiber cables were built and owned by the dominant companies, NTT East and West, but the usage charge for their cables was constrained by access price regulation. KDDI, the second largest telecom company in Japan, which had previously used NTT's optical fiber cables to provide internet services, finalized an agreement with PoweredCom for the use of its optical fiber cables as a bypass technology. The wholesale price for the use of this bypass technology is unregulated. Ultimately, KDDI and PoweredCom agreed to a vertical merger in October 2005. We also find examples of asymmetric access regulation with respect to bypass technology in the European Union (EU) broadband market in the form of *Significant Market Power* (SMP) assessments. In the Netherlands, for example, only the Digital Subscriber Line (DSL) operator must provide access at a regulated price, whereas cable networks have not been regulated.[3] Our strategy for modelling a bypass environment, as illustrated in these examples, allows us to examine how vertical market structure is endogenously determined through an entrant's incentives not only to use bypass technology but also to merge with an upstream firm that owns bypass technology.

Assuming that infrastructure investment has a demand-enhancing effect with spillovers to other firms through access to the infrastructure, we examine the welfare implications of an incumbent's strategic infrastructure investment given the option of bypass. We show that unexpectedly, an incumbent's strategic investment in infrastructure generates overuse of bypass technology by an entrant and excess entry into the market from a welfare perspective. Moreover, if a vertical merger between an entrant and an upstream firm that has bypass technology is allowed, such a merger may occur excessively in equilibrium.

We will demonstrate that the driving force generating these findings is an incumbent's strategic opportunity to invest in infrastructure. In our model, infrastructure investment contributes to social welfare by upgrading the quality of the final goods supplied not only

[3] See de Bijl and Peitz (2008). Additionally, Huigen and Cave (2008) describe the debate on access regulation and infrastructure investment in the EU broadband market.

by an incumbent but also by entrants through access spillover, whereas bypass technology provides a cost-reducing benefit to the entrant. Because an incumbent's incentive to invest in infrastructure is private (i.e., the incumbent does not necessarily care about the benefits that consumers gain through quality upgrades as a result of such investment), the level of investment exerted by the incumbent falls below the welfare-maximizing level. Thus, when an incumbent's production technology is less efficient than the bypass technology and there is a large degree of spillover through access, the incumbent's investment in infrastructure upgrades will be low, and the spillover benefits obtained by entrants will decrease. Hence, from a welfare perspective, the entrant has an incentive to overuse bypass. A vertical merger may occur excessively for the same reason.

On the other hand, when the degree of spillover is small and the investment cost is low, a large investment by a monopoly (foreclosure) can be efficient from a welfare perspective. However, in equilibrium, the difference in quality between the final goods of the incumbent and those of the entrant will be limited due to the incumbent's private incentive to underinvest. As a result of this small quality difference, an entrant has an incentive to excessively enter the retail market by using bypass technology that provides cost-reducing benefits. It is for this reason that excess entry occurs in equilibrium. Hence, we argue that policy should seek to provide appropriate incentives for incumbents or network owners to invest in infrastructure.

The remainder of this paper is structured as follows. Section 2 explains the model framework. Section 3 provides our analysis of the model. Section 4 examines the possibility of a vertical merger between an entrant and an upstream firm that has bypass technology. In Section 5, we discuss some policy implications of the analytical results. Section 6 concludes the paper.

2 The Model

Let us consider two vertically related sectors, an *upstream* sector and a *downstream* sector. The two sectors are required to supply goods to consumers in a market. We assume that there are three firms: firm m, firm e, and firm u. Firm m has infrastructure upstream and a production facility downstream (i.e., it is a vertically integrated firm), firm e only has a production facility downstream, and firm u only has bypass technology upstream. Firm m's infrastructure can provide an input that both it and firm e can use. Furthermore, firm m's investment in infrastructure upgrades has demand-enhancing effects because it improves the quality of the final goods sold in the downstream sector.

Like firm m's infrastructure, the bypass technology provided by firm u can produce an input for downstream production. Firm u's bypass technology may be superior to firm m's infrastructure in that it may be used to provide the input to firm e more inexpensively than firm m can. However, the bypass technology is assumed to be costly to invest in, and its capacity is assumed to be limited - it may only be used by one firm.[4]

To serve its consumers, firm e requires an input produced in the upstream sector. In our model, firm e is allowed to access firm m's infrastructure or to use firm u's bypass technology. That is, firm e can use one of two potential strategies for entering the market. The first is an *access strategy*: firm e can access firm m's infrastructure by paying an access charge a set by a regulator. The second is a *bypass strategy*: firm e can use firm u's bypass technology by paying the wholesale price w that has been set by firm u.[5] Using one of these two strategies, firm e can compete with firm m in the market. Moreover, in Section 4, we examine as a third alternative a *vertical merger* strategy in which firm u proposes a vertical merger with firm e.

Let us formulate the situation more specifically. Following Foros (2004), we employ a linear inverse demand system by supposing that heterogeneous consumers with unit demand for a service are uniformly distributed.[6] When firm e accesses firm m's infrastructure, the linear demand system is represented by

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

where p^i and q^i $(i = m,\ e)$ are, respectively, the price and quantity of the goods supplied by firm i, $V\ (> 0)$ is a constant, and x^m is the level of firm m's infrastructure investment. Here, $s\ (\in [0, 1])$ represents the (unit) degree of *spillover* to firm e that is generated by its use of firm m's infrastructure. In fact, when a dominant integrated incumbent upgrades its narrowband to broadband, a rival Internet provider can benefit from the investment by accessing the incumbent's network. For the sake of simplicity, we restrict our attention to the case in which the benefits generated for the rival are at most the same as the benefits obtained by the incumbent.[7]

Similarly, when firm e uses firm u's bypass technology, the linear demand system is represented by

[4] The assumption of limited capacity with regard to bypass technology is standard in the access pricing literature. See, for example, Armstrong (2001).

[5] In this paper, we assume that firm u unilaterally sets the wholesale price w. Although other formulations for setting w alter the distribution of profits between firms e and u, they do not affect our principal findings.

[6] See Foros (2004) for the derivation of this type of linear inverse demand system for a broadband Internet demand.

[7] As will be shown in the analysis of Sections 3 and 4, the qualitative result for the case in which $s > 1$ is the same as that of the case in which $s = 1$.

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

Note that when firm e uses firm u's bypass technology, there is no spillover to firm e's goods from firm m's investment, because firm e does not access firm m's infrastructure. However, it may be beneficial for firm e to use firm u's bypass technology, because this technology provides a cost-reducing benefit to firm e.

One unit of input (i.e., the output produced upstream) produces one unit of output downstream. For the sake of simplicity, we assume that the (constant) marginal access cost c that firm m incurs from firm e is the same as its marginal production cost upstream. We also assume that the production cost downstream for each firm is zero. Firm u's (constant) marginal production cost is denoted by c^u. As noted above, the production cost of the bypass technology can be more or less than that of the incumbent's production technology: $c \lesseqgtr c^u$.

Infrastructure upgrades can be achieved through some investment cost incurred by firm m, and such investments have demand-enhancing effects. We suppose that the investment cost is represented by a quadratic function, $I(x^m) = \frac{1}{2}\gamma (x^m)^2$, with the investment cost parameter $\gamma (> 0)$.

An access charge a is the only policy instrument that is available to the regulator. We assume Cournot competition between firm m and firm e in the downstream sector.[8] Firm m's profit is then given by

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

if firm e accesses firm m's infrastructure. Similarly, if firm e uses firm u's bypass technology, firm m's profit is

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

Firm e's profit is

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

if firm e accesses firm m's infrastructure.

When firm e uses firm u's bypass technology by paying a wholesale price w that is set by firm u, firm e's profit is

[8] In the broadband Internet market, the assumption of Cournot competition is justified by the fact that Internet service providers require regional and global backing (i.e., they face capacity constraints). See Faulhaber and Hogendorn (2000) and Foros (2004) for a detailed discussion of this point.

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

and firm u's profit is[9]

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

The timing of the game is illustrated in Figure 1. Because infrastructure investment is irreversible and a regulator has a limited ability to commit to an access charge, it is natural to assume that firm m invests in infrastructure before the regulator sets the access charge. Hence, in the first stage, firm m determines the level of investment x^m. In the second stage, given x^m, the regulator sets the access charge a. In the third stage, firm u sets the wholesale price w, given x^m and a. Then, in the fourth stage, given x^m, a, and w, firm e decides whether to enter the market and, if so, what its entry strategy will be – entry with access or entry with bypass. In the fifth stage, firms m and e compete downstream in Cournot fashion. If firm e does not enter the market, firm m sets its monopoly price and quantity.

In Section 4, we allow firm u to propose a vertical merger to firm e, in addition to the option of the bypass strategy. In the case of a vertical merger, firm e can use the bypass technology with an upstream production cost c^u. Thus, a vertical merger can be interpreted as a case in which the entrant itself owns the bypass technology, as in Sappington (2005), Laffont and Tirole (1990), and Armstrong (2001).

[Insert Figure 1 here]

3 Equilibria with Access, Bypass, and Foreclosure

For the sake of analytical tractability, we make the following assumptions.

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

Assumption (i) states that the demand is sufficiently large relative to the cost difference between firm m and firm e.[10] Assumption (ii) is made for practical reasons. It is rare in the policy arena for access charges to be set below marginal access cost.[11] Assumption (iii) guarantees interior solutions for profit maximization by firm m and for welfare-maximizing investment in the analysis that follows.

[9] For the sake of simplicity, firm u's reservation profit is assumed to be zero.

[10] Recall that we allow for $\Delta c \equiv c - c^u > 0$.

[11] Foros (2004) also confines the analysis to the case in which the access charge is not lower than the access cost.

3.1 Firm e's entry strategy and the wholesale price set by firm u

In the fifth stage, given the market structure, the equilibrium quantities and profits are determined. These are summarized in Table 1. There are three alternative market structures; an *access duopoly*, a *bypass duopoly*, and *foreclosure* (monopoly). Note that the bypass duopoly will vary in terms of whether the access price regulation is binding when firm u determines w.

[Insert Table 1 here]

In the fourth stage, given x^m, a, and w, firm e makes its entry decision, choosing one of three alternatives; entry with access, entry with bypass, or no entry.

Firm e chooses entry with access if either $\pi^{e*A} \geq \pi^{e*B} \geq 0$ or $\pi^{e*A} \geq 0 \geq \pi^{e*B}$. Hence, irrespective of which condition holds, the followings must hold:

$$\pi^{e*A} \geq 0, \tag{1}$$
$$\pi^{e*A} \geq \pi^{e*B}. \tag{2}$$

From (1), we have

$$a \leq \left(\frac{V+c}{2}\right) + \left(\frac{2s-1}{2}\right) x^m. \tag{3}$$

From (2), we have

$$a \leq w + sx^m \text{ or } w \geq a - sx^m \equiv \overline{w}. \tag{4}$$

Note that firm e can choose entry with access despite the fact that the access charge exceeds the wholesale price set by firm u (i.e., $a > w$) as long as (4) is satisfied. This occurs because entry with access has spillover benefits for firm e, if firm m upgrades its infrastructure. Therefore, $\overline{w} \equiv a - sx^m$ can be interpreted as *the effective access charge.*

Similarly, we verify that firm e chooses entry with bypass if the following conditions hold:

$$\pi^{e*B} \geq 0, \tag{5}$$
$$\pi^{e*B} \geq \pi^{e*A}. \tag{6}$$

From (5), we have

$$x^m \leq V + c - 2w. \tag{7}$$

From (6), we have

$$a \geq w + sx^m \text{ or } w \leq \overline{w}, \tag{8}$$

which is the opposite of (4).

Finally, firm e chooses no entry if $\pi^{e*A} < 0$ and $\pi^{e*B} < 0$. That is, firm e chooses no entry if the following conditions hold:

$$\begin{aligned} a &> \left(\frac{V+c}{2}\right) + \left(\frac{2s-1}{2}\right) x^m, \text{ and} \\ x^m &> V + c - 2w. \end{aligned}$$

Anticipating firm e's entry behavior in the fourth stage, firm u proposes the wholesale price w given x^m and a. Firm u's problem is thus as follows:

$$\underset{w}{Max}\ \pi^{u*B} = (w - c^u)\, q^{e*B}(w) \quad s.t.\ (7) \text{ and } (8), \tag{9}$$

where $q^{e*B}(w) = (V - x^m - 2w + c)/3$. If neither constraint in problem (9) is not binding, firm u's profit-maximizing wholesale price w^* is

$$w^* = \frac{1}{4}\left(V - x^m + c + 2c^u\right). \tag{10}$$

Hence, we have the following two cases[12]: (i) $w^* < \overline{w}$ and (ii) $w^* \geq \overline{w}$.

(i) When $w^* < \overline{w}$, firm u can propose w^*. Rewriting $w^* < \overline{w}$, we obtain

$$a > \left(\frac{V+c+2c^u}{4}\right) + \left(\frac{4s-1}{4}\right) x^m. \tag{11}$$

That is, if (11) holds, firm u proposes w^*. Then firm e can accept w^* as long as $q^{e*B}(w^*) \geq 0$; that is,

$$x^m \leq V + c - 2c^u \equiv \overline{x}^m. \tag{12}$$

(ii) When $w^* \geq \overline{w}$, i.e., $a \leq ((V + c + 2c^u)/4) + ((4s-1)/4)\, x^m$, firm u proposes $\overline{w}$. Because firm u proposes $\overline{w}$ only if it obtains a nonnegative profit by doing so, the condition that $\pi^{u*B}(\overline{w}) \geq 0$ is required in this case. That is,

$$a \geq c^u + sx^m \tag{13}$$

[Insert Figure 2 here.]

[12] We can ignore the case in which (7) is binding as long as V is sufficiently large.

Figure 2 summarizes firm e's choice of entry strategy and firm u's behavior in setting the wholesale price w when $1/2 < s \leq 1$. In this figure, we see the following four critical lines:

$$a = \left(\frac{V+c}{2}\right) + \left(\frac{2s-1}{2}\right) x^m \tag{14}$$

$$a = \left(\frac{V+c+2c^u}{4}\right) + \left(\frac{4s-1}{4}\right) x^m \tag{15}$$

$$a = c^u + sx^m \tag{16}$$

$$x^m = \overline{x}^m \left(\equiv V + c - 2c^u\right) \tag{17}$$

Equation (14) states the threshold condition for firm e's decision to enter with access. Below (above) this line, firm e enters (does not enter) the market by accessing firm m's infrastructure. That is, when the 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 that firm e incurs by accessing firm m's infrastructure. Equation (15) represents the threshold at which the access price regulation is binding for firm u's choice of the profit-maximizing wholesale price w^*, given by (10) (i.e., $w^* \gtreqless \overline{w}$). Equation (16) represents the threshold at which firm u has an incentive to offer the binding wholesale price, which is equivalent to the effective access charge $\overline{w}$ (i.e., whether firm u can obtain a positive profit, or $\overline{w} \gtreqless c^u$.) The vertical line (17) represents the threshold at which firm e enters the market by accepting the wholesale price w^* offered by firm u given that the access price regulation is nonbinding. In the lower part of Figure 2, in the region enclosed by (14) and (16), firm e adopts the access strategy. In the upper-left part of the figure, in the region enclosed by (16) and (17), firm e adopts the bypass strategy. In the region enclosed by (15) and (16), firm e can use the bypass technology not by paying w^* but by paying the effective access charge $\overline{w}$ (i.e., this region represents "bypass with access price regulation (APR) binding").[13] Finally, in the upper-right portion of the figure, in the region enclosed by (14) and (17), firm e does not enter the market (the "foreclosure" region).

We mention two remarkable findings that are visible in Figure 2. First, the existence of the bypass technology increases the probability that firm e enters the market. Indeed, it is easy to see that if there is no bypass technology, only the threshold (14) will appear in Figure 2, and the foreclosure region will be larger than in our analysis. In this sense,

[13] Strictly speaking, the wholesale price offered by firm u is $\overline{w} - \epsilon$ (i.e., a fraction less than $\overline{w}$). For the sake of analytical simplicity, we ignore ϵ and assume that firm e, when indifferent, prefers the bypass strategy to the access strategy.

the existence of bypass contributes to allocative efficiency in network industries.

Second, the access region is smaller in Figure 2 than it is in the case in which firm e has only the access strategy available to it. In particular, in the region enclosed by (14) and (16), and where $x^m \leq \overline{x}^m$, firm e uses firm u's bypass technology instead of accessing firm m's infrastructure. Note that although the use of the bypass technology involves the double marginalization problem (i.e., $w > c^u$), it may increase productive efficiency as long as $c^u < c$.

Figure 2 only illustrates the case in which $1/2 < s \leq 1$. The qualitative features of firm e's entry decision do not change, even when $0 \leq s \leq 1/2$. However, we should note that when firm m's strategic opportunity for infrastructure investment is introduced, firm e's choice of an entry strategy crucially depends on the level of s.[14]

In the second stage, the regulator sets the access charge a. It is easy to verify that as long as V is sufficiently large, the regulator will wish to adopt a cost-based access charge, i.e., $a^* = c$, irrespective of the level of x^m because imperfect competition will prevail in the retail market.[15]

Before analyzing firm m's strategic incentives to invest in infrastructure upgrades in the first stage, we examine the welfare implications of firm e's choice of entry strategy under asymmetric access regulation, when firm u offers w and when the level of investment x^m is taken as given. In fact, we can show that when firm m has no opportunity for strategic infrastructure investment, asymmetric access regulation definitely induces firm e to choose production-efficient technology as long as $a^* = c$. Because this is an important benchmark result, we present it as a proposition.

Proposition 1 *Suppose that an incumbent firm has no opportunity for strategic infrastructure investment. In such a case, asymmetric access regulation encourages an entrant to select technology that is production efficient from a social perspective as long as the access charge is set to the access cost.*

Proof. See Appendix A. ■

The issue of production-efficient technology selection by entrants has been discussed in several studies, including Sappington (2005) and Gayle and Weisman (2007).[16] Our

[14] The corresponding figures for the case in which $0 \leq s \leq 1/2$ are available upon request.

[15] When V is not sufficiently large but still generates a positive profit for firm m, the regulator has an incentive to deviate from a cost-based access charge (i.e., to increase the access charge above the level of access cost) given that an incumbent can invest strategically. See Mizuno and Yoshino (2012) for an analysis of this scenario.

[16] Mandy (2009) identifies a set of access prices that induce productive efficiency when an entrant has bypass technology. Bloch and Gautier (2012) show that allowing an incumbent to set the access charge revives productive efficiency under general conditions for the demand function.

model framework is different in two respects. First, an entrant can enjoy the demand-enhancing effects generated by infrastructure upgrades when it accesses an incumbent's infrastructure. This advantage should be considered a benefit of access when we examine productive efficiency in the choice between access and bypass. Second, in the existing literature, the entrant has been implicitly assumed to possess its own bypass, whereas in this paper, an upstream firm owns the bypass technology and has market power over input provision. This implies that the upstream firm can set a wholesale price above the cost of providing the bypass technology. Hence, it is possible that entrants will not choose bypass even when bypass involves the use of more production-efficient technology compared to access. Bearing these two points in mind, we show that given the level of an incumbent's infrastructure investment, the entrant always chooses technology that is production efficient from a welfare perspective as long as the access charge is set equal to the access cost under asymmetric access regulation.

There are two factors that induce this production efficiency result. First, there is implicit competition between firm u and the regulator in the upstream sector. In fact, in offering a wholesale price w to firm e, firm u must set a level of w that is acceptable to firm e. Hence, the level of w that is offered by firm u is subject to the upper constraint on the effective access charge, $\overline{w} \equiv a - sx^m$. Second, anticipating this implicit competition with firm u, the regulator sets $a^* = c$ to maximize social welfare. Then, firm e chooses access (bypass, respectively) if and only if $c - sx^m \leq c^u$ or $c \leq c^u + sx^m$ ($c - sx^m > c^u$ or $c > c^u + sx^m$), which is the production-efficiency condition in our model.

The result of Proposition 1 is consistent with the results in the existing literature. Unlike Sappington (2005), we assume Cournot competition in the downstream market. According to Gayle and Weisman (2007), the difference between the access charge and the input price associated with bypass is significant under Cournot competition. In this scenario, asymmetric access regulation with $a^* = c$ induces firm e to choose the technology that is socially efficient.

In the next subsection, we analyze firm m's strategic incentive to invest in infrastructure upgrades in the first stage. We then show that firm m's strategic infrastructure investment unexpectedly causes firm e to overuse bypass from a welfare perspective. That is, an entrant's technology choice is *not* productively efficient under asymmetric access regulation when an incumbent has a strategic opportunity to invest in infrastructure upgrades.

3.2 Firm m's strategic investment and the equilibrium market structure

Anticipating $a^* = c$ and firm e's choice of an entry strategy with the wholesale price w set by firm u, in the first stage, firm m invests in infrastructure with the aim of maximizing its profits. The procedure that is used to derive firm m's profit-maximizing investment requires the cases to be classified according to the degree of s and the magnitude of the cost difference, $\Delta c \equiv c - c^u$. Given $a^* = c$, the classification of the equilibrium market structure according to the two parameters is as follows. (In the classification, we define $Y \equiv V - c$.) See Appendix B for an outline of the derivation of firm m's profit-maximizing investment in each of the cases below.

[Insert Figures 3 here.]

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

In this case, $a^* = c < c^u$. As observed in Figure 2, when $a^* = c < c^u$, firm e adopts the access strategy for entry. Hence, an access duopoly is realized in equilibrium.

Case 2: When $1/2 \leq s \leq 1$ *and* $0 < \Delta c \leq 4Y/\left(11 + \sqrt{33}\right)$.

Restricting our attention to the vertical axis of Figure 2, we see that the access or bypass strategy may be chosen by firm e because $\Delta c > 0$, i.e., $a^* = c > c^u$. In fact, either an access duopoly or a bypass duopoly may exist in equilibrium, depending on the level of the investment cost parameter γ. See the region of Figure 3 where $s \in [1/2,\ 1)$. The threshold line that separates the region associated with access duopoly from that of bypass duopoly is represented by (23) in Appendix B. The condition that $0 < \Delta c \leq 4Y/\left(11 + \sqrt{33}\right)$ represents the case in which (23) intersects the line $\gamma = 11/9$ at least once. In this case, when γ is small and s is large, an access duopoly occurs in equilibrium. Otherwise, a bypass duopoly occurs in equilibrium.

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

Because $\Delta c \leq 0$, firm e chooses the access strategy (except when x^m is sufficiently large, which is irrelevant from firm m's point of view). Thus an access duopoly is realized in equilibrium.

Case 4: When $1/4 \leq s < 1/2$ *and* $0 < \Delta c \leq 4Y/\left(11 + \sqrt{33}\right)$.

According to the assumption that $Y > 2\Delta c$, firm e selects not only the access strategy but also the bypass strategy, depending on the level of x^m. Then, given firm m's investment decision, the equilibrium market structure is as given in Figure 3 in the region where $s \in [1/4,\ 1/2)$. In this case, when γ is small (large), an access duopoly (a bypass duopoly) is realized in equilibrium.

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

Because $\Delta c \leq 0$, firm e chooses the access strategy for entry (except when x^m is sufficiently large). Then, given firm m's investment decision, an access duopoly occurs in equilibrium, whereas foreclosure is also possible when both γ and s are small.

Case 6: When $0 \leq s \leq 1/4$ *and* $0 < \Delta c \leq 4Y/\left(11+\sqrt{33}\right)$.

Two cases must be analyzed separately, depending on the level of $c\,(= a^*)$.[17] When $c\,(= a^{**}) < c^u + s\overline{x}^m$, i.e., $\Delta c/\left(Y + 2\Delta c\right) < s \leq 1/4$,[18] firm e's entry strategy changes from bypass to access and then to no entry (foreclosure) as x^m increases. However, when $c^u + s\overline{x}^m \leq c < \left(V + c + 2c^u\right)/4$, i.e., $0 \leq s \leq \Delta c/\left(Y + 2\Delta c\right)$, the strategy changes from bypass to foreclosure. Through firm m's investment behavior, when $\Delta c/\left(Y + 2\Delta c\right) < s \leq 1/4$, a bypass duopoly prevails unless s is close to $1/4$ and γ is close to $11/9$.[19] When $0 \leq s \leq \Delta c/\left(Y + 2\Delta c\right)$, the equilibrium market structure becomes a bypass duopoly.

Case 7: When $4Y/\left(11+\sqrt{33}\right) < \Delta c < (1/2)\,Y$.

In this case, (23) (i.e., the threshold line that separates the region associated with access duopoly from that of bypass duopoly) in Appendix B does not intersect the line $\gamma = 11/9$. Therefore, for any $s \in [0,\ 1]$, a bypass duopoly occurs in equilibrium.

For Cases 1 to 7 above, the equilibrium market structure is summarized as follows:

(i) When $\Delta c \leq 0$, an access duopoly occurs in equilibrium except when s and γ are small. When s and γ are small, a monopoly by firm m (i.e., foreclosure) is also possible.

(ii) When $0 < \Delta c \leq 4Y/\left(11+\sqrt{33}\right)$, two types of duopolies are possible. When s is large and γ is small, an access duopoly occurs in equilibrium. Otherwise, a bypass duopoly occurs.

(iii) When $4Y/\left(11+\sqrt{33}\right) < \Delta c < (1/2)\,Y$, a bypass duopoly occurs in equilibrium.

We make three observations. First, when $c - sx^m \left(= a^* - sx^m\right) \leq (>)\, c^u$, i.e., $x^m > (\leq)\, \overline{x}^{mB} \equiv \Delta c/s$, firm e adopts the access (bypass) strategy, as stated in Proposition 1. That is, given firm m's infrastructure investment x^m, firm e's technology choice will be production efficient from a welfare perspective. However, because x^m is endogenously determined by firm m in our model, whether the equilibrium market structure that results from firm m's strategic investment behavior is socially desirable is unclear. Hence, we must investigate this point below.

[17] Readers can validate this assertion by drawing a figure that is similar to Figure 2 for the case in which $0 \leq s \leq 1/4$.

[18] Note that $\Delta c/\left(Y + 2\Delta c\right) < 1/4$ as long as $Y > 2\Delta c$.

[19] In particular, for $\Delta c \in \left[(7/39)\,Y,\ 4Y/\left(11+\sqrt{33}\right)\right]$, an access duopoly occurs when s is close to $1/4$ and γ is close to $11/9$. For $\Delta c \in [0,\ (7/39)\,Y]$, a bypass duopoly occurs in that range.

Second, when $\Delta c > 0$ and Δc is large (i.e., when $4Y/\left(11+\sqrt{33}\right) < \Delta c < (1/2)\,Y$), only a bypass duopoly occurs in equilibrium. When firm u's bypass technology is significantly more efficient than firm m's production technology, firm e's incentive to use the bypass technology is substantial.[20] Then, given a level of the spillover effect, a large amount of investment is required for firm m to induce firm e to access its infrastructure. However, it is not beneficial for firm m to make such a large amount of investment. Therefore, the main driving force that generates a bypass duopoly in equilibrium is firm m's weak incentive to invest in infrastructure. Again, we should note that a bypass duopoly only occurs when $c - sx^m\,(= a^* - sx^m) > c^u$.

Third, foreclosure does not occur in equilibrium because firm m does not need to foreclose firm e when it can take advantage of firm u's bargaining power in setting the wholesale price w. When s is small (i.e., when $c^u + s\overline{x}^m \leq c$ or $0 \leq s \leq \Delta c/\left(Y + 2\Delta c\right)$), firm e has an incentive to use firm u's bypass technology by paying w, even if w is high. Then, by implementing $x^{m*B}\,(= 7\left(5Y - 2\Delta c\right)/\left(72\gamma - 49\right))$,[21] firm m can cause the wholesale price set by firm u, i.e., w^*, to be sufficiently high that $w^* > c$.[22] Firm m can then enhance its profits in the retail market through a decrease in firm e's production that is caused by the high value of w^*. Therefore, firm m does not need to invest more than $\overline{x}^m$ in seeking to exclude firm e from the market, and foreclosure does not occur in equilibrium.

We now evaluate the equilibrium market structure from a welfare perspective. In doing so, we define the second-best optimum as an environment in which the regulator can control both x^m and a to maximize social welfare. To characterize the second-best optimum, we must derive the welfare-maximizing investment levels for each market structure and compare the levels of social welfare that result.[23] In fact, the welfare-maximizing investment problem in an access duopoly is represented by $\max_{x^m} W^A$, where

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

The welfare-maximizing investment problem in a bypass duopoly is represented by $\max_{x^m} W^B$, where

$$W^B = \left(V + x^m\right)q^{m*B} + Vq^{e*B} - \frac{1}{2}\left(q^{m*B} + q^{e*B}\right)^2 - cq^{m*B} - c^u q^{e*B} - \frac{1}{2}\gamma\left(x^m\right)^2.$$

[20] The threshold $\overline{x}^{mB} \equiv \Delta c/s$ becomes large, as Appendix B demonstrates.

[21] $x^{m*B} < \overline{x}^m$ holds as long as $\gamma > 11/9$.

[22] See equation (10).

[23] Note that, whatever market structure is realized, the welfare-maximizing access charge is $a^{**} = c$ as long as V is sufficiently large.

Finally, the welfare-maximizing investment problem in a monopoly is represented by $\max_{x^m} W^F$, where

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

We then compare the maximized social welfare in the three market structures. See Appendix C for the derivation of the second-best market structure.

Figure 4 depicts the second-best market structure when $0 < \Delta c \leq 5Y/17$.[24]

[Insert Figure 4 here.]

In comparing the equilibrium market structure with the second-best market structure, we obtain the following proposition:

Proposition 2 *Suppose that an incumbent's production technology is less efficient than the bypass technology of an upstream firm (i.e., $\Delta c \equiv c - c^u > 0$). Then, when the degree of spillover is large, the bypass technology is overused (or access to infrastructure is insufficient) from a welfare perspective.*

Proposition 2 states that in equilibrium, the vertical market structure is distorted to favor a bypass duopoly when firm m's production technology is inefficient and there is a large degree of spillover. Overuse of bypass can then be explained by firm m's incentive to underinvest in infrastructure, as shown below.

Recall that in our model, the use of bypass has both a benefit and a cost from a welfare perspective: the benefit is the availability of more efficient production technology (i.e., $\Delta c \equiv c - c^u > 0$), whereas the cost is the loss of the spillover that would have been generated by firm m's investment in infrastructure upgrades. When the degree of spillover is large, the cost of the use of bypass outweighs the benefits; thus, an access duopoly with a regulated access charge, $a^* = c$, and a sufficient level of infrastructure investment is preferable from a welfare perspective. However, when firm m's production technology is inefficient, its profit from retail market competition is small. Because profit is the only driving force governing firm m's investment decisions, firm m's investment incentives are weak. Then, when the degree of spillover is large, an incumbent's underinvestment reduces the spillover benefits that an entrant obtains. Therefore, the entrant has an incentive to use bypass more than is advisable from a welfare perspective.

[24] When $5Y/17 < \Delta c \leq Y/2$, the qualitative features of the second-best market structure are the same as in Figure 4 except that the (pure) foreclosure region in Figure 4 disappears.

Note that in our model, an incumbent's underinvestment generates two types of costs through the overuse of bypass. The first is the loss of spillover that is generated by access; the second is double marginalization. In the next section, we introduce the potential for vertical mergers so that we can examine how these distortions can be altered.

The next proposition concerns the distortions that occurs in a horizontal market structure.

Proposition 3 *Suppose that an incumbent's production technology is less efficient than the bypass technology of an upstream firm (i.e.,* $\Delta c \equiv c - c^u > 0$*). Then, when the degree of spillover is small and the incumbent's investment cost is low, there is excess entry with bypass in equilibrium.*

As stated above, firm e adopts the bypass strategy when the effective access charge exceeds firm u's production costs (i.e., $\overline{w} = a^* - sx^m \,(= c - sx^m) > c^u$) if both x^m and firm e's entry are taken as given. However, when firm m strategically chooses its infrastructure investment, whether firm e's entry should be allowed becomes a different issue. According to Proposition 3, excess entry can occur when the degree of spillover is small and when firm m's investment cost is low. Indeed, excess entry is generated by firm m's private incentive to invest in infrastructure, which is weaker than the socially desirable level. Hence, to eliminate excess entry via bypass, policies should be put in place that incentivize infrastructure investment by incumbents.

We have already noted that the overuse of bypass and excess entry are generated by firm m's weak incentives to invest. In fact, we can ensure underinvestment in equilibrium for any technological environment, as stated in the following proposition:

Proposition 4 *When an entrant has both the access strategy and the bypass strategy available, an incumbent has less of an incentive to invest in infrastructure in equilibrium than in the second-best optimum, irrespective of the cost of investment.*

Proof. See Appendix D. ■

4 On the Possibility of a Vertical Merger

Section 3 indicated that when an entrant has both access and bypass available as entry strategies, the equilibrium vertical market structure is distorted to favor a bypass duopoly when the incumbent's production technology is inefficient and the degree of spillover is large. This implies two types of costs generated by the loss of the spillover effect and the double marginalization problem. In this section, we introduce the possibility of a vertical merger between the entrant and the upstream firm with the bypass technology to examine how such costs can be reduced. As stated in Section 2, a vertical merger can be interpreted as a case in which the entrant itself owns the bypass technology because in that situation, firm e can use the bypass technology with an upstream production cost c^u. In the case of a vertical merger, the joint profit is defined by

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

4.1 Firm e's entry strategies with a vertical merger

We assume that firm u can propose a vertical merger with firm e in the third stage. We also assume that if firm e rejects firm u's proposal, firm u can still offer firm e the wholesale price w, as in Section 3. Thus, firm e can choose from three strategies for entry. In the fourth stage, firm e decides whether to enter the market and, once it has made this decision, chooses one of three entry strategies: to access firm m's infrastructure, to use firm u's bypass technology, or to accept firm u's proposal of a vertical merger.

[Insert Figure 5 here.]

When firm u proposes a vertical merger, the condition under which firm e accepts firm u's proposal depends on the situation in which there is no possibility of a vertical merger. In the case in which firm u offers $\overline{w}$, the condition under which firm e accepts firm u's proposal of a vertical merger is

$$\pi^{*M} - \pi^{u*B}\left(\overline{w}\right) \geq \pi^{e*B}\left(\overline{w}\right) \left(= \pi^{e*A}\right), \tag{18}$$

where π^{*M} is the joint profit under a vertical merger, $\pi^{u*B}\,(.)$ $(\pi^{e*B}\,(.))$ is firm u's (firm e's) profit if it selects the bypass strategy, and π^{e*A} is firm e's profit if it selects the access strategy. In the case in which firm u offers w^*, the condition under which firm e accepts firm u's proposal is

$$\pi^{*M} - \pi^{u*B}\left(w^*\right) \geq \pi^{e*B}\left(w^*\right). \tag{19}$$

In the case in which firm u does not offer firm e the bypass technology, the condition under which firm e accepts firm u's proposal is

$$\pi^{*M} \geq \pi^{e*A} \tag{20}$$

Condition (19) is always satisfied, provided that we assume Cournot competition in the retail market and that firm u sets w. Based on simple calculations and a simple rearrangement of terms, (18) can be rewritten as

$$a \geq -\left(\frac{V + c - 4c^u}{2}\right) + \left(\frac{2s + 1}{2}\right) x^m. \tag{21}$$

By rewriting (20), we obtain the same condition as (13). Therefore, using (14) to (17) and (21), we can depict firm e's entry decision under the possibility of a vertical merger, as shown in Figure 5. In particular, given that (16) represents the threshold at which firm u obtains a positive profit (i.e., $\overline{w} \gtreqless c^u$), with the help of (21), we see that in the upper left part of Figure 5, in the region enclosed by (16) and (17), firm u proposes a vertical merger, and firm e accepts the proposal. Firm e's decisions in the other parts of Figure 5 are identical to those in Figure 2.

A notable finding that we discover when we compare Figure 5 with Figure 2 is that the bypass strategy is wholly replaced by the vertical merger strategy. This result crucially depends on the mode of competition downstream and the procedure for setting the wholesale price w. In our model, Cournot competition is assumed in the downstream market, and the wholesale price w is assumed to be unilaterally set by firm u if its merger proposal is rejected. On the other hand, as in Ordover et al. (1990), where firm m and firm e compete downstream on price and firm u can communicate with firm e, the bypass strategy may be preferable to the vertical merger strategy in the sense that both firm u and firm e are better off under the former than under the latter. In that case, the bypass strategy may reappear in some part of the vertical merger region in Figure 5.

The qualitative features of firm e's entry decision do not change when the range of s changes from $s > 1/2$ to $s \leq 1/2$. Hence, we omit the figure for the case in which $s \leq 1/2$, as in Section 3.

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

In the second stage, the regulator sets $a^* = c$ because V is sufficiently large and imperfect competition prevails in the retail market. Then, in the first stage, given $a^* = c$ and firm e's choice of entry strategy, firm m invests in infrastructure to maximize its profits. The procedures used to derive firm m's profit-maximizing investment and the classification of cases are the same as in Section 3. Hence, here we report a summary of the equilibrium market structure. See Appendix E for an outline of the derivation.

[Insert Figure 6 here.]

(i) When $\Delta c\,(\equiv c - c^u) \leq 0$, an access duopoly prevails, except when s and γ are small. When s and γ are small, a monopoly by firm m (i.e., foreclosure) is also possible.

(ii) When $0 < \Delta c \leq (1/10)\,Y$, all three types of equilibrium market structure are possible. See Figure 6. When s is large and γ is small, an access duopoly occurs in equilibrium. When both s and γ are small, a vertical merger duopoly or a monopoly by firm m (i.e., foreclosure) is also possible in equilibrium. Otherwise, a vertical merger duopoly occurs in equilibrium.

(iii) When $(1/10)\,Y < \Delta c \leq 4Y/\left(11+\sqrt{33}\right)$, two types of equilibrium market structure are possible. When s is large and γ is small, an access duopoly occurs in equilibrium. Otherwise, a vertical merger duopoly occurs.

(iv) When $4Y/\left(11+\sqrt{33}\right) < \Delta c < (1/2)\,Y$, only a vertical merger duopoly occurs in equilibrium.

In comparing Figures 6 and 3, we see that the vertical merger duopoly region wholly replaces the bypass duopoly region. The characteristics of the equilibrium market structures are the same as in Section 3, except that when $0 < \Delta c \leq (1/10)\,Y$, foreclosure can occur in the equilibrium in which firm u is able to propose a vertical merger. This is because in a vertical merger, firm e can use the bypass technology at an efficient input cost c^u and enjoy one of the benefits of vertical merger (i.e., the resolution of the double marginalization problem). Then, if firm m allows firm e to enter the market, firm m's profit in the retail market diminishes. Hence, with an efficient investment technology (i.e., a small γ), firm m has a strong incentive to invest up to $\overline{x}^{mB} = \Delta c/s$ to foreclose firm e. Thus, foreclosure occurs in equilibrium. On the other hand, when $(1/10)\,Y < \Delta c$, the size of the market is relatively small, which implies that firm m's monopoly profit is small. Then, firm m's incentive to foreclose firm e is less than when $0 < \Delta c \leq (1/10)\,Y$. Hence, when $(1/10)\,Y < \Delta c$, foreclosure is not an equilibrium.

[Insert Figure 7 here.]

We now compare the equilibrium and the second-best optimum, as in Section 3. The second-best market structures when firm e can propose a vertical merger are presented in Figure 7 for the case in which $0 < \Delta c \leq 5Y/17$. See Appendix F for a sketch of the derivation procedure. In comparing the equilibrium market structures with those in the second-best optimum, we obtain the following propositions:

Proposition 5 *Suppose that an incumbent's production technology is less efficient than the bypass technology of an upstream firm (i.e., $\Delta c \equiv c - c^u > 0$). Then, when the degree of spillover is large, a vertical merger occurs excessively from a welfare perspective.*

Proposition 6 *Suppose that an incumbent's production technology efficient than the bypass technology of an upstream firm (i.e., $\Delta c \equiv c - c^u > (<)\, 0$). Then, when the degree of spillover is small and the incumbent's investment cost is low, there is excess entry with a vertical merger (or with access) in equilibrium.*

Proposition 5 states that in equilibrium, when firm m's production technology is inefficient and the degree of spillover is large, the vertical market structure is distorted towards a vertical merger duopoly. Once again, the excessive occurrence of a vertical merger can be explained by firm m's weak incentive to invest in infrastructure. When the degree of spillover is large, an access duopoly through a regulated access charge $a^* = c$ is desirable from a welfare perspective. However, when firm m's production technology is inefficient, its profits in the retail market are limited. Because profits are the only driving force behind firm m's investment decisions, firm m has a weak incentive to invest in infrastructure. Firm m's diminished investment incentive then increases firm e's incentive to vertically merge with firm u (see Figure 5). The explanation for Proposition 6 is similar to the explanation for Proposition 3.

5 Discussion: Policy Implications

Based on the propositions derived in the previous sections, we arrive at a general conclusion. This conclusion is that given an incumbent's (or a network owner's) strategic opportunity to invest in infrastructure, horizontal or vertical market structures in equilibrium can become distorted when a bypass technology exists. Recall that if the infrastructure investment (or capacity) is given, an entrant's make-or-buy decision does not distort productive efficiency according to Proposition 1. However, when the infrastructure investment is determined strategically by the incumbent, the equilibrium market structure is distorted in favor of the overuse of bypass technology or vertical mergers and excess entry. Hence, the driving force behind the distortion in the equilibrium market structure is the incumbent's strategic opportunity to invest in infrastructure.

More precisely, the equilibrium market structure is distorted by the incumbent's weak incentive to invest in infrastructure. Infrastructure investment contributes to social welfare by increasing the quality of the final goods supplied not only by the incumbent but also by the entrant through access to the infrastructure, whereas a bypass technology provides a cost-reducing benefit to the entrant. Because an incumbent's incentive to invest in infrastructure is private (i.e., the incumbent does not care about the benefits that consumers gain through quality upgrades as a result of such investment), the level of investment is less than optimal from a welfare perspective. If the degree of spillover is large, an incumbent's underinvestment lowers the spillover benefits that an entrant can potentially obtain. Hence, the entrant has an incentive to overuse the bypass technology. Excessive occurrence of a vertical merger is explained by the same reasoning.

On the other hand, when the degree of spillover is small and the investment cost is low, a large investment by an incumbent with a monopoly (foreclosure) can be efficient from a welfare perspective. However, in equilibrium, in this case, the difference between the quality of the final goods produced by the incumbent and that of the final goods produced by the entrant is diminished due to the incumbent's private incentive to underinvest. As a result of this diminished difference in quality, the entrant has an incentive to excessively enter the retail market by using the bypass technology that provides a cost-reducing benefit. For this reason, excess entry occurs in equilibrium.

Given this line of reasoning, it is clear that policy suggestions about how to appropriately incentivize infrastructure investment by incumbents (or network owners) are in order. Here we suggest two ways in which such an incentive may be provided to firm m in our model. The first is for the regulator to commit to an access charge. Full commitment of the regulator to an access charge make the regulator a first-mover in our model. More specifically, if the regulator commits to an access charge that is higher than $a^* = c$, firm m will be more likely to invest in infrastructure and to choose foreclosure when the degree of spillover s is near zero.

The second effective (and direct) remedy involves allowing the regulator to initiate infrastructure investment itself if the regulator knows the extent of the demand-enhancing effects of infrastructure investment.[25] In examining this scenario, however, we should be mindful of the trade-off between a regulator's ability to commit to an appropriate vision of infrastructure development and the loss that may result from decreased competition in network industries.

As a final remark, we should mention one caveat regarding our analytical results. The dominant policy stance regarding network industries in recent years has emphasized

[25] In a framework that involves coalition formation in the building of infrastructure, Mizuno and Shinkai (2006) propose the delegation of the initiatives for infrastructure investment to a regulator when the cost-reducing effect of infrastructure is large. However, they conclude that when this effect is small, a network owner has a sufficient incentive from a welfare perspective to undertake infrastructure investment and thus suggest that the regulator should not intervene in this case.

the need for competition, with regulators concerned that an incumbent's market power can be used to exclude potential entrants. At first glance, our discussion of "excess entry" in the above analysis may appear to be contrary to this element of contemporary competition policy. However, this is not the case. Our conclusions are based on the fundamental assumption that an appropriate access charge is set and there are no non-price exclusionary tools other than infrastructure investment. If an incumbent has private information about access cost or other exclusionary tools, such as tying, advertising, etc., foreclosure should be carefully monitored. On the other hand, assuming that these issues are effectively addressed in the policy arena, our analysis provides insight into the relationship between an incumbent's strategic infrastructure investment and distortions in the equilibrium market structure. In this sense, our conclusions should be considered complementary to contemporary regulatory policy.

6 Concluding Remarks

In this paper, we have examined how the existence of bypass technology affects market structure in network industries when an incumbent has a strategic opportunity to invest in infrastructure. We have supposed that access price regulation is a necessary tool for enhancing allocative efficiency in a retail market with imperfect competition. Given access price regulation, we have allowed entrants the opportunity to use bypass technology either by paying a wholesale price set by an upstream firm or by engaging in vertical mergers with that firm.

We have shown that an incumbent's strategic investment unexpectedly generates not only excess entry but also the overuse of bypass technology from a welfare perspective. Moreover, if a vertical merger between an entrant and an upstream firm that has bypass is allowed, then such a merger may occur excessively in equilibrium.

As the driving force behind these findings is incumbents' weak incentive to invest in infrastructure, we advocate policies that provide appropriate incentives for incumbents to invest. More specifically, we have proposed full commitment to a regulated access charge and the delegation of infrastructure development initiatives to regulators as possible ways to remedy the problem. In an open access environment, other policy ideas that could promote infrastructure investment might also be proposed. However, the effects of such policies may depend on the characteristics of different network industries. Hence, as suggested by Armstrong and Sappington (2006), future research should investigate the effects of different policies in promoting infrastructure investment, as these effects will vary with the characteristics of different network industries.

Appendix

A. The proof of Proposition 1

In our model, given firm m's investment x^m, technology choice will be efficient from a welfare perspective if firm e decides to access firm m's infrastructure (bypass, respectively) if and only if $c-sx^m \leq c^u$ or $c \leq c^u+sx^m$ ($c-sx^m > c^u$ or $c > c^u+sx^m$). We must therefore determine whether firm e's choice satisfies this condition in equilibrium irrespective of the relative magnitudes of c and c^u and the degree of s.

Consider the case in which $s \in [1/2,\ 1]$. For this proof, we refer to Figure 2.

(i) Suppose that $c \leq c^u$. Then, from Figure 2, it is apparent that firm e chooses access, because $a^* = c \leq c^u$.

(ii) Suppose that $c > c^u$. According to Figure 2, for $x^m < \overline{x}^{mB}$ ($\equiv \Delta c/s$), firm e chooses bypass with $\overline{w} \equiv a - sx^m$ provided that $a^* = c$. On the other hand, for $x^m \geq \overline{x}^{mB}$ ($\equiv \Delta c/s$), firm e chooses access provided that $a^* = c$. This dividing condition for x^m is equivalent to that of efficient technology choice from a welfare perspective.

We can analyze the case in which $s \in (0,\ 1/2)$ by using the same reasoning as (i) and (ii). Thus, we prove the proposition. ■

B. Firm m's problem regarding strategic infrastructure investment

As in Figure 2, firm e's entry decision depends on the level of s. Moreover, because the regulator sets $a^* = c$, the magnitude of the cost difference $\Delta c \equiv c - c^u$ is also a crucial parameter of firm e's entry decision. Firm m's investment problem should then be examined separately for all seven cases stated in the text.

We report only the threshold investment levels and the equations for the threshold lines that can be used to determine the equilibrium market structure in each case. Based on Figure 2 and the result that $a^* = c$, the threshold investment level that separates the bypass strategy from the access strategy is given by

$$\overline{x}^{mB} = \frac{\Delta c}{s}.$$

Note that according to Figure 2, as long as $c\,(= a^*) < c^u + s\overline{x}^m$ (see the vertical axis in the figure), i.e., $\Delta c/\,(Y + 2\Delta c) < s$, the access price regulation is binding at $\overline{x}^{mB}$ when firm e adopts the bypass strategy. This means that firm e's profit under the bypass strategy is the same as its profit under the access strategy. Hence, provided that

$c\,(= a^*) < c^u + s\overline{x}^m$, firm m can achieve its profit-maximizing investment x^{m*A} where

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

irrespective of whether the market is an access duopoly or a bypass duopoly. The equilibrium market structure is then determined by whether firm m's profit under a bypass duopoly is larger than that under an access duopoly. This is equivalent to the condition that $x^{m*A} \lesseqgtr \overline{x}^{mB}$, because firm m's profit is continuous and concave in x^m. In particular, when $x^{m*A} \leq (>)\, \overline{x}^{mB}$, the equilibrium market structure becomes a bypass duopoly (an access duopoly). The threshold line that defines the condition that $x^{m*A} = \overline{x}^{mB}$ is given by

$$\gamma = \frac{2}{9\Delta c}\left[-\,(Y-\Delta c)\,s^2 + 2\,(Y-2\Delta c)\,s + 4\Delta c\right]. \tag{22}$$

Here, we should note that (22) does not intersect $\gamma = 9/11$ when $4Y/\left(11+\sqrt{33}\right) < \Delta c$, as stated in the text.

However, when $c\,(= a^{**}) \geq c^u + s\overline{x}^m$, i.e., $0 < s \leq \Delta c/\,(Y + 2\Delta c)$, the access price regulation is nonbinding when firm e adopts the bypass strategy. Hence, the threshold investment $\overline{x}^m$ should be compared with firm m's profit-maximizing investment under the bypass strategy, x^{m*B}, given by

$$x^{m*B} = \frac{7\,(5Y - 2\Delta c)}{72\gamma - 49}.$$

The condition under which firm m will prefer firm e to enter with a bypass strategy is $x^{m*B} \leq \overline{x}^m$. The condition, $x^{m*B} \leq \overline{x}^m$, can thus be rewritten as

$$\gamma \geq \frac{7\,(Y+\Delta c)}{6\,(Y+2\Delta c)}.$$

Because $7\,(Y+\Delta c)\,/6\,(Y+2\Delta c) < 11/9$, we confirm that when $0 < s \leq \Delta c/\,(Y+2\Delta c)$, the equilibrium market structure is a bypass duopoly.

Finally, when $4Y/\left(11+\sqrt{33}\right) < \Delta c < (1/2)\,Y$, the maximum value of the threshold line (22) is less than 11/9. Hence, the equilibrium market structure must be a bypass duopoly in this case.

C. The second-best market structure

We report only the threshold investment levels and the equations for the threshold lines.

Given vertical axis a in Figure 2, as long as $c\,(= a^*) < c^u + s\overline{x}^m$, i.e., $\Delta c/\,(Y+2\Delta c) <$

s, the access price regulation is binding at $\overline{x}^{mB}$ when firm e adopts the bypass strategy. Thus, firm e's profit under the bypass strategy is the same as it is under the access strategy. Hence, the regulator can achieve the welfare-maximizing investment x^{m**A} where

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

irrespective of whether the market is an access duopoly or a bypass duopoly. Hence, the second-best market structure is determined by the condition that $x^{m**A} \lesseqgtr \overline{x}^{mB}$ because all the social welfare functions, W^A, W^B, and W^F, are continuous and concave in x^m. In particular, when $x^{m**A} \leq (>)\, \overline{x}^{mB}$, the second-best market structure is a bypass duopoly (an access duopoly). The threshold line that defines the condition that $x^{m**A} \lesseqgtr \overline{x}^{mB}$ is given by

$$\gamma = \frac{1}{9\Delta c}\left[(4Y + 11\Delta c)\, s^2 + 2(2Y - 7\Delta c)\, s + 11\Delta c\right]. \tag{23}$$

Yet, when $c\,(= a^{**}) \geq c^u + s\overline{x}^m$ or $0 < s \leq \Delta c / (Y + 2\Delta c)$, the access price regulation is nonbinding when firm e adopts the bypass strategy. Hence, the threshold investment $\overline{x}^m$ should be compared with the welfare-maximizing investment under the bypass strategy, x^{m**B}, which is given by

$$x^{m**B} = \frac{85Y - 58\Delta c}{144\gamma - 143}.$$

Then the condition under which the regulator will wish firm e to enter with the bypass strategy is $x^{m**B} \leq \overline{x}^m$, which can be rewritten as

$$\gamma \geq \frac{19(Y + \Delta c)}{12(Y + 2\Delta c)}.$$

Similarly, the condition under which the regulator strictly prefers foreclosure to bypass duopoly is $x^{m**F} \geq \overline{x}^m$, where x^{m**F} is given by

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

This condition can be rewritten as

$$\gamma \leq \frac{3(Y + \Delta c)}{2(Y + 2\Delta c)}. \tag{24}$$

Note that the condition under which firm e enters the market with the access strategy is

$c\,(= a^*) \leq ((V + c)/2) + ((2s - 1)/2)\, x^m$. This condition can be rewritten as

$$x^m \leq \overline{x}^{mA} \equiv \frac{Y}{1 - 2s}$$

The condition under which the regulator can choose x^{m**A} rather than $\overline{x}^{mA}$ under an access duopoly, i.e., $x^{m**A} \leq \overline{x}^{mA}$, is given by

$$\gamma \geq \frac{1}{3}(1 - s)(5 - s).$$

Similarly, the condition under which the regulator can choose x^{m**F} rather than $\overline{x}^{mA}$ under foreclosure, i.e., $x^{m**F} \geq \overline{x}^{mA}$, is given by

$$\gamma \leq \frac{3}{2}(1 - s).$$

Based on all of the above conditions, we can determine the second-best market structure, as in Figure 4, when $0 < \Delta c \leq (5/17)\, Y$. When $(5/17)\, Y < \Delta c \leq (1/2)\, Y$, the second-best market structure can be determined by using the above inequalities.

D. The proof of Proposition 4

This proof only requires a comparison of the level of investment at the equilibrium and the second-best optimum. In fact, we can show that $x^{m**F} > \overline{x}^m > x^{m**B} > x^{m*B}$ and that $x^{m**A} > x^{m*A}$. Using these inequalities and comparing Figure 3 with Figure 4, we obtain the result. ■

E. The equilibrium market structure when firm u can propose a vertical merger

As noted in the text, firm e's entry decision depends on the level of s and the magnitude of the cost difference $\Delta c \equiv c - c^u$. Using Figure 5 and the associated figures for the case in which $s \in (1/4,\ 1/2]$ and the case in which $s \in [0,\ 1/4]$, we ensure that firm m's investment problem can be examined separately for each of the seven cases, as in Section 3. In addition, as the procedure for each case is the same as in Appendix B, we report only the threshold investment levels and the equations of the threshold lines, as in Appendix B.

The threshold line that indicates whether firm m strictly prefers an access duopoly to a vertical merger duopoly is defined by the condition $x^{m*A} \lesseqgtr \overline{x}^{mB}$ because of the continuity and concavity of firm m's profit function with respect to x^m. Hence, it is given by (22). On the other hand, the threshold line that indicates whether firm m strictly prefers a vertical merger duopoly to an access duopoly is defined by $x^{m*M} \lesseqgtr \overline{x}^{mB}$ where x^{m*M} is firm m's profit-maximizing investment under a vertical merger duopoly, which is given by

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

The threshold line of the condition $x^{m*M} = \overline{x}^{mB}$ is then given by

$$\gamma = \frac{8}{9} + \frac{4(Y - \Delta c)}{9\Delta c} s. \tag{25}$$

Here, we should note that when firm m chooses $\overline{x}^{mB}$, firm e strictly prefers a vertical merger duopoly to an access duopoly, as firm u can use a vertical merger to provide firm e with a profit that is strictly higher than the amount that firm e will obtain through access: At $\overline{x}^{mB}$ when $a^* = c$, (21) holds, which means $\pi^{*M} - \pi^{u*B}(\overline{w}) \geq \pi^{e*B}(\overline{w}) = \pi^{e*A}$ (see Figure 5).

When $c\,(= a^*) \geq c^u + s\overline{x}^m$, i.e., $0 < s \leq \Delta c / (Y + 2\Delta c)$, the threshold line that indicates whether firm m strictly prefers a vertical merger duopoly to foreclosure is defined by the condition $x^{m*M} \lesseqgtr \overline{x}^m$. Then, the threshold line for the condition $x^{m*M} = \overline{x}^m$ is given by

$$\gamma = \frac{4(Y + \Delta c)}{3(Y + 2\Delta c)}. \tag{26}$$

We should note that when $\Delta c > (1/10)\,Y$, we have $4(Y + \Delta c)/3(Y + 2\Delta c) < 11/9$. In this case, the foreclosure region disappears.

F. The second-best market structure when firm e can propose a vertical merger

The classification of cases is the same as in Appendix E. We report only the threshold investment levels and the equations of the threshold lines.

The threshold line that indicates whether the regulator strictly prefers an access duopoly to a vertical merger duopoly is characterized by the condition $x^{m**A} \lesseqgtr \overline{x}^{mB}$ because of the continuity and concavity of the social welfare function with respect to x^m. Hence, it is given by (22). However, the threshold line that indicates whether the regulator strictly prefers a vertical-merger duopoly to an access duopoly is defined by the condition $x^{m**M} \lesseqgtr \overline{x}^{mB}$, where x^{m**M} is the welfare-maximizing investment under a vertical merger duopoly. Indeed, x^{m**M} is given by

$$x^{m**M} = \frac{4Y - 7\Delta c}{9\gamma - 11}.$$

The threshold line of the condition $x^{m**M} = \overline{x}^{mB}$ is then given by

$$\gamma = \frac{11}{9} + \frac{4Y - 7\Delta c}{9\Delta c} s. \tag{27}$$

When $c\,(= a^{**}) \geq c^u + s\overline{x}^m$ or $0 < s \leq \Delta c/\left(Y + 2\Delta c\right)$, the threshold line that indicates whether firm m strictly prefers a vertical merger duopoly to foreclosure is defined by the condition $x^{m**M} \lesseqgtr \overline{x}^m$. That is, the threshold line is given by

$$\gamma = \frac{5\left(Y + \Delta c\right)}{3\left(Y + 2\Delta c\right)}. \tag{28}$$

Similarly, the condition under which firm m strictly prefers foreclosure to bypass duopoly is $x^{m**F} \geq \overline{x}^m$, which is given by (24). Once again, the foreclosure region disappears when $(5/17)\,Y < \Delta c \leq (1/2)\,Y$.

We make a final remark to describe Figure 7. The region enclosed by (23) from above and by (27) from below, which occurs for $s > \widehat{s} \equiv 7\Delta c/\left(4Y + 11\Delta c\right)$ (i.e., $\widehat{s} \equiv 7\Delta c/\left(4Y + 11\Delta c\right)$ is the intersection of (23) and (27)), represents the region in which the social welfare under a vertical merger duopoly is denoted by $W^M\left(x^{m**M}\right)$, whereas the social welfare under an access duopoly is denoted by $W^A\left(x^{m**A}\right)$. To compare $W^M\left(x^{m**M}\right)$ with $W^A\left(x^{m**A}\right)$, let us define $\Delta W^{MA} \equiv W^M\left(x^{m**M}\right) - W^A\left(x^{m**A}\right)$. We can verify that there exists a threshold line that indicates $\Delta W^{MA} = 0$, above (below) which we have $\Delta W^{MA} > (<)\,0$, in the region enclosed by (23) from above and by (27) from below. This result is shown as follows. From the definition of (27), we have $W^M\left(\overline{x}^{mB}\right) = W^M\left(x^{m**M}\right)$. In addition, it is easy to see that $W^M\left(\overline{x}^{mB}\right) = W^A\left(\overline{x}^{mB}\right)$. Hence, on the threshold line (27), we have

$$W^M\left(x^{m**M}\right) = W^M\left(\overline{x}^{mB}\right) = W^A\left(\overline{x}^{mB}\right) \leq W^A\left(x^{m**A}\right).$$

However, using the envelope theorem and the fact that $x^{m**M} < x^{m**A}$, we have

$$\frac{d\Delta W^{MA}}{d\gamma} = -\frac{1}{2}\left[\left(x^{m**M}\right)^2 - \left(x^{m**A}\right)^2\right] > 0 \text{ for any } s.$$

Consequently, we have a unique threshold line that indicates $\Delta W^{MA} = 0$. In addition, this threshold line should be an upward sloping curve, as we have

$$\frac{dW^A\left(x^{m**A}\right)}{ds} = \frac{\partial W^A\left(x^{m**A}\right)}{\partial s} = x^{m**A} q^{e*A}\left(x^{m**A}\right) > 0 \text{ for any } \gamma.$$

References

[1] Armstrong, M., 2001, "Access Pricing, Bypass, and Universal Service", *American Economic Review* 91, 297–301.

[2] Armstrong, M. and Sappington, D. E. M., 2006, "Regulation, Competition, and Liberalization", *Journal of Economic Literature* 44, 325–366.

[3] de Bijl, P. and Peitz, M., 2008, "Innovation, Convergence and the Role of Regulation in the Netherlands and Beyond", *Telecommunications Policy* 32, 744-754.

[4] Faulhaber, G. R. and Hogendorn, C., 2000, "The Market Structure of Broadband Telecommunications", *Journal of Industrial Economics* XLVIII, 305–329.

[5] Foros, ∅, 2004, "Strategic Investments with Spillovers, Vertical Integration and Foreclosure in the Broadband Access Market", *International Journal of Industrial Organization* 22, 1–24.

[6] Bloch, F. and Gautier, A., 2012, "Strategic Bypass Deterrence", a paper presented at *the 10th International Industrial Organization Conference*, Arlington.

[7] Gayle, P.G. and Weisman, D.L., 2007, "Are Input Prices Irrelevant for Make-or-Buy Decisions?", *Journal of Regulatory Economics* 32, 195-207.

[8] Huigen, J. and Cave, M., 2008, "Regulation and the Promotion of Investment in Next Generation Networks—A European Dilemma", *Telecommunications Policy* 32, 713–721.

[9] Kotakorpi, K., 2006, "Access Price Regulation, Investment, and Entry in Telecommunications", *International Journal of Industrial Organization* 24, 1013–1020.

[10] Laffont, J.-J. and Tirole, J., 1990, "Bypass and Creamskimming", *American Economic Review* 80, 1042–1061.

[11] Mandy, D.M., 2009, "Pricing Inputs to Induce Efficient Make-or-Buy Decisions", *Journal of Regulatory Economics* 36, 29-43.

[12] Mizuno, K., and Shinkai, T., 2006, "Delegating Infrastructure Projects with Open Access", *Journal of Economics* 88, 243–261.

[13] Mizuno, K., and Yoshino, I., 2012, "Distorted Access Regulation with Strategic Investments: Regulatory Non-Commitment and Spillovers Revisited", *Information Economics and Policy* 24, 120-131.

[14] Ordover, J. A., Saloner, G., and Salop, S. C., 1990, "Equilibrium Market Foreclosure", *American Economic Review* 80, 127–142.

[15] Sappington, D. E. M., 2005, "On the Irrelevance of Input Prices for Make-or-Buy Decisions", *American Economic Review* 95, 1631–1638.

		Firm m		Firm e		Firm u	
		q^{m*}	$\tilde{\pi}^{m*}$	q^{e*}	π^{e*}	q^{u*}	π^{u*}
Access Duopoly		$q^{m*A} = \frac{1}{3}\left(V+(2-s)x^m+a-2c\right)$	$\tilde{\pi}^{m*A} = \left(q^{m*A}\right)^2 + (a-c)q^{e*A}$	$q^{e*A} = \frac{1}{3}\left(V+(2s-1)x^m+c-2a\right)$	$\pi^{e*A} = \left(q^{e*A}\right)^2$	0	0
Bypass Duopoly	**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	$\bar{q}^{m*B}\left(=q^{m*A}\right) = \frac{1}{3}\left(V+(2-s)x^m+a-2c\right)$	$\bar{\tilde{\pi}}^{m*B} = \left(\bar{q}^{m*B}\right)^2$	$\bar{q}^{e*B}\left(=q^{e*A}\right) = \frac{1}{3}\left(V+(2s-1)x^m+c-2a\right)$	$\bar{\pi}^{e*B} = \left(\bar{q}^{e*B}\right)^2$	$\bar{q}^{u*B} = \bar{q}^{e*B}$	$\bar{\pi}^{u*B} = \left(a-sx^m-c^u\right)\bar{q}^{e*B}$
Foreclosure (Monopoly)		$q^{m*F} = \frac{1}{2}\left(V+x^m-c\right)$	$\tilde{\pi}^{m*F} = \left(q^{m*F}\right)^2$	0		0	
Vertical Merger Duopoly				**Firm e + Firm u**			
		$q^{m*M} = \frac{1}{3}\left(V+2x^m+c^u-2c\right)$	$\tilde{\pi}^{m*M} = \left(q^{m*M}\right)^2$	$q^{e*M}\left(=q^{u*M}\right) = \frac{1}{3}\left(V-x^m+c-2c^u\right)$		$\pi^{*M}\left(\equiv \pi^{e*M}+\pi^{u*M}\right) = \left(q^{e*M}\right)^2$	

Table 1 Equilibrium Production and 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.

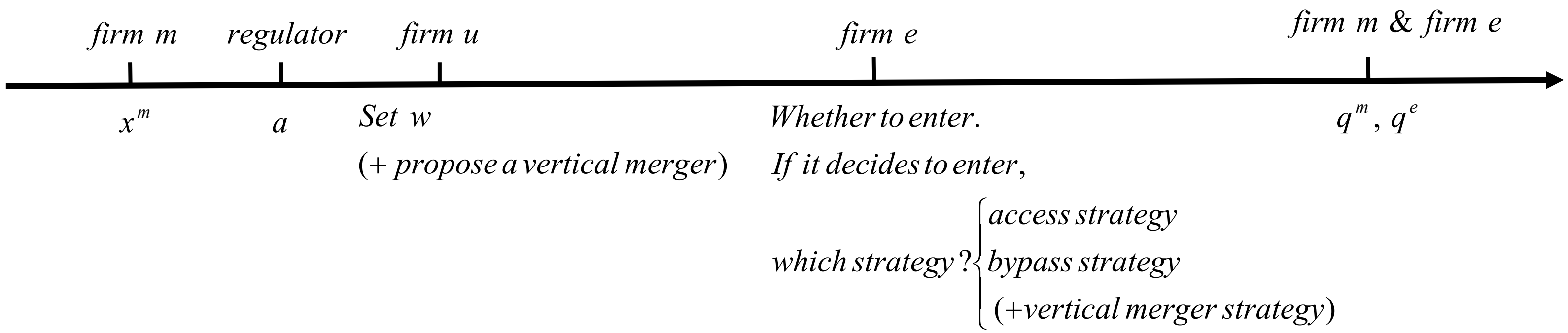

Figure 1 Timing of the Game

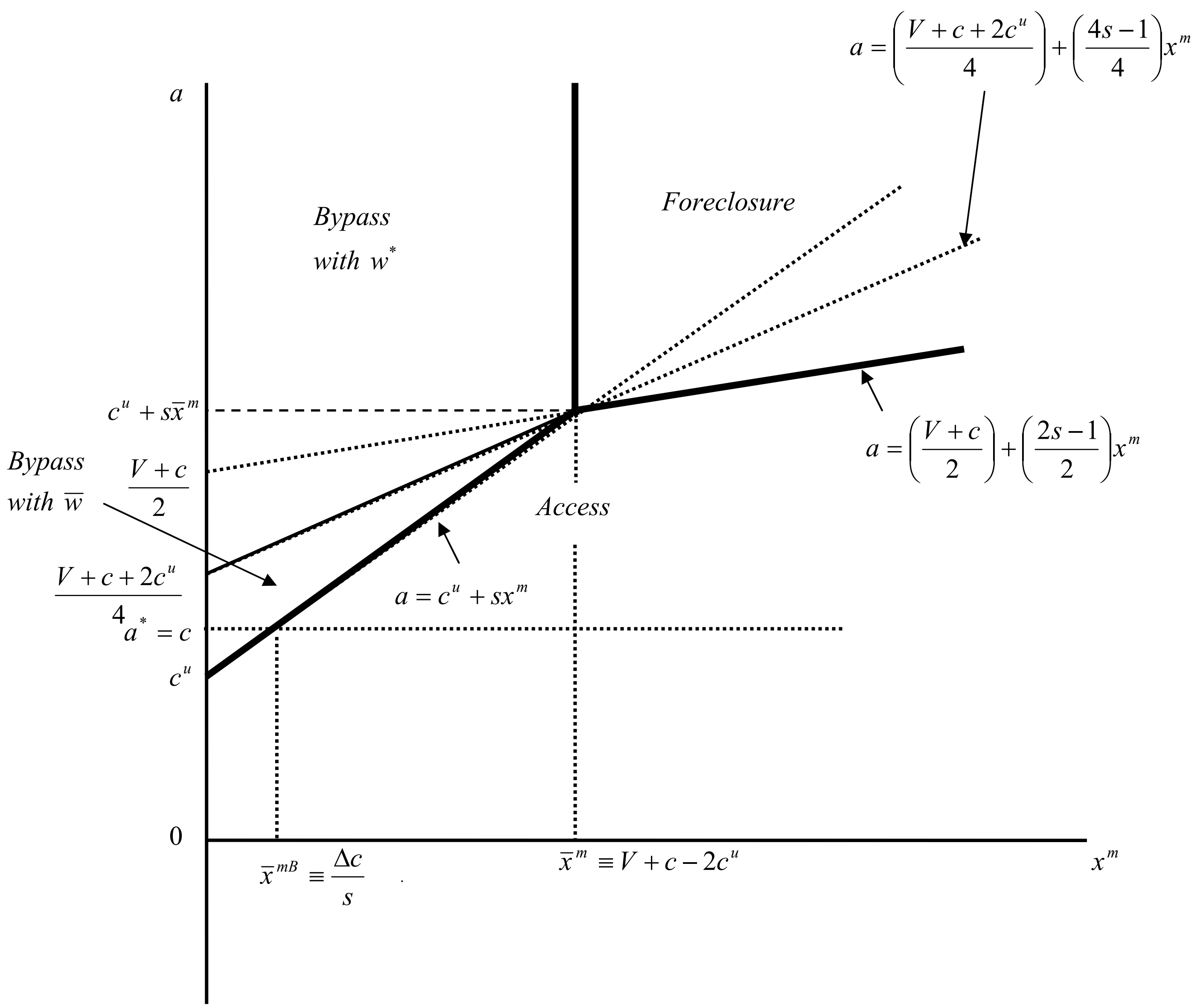

Figure 2 Firm *e*'s Entry and the Wholesale Price set by Firm *u*: The Case in which $\frac{1}{2} < s \leq 1$

Note:

(i) $Y \equiv V - c$. (ii) $w^* = \frac{1}{4}\left(V - x^m + c + 2c^u\right)$ and $\bar{w} \equiv a - sx^m$.

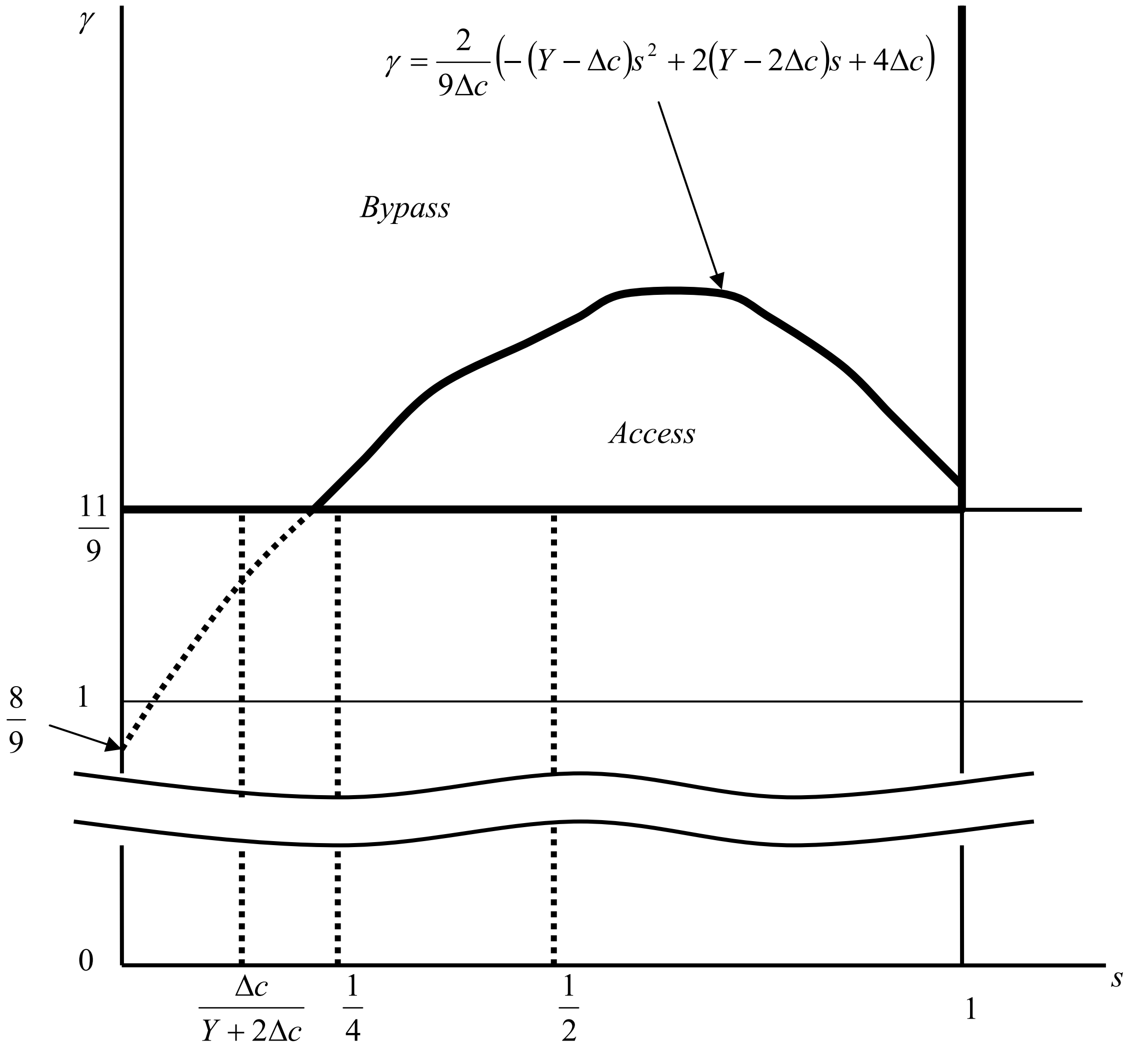

Figure 3 Equilibrium Market Structure:

The Case in which $0 < \Delta c \leq \left(\frac{4}{11+\sqrt{33}}\right)Y$

Note:

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

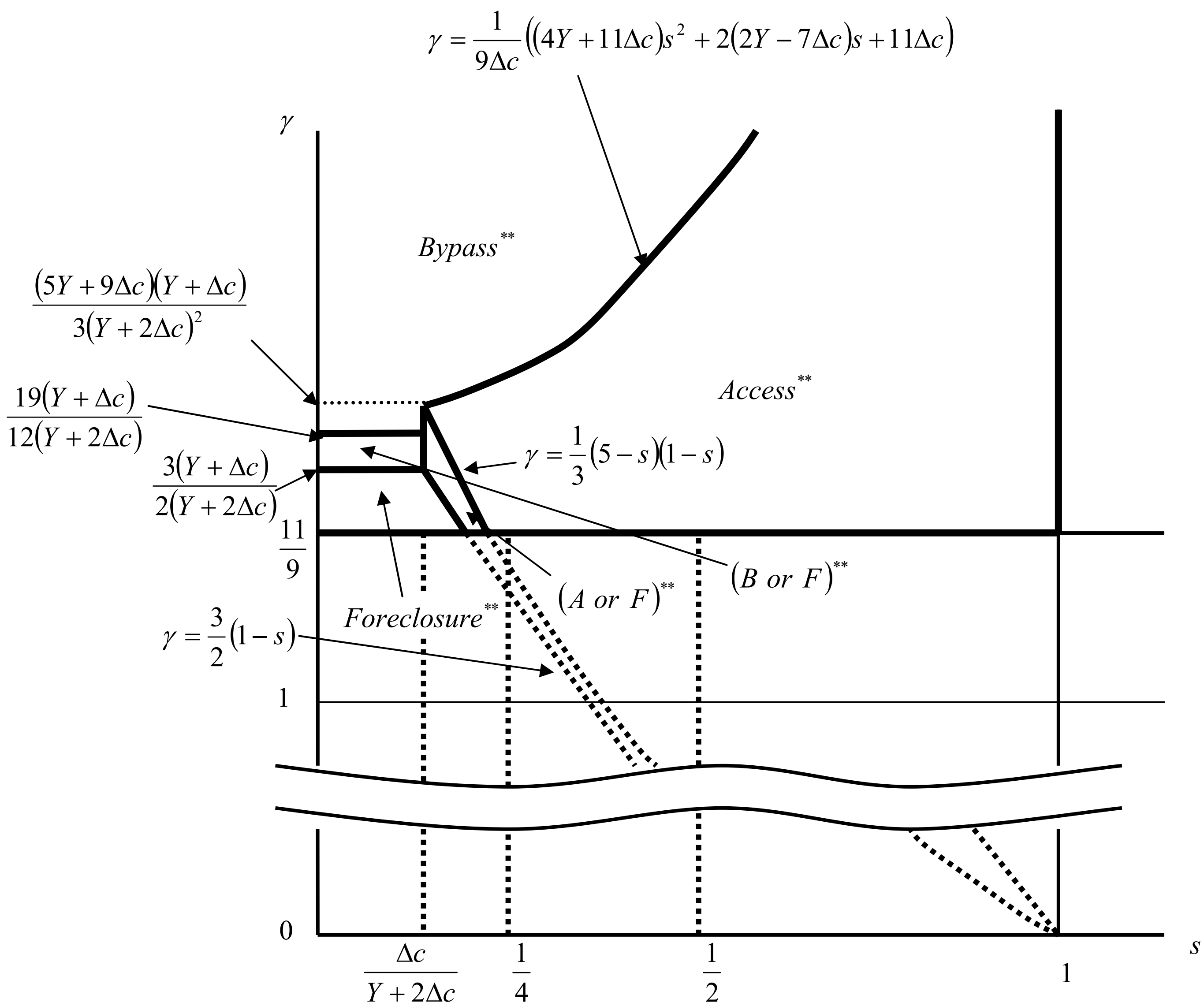

Figure 4 Second-Best Market Structure:

The Case in which $0 < \Delta c \leq \frac{5}{17}Y$

Notes:

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

(ii) "*B or F*" represents "Bypass or Foreclosure".

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

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

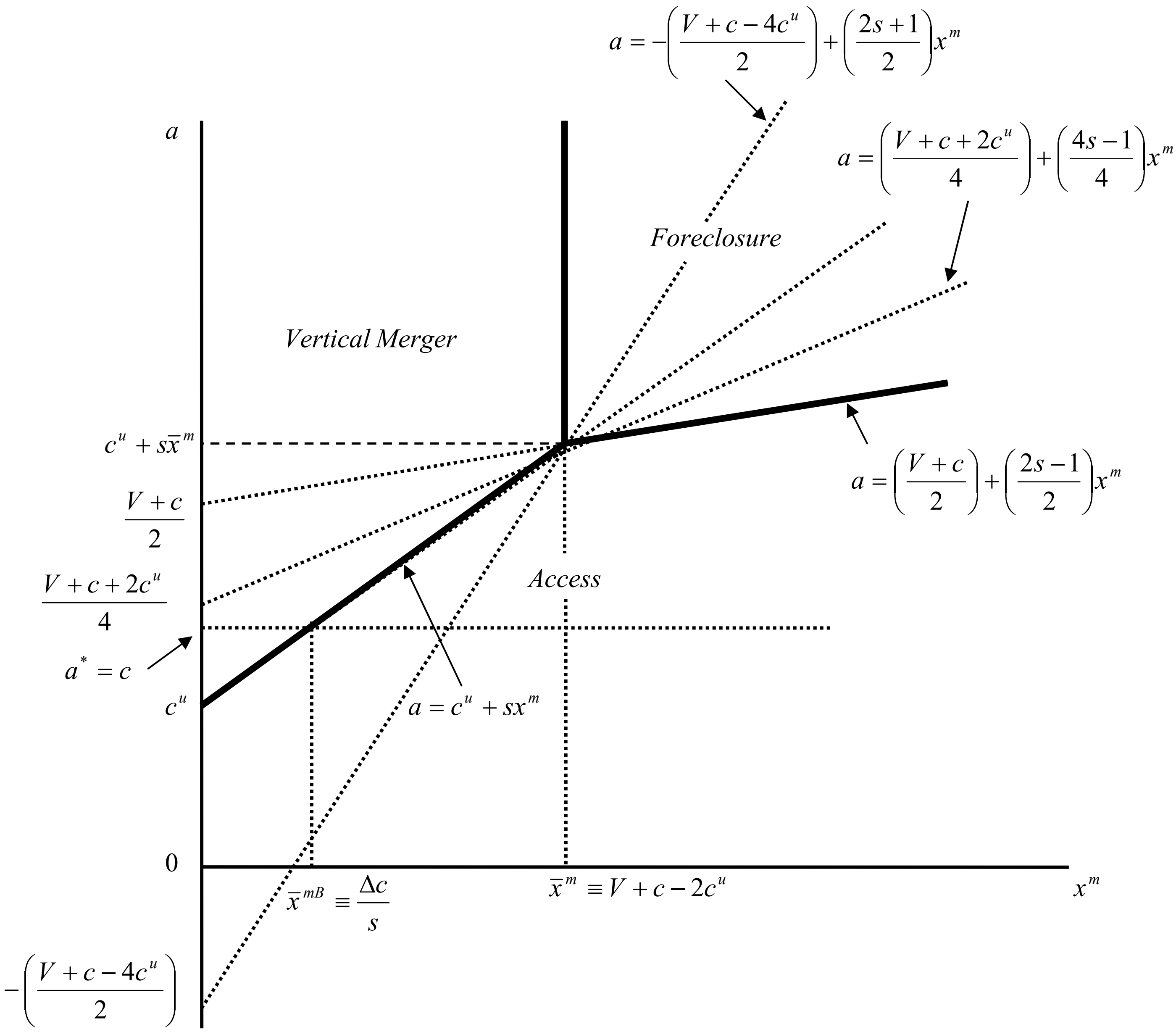

Figure 5　Firm *e*'s Entry and a Vertical Merger:
The Case in which $\frac{1}{2} < s \leq 1$

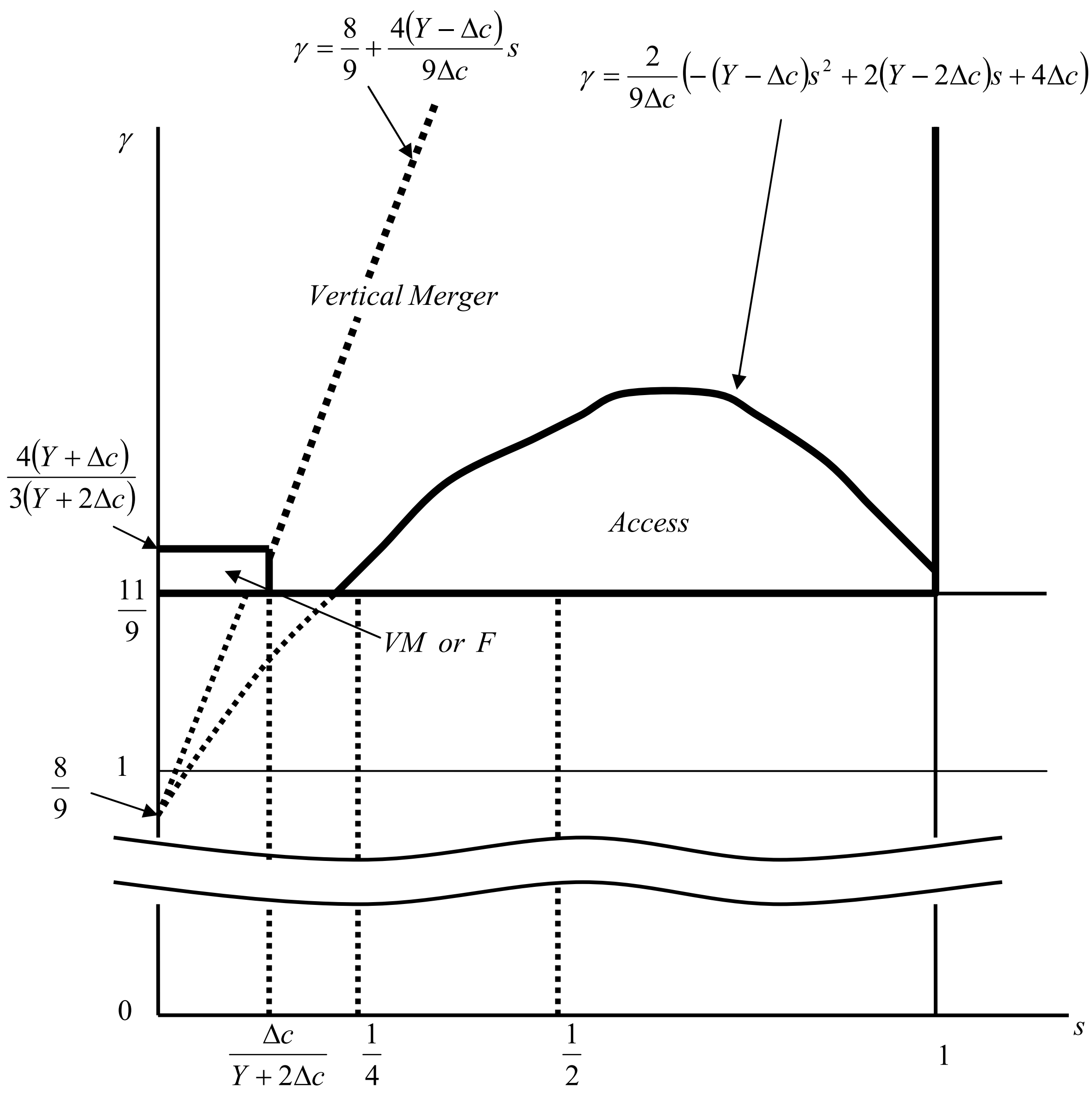

Figure 6 Equilibrium Market Structure with a Vertical Merger: The Case in which $0 < \Delta c \leq \frac{1}{10} Y$

Notes:

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

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

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

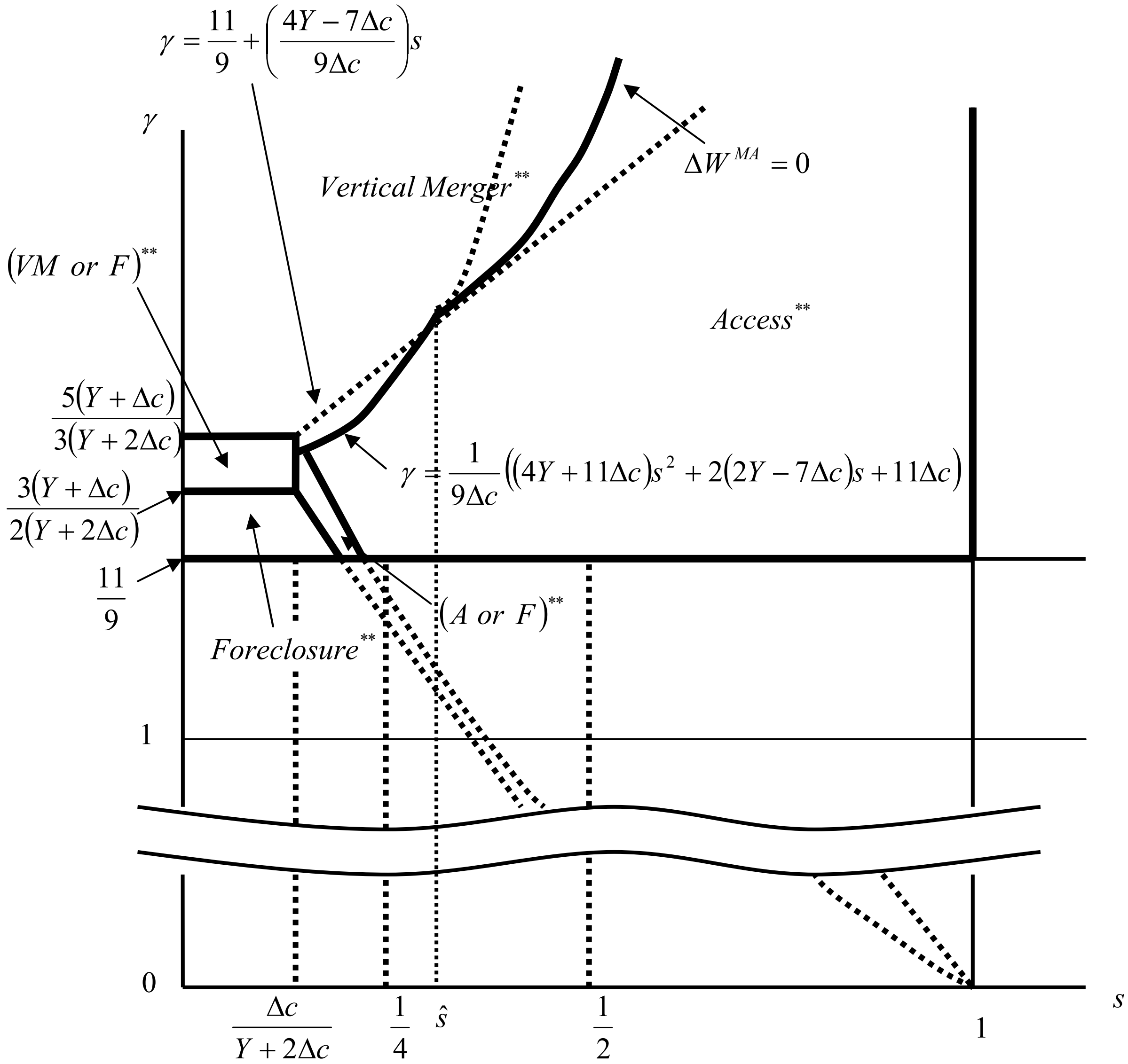

Figure 7 Second-Best Market Structure with a Vertical Merger: The Case in which $0 < \Delta c \leq \frac{5}{17}Y$

Notes:

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

(ii) $\Delta W^{MA} \equiv W^M\left(x^{m**M}\right) - W^A\left(x^{m**A}\right)$ and $\hat{s} \equiv 7\Delta c/(4Y + 11\Delta c)$.

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

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

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