

Stepping Stone or Stonewall? Progressive Entry and the Incentives to Invest in Alternative Infrastructures

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Abstract

We provide a model to study how a phase of service-based competition during which the competitive local exchange carriers' (CLECs) lease access to the incumbent local exchange carrier's (ILEC) network affects the CLECs' incentives to build alternative infrastructures. In line with the "stepping stone" or "ladder of investment" arguments, we assume that service-based competition allows the entrants to step in the market by building market share progressively. We show that the stepping stone effect works in the opposite direction than the one expected, hence, service-based competition retards facility-based entry, when facility-based entry could occur in the short run and/or market share acquisition goes fast. When market share acquisition depends on the entrant's sales, we show that a decrease of the access charge can accelerate facility-based entry.

Keywords: Telecoms; Investment; One-way Access; Progressive Entry; Stepping Stone.

JEL Codes: L1, O3.

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1 Introduction

In most countries, telecom regulators promote the development of facility-based competition in the long-term.¹ However, the deployment of new infrastructures is costly, risky and highly irreversible, thus potential entrants are rarely able to build their own infrastructure from the outset. This is why a large majority of the national regulatory authorities in industrialized countries have mandated the unbundling of the incumbents' local loop, in order to develop service-based competition in the broadband market.

Although there are clear benefits of service-based competition in the short-term, its effects on facility-based competition have raised a lot of debates. On the one hand, some argue that service-based competition and facility-based competition are substitutes. The idea is that service-based competition lowers the entrant's investment incentives, because it increases the opportunity cost of building its own network. This is known as the *replacement effect*. On the other hand, others have argued that a phase of service-based competition allows entrants to step in the market, to acquire information and/or a customer base progressively, hence, that it enhances their investment incentives. In other words, service-based and facility-based competition are complements rather than substitutes. This is often referred to as the *stepping stone* argument in the US and the *ladder of investment* argument (Cave, 2006) in Europe.

In this paper we propose a model in which the entrant acquires market share progressively and we study whether service-based competition and facility-based competition are substitutes or complements

We first present a general model with reduced-form profits. There are two firms, an incumbent and a potential entrant. The entrant can enter either by leasing access to the incumbent's facilities or by building its own infrastructure. When the entrant enters the market, it progressively accumulates market share, therefore we allow for a "stepping stone". The "stepping stone" or "ladder of investment" arguments state that the phase of service-based competition accelerates facility-based entry. We show that this conventional wisdom might be wrong. When facility-based entry is a short-term possibility, the "stepping stone" effect by which the entrant accumulate market share does not accelerate but rather delay the entrant's investment. However, if the market share acquisition is slow or if facility-based entry is a long-term perspective, then the phase of service-based

¹The development of alternative infrastructures would more effectively regulate the market power of the incumbent by increasing competition in the upstream market, and would gradually reduce the need for regulatory control.

competition accelerates facility-based entry. Finally, we presented an extension in which the speed of market share acquisition depends on the quantities sold by the entrant. In this extension, we showed that a decrease of the access charge does not necessarily retard facility-based entry as expected traditionally. Indeed, while a decrease of the access charge always leads to an increase of the replacement effect, it also leads to a decrease the stepping stone effect. Therefore, if the date of facility-based entry without a phase of service-based competition is high enough, a decrease of the access charge can accelerate facility-based entry.

The "stepping stone" argument has been heavily undermined by empirical research. All econometric studies we are aware provide support against the "stepping stone" hypothesis. After estimating a multivariate regression equation on semiannual state-level on US data, Hazlett and Bazelon (2005) show that "increases in UNE-P lines lead to decreases in CLEC-owned lines two or three periods later". Based on EU broadband penetration data, Crandall and Sidak (2007) reach the same conclusion. Likewise, Hausman and Sidak (2005) found no evidence in favor of the "stepping stone" hypothesis in the US, the UK, New Zealand, Canada, and Germany.²

While the progressive nature of entry as a key factor in the entrant's decision to invest has already been recognized in policy debates, there is to our knowledge no formal paper addressing it. This paper aims at filling this gap.

The rest of the paper is organized as follows. In Section 2, we outline the general model. In Section 3, we solve for the equilibrium, and study the impact of service-based competition on facility-based competition. In Section 4 we provide two examples of settings which fit with the assumptions of the general model. Section 5 presents an extension in which market share acquisition depends on the current sales of the entrant. Finally, we conclude.

2 The model

In this model, we consider an incumbent operator, which owns the local loop and is active on the broadband market and a potential entrant, which needs access to the local loop to provide services to end consumers. The potential entrant can enter the market either on the basis of services or

²However, one major problem with these analysis concerns the ratio used to validate or reject the stepping stone. This ratio is the "CLEC-Owned Lines as a percentage of total CLEC Lines". As Hausman and Sidak (2005) notice, "it is possible that mature CLECs have, in fact, made the transition to facilities-based lines but entry by new UNE-based CLECs is artificially inflating the share of CLEC lines that are UNEs". Therefore, Hausman and Sidak (2005) study individual data, in particular from 17 specific American CLECs. They highlight that a very small share of those CLECs have increased their share of facilities-based lines from the first quarter 2000 through the fourth quarter 2000. This result suggests that mandatory unbundling does not provide a stepping-stone for facilities-based investments.

on the basis of facilities. Service-based entry takes place when there is local loop unbundling and the entrant decides to lease access to the incumbent's local network. Facility-based entry occurs when the entrant decides to build its own local infrastructure. We assume that entry is gradual; for instance, consumers can become aware progressively of the existence of the entrant, or the perceived quality of service of the entrant can increase progressively over time.³ Then, we determine whether service-based competition and facility-based competition are substitutes or complements, that is, whether a phase of service-based competition retards or rather accelerates the development of facility-based competition.

Firms The incumbent (I) and the entrant (E) have a constant marginal cost of providing broadband services which is normalized to zero. If the entrant enters on the basis of services, it has to pay an access charge r to the incumbent, which is determined by the regulator. To simplify the analysis, we assume that the entrant bears no fixed cost when it leases the incumbent's loops.⁴ Finally, time is continuous and the time horizon is infinite, and firms maximize their discounted profits.

Profit Flows At any time, the industry structure is characterized by either monopoly, service-based competition or facility-based competition. Let π_i^j denote the profit flow of firm $i = I, E$, where $j = M, F, S$ stand for monopoly, facility-based competition and service-based competition, respectively. The net discounted profits are denoted by Π_i .

When the entrant enters the market, we assume that it builds market share progressively. For instance, prior to entry, consumers might be unaware of the existence of the entrant; after entry, the proportion might then progressively increase over time. Another interpretation would be that the consumers perceive the entrant's quality of service as lower than that of the incumbent, but the gap in perceived qualities of service decreases over time. Formally, we assume that when the entrant enters the market at date T , at each time $t \geq T$ the state of nature is given by $\phi(t - T)$, where in our two examples ϕ represents the proportion of consumers aware of the existence of the new entrant and the quality of the entrant's product, respectively.

Assumption 1. ϕ is differentiable in t , $\phi'(x) \geq 0$, and ϕ is bounded from above.

³In Section 4, we will develop these two examples.

⁴In reality, with unbundling of the local loop, entrants incur a positive entry cost which is due to co-location and order handling. However, these costs are negligible when compared to the cost of building a new infrastructure.

Assumption 1 implies that $\lim_{x \rightarrow \infty} \phi(x) = \bar{\phi}$. We assume that profit flows are continuous with respect to ϕ , however, we do not assume any a priori relation between profit flows and ϕ . Since we consider that the entrant acquires market share progressively through this process, we assume that the entrant's market share increases with ϕ .⁵ Finally, we denote $\Delta\pi_i(\phi, r) = \pi_i^F(\phi) - \pi_i^S(\phi, r)$.

Assumption 2. The profit flows are characterized with the following.

- (i) for all r and ϕ , $\partial\pi_E^S(\phi, r)/\partial r \leq 0$ and $\partial\pi_I^S(\phi, r)/\partial r \geq 0$.
- (ii) there exists \bar{r} such that for all $r \geq \bar{r}$ and ϕ , $0 \leq \pi_E^S(\phi, r) \leq \pi_E^F(\phi)$.
- (iii) for all r , we have $0 \leq \Delta\pi_E(\phi(0), r) < \Delta\pi_E(\bar{\phi}, r)$.
- (iv) $\int_0^\infty e^{-\rho x} [\pi_E^F(\phi(x)) - \pi_E^F(\phi(0))] dx \geq 0$.
- (v) $\int_0^\infty e^{-\rho x} [\pi_E^F(\phi(x)) - \pi_E^F(\bar{\phi})] dx \leq 0$.

Assumption 2(i) means that a higher access charge (weakly) hurts the entrant and benefits the incumbent; this is due to the fact that a higher access charge implies a higher perceived marginal cost for the entrant, hence, translates not only into higher access revenues but also into a cost advantage for the incumbent. Assumption 2(ii) implies that the entrant prefers facility-based competition to service-based competition for sufficiently high values of the access charge. Indeed, its perceived marginal cost is higher under service-based competition than under facility-based competition. Besides, possibilities of differentiation might be larger under facility-based competition, or the entrant might install a more efficient access technology when building its own infrastructure. Assumption 2(iii) states that the profit incentive to switch from service-based to facility-based competition is higher in the long run than at the beginning of the progressive entry process. Assumptions 2(iv) and 2(v) are satisfied for instance if π_E^F increases with ϕ .

Notice that we assume that ϕ depends only on the time spent on the market.⁶ In Section 5 we will consider an example in which market share acquisition depends on flow profits, hence, ϕ depends on the nature of competition.

Cost of building an infrastructure The cost of building a new local infrastructure is denoted by $C(t)$. We make the following assumptions.

⁵We make this assumption to clarify the exposition. Notice, however, that from a formal point of view, this is not a necessary assumption.

⁶Hence, the value of ϕ is endogenous to the entrant's decision of timing of entry.

Assumption 3.

- (i) $C'(t) \leq 0$, $C''(t) \geq 0$, and $\lim_{t \rightarrow \infty} C(t) = 0$.
- (ii) $C(0)$ is sufficiently large so that entry never happens at $t = 0$.

The investment cost declines over time due to technological progress. Since we are interested in studying how the entrant's decision to build an infrastructure is affected by the terms of service-based competition and market share acquisition, we assume away immediate facility-based entry with Assumption 3(ii). Assumptions 2(ii) and 3(i) together imply that the entrant always ends up building its own infrastructure.

The timing At the beginning of the game, the regulator chooses whether or not to unbundle the incumbent's local loop. If it chooses to unbundle the local loop, it commits to the rental price r for the loops. Then, at each time, the entrant observes the state of nature, ϕ , and decides whether to stay out of the market, to lease loops from the incumbent (if it is possible) or to build its infrastructure.

3 The Equilibrium

In this section, we determine the entrant's optimal entry date. We begin by computing the optimal date of facility-based entry when there is no unbundling of the local loop. We refer to this case with the superscript "nu". Then, we characterize the entrant's entry strategy when there is unbundling. We refer to this case with the superscript "u".

3.1 Case 1: without unbundling of the local loop

The entrant can enter only via building its own infrastructure. It chooses an adoption date, t , in order to maximize its discounted profit,

$$\Pi_E^{nu}(t) = \int_t^\infty \pi_E^F(\phi(x-t)) e^{-\rho x} dx - C(t).$$

Let us assume that $\Pi_E^{nu}(t)$ is concave in t . Then, the optimal adoption date, t^{nu} , satisfies the following first order condition

$$-\rho e^{-\rho t^{nu}} \int_0^\infty \pi_E^F(\phi(x)) e^{-\rho x} dx - C'(t^{nu}) = 0, \tag{1}$$

which can be rewritten as

$$-\pi_E^F(\phi(0))e^{-\rho t^{nu}} + \int_{t^{nu}}^{\infty} \frac{d\pi_E^F(\phi(x-t^{nu}))}{dt} e^{-\rho x} dx = C'(t^{nu}). \quad (2)$$

The entrant equates its marginal discounted facility-based revenues with the marginal investment cost. At a given date t , if its marginal investment cost is higher than its marginal revenue, the optimal decision of the entrant is to wait. If the entrant waits for a period dt , it reduces its investment cost by an amount $dC(t)$, but sacrifices some revenues. These foregone revenues are composed of two parts. First, the entrant gives up some facility-based profits during the period dt ; this corresponds to the term $\pi_E^F(\phi(0))e^{-\rho t}dt$. Second, the entrant does not accumulate market share during the period dt , which decreases its future discounted profits; this corresponds to the term $\left(\int_t^{\infty} \frac{d\pi_E^F(\phi(x-t))}{dt} e^{-\rho x} dx\right) dt$. Notice that this second term disappears if ϕ is constant.

Since $C'' > 0$, then t^{nu} is higher for a higher π_E^F ; a higher profit flow from facility-based competition implies an earlier date of facility-based entry. Similarly, if π_E^F is increasing with ϕ , then t^{nu} is higher for a higher ϕ' ; that is, if the acquisition of market share goes faster, then facility-based entry takes place earlier.

3.2 Case 2: with unbundling of the local loop

When there is unbundling of the local loop, it is a dominant strategy for the entrant to lease access to the incumbent's infrastructure, from Assumption 2(ii). As the entrant leases access to the incumbent's loops prior to building its own infrastructure, its discounted profit is given by

$$\Pi_E^u(t) = \int_0^t \pi_E^S(\phi(x), r) e^{-\rho x} dx + \int_t^{\infty} \pi_E^F(\phi(x)) e^{-\rho x} dx - C(t).$$

We assume that $\Pi_E^u(t)$ is concave in t . The optimal facility-based entry date then satisfies the first order condition,

$$-\left[\pi_E^F(\phi(t^u)) - \pi_E^S(\phi(t^u), r)\right] e^{-\rho t^u} - C'(t^u) = 0. \quad (3)$$

For a given $\phi(\cdot)$, the higher π_E^S , the later the entry date. This is due to a "replacement effect"; the entrant has less incentives to build its own infrastructure if it receives higher profits from service-based competition.

Besides, if $\Delta\pi_E(\phi, r)$ is strictly increasing (resp., decreasing) with ϕ , the higher ϕ' , the earlier (resp., later) the entrant's facility-based entry date. That is, if the entrant's market share acquisition

goes faster, it can either increase or decrease the magnitude of the replacement effect, which in turn will either retard or accelerate facility-based entry.

3.3 Service-based and facility-based competition: substitutes or complements?

We can now compare the dates of facility-based entry with and without a phase of service-based entry. The first order condition with a phase of service-based competition is given by (3), and it can be rewritten as $FOC^u = 0$, where $FOC^u = -[\pi_E^F(\phi(t^u)) - \pi_E^S(\phi(t^u), r)]e^{-\rho t^u} - C'(t^u)$. Similarly, the first order condition without a phase of service-based competition, given by (1), can be written as $FOC^{nu} = 0$. To compare the date of facility-based entry with and without unbundling, it helps to rewrite FOC^u as follows:

$$FOC^u = FOC^{nu} + \underbrace{\pi_E^S(\phi(t), r)e^{-\rho t}}_{(I)} + \underbrace{\Sigma(t)}_{(II)}, \quad (4)$$

where

$$\Sigma(t) = \rho e^{-\rho t} \left(\int_0^t e^{-\rho x} (\pi_E^F(\phi(x)) - \pi_E^F(\phi(t))) dx + \int_t^\infty e^{-\rho x} (\pi_E^F(\phi(x)) - \pi_E^F(\phi(t))) dx \right).$$

Notice that the date of facility-based entry is later with a phase of service-based entry if and only if $FOC^u > FOC^{nu}$. Whether $FOC^u > FOC^{nu}$ or $FOC^u < FOC^{nu}$ depends on the sign of the sum of two terms, term (I) and term (II) in equation (4). Term (I) represents the standard "replacement effect". It is positive, hence it tends to retard facility-based entry. The second term, term (II), corresponds to a "ladder of investment" or "stepping stone" effect. It represents the effect of the entrant's progressive acquisition of market share on its incentives to invest in a proprietary network, and it is equal to zero if ϕ is constant. The conventional wisdom in the telecoms industry is that this "stepping stone" effect accelerates facility-based entry, hence, that it is negative. However, the following proposition shows that this conventional wisdom might be wrong and that a progressive accumulation of market share in a phase of service-based competition might actually delay the entrant's investment.

Proposition 1 *The stepping stone effect, $\Sigma(t)$, can be either positive or negative. It is positive for sufficiently low values of t , and negative for sufficiently high values of t .*

Proof. The sign of $\Sigma(t)$ is the sign of $A(t)$, where

$$A(t) = \int_0^t e^{-\rho x} (\pi_E^F(\phi(x)) - \pi_E^F(\phi(t))) dx + \int_t^\infty e^{-\rho x} (\pi_E^F(\phi(x)) - \pi_E^F(\phi(t))) dx. \quad (5)$$

From Assumption 2(iv), we have $\lim_{t \rightarrow 0} A(t) > 0$, and from Assumption 2(v), we have $\lim_{t \rightarrow \infty} A(t) < 0$. Therefore, the sign of A changes at least one time. By continuity of $A(t)$, A is positive when t is sufficiently small, whereas A is negative when t is sufficiently high. ■

Proposition 1 shows that the stepping stone effect can either accelerate or retard facility-based entry. The following remark introduces an additional assumption to give a simple condition under which facility-based entry is accelerated.

Remark 1 *If $\pi_E^F(\phi)$ is strictly increasing with ϕ , there is a unique \tilde{t} such that the stepping stone effect delays facility-based entry if $t^{nu} \leq \tilde{t}$, and accelerates facility-based entry otherwise.*

Proof. If $\pi_E^F(\phi)$ is increasing with ϕ , $A(t)$ is decreasing as

$$\frac{dA(t)}{dt} = - \int_0^\infty \phi'(t) \frac{d\pi_E^F(\phi(t))}{d\phi} e^{-\rho x} dx \leq 0,$$

where A is given by (5). Besides, we have $\lim_{t \rightarrow 0} A(t) > 0$ and $\lim_{t \rightarrow \infty} A(t) < 0$. Therefore, A is positive for low values of t and negative otherwise. Since the sign of $\Sigma(t)$ is the sign of $A(t)$, it follows that there is a unique t , which we denote by \tilde{t} , such that $\Sigma(t) \geq 0$ for all $t \in [0, \tilde{t}]$, and $\Sigma(t) \leq 0$ for all $t > \tilde{t}$. ■

The conventional wisdom states that a phase of service-based competition can be a complement to facility-based competition, because it allows the entrant to increase progressively its market share. Our result shows that this idea is shortsighted. If facility-based competition is a long-term perspective, that is, t^{nu} is high, it proves correct. However, if there is potential facility-based entry in the short or medium term, this "stepping stone" effect in the phase of service-based competition might actually retard facility-based competition. The intuition is that the entrant can have incentives to extend the phase of service-based competition to accumulate more market share, which delays facility-based entry.

Indeed, consider that the entrant retards its facility-based entry from date t to date $t + dt$. The stepping stone effect (that is, term $\Sigma(t)$) is affected as follows. First, the entrant will not capture the gains associated to the stepping stone effect during the period dt ; compared to the no- unbundling benchmark, the entrant loses some profit proportional to $(\pi_E^F(\phi(t)) - \pi_E^F(\phi(0))) dt$.

Second, during this period dt , the entrant will accumulate more market share, therefore, after the period, the gains associated to the stepping stone effect will be higher for the rest of time. Notice that the first effect gives an incentive to adopt earlier, whereas the second effect gives an incentive to adopt later. When t is low, the magnitude of first effect is very small, hence, the second effect dominates, and the stepping stone has the unconventional effect. Whereas, if t is high, the magnitude of the first effect is high, hence, it dominates the second effect, and the stepping stone has the conventional effect.

If the stepping stone effect is positive, that is, if it retards facility-based entry, then both the stepping stone effect and the replacement effect delay the date of facility-based entry. In this case, service-based competition and facility-based competition are unambiguously substitutes. If the stepping stone effect is negative, then the phase of service-based competition can either accelerate (if $\pi_E^S(\phi(t^{nu}), r) e^{-\rho t^{nu}} + \Sigma(t^{nu}) \leq 0$) or retard (if $\pi_E^S(\phi(t^{nu}), r) e^{-\rho t^{nu}} + \Sigma(t^{nu}) \geq 0$) facility-based entry. Service-based and facility-based competition can be either substitutes or complements.

Proposition 2 *When the optimal facility-based entry date without unbundling, t^{nu} , is sufficiently high (resp., small), then a phase of service-based competition accelerates (resp., delays) facility-based entry.*

Proof. Equation (4) can be rewritten as follows:

$$FOC^u = FOC^{nu} + e^{-\rho t} \left[\pi_E^S(\phi(t), r) - \pi_E^F(\phi(t)) + \rho \int_t^\infty e^{-\rho x} (\pi_E^F(\phi(x))) dx \right].$$

This equation shows that the effect of an unbundling policy on the date of facility-based entry depends on the sign of $\pi_E^S(\phi(t), r) - \pi_E^F(\phi(t)) + \rho \int_t^\infty e^{-\rho x} (\pi_E^F(\phi(x))) dx$. Let

$$B(t) = \pi_E^S(\phi(t), r) - \pi_E^F(\phi(t)) + \rho \int_t^\infty e^{-\rho x} (\pi_E^F(\phi(x))) dx.$$

Under Assumption 2(iv), we have

$$\lim_{t \rightarrow 0} B(t) = \int_0^\infty e^{-\rho x} [\pi_E^F(\phi(x)) - \pi_E^F(\phi(0)) + \pi_E^S(\phi(0), r)] dx \geq 0,$$

and under Assumption 2(iii), we have

$$\lim_{t \rightarrow \infty} B(t) = -\Delta\pi_E(\bar{\phi}, r) \leq 0.$$

Therefore, the sign of $B(t)$ changes at least once. Since $B(t)$ is continuous in t , this shows that unbundling accelerates (resp., delays) facility-based entry when t^{nu} is sufficiently high (resp., sufficiently small). ■

Remark 2 *If $\Delta\pi_E(\phi, r)$ is strictly increasing with ϕ , there is a unique \bar{t} such that for all $t^{nu} \leq \bar{t}$, unbundling delays facility-based competition, and accelerates facility-based competition otherwise.*

Proof. If $\Delta\pi_E(\phi(t), r)$ is strictly increasing with ϕ , then $B(t)$ is strictly decreasing with t (notice that it is a sufficient but not a necessary condition). Since $B(0) \geq 0$ and $\lim_{t \rightarrow \infty} B(t) \leq 0$, there is a unique \bar{t} such that $B(\bar{t}) = 0$. ■

The Proposition and the follow-up Remark show that by incorporating a stepping stone/ladder of investment feature in a model of infrastructure investment, the phase of service-based competition and facility-based competition might be substitutes, when the date of facility-based entry without unbundling is low. However, if the perspectives of facility-based entry are tiny, that is, if facility-based entry would occur late without a phase of service-based competition, then service-based competition and facility-based competition are complements; that is, unbundling of the local loop accelerates the entrant's infrastructure development.

Finally, notice that the stepping stone effect is independent of the access charge, and does not depend on service-based profits. In other words, to the extent that ϕ does not depend on r , the regulation of the access charge does not affect the process by which the entrant accumulates market share.⁷ Since the access charge affects only the replacement effect, and the magnitude of the replacement effect decreases with r , the regulator should set a high access charge to accelerate facility-based entry.

4 Two Examples

In this section we propose two examples that fit with our Assumptions 1-3. First, we build a model of Cournot competition with quality differentiation à la Katz and Shapiro (1985). We assume that the quality of the entrant's service is increasing over time and converging to the incumbent's quality level. This might be due to a "learning by doing" effect (the quality of service increases with the time spent in the market). Second, we introduce a simplified version of Grossman and Shapiro (1984)'s model of Hotelling competition model with uninformed consumers. In this example, we

⁷Notice that the entrant's market share can depend on r , even if ϕ does not depend on r .

consider that some consumers are unaware of the existence of the entrant, when it enters the market, but that the proportion of uninformed consumers converges to zero over time.

In both examples, we assume that the investment cost function has the following form, which satisfies Assumption 3(i): $C(t) = \gamma e^{-\beta t}$, where $\gamma > 0$ and $\beta > 0$. We assume that γ is sufficiently high so that Assumption 3(ii) is satisfied.

4.1 A model of Cournot competition with quality differentiation

4.1.1 The model

We use the same setting as Katz and Shapiro (1985). The indirect utility of a consumer of type τ is $U = \tau + \phi_i - p_i$, where ϕ_i and p_i denote the quality and price of firm i , with $i = I, E$. Consumers' types are uniformly distributed over $[0, 1]$. Firms compete with respect to quantities and as in the main setting we normalize marginal costs to zero. We assume that $0 < r \leq (1 - \phi_I)/2$. The lower bound for the access charge means that firm E has incentives to build its own infrastructure in the long run,⁸ whereas the upper bound $r \leq (1 - \phi_I)/2$ implies that firm E has a positive demand even if its quality is equal to zero.

If firm I and firm E are both active in the market, their quality-adjusted prices are the same, that is, we have $p_I - \phi_I = p_E - \phi_E = \tilde{p}$. The marginal consumer is defined by $\tau = \tilde{p}$, hence from the uniform distribution assumption, the total demand is given by $Q = q_I + q_E = 1 - \tilde{p}$. Each firm $i = I, E$ maximizes its profit flow with respect to q_i , with $p_E = 1 - (q_I + q_E) + \phi_E$ and $p_I = 1 - (q_I + q_E) + \phi_I$.⁹ Solving for the Nash equilibrium, we obtain the profit flows under service-based and facility-based competition.

Under service-based competition, the equilibrium profit flows are as follows:

$$\pi_I^S(r, \phi_E) = \frac{(1 + 2\phi_I - \phi_E)^2}{9} + \frac{(5 - 5r + \phi_I + 4\phi_E)}{9}r,$$

and

$$\pi_E^S(r, \phi_E) = \frac{(1 + 2\phi_E - \phi_I - 2r)^2}{9}.$$

In equilibrium, the entrant's market share is:

⁸The only incentive for firm E to build its own infrastructure is to avoid paying the access charge. We do not assume any other advantage of facility-based competition over service-based competition for the entrant.

⁹To simplify the analysis, we assume that firms set prices to maximize their current flow profits. In other words, firms are myopic when setting prices. Another interpretation is that we focus on the short-run price equilibrium.

$$\frac{1 + 2\phi_E - \phi_I - 2r}{2 + \phi_E + \phi_I - r},$$

and it is increasing with ϕ_E . Under facility-based competition, the equilibrium profit flows are as follows:

$$\pi_I^F(\phi_E) = \frac{(1 + 2\phi_I - \phi_E)^2}{9},$$

and

$$\pi_E^F(\phi_E) = \frac{(1 + 2\phi_E - \phi_I)^2}{9}.$$

We assume that $\phi_E \equiv \phi_E(x)$, where x represents the time the entrant has spent in the market, and we assume that $\phi_E(\cdot)$ satisfies Assumption 1. Finally, we assume that $\phi_E(0) \geq 0$, and $\lim_{t \rightarrow \infty} \phi_E(t) = \phi_I$. It can be easily checked that with this setting, Assumptions 2(i)-2(v) are satisfied.¹⁰

4.1.2 A numerical application

In this section we assume that the entrant's quality improvement $\phi(x)$ is given by:

$$\phi(x) = \begin{cases} ax & \text{if } 0 \leq x \leq \phi_I/a \\ \phi_I & \text{otherwise} \end{cases},$$

where x represents the time firm E has spent on the market, and a represents a parameter which can be interpreted as the "speed" of the learning-by-doing process. To illustrate our results, we revert to numerical applications. We set $\beta = 1/10$, $\gamma = 3$, $\phi_I = 3/4$, $\rho = 5/100$, and $r = 1/10$. Figure 1 below shows the value of the stepping stone effect as a function of the date of facility-based entry in the no-unbundling regime, t^{nu} . As the figure shows, the stepping stone effect is positive (that is, it retards facility-based entry compared to the no-unbundling regime) for low values of t^{nu} , whereas it is negative (that is, it accelerates facility-based entry) for high values of t^{nu} . If the speed of the learning-by-doing process is higher, that is, a is higher, the magnitude of the stepping stone effect is higher.

¹⁰ Assumptions 2(iv) and 2(v) are satisfied as π_E^F increases with ϕ .

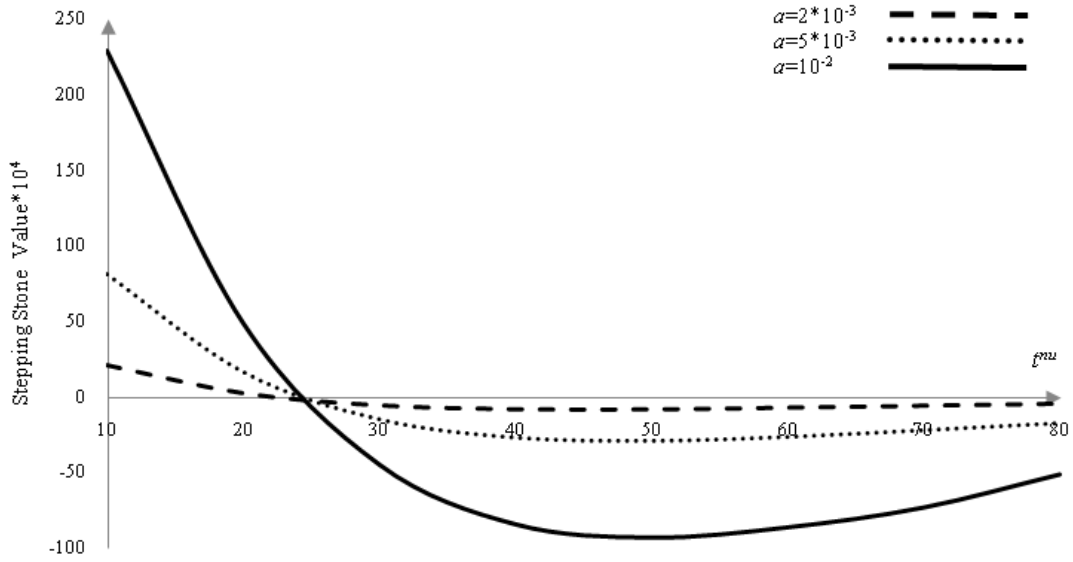


Figure 1: Value of the stepping stone effect for different values of a .

Figure 2 shows how the date of facility-based entry under the no-unbundling and the unbundling regimes vary with the speed a . The figure shows that under both regimes the date of facility-based entry decreases with the speed of the learning-by-doing process. That is, the entrant builds its own infrastructure earlier if it acquires market share faster (through quality improvements). Besides, an unbundling policy accelerates facility-based entry if a is not too high, and retards facility-based entry otherwise. This result suggests that unbundling might be a relevant policy to facilitate entrant's investment, if the speed of market share acquisition is low.

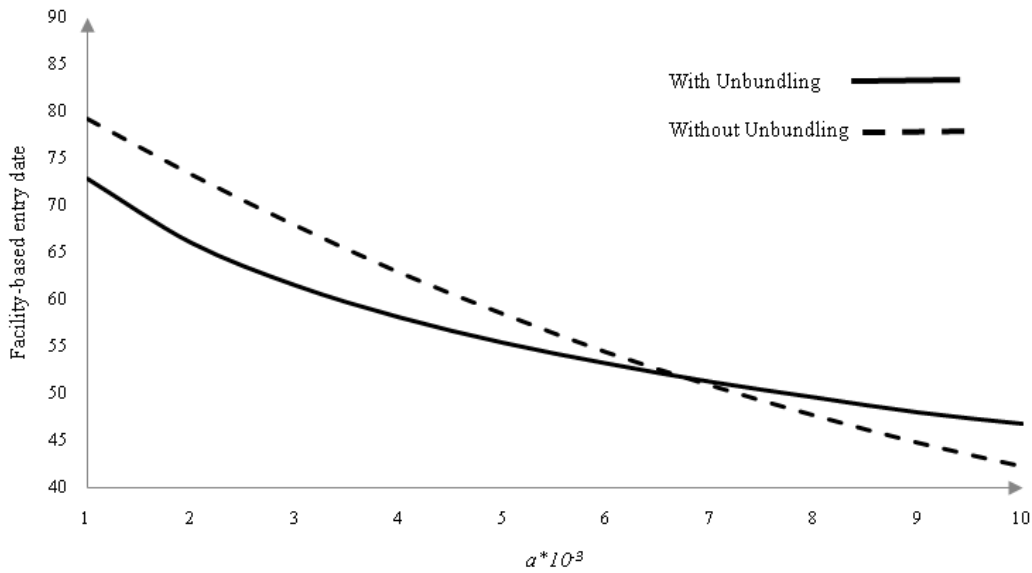


Figure 2: Facility-based entry date as a function of a .

Finally, Figure 3 shows the impact of the unbundling regime on the date of facility-based entry for different values of a and γ . One can see that if the cost of infrastructure γ becomes higher, there is a larger range of values of the parameter a such that an unbundling policy accelerates facility-based entry.

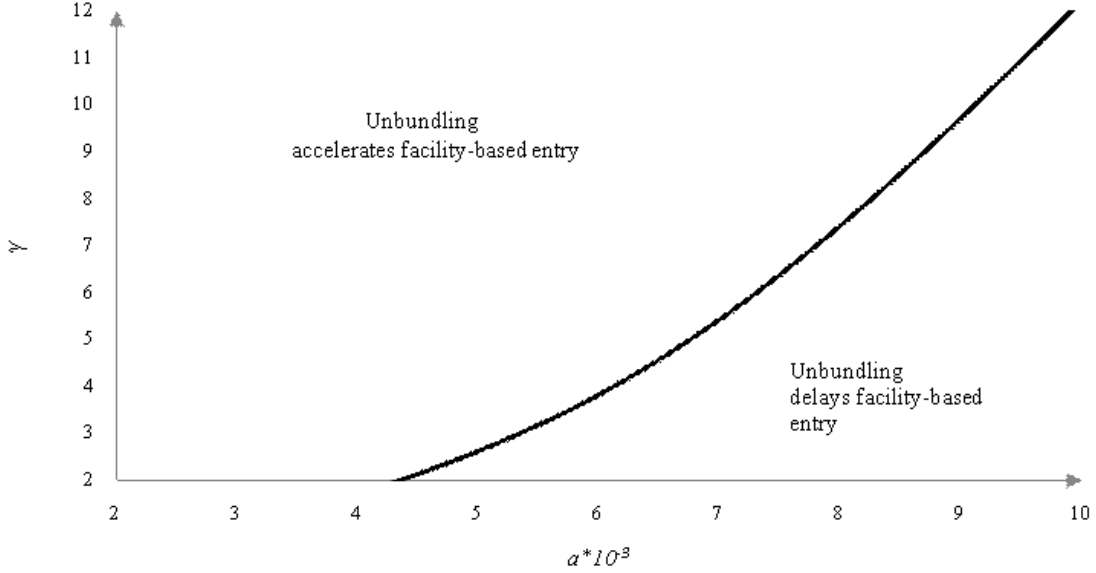


Figure 3: Impact of unbundling on the date of facility-based entry.

4.2 A model of Hotelling competition with uninformed consumers

We use a simplified version of Grossman and Shapiro (1984)’s model (see: Tirole, 1988, Chapter 7). A mass 1 of consumers is uniformly distributed over the segment $[0, 1]$. While all consumers are informed of the existence of firm I , only a proportion $\phi \in [0, 1]$ is informed of the existence of firm E .

We assume that firm I is located at the extreme left (at $x_I = 0$), while firm E is located at the extreme right (at $x_E = 1$). The utility of a consumer of type $y \in [0, 1]$ is $U_I = v_I - p_I - by$ if he subscribes to firm I , where it is equal to $U_E = v_E - p_E - b(1 - y)$ if he subscribes to firm E , where b denotes the transportation cost, v_i is a fixed utility derived from the consumption of firm i ’s service and p_i is the price charged by firm i , with $i = I, E$.

We assume that under service-based competition, we have $v_I = v_E = v$, whereas under facility-based competition, we have $v_I = v$ and $v_E = v + d$, where $d \in (0, 4b - v]$. To simplify the analysis,

we assume that the access charge is set at marginal cost, that is, $r = 0$. Finally we assume that $b \in [v/4, v/2]$. The lower bound for b implies that an equilibrium in pure strategies exists. The upper bound for b implies that all uninformed consumers subscribe to firm I even if firm I sets the monopoly price.

If firm E is active, there are two strategic configurations, depending on whether firm I decides to compete for informed consumers with firm E or not. Indeed, whenever there are uninformed consumers, firm I faces a trade-off. On the one hand, it can set a high price to exploit its captive customers, but it would then obtain a small share of informed consumers. On the other hand, it could set a low price to compete with firm E for informed consumers, but then it would not milk his captive consumers. We find that there is a threshold value of ϕ , which we denote by $\bar{\phi}^\tau$, where $\tau = S, F$, such that firm I chooses the monopolistic strategy if $\phi \leq \bar{\phi}^\tau$, and chooses the aggressive strategy otherwise, with

$$\bar{\phi}^S = \frac{4b}{3v - 2b} \text{ and } \bar{\phi}^F = \frac{4b}{3v + d - 2b}.$$

Under service-based competition, the equilibrium profit flows are as follows:

$$\pi_I^S(\phi) = \begin{cases} v - b & \phi = 0 \\ \frac{b(4v + \phi v) - 4b^2 - \phi v^2}{4b} & \text{si } 0 < \phi \leq \bar{\phi}^S, \\ \frac{b(4 - \phi)^2}{18\phi} & \bar{\phi}^S < \phi \leq 1 \end{cases},$$

and

$$\pi_E^S(\phi) = \begin{cases} 0 & \phi = 0 \\ \frac{\phi v^2}{8b} & \text{si } 0 < \phi \leq \bar{\phi}^S, \\ \frac{b(2 + \phi)^2}{18\phi} & \bar{\phi}^S < \phi \leq 1 \end{cases},$$

whereas under facility-based competition, the equilibrium profit flows are as follows:

$$\pi_I^F(\phi) = \begin{cases} v - b & \phi = 0 \\ \frac{(v - b)(4b - \phi(d + v))}{4b} & \text{si } 0 < \phi \leq \bar{\phi}^F, \\ \frac{(d\phi - b(4 - \phi))^2}{18b\phi} & \bar{\phi}^F < \phi \leq 1 \end{cases},$$

and

$$\pi_E^F(\phi) = \begin{cases} 0 & \phi = 0 \\ \frac{\phi(d + v)^2}{8b} & \text{si } 0 < \phi \leq \bar{\phi}^F, \\ \frac{(d\phi + b(2 + \phi))^2}{18b\phi} & \bar{\phi}^F < \phi \leq 1 \end{cases}.$$

Notice that, in contrast with the first example, in this setting the entrant's profit flow under service-based competition is not monotone with respect to ϕ . If $\phi \leq \bar{\phi}^S$, the entrant's profit flow increases with ϕ , as a higher proportion of consumers becomes informed of the existence of the entrant and firm I does not react to entry. But for $\phi > \bar{\phi}^S$, the entrant's profit is decreasing with ϕ , because firm I switches from the monopoly to the aggressive strategy, which harms the entrant. Under facility-based competition, the entrant's profit flow is increasing with ϕ for $\phi \leq \bar{\phi}^F$, and it can be either increasing or decreasing with ϕ for $\phi > \bar{\phi}^F$.

We assume that $\phi \equiv \phi(x)$, where x represents the time the entrant has spent on the market and $\phi(\cdot)$ satisfies Assumption 1. We assume that $\phi(0) \geq 0$, and $\lim_{t \rightarrow \infty} \phi(t) = 1$.

It can be checked that Assumption 2(i), 2(ii), 2(iii) and 3(i) are satisfied. In this setting, the entrant's profit flow does not always increase with ϕ , however, if $\phi(0) = 0$ and if profit flows are positive, Assumption 2(iv) is satisfied. Finally, if ρ is sufficiently high, then Assumption 2(v) is satisfied, and if γ is sufficiently high, Assumption 3(ii) is also satisfied.

In equilibrium, the entrant's market share is:

ϕ if firm I chooses the monopolistic strategy,

and

$$\frac{d\phi + b(2 + \phi)}{6b} \text{ if firm } I \text{ chooses the aggressive strategy.}$$

This market share is increasing with ϕ .

The main results being similar to the previous case for a large range of values of the parameters, we do not provide a numerical application in this setting.

5 "Endogenous" market share acquisition

So far, we have assumed that the acquisition of market share for the entrant depends only on the time spent in the market. However, we could assume more realistically that the acquisition of market share - through quality improvements, information of consumers, etc. - depends on the current profits of the entrant. For instance, Cave (2006) argues that new entrants' investments depend on their current profits and/or their current customer base.¹¹ In this section we extend our

¹¹"[Entrants] may have to acquire capital assets progressively, as they acquire customers and revenues" (Cave, 2006, p. 224).

model of Cournot competition with quality differentiation of Section 4, by assuming that the speed of market share acquisition depends on the entrant's customer base.¹² Interestingly, we show that a small access charge could either retard or accelerate facility-based entry.

If the entrant has entered the market, we now assume that its quality of service evolves according to the following process:

$$\frac{d\phi_E}{dt} = \begin{cases} \lambda q_E & \text{if } \phi_E \leq \phi_I \\ 0 & \text{otherwise} \end{cases}. \quad (6)$$

In other words, there is a "learning by doing" effect: the entrant's quality improves faster if its customer base (hence, its production) is larger. In order to simplify the resolution, we still assume that the firms maximize their current profit flows.

The solutions of the differential equation (6) are as follows. If there is no unbundling, we have

$$\phi_E^{nu}(x) = \begin{cases} (1/2)(1 - \phi_I)(e^{(2\lambda x)/3} - 1) & \text{if } 0 \leq \phi_E^{nu}(x) \leq \phi_I \\ \phi_I & \text{if } \phi_E^{nu}(x) > \phi_I \end{cases}, \quad (7)$$

where x represents the time spent in the market. If there is a phase of service-based competition, and facility-based entry takes place at date t , we have

$$\phi_E^u(x, t, r) = \begin{cases} (1/2)(1 - \phi_I - 2r)(e^{(2\lambda x)/3} - 1) & \text{if } 0 \leq x \leq t \\ \psi(x, t, r) & \text{if } x > t \text{ and } \phi_E^u(x, t, r) \leq \phi_I \\ \phi_I & \text{if } \phi_E^u(x, t, r) > \phi_I \end{cases}, \quad (8)$$

where $\psi(x, t, r) = (1/2)e^{-(2\lambda t)/3}(2re^{(2\lambda x)/3} + (\phi_I - 1)e^{(2\lambda t)/3} + (1 - \phi_I - 2r)e^{(2\lambda(t+x))/3})$.

When there is no unbundling, the date of facility-based entry is given by (2), with $\phi = \phi_E^{nu}(x)$, and $\phi_E^{nu}(x)$ is given by (7). When there is unbundling of the local loop, it is a dominant strategy for the entrant to lease access to the incumbent's infrastructure, by Assumption 2(ii). As the entrant leases access to the incumbent's loops prior to building its own infrastructure, its discounted profit is given by

$$\Pi_E^u(t) = \int_0^t \pi_E^S(\phi_E^u(x, t, r), r) e^{-\rho x} dx + \int_t^\infty \pi_E^F(\phi_E^u(x, t, r)) e^{-\rho x} dx - C(t),$$

where $\phi_E^u(x, t, r)$ is given by (8). We assume that $\Pi_E^u(t)$ is concave in t , therefore, the optimal

¹²With our second model of Hotelling competition with uninformed consumer, we could assume that the speed of the word of mouth process depends on the number of informed consumers.

facility-based entry date, t^u , satisfies the first order condition,

$$- [\pi_E^F(\phi_E^u(t^{u*}, t^{u*}, r)) - \pi_E^S(\phi_E^u(t^{u*}, t^{u*}, r), r)] e^{-\rho t^{u*}} + \int_{t^{u*}}^{\infty} \frac{d}{dt} \pi_E^F(\phi_E^u(x, t^{u*}, r)) e^{-\rho x} dx - C'(t^{u*}) = 0. \quad (9)$$

Notice that, compared to the first order condition in the baseline model, (3), the first order condition (9) contains an additional term, $(\int_{t^{u*}}^{\infty} \frac{d}{dt} \pi_E^F(\phi_E^u(x, t^{u*}, r)) e^{-\rho x} dx)$. The intuition is that the quantity produced during a period dt is smaller under service-based competition than under facility-based competition, as the entrant has to pay the access charge under service-based competition. Therefore, quality improvements are faster under facility-based than under service-based competition. It follows that, if the entrant delays its facility-based entry for a period dt , its quality improvements will be lower during this period, which affects all its future profit flows until the stationary quality level is reached.

Interestingly enough, an increase of the access charge has an ambiguous effect. First, the access charge has a direct effect. If ϕ_E^u is given and the access charge r increases, the replacement effect is softened, as the entrant makes lower profits under service-based competition. This tends to accelerate facility-based entry, as in the baseline model. Second, the access charge has two indirect effect through the quality improvement process, ϕ_E^u , which are absent in the baseline model. Indeed, if the access charge increases, the quality improvements slow down, hence the quality level at a given date, $\phi_E^u(t^u, t^u, r)$, decreases. This affects the profit incentive of the entrant, $\Delta\pi_E$, which is reduced.¹³ This tends to retard facility-based entry. Finally, as ϕ_E^u decreases, the term $(\int_{t^{u*}}^{\infty} \frac{d}{dt} \pi_E^F(\phi_E^u(x, t^u, r)) e^{-\rho x} dx)$, which represents the loss in quality acquisition associated to waiting, is decreased.¹⁴ This tends to accelerate facility-based entry.

Figure 4 below shows the date of facility-based entry as a function of the parameter λ in (6).¹⁵ When the date of facility-based entry with a phase of service-based competition is small, a decrease of the access charge delays facility-based entry, which corresponds to the expected effect. However, if the date of facility-based entry is high, a decrease of the access charge has the opposite effect; it accelerates facility-based entry. This is due to the fact the stepping stone effect accelerates facility-based entry when the date of facility-based entry is high. In this case, setting a low access charge strengthens the stepping stone effect and accelerates the entrant's investment.

¹³Indeed, in this setting, $\Delta\pi_E$ is an increasing function of ϕ_E^u .

¹⁴This is due to the fact that $\partial^2 \pi_E^F / \partial r \partial \phi_E^u \leq 0$ in our setting.

¹⁵We set $\phi_I = 3/4$, $\rho = 5/100$ and $r = 1/10$.

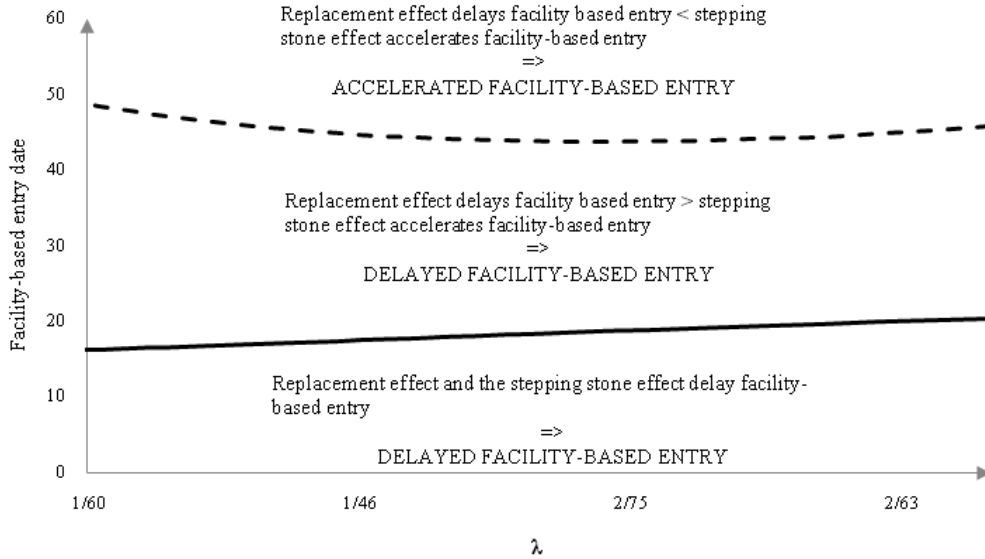


Figure 4: Impact of a decrease of the access charge r on the replacement effect, the stepping stone effect and the facility-based entry.

6 Conclusion

The question we addressed in this paper is how service-based competition affects an entrant's incentives to invest in an infrastructure, when the entrant steps in the market progressively. The conventional wisdom - the so-called "stepping stone" or "ladder of investment" arguments - states that a phase of service-based competition accelerates facility-based entry because it allows the entrant to build market share progressively, enhancing its investment incentives.

We show that this conventional wisdom might be wrong. When facility-based entry is a short-term possibility, the "stepping stone" effect by which the entrant accumulate market share does not accelerate but rather delay the entrant's investment. However, if the market share acquisition is slow or if facility-based entry is a long-term perspective, then the phase of service-based competition accelerates facility-based entry. Finally, we presented an extension in which the speed of market share acquisition depends on the quantities sold by the entrant. In this extension, we showed that a decrease of the access charge does not necessarily retard facility-based entry as expected traditionally. Indeed, while a decrease of the access charge always leads to an increase of the replacement effect, it also leads to a decrease the stepping stone effect. Therefore, if the date of facility-based entry without a phase of service-based competition is high enough, a decrease of the access charge can accelerate facility-based entry.

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