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# Access Regulation and Welfare

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**Abstract:** In a 2006 paper, Graeme Guthrie underlined that "[T]he impact of access price level on investment is not yet fully understood" and that "even less is known about the overall impact on welfare" (Guthrie 2006, p. 965). Although important progress has been made on the former issue, the latter remains largely underinvestigated. This paper contributes to addressing this question by analyzing the optimal access price in different investment games. Our main findings are as follows: 1. When only one firm can invest and when only service-based competition is feasible, the optimal access price is such that the flat part is as high as possible and the variable part equals the marginal cost. 2. When several firms can invest, the optimal access price is such that the flat part is as high as possible and the variable part is higher than the marginal cost. Hence, the optimal variable part is lower when only service-based competition is possible than when several firms can invest, although there is too much duplication in the latter case. This result arises because the variable part determines both private incentives to invest and to duplicate and the extent to which investment and duplication are socially desirable.

**Keywords:** Access regulation; Infrastructure investment; Welfare.

**JEL Classification Numbers:** L13, L43, L51.

# 1. Introduction

Access regulation – i.e. the requirement for the firms that own essential facilities to provide access to the other firms at a regulated price – is a key instrument for promoting competition in network industries. It is generally accepted that this regulation facilitates the entry of new firms and strengthens the intensity of competition. As maintaining and developing networks requires significant investments, it is also necessary to consider the impact of access regulation on the incentives to invest. Regardless of the network industry concerned, incumbent firms must invest heavily to maintain, expand, and improve the historical infrastructures. In some network industries, there is also the issue of bypass; For instance in telecommunications, the development of a certain degree of "facilities-based competition" is usually regarded as desirable[1]. Finally, it is sometimes necessary to roll out new infrastructures (e.g. fiber-optic telecommunications networks). In this paper we therefore analyze the impact of access regulation on infrastructure investment.

In a 2006 paper, Graeme Guthrie underlined that "[T]he impact of access price level on investment is not yet fully understood" and that "even less is known about the overall impact on welfare" [1]. Although important progress has been made on the former issue, the latter remains largely underinvestigated. This paper contributes to addressing this question by analyzing the optimal access price – linear and two-part tariff – in different investment games: investment in a new infrastructure when only service-based competition is possible; bypass investment when an incumbent has already build an infrastructure; competition for rolling out new infrastructures[2].

The outline of the paper is as follows. In Section 2, we review the theoretical literature on access regulation and infrastructure investment[3]. In Section 3, we present the basic assumptions of our model. We analyze the optimal access price in sections 4, 5 and 6. In Section 4, we focus on an case where an incumbent firm can invest to build a new infrastructure, and where only service-based competition is feasible. In Section 5, we analyze a case where an entrant can access or bypass the infrastructure previously build by an incumbent. In Section 6, the consider the case where two firms are competiting for rolling out a new infrastructure.

# 2. Literature review

Within the theoretical literature on access regulation and infrastructure investment, one can distinguish between three types of studies: The papers where it is assumed that only an incumbent firm can invest, and that only service-based competition is possible ("literature on service-based competition"); The papers focusing on the decision

[1]"Facilities-based competition" means competition among several firms that have their own physical infrastructure. In contrast, "service-based competition" refers to situations where only one firm (usually the incumbent) has an infrastructure.

[2]Like most previous studies on access regulation and infrastructure investment, our paper focuses on one-way access and on the case where there is only one vertically integrated firm. See [2] on two-way access and investment, and [3] on access regulation when there are several vertically integrated firms.

[3]See [4], pp. 568-571 for a review of the empirical studies.

of an entrant to access or to bypass an existing infrastructure ("literature on access or bypass?"); The papers dealing with situations where several firms can build a new infrastructure ("literature on competition for rolling out new infrastructures"). This section reviews this literature, and underlines that relatively little attention has been paid to the question of the optimal access price.

## 2.1. Service-based competition

The literature on service-based competition (SBC) assumes that one firm (the incumbent) can invest to build a new infrastructure or to improve the existing one, and that one or several other firms (the entrants) access the infrastructure. Intuitively, in this framework, the regulator has to tradeoff between "static efficiency" and investment: On the one hand lowering the access price will reduce the retail prices (higher static efficiency); On the other hand, it will probably reduce the profitability of investment, and hence the incentives to invest.

The first theoretical investigations on access regulation and infrastructure investment under SBC confirm this intuition. In particular, [5] and [6] show that a regulated access price that equals marginal cost reduces investment by the incumbent in comparison with the (higher) unregulated access price. They also underline that access regulation may increase the likelihood of foreclosure. In other words, access regulation does not always reach its goal: instead of strengthening competition, access regulation may result in a monopoly. [7] shows that the lower is the access price, the lower is the incumbent's investment in quality improvement, and the higher is the investment in cost-reduction.

The impact of access regulation on welfare is analyzed explicitly in [5] , [6] and [7]. However, the first two papers only provide a comparison between two extreme cases (unregulated access price and access price set at marginal cost by the regulator) and are not intended to determine whether there is an optimal balance between encouraging competition and preserving the incumbent's incentives to invest. [7] pays more attention to this issue, and determines an optimal tradeoff between increasing the intensity of competition, and providing incentives for cost reduction and quality improvement.

The relationship between access price regulation and welfare has been more extensively analyzed in some recent studies. [8] examines the effect of different regulatory regimes (fully distributed costs, regulatory holiday, risk-sharing and long run incremental costs regulation) on consumer surplus in a contex of uncertainty on consumers' willingness to pay. Interestingly, the different regimes lead to different tradeoffs between investment and competitive intensity. Finally, the authors show that risk-sharing is the most efficient regulation followed by fully distributed costs, regulatory holiday and long run incremental costs regulation. [9] also analyzes the impact of access price regulation on welfare under SBC. It focuses on how and to what extent two-part tariffs can solve the "dynamic consistency problem" (the fact that "[b]efore the network is deployed, it is socially optimal to set high access tariffs to promote investment" and that "once the network is deployed, it is socially optimal to set the access tariff to promote competition in the retail market".[9], p. 323). It this model, the flat part of the access price appears as an efficient tool to promote investment since it is not subject to the dynamic consistency problem. However, it is not always possible to induce investment with a purely flat access price and a positive variable ( "usage-based" or "per unit") charge may be necessary, although it is subject to the dynamic consistency problem.

## 2.2. Access or bypass

Focusing on the impact of access regulation on the incumbent's incentives to invest when only service-based competition is relevant in network industries where infrastructures are pure essential facilities[4]. However, in some other network industries such as telecommunications, facilities-based competition (FBC) is feasible and often considered as desirable. In this context, access regulation raises another issue: How does it affect the entrants' incentives to build their own infrastructure, i.e. to bypass the incumbent's network? In other words, it is necessary to study the impact of access regulation not only on the incentives to invest of the firm subject to this regulation (the incumbent) but also on the incentives to invest of the firms that benefit from this regulation (the entrants).

Intuitively, the lower is the access price, the lower are the incentives to bypass because any decrease in the access price increases the profit earned by an entrant when he decides to access the incumbent's network. This first intuition is supported by [10]: If the rationale behind the entrants' infrastructure investment is a "build-or-buy" strategy, then lowering the access price reduces the incentives to bypass because it makes the option "buy" relatively more attractive than the option "build"[5].

The theory of the ladder of investment [11] argues, however, that FBC is facilitated by a prior development of SBC. This theory is based on the idea that entry is necessarily progressive: Before making a massive and largely irreversible investment to roll out their own infrastructure, the entrants have to start with resale-based (or service-based) entry in order to gain information (e.g. on demand and operating costs), to establish their reputation, and to build up a customer base[6]. However, the theory of the ladder of investment does not put into question the existence of a substitutability relationship between SBC and FBC once SBC is established. Indeed, [11] underlines that increasing the access price over time is necessary to encourage the entrants to "climb the ladder", i.e. to build their own infrastructure[7].

The literature on access or bypass assumes that FBC is ultimately socially desirable,

[4]For example, it is not possible to duplicate gas or electricity distribution networks.

[5]It should be noted that low access prices do not always result from regulation. As emphasized by [10], the incumbent may set a low access price in order to delay the deployment of competing infrastructures.

[6]See [12] for a critical reading of this theory.

[7]The principle of the ladder of investment has been modeled by [13] and [14]. [13] points out that the assumption of complementarity between SBC and FBC is satisfied only under restrictive conditions. [14] highlights that the transition from SBC to FBC requires an increase in the regulated access price and that a regulatory moratorium or "sunset clause" is inadequate (this result was also obtained by [10]). It also points out that if several operators enter the market sequentially, discrimination in access prices is necessary.

and focuses on how to regulate the access price to promote it. In this paper, we emphasize that the extent to which FBC is socially desirable depends fundamentally on the access price.

## 2.3. Competition for rolling out new infrastructures

The last situation analyzed by the literature is the case where several (generally two) firms can build a new network. A typical application is competition for rolling out optic-fiber telecommunications networks. The literature on access regulation and investment in a context of competition for rolling out new infrastructures includes [15],[16], [17] and [18].

These papers are based on the concept of investment rivalry (see in particular [19]). Their first contribution is to point out that investment is not always a non-strategic profit maximization decision. The rationale behind infrastructure investment can be profit maximization (in the standard sense of "choosing the level of investment such that the marginal benefit from investment equals its marginal cost") but also preemption. Indeed, under certain conditions (roughly speaking if there is more to gain as an access provider than as an access seeker) each firm would like to be the first to roll out the new infrastructure. In this case, firms engage in an investment race (preemption equilibrium) that results in earlier investments than in the case where firms choose the investment date that maximizes their profits (waiting equilibrium).

In this framework, [15] and [18] show that access price regulation can be used to induce a race between firms and to ensure that investment will occur at the socially optimal time. Furthermore, when there is no investment race, the impact of access regulation on investment is basically the same as analyzed by the literature reviewed in Section 2.1: A lower access price dampens (or delay) the deployment of a new infrastructure because it reduces the profitability of investment.

Once a new infrastructure has been built by a firm, it may be duplicated by another firm. It is therefore necessary to study the impact of access regulation not only on the incentives to roll out a new infrastructure but also on the incentives to duplicate this infrastructure. This is done by [16], [17] and [18]. The basic mechanisms here are not different from those described by the literature reviewed in Section 2.2. However, it should be noted that bypass affects the relationship between the access price and the timing of the first investment. More specifically, when bypass is impossible, the higher is the access price, the earlier is the deployment of the new infrastructure both in the waiting and the preemption equilibriums. As shown by [18], this is not always true for the preemption equilibrium when bypass is feasible.

Among the studies on competition for rolling out new infrastructures, [15] and [18] try to determine the optimal regulation. They analyze the existence of a first best, i.e. of a two-part access price whose variable price is set at (or below) marginal cost in order to minimize retail prices, and whose flat part is set so as to induce optimal investment dates. As we emphasize in this paper, the flat part is not always sufficient to achieve socially optimal investment decisions. In this case, the question of the optimal variable part remains largely unresolved.

Thus, the main contribution of our paper is to study the optimal access price (linear and two-part tariff) in the different configurations analyzed by the previous literature (service-based competition, access or bypass, and competition for rolling out new infrastructures). For this, we extend the model of geographical coverage introduced by [20].

# 3. The model

The model we propose is a sequential game. It has three stages which unfold as follows. In stage 1, the regulatory authority sets the access price[8]. In stage 2, the firm(s) decide where to invest. In stage 3, the firms compete in the retail market.

The regulatory authority sets the access price that maximizes welfare. We assume that the access price can be either a linear tariff $r$ or a two-part tariff including a linear part $r$ and a flat part $R$. Furthermore, we assume that the access price is the same allover the country. Although the realism of this assumption can be discussed, it provides a simple representation of the fundamental tradeoffs faced by regulators[9].

As regards the investment decisions, we assume that the firms decide whether to invest or not in each "location" of the "country". The "country" is represented as a continuum $[0; \overline{x}]$ of "locations". The investment cost in location $x$ is $c(x)$ and $c' > 0$. A possible interpretation of this assumption is that when $x$ increases the population density decreases, which in turn increases the investment cost. To keep the model as simple as possible, we assume that $c(x) = \theta x$ with $\theta > 0$.

The strategies "investing in a new infrastructure" and "not investing" are denoted respectively $I$ and $N$. The local profit of a firm – i.e. its profit in a given location – is denoted $\Pi_{i,j}$ where $i \in \{N, I\}$ is the strategy it has adopted and $j \in \{N, I\}$ the strategy adopted by its competitor. The local welfare is denoted $W_{N,N}$ when neither firm has invested, $W_{I,I}$ when both of them have invested, and $W_{I,N}$ when only one firm has invested. Similarly, the local consumer surplus is $S_{N,N}$ when neither firm has invested, $S_{I,I}$ when both of them have invested, and $S_{I,N}$ when only one firm has invested[10].

Like other papers on access regulation and infrastructure investment, we assume that firms compete *à la* Cournot[11]. When no infrastructure is build, services cannot be provided and $\Pi_{N,N} = S_{N,N} = W_{N,N} = 0$. When only one firm builds a new infrastructure, we assume that there is no quality differentiation between the access provider and the access seeker. Furthermore, we assume that the quality is the same when only one firm invests and when both of them do. This assumption allows us to explore in detail

[8] The assumption that the regulatory authority plays first means that it can commit to a policy.

[9] If the prices are set area-by-area, the tradeoffs described in our model will just arise locally instead of nationally.

[10] $\Pi_{i,j}$, $W_{i,j}$ and $S_{i,j}$ represent gross values. Subtract the investment cost ($c(x)$ under SBC, and $2c(x)$ under FBC) for net values.

[11] It is a well known result that Cournot equilibrium is equivalent to the equilibrium of a two-stage game where firms first set their capacities, and then compete in price. See [5] p. 7-9 or Nitsche and [8] note 17 for a further justification of the assumption of Cournot competition. or

the case where the incentive to bypass depends only on the access price. We normalize to 1 the willingness to pay of the consumer with the highest valuation for the service. Consequently, the inverse demand in each location where at least one firm has invested is $P = 1 - Q$, where $Q$ is the total quantity. Finally, we assume that the marginal costs are constant, and in order to keep the notations as simple as possible we normalize them to zero.

Given these assumptions, the local profits are as follows.

- When only one firm has invested, $\Pi_{I,N} = (1 - Q_{I,N} - Q_{N,I})Q_{I,N} + r.Q_{N,I} + R$ and $\Pi_{N,I} = (1 - Q_{I,N} - Q_{N,I} - r)Q_{N,I} - R$ where $Q_{I,N}$ is the quantity set by the investing firm, and $Q_{N,I}$ the quantity set by the non-investing firm.

- When both firms have invested, $\Pi^a_{I,I} = (1-Q^a_{I,I}-Q^b_{I,I})Q^a_{I,I}$ and $\Pi^b_{I,I} = (1-Q^a_{I,I}-Q^b_{I,I})Q^b_{I,I}$ where $Q^a_{I,I}$ and $Q^b_{I,I}$ are the quantities set by firms $a$ and $b$, respectively.

When only one firm has builds the new infrastructure, we find that the investing firm forecloses the market if $r > 1/2$. Assuming that $r \leq 1/2$, the local profits, welfare, and surpluses are defined as follows.

**Definition 1.** If neither firm has invested, $\Pi_{N,N} = S_{N,N} = W_{N,N} = 0$. If only one firm has invested, $\Pi_{I,N}(r, R) = \pi_{I,N}(r) + R$ and $\Pi_{N,I}(r, R) = \pi_{N,I}(r) - R$ where $\pi_{I,N}(r) = \frac{1}{9}(-5r^2 + 5r + 1)$ and $\pi_{N,I}(r) = \frac{1}{9}(2r - 1)^2$; The corresponding consumer surplus and welfare are $S_{I,N}(r) = \frac{1}{18}(r - 2)^2$ and $W_{I,N}(r) = \frac{1}{18}(-r^2 - 2r + 8)$. If both firms have invested, $\Pi^a_{I,I} = \Pi^b_{I,I} = \Pi_{I,I} = \frac{1}{9}$, $S_{I,I} = \frac{2}{9}$ and $W_{I,I} = \frac{4}{9}$.

Obviously, the access price has no impact on the local profits, consumer surpluses and welfares when neither firm has invested, and when both of them have. When only one firm has invested, the profit of the investing firm is an increasing function of the variable part $r$ of the access price ($\frac{\partial \Pi_{I,N}(r,R)}{\partial r} > 0$). The profit of the non-investing firm, consumer surplus and welfare are decreasing functions of $r$ ($\frac{\partial \Pi_{N,I}(r,R)}{\partial r} < 0$, $\frac{dS_{N,I}(r)}{dr} < 0$, and $\frac{dW_{I,N}(r)}{dr} < 0$). The profits of the investing firm and of the non-investing firm are an increasing and a decreasing function of the flat part $R$ of the access price, respectively ($\frac{\partial \Pi_{I,N}(r,R)}{\partial R} > 0$ and $\frac{\partial \Pi_{N,I}(r,R)}{\partial R} < 0$). $R$ has no impact on consumer surplus and welfare. Basically, this results arise because the variable part affects the equilibrium quantities, whereas the flat part is just a transfer between the non-investing and the investing firm.

The private incentives to invest can be defined as the difference between postinvestment and preinvestment profits. The social benefits from investment can be defined as the difference between welfare after and before investment. Consequently, the private incentives to build a new infrastructure and to bypass are $\Pi_{I,N}(r, R) - \Pi_{N,N}$ and $\Pi_{I,I} - \Pi_{N,I}(r, R)$, respectively; The social benefits from the new infrastructure and from the bypass investments are $W_{I,N}(r) - W_{N,N}$ and $W_{I,I} - W_{N,I}(r)$, respectively. From Definition 1, we infer the following results.

**Lemma 1.** *i. Any increase (resp. decrease) in the variable part of the access price increases (resp. decreases) the private incentives to build a new infrastructure and to bypass. ii. Any increase (resp. decrease) in the variable part of the access price reduces* *the social benefit from the new infrastructure investment, but increases (resp. decreases) the social benefit from the bypass investment. iii. Any increase (resp. decrease) in the flat part of the access price increases (resp. decreases) the private incentives to build a new infrastructure and to bypass, but has no impact on the social benefits from these investments.*

*Proof.* From Definition 1, $\Pi_{I,N}(r,R)-\Pi_{N,N}=\frac{1}{9}(-5r^2+5r+1)+R$, $\Pi_{I,I}-\Pi_{N,I}(r,R)=-\frac{4}{9}r(r-1)$, $W_{I,N}(r)-W_{N,N}=\frac{1}{18}(-r^2-2r+8)$, and $W_{I,I}-W_{N,I}(r)=\frac{1}{18}r(r+2)$. i. $\frac{\partial\left[\Pi_{I,N}(r,R)-\Pi_{N,N}\right]}{\partial r}=\frac{5}{9}-\frac{10}{9}r>0$ and $\frac{\partial\left[\Pi_{I,I}-\Pi_{N,I}(r,R)\right]}{\partial r}=\frac{4}{9}-\frac{8}{9}r>0$. ii. $\frac{d\left[W_{I,N}(r)-W_{N,N}\right]}{dr}=-\frac{1}{9}(r+1)<0$ and $\frac{d\left[W_{I,I}-W_{N,I}(r)\right]}{dr}=\frac{1}{9}(r+1)>0$. iii. $\frac{\partial\left[\Pi_{I,N}(r,R)-\Pi_{N,N}\right]}{\partial R}=1$ and $\frac{\partial\left[\Pi_{I,I}-\Pi_{N,I}(r,R)\right]}{\partial R}=1$; $W_{I,N}(r)-W_{N,N}$ and $W_{I,I}-W_{N,I}(r)$ are independent from $R$. $\square$

The results highlighted in Lemma 1 are standard. However, as will be shown in the following sections, the fact that the variable part of the access price affects at the same time the private incentives to invest and the social benefits from investment has some important consequences that have not been analyzed in the literature.

# 4. Service-based competition

In this section, we assume that only one firm can build an infrastructure and that the other firm accesses the infrastructure at a regulated access price. In this case, investment occurs as long as the local profits are not lower than the investment costs, i.e. if $\Pi_{I,N}(r,R)\geq\theta x$. The total welfare (hereinafter "welfare") is the sum of the local welfares minus the investment costs. We find

$$W_1(r,R)=\int_0^{\frac{1}{\theta}\Pi_{I,N}(r,R)}\left[W_{I,N}(r)-\theta x\right]dx=\frac{1}{2\theta}\Pi_{I,N}(r,R)\left[2W_{I,N}(r)-\Pi_{I,N}(r,R)\right]. \tag{1}$$

## 4.1. Linear access price

Let us first focus on the simple case where the access price is linear, i.e. where $R=0$ and $r\geq 0$. The impact of a variation in $r$ on welfare is represented by

$$\left.\frac{\partial W_1}{\partial r}\right|_{R=0}=\underbrace{\frac{1}{\theta}\pi_{I,N}(r)\frac{dW_{I,N}(r)}{dr}}_{Local-welfare\ effect}+\underbrace{\frac{1}{\theta}\left(W_{I,N}(r)-\pi_{I,N}(r)\right)\frac{d\pi_{I,N}(r)}{dr}}_{Coverage\ effect}. \tag{2}$$

Any variation in $r$ has conflicting effects on welfare. On the one hand, any increase (resp. decrease) in the access price decreases (resp. increases) welfare in the covered area, i.e. in the area where the firm has invested (Local-welfare effect, $\frac{1}{\theta}\pi_{I,N}(r)\frac{dW_{I,N}(r)}{dr}<0$). On the other hand, any increase (resp. decrease) in the access price improves (resp. deters) coverage (Coverage effect, $\frac{1}{\theta}\left(W_{I,N}(r)-\pi_{I,N}(r)\right)\frac{d\pi_{I,N}(r)}{dr}>0$). As the social benefit from investment is higher than the private incentive to invest (from Definition

1, $W_{I,N}(r) - W_{N,N} > \pi_{I,N}(r) - \Pi_{N,N}$), any increase (resp. decrease) in the size of the covered area increases (resp. decreases) welfare.

From Equation 2 and Definition 1, we find

$$\left.\frac{\partial W_1}{\partial r}\right|_{R=0} = \frac{1}{162\theta}\left(-80r^3 + 165r^2 - 132r + 28\right) \text{ and } \left.\frac{\partial^2 W_1}{\partial r^2}\right|_{R=0} = \frac{1}{162\theta}\left(-240r^2 + 330r - 132\right).$$

Since the second order condition is satisfied – for any $r \in \left[0; \frac{1}{2}\right]$, $\left.\frac{\partial^2 W_I}{\partial r^2}\right|_{R=0} < 0$ –, the optimal access price $r_1^*$ is such that $\left.\frac{\partial W_1}{\partial r}\right|_{R=0} = 0$. It can be easily shown that $r_1^*$ – i.e. the access price that optimally trades off between welfare in the covered area and coverage – is neither cost oriented (in $r = 0$, $\left.\frac{\partial W_1}{\partial r}\right|_{R=0} > 0$) nor maximal (in $r = \frac{1}{2}$, $\left.\frac{\partial W_1}{\partial r}\right|_{R=0} < 0$).

## 4.2. Two-part tariff

Can the regulator achieve the first-best when he has two instruments – the flat and the variable parts of the access price – for two objectives – maximizing welfare in the covered area and promoting optimal coverage? Whatever the access price the social benefit from investment is higher than the private incentive to invest (from Definition 1,$w_{I,N}(r) - w_{N,N} > \Pi_{I,N}(r,R) - \Pi_{N,N}$ for any $\{r, R\}$). As a consequence, coverage is always be too narrow from a social point of view, and we can already say that the equilibrium will not be a first-best.

Since, the flat part of the access price $R$ has no impact on welfare in the covered area, since any increase in $R$ increases the size of the coveraged area (see Lemma 1), and since coverage is always too narrow, the optimal flat part is as high as possible: From Equation 1 and from Definition 1, $\frac{\partial W_1}{\partial R} = \frac{1}{162\theta}\left(82r^2 - 108r - 162R + 54\right) > 0$; Consequently, the optimal flat part is $R_1^{**} = \pi_{N,I}(r)$.

A similar result was obtained by [9]. However, unlike [9], our model indicates that the optimal variable part is cost-oriented: With $R = \pi_{N,I}(r)$ we find $W_1 = \frac{1}{54\theta}(r + 1)(r-2)^2$, which is strictly decreasing in $r$; Consequently, the optimal variable part is $r_1^{**} = 0$. This result can be explained as follows.

For any flat part $R$, the impact of a variation in $r$ on welfare is given by

$$\frac{\partial W_1}{\partial r} = \underbrace{\frac{1}{\theta}\frac{dW_{I,N}(r)}{dr}\Pi_{I,N}(r,R)}_{Local-welfare\ effect\ L} + \underbrace{\frac{1}{\theta}\frac{\partial \Pi_{I,N}(r,R)}{\partial r}\left(W_{I,N}(r) - \Pi_{I,N}(r,R)\right)}_{Coverage\ effect\ C}. \tag{3}$$

As in Section 4.1, any increase in $r$ has two opposite effects on welfare: It decreases welfare in the covered area, which in turn decreases the total welfare (negative local-welfare effect $L < 0$); It increases coverage, which in turn increases the total welfare (positive coverage effect $C > 0$). Given these effects, the fact that $r_1^{**} = 0$ is explained by the combination of the three following mechanisms.

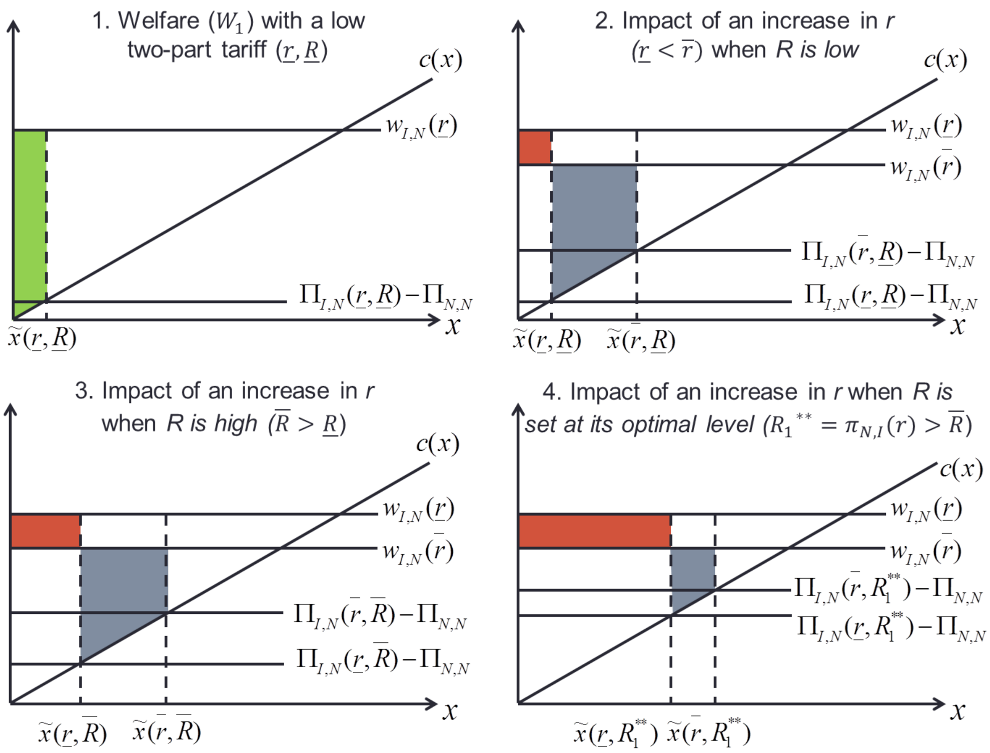
- Mechanism 1. The higher is the flat part, the broader is coverage, and the stronger is the negative local-welfare effect:$\frac{\partial L}{\partial R} = \frac{1}{\theta}\frac{dW_{I,N}(r)}{dr} < 0$.

- Mechanism 2. The higher is the flat part, the broader is coverage, and the weaker is the positive coverage effect: $\frac{\partial C}{\partial R} = -\frac{1}{\theta}\frac{\partial \Pi_{I,N}(r,R)}{\partial r} < 0$.

- Mechanism 3. The increase in coverage is mitigated when the flat part is set at its optimal level: If $R = \pi_{N,I}(r)$, $\frac{\partial \Pi_{I,N}(r,R)}{\partial r} = \frac{d\pi_{I,N}(r)}{dr} + \frac{d\pi_{N,I}(r)}{dr}$; From Definition 1 $\frac{d\pi_{N,I}(r)}{dr} < 0$.

These mechanisms are illustred graphically in Figure ??. The positive coverage effect and the negative local-welfare effect are represented by the blue and the red areas, respectively. Mechanism 1 is reflected by the fact that the red area is larger in Figure ??.3 than in Figure ??.2, and larger in Figure ??.4 than in Figure ??.3. The difference between the blue areas in Figures ??.3 and ??.2 illustrates Mechanism 2: The increase in coverage is the same in Figure ??.3 and ??.2 ($\widetilde{x}(\overline{r}, \underline{R}) - \widetilde{x}(\underline{r}, \underline{R}) = \widetilde{x}(\overline{r}, \underline{R}) - \widetilde{x}(\underline{r}, \underline{R})$), but the blue area is larger in ??.2 because $\widetilde{x}(\underline{r}, \underline{R}) < \widetilde{x}(\underline{r}, \overline{R})$. Mechanism 3 is represented by the fact that the increase in coverage is stronger in Figure ??.3 than in Figure ??.4 ($\widetilde{x}(\overline{r}, R_1^{**}) - \widetilde{x}(\underline{r}, R_1^{**}) < \widetilde{x}(\overline{r}, \underline{R}) - \widetilde{x}(\underline{r}, \underline{R})$).

**Figure 1. Access price and welfare**




These results obtained in this section can be summarized as follows.

**Proposition 1.** *When only one firm can invest and when only service-based competition is feasible, the optimal two-part access price is such that the flat part is as high as possible and the variable part equals the marginal cost.*

# 5. Access or bypass

We assume now that a firm (the incumbent) has already covered a given number of locations and that an entrant decides whether to access the existing infrastructure or to bypass. Bypass occurs as long as $\Pi_{I,I} - \Pi_{N,I}(r,R) \geq \theta x$. We denote $l$ the last location that has already been covered by the incumbent and assume that $l > \frac{1}{\theta}\left[\Pi_{I,I} - \Pi_{N,I}(r,R)\right]$[12]. Welfare is then

$$W_2(r,R) = \int_0^{\frac{1}{\theta}\left(\Pi_{I,I}-\Pi_{N,I}(r,R)\right)} (W_{I,I} - 2\theta x)dx + \int_{\frac{1}{\theta}\left(\Pi_{I,I}-\Pi_{N,I}(r,R)\right)}^{l} (W_{I,N}(r) - \theta x)\, dx$$

$$\Leftrightarrow W_2(r,R) = \frac{1}{2\theta}\left(\Pi_{I,I} - \Pi_{N,I}(r,R)\right)\left(2\left(W_{I,I} - W_{I,N}(r)\right) - \left(\Pi_{I,I} - \Pi_{N,I}(r,R)\right)\right) + \frac{l}{2}\left(2W_{I,N}(r) - \theta l\right). \tag{4}$$

First, it should be noted that when it occurs bypass always takes place in too many locations. In fact, for any $r > 0$, the private incentive to bypass is higher than the social benefit from bypass (from Definition 1 $\Pi_{I,I} - \Pi_{N,I}(r,R) > W_{I,I} - W_{I,N}(r)$ if $r > 0$); If $r = 0$, $\Pi_{I,I} - \Pi_{N,I}(r,R) = 0$ and bypass never occurs. As a consequence, any increase in $R$ worsens overinvestment and decreases $W_2$. Formally, $\frac{\partial W_2}{\partial R} = \frac{1}{\theta}(W_{I,I} - W_{I,N}(r)) - \frac{1}{\theta}(\Pi_{I,I} - \Pi_{N,I}(r,R)) < 0$ and the optimal flat part is $R_2^{**} = 0$. Of course, $R_2^{**} = 0$ is not a general result but a consequence of the assumption that there is no product differentiation.

This assumption also implies that getting around the access charge is the only reason why a firm may have an incentive to bypass. Similarly, the only social benefit from bypass results from the fact that the entrant does not have to pay an access charge. As a consequence, SBC with $r = 0$ is always better than FBC: It results in the same local welfare ($W_{I,N}(0) = W_{I,I}$) but requires only half the investment cost. Finally, the optimal variable part is $r_2^{**} = 0$, and bypass never occurs.

Although the study of the optimal access price is of no particular interest here, things get more interesting when we analyze together the impact of access regulation on coverage and on bypass. As we will show in Section 6, contrary to what intuition may suggest the optimal variable part when bypass is possible is higher than in the case where only SBC is feasible.

# 6. Competition for rolling out new infrastructures

In this section, we assume that both firms can build a new infrastructure, and that they make their investment decisions simulaneously. We thus have a strategic investment game that can be represented by the following matrix of payoffs (Table 1)

**Table 1. Competition for rolling out new infrastructures: The investment game**

[12] This assumption means that the entrant may only invest in the locations that were previously covered by the incumbent. In other words, the entrant cannot extend coverage.

| | | Firm B | |
|---|---|---|---|
| | | N | I |
| Firm A | N | 0;0 | $\Pi_{N,I}(a,A)$; $\Pi_{I,N}(a,A)-\theta x$ |
| | I | $\Pi_{I,N}(a,A)-\theta x$; $\Pi_{N,I}(a,A)$ | $\Pi_{I,I}-\theta x$; $\Pi_{I,I}-\theta x$ |

If $\theta x < \Pi_{I,I} - \Pi_{N,I}(r,R)$, the only equilibrium of the investment game is $\{I;I\}$. If $\Pi_{I,I} - \Pi_{N,I}(r,R) < \theta x < \Pi_{I,N}(r,R)$, there are two symmetric Nash equilibria $\{I;N\}$ and $\{N;I\}$, and we assume that the firms will select one of them. If $\Pi_{I,N}(r,R) < \theta x$, the only Nash equilibrium is $\{N;N\}$. When $\theta x = \Pi_{I,I} - \Pi_{N,I}(r,R)$, there are three Nash equilibria: $\{I;I\},\{I;N\}$ and $\{N;I\}$. Since $I$ is weakly dominant, it can be assumed that the equilibrium $\{I;I\}$ will be selected. When $\theta x = \Pi_{I,N}(r,R)$, there are three Nash equilibriums: $\{N;N\},\{I;N\}$ and $\{N;I\}$. Since $N$ is weakly dominant, it can be assumed that the equilibrium $\{N;N\}$ will be selected. Consequently, there is FBC in the area where $\theta x \leq \Pi_{I,I} - \Pi_{N,I}(r,R)$, SBC in the area where $\Pi_{I,I} - \Pi_{N,I}(r,R) < \theta x < \Pi_{I,N}(r,R)$; the area where $\Pi_{I,N}(r,R) \leq \theta x$ is uncovered. Welfare is then

$$W_3 = \int_0^{\frac{1}{\theta}\left[\Pi_{I,I}-\Pi_{N,I}(r,R)\right]} (W_{I,I} - 2\theta x)dx + \int_{\frac{1}{\theta}\left[\Pi_{I,I}-\Pi_{N,I}(r,R)\right]}^{\frac{1}{\theta}\Pi_{I,N}(r,R)} \left[W_{I,N}(r) - \theta x\right] dx$$

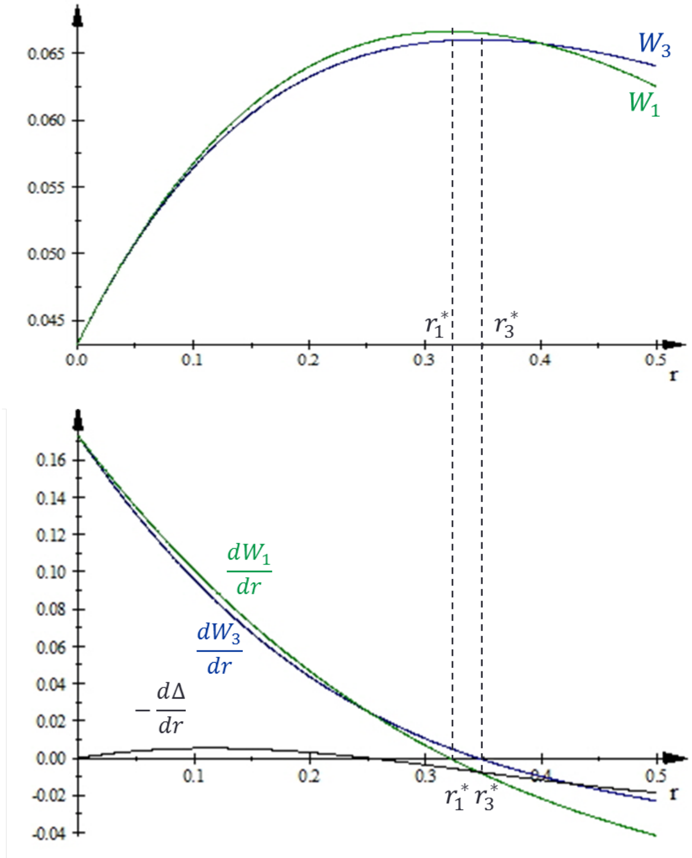
$$\Leftrightarrow W_3 = \frac{1}{2\theta}\left(\Pi_{I,I} - \Pi_{N,I}(r,R)\right)\left(2\left(W_{I,I} - W_{I,N}(r)\right) - \left(\Pi_{I,I} - \Pi_{N,I}(r,R)\right)\right) + \frac{1}{2\theta}\Pi_{I,N}(r,R)\left(2W_{I,N}(r) - \Pi_{I,N}(r,R)\right). \quad (5)$$

## 6.1. Linear access price

As in Section 4, we first assume that the access price is linear ($R = 0$; $r \geq 0$). A graphical comparison of $W_3$ and $W_1$ reveals a surprising result (see Figure 2[13]): the access price that maximizes welfare when only SBC is feasible ($W_1$) is lower than the access price that maximizes welfare when bypass (or “duplication”) is possible ($W_3$). Intuitively, as duplication occurs in too many locations and as reducing the access price lessens the incentive to duplicate (see Section 2.2) one might expect that the access price that maximizes $W_3$ is lower than the one that maximizes $W_1$.

**Figure 2. Welfare with a linear access price ($R = 0$; $r \geq 0$; $\theta = 1$)**

[13] In Figure 2, we assumed that $\theta = 1$. However, the shape of the curves is not affected by $\theta$, and the representation provided by Figure 2 is valid for any $\theta > 0$.




Welfare under competition for rolling out new infrastructures can be written $W_3 = W_1 + \Delta(r)$, where $\Delta(r) = \frac{1}{2\theta}\left(\Pi_{I,I} - \pi_{N,I}(r)\right)\left(2\left(W_{I,I} - W_{I,N}(r)\right) - \left(\Pi_{I,I} - \pi_{N,I}(r)\right)\right)$ represents the gain or the loss from having FBC instead of SBC in the locations where both firms invest; $W_1$ is defined by Equation 1 and represents welfare when only SBC is feasible[14]. First, it should be noted that $\Delta(r)$ is not always negative: The fact that there is too much duplication does not mean that there should not be duplication at all. Indeed, we find that $\Delta(r)$ is negative for low values of $r$ but positive for high values: From Definition 1, $\Delta(r) = -\frac{2}{81}\frac{r^2}{\theta}(5r^2 - 7r + 2) \Rightarrow \Delta(r) = 0$ if $r \in \left\{0; \frac{2}{5}\right\}$, $\Delta(r) < 0$ if $r \in \left]0; \frac{2}{5}\right[$, and $\Delta(r) > 0$ if $r \in \left]\frac{2}{5}; \frac{1}{2}\right]$.

The impact on welfare of any variation in $r$ is

$$\left.\frac{\partial W_3}{\partial r}\right|_{R=0} = \left.\frac{\partial W_1}{\partial r}\right|_{R=0} + \underbrace{\frac{1}{\theta}\left(\left(\Pi_{I,I} - \pi_{N,I}(r)\right) - \left(W_{I,I} - W_{I,N}(r)\right)\right)\frac{d\pi_{N,I}(r)}{dr}}_{Duplication\ effect} \underbrace{- \frac{1}{\theta}\left(\Pi_{I,I} - \pi_{N,I}(r)\right)\frac{dW_{I,N}(r)}{dr}}_{Welfare-under-SBC\ effect}. \quad (6)$$

It is the sum of $\left.\frac{\partial W_1}{\partial r}\right|_{R=0}$ and of two new effects: the "duplication effect" and the "welfare-under-SBC effect". $\left.\frac{\partial W_1}{\partial r}\right|_{R=0}$ is defined in Equation 2 and can be described as the sum of a "coverage effect" and a "local-welfare effect" (see Section 4.1). The "duplication effect" indicates that any increase (resp. decrease) in $r$ increases (resp. decreases) the number of locations where duplication takes place, which in turn decreases

[14]Remark: If $r = 0$, then $\Delta = 0$ and $W_3 = W_1$.

(resp. increases) welfare ($\frac{1}{\theta}\left((\Pi_{I,I}-\pi_{N,I}(r))-(W_{I,I}-W_{I,N}(r))\right)\frac{d\pi_{N,I}(r)}{dr}<0$). The "welfare-under-SBC effect" indicates that any increase (resp. decrease) in $r$ decreases (resp. increases) the local welfare under SBC and thus increases the social benefit from duplication, which in turn increases welfare ($-\frac{1}{\theta}\left(\Pi_{I,I}-\pi_{N,I}(r)\right)\frac{dW_{I,N}(r)}{dr}>0$).

The sum of the duplication effect and the welfare-under-SBC effect describes how the access price affects the gain or the loss from having FBC instead of SBC. It can be written $\frac{d\Delta(r)}{dr}=-\frac{2}{81}\frac{r}{\theta}(20r^2-21r+4)$. We infer that an increase in the access price

- increases the loss resulting from duplication if $r$ is low – if $r\in\left]0;\frac{1}{4}\right[$, then $\Delta<0$ and $\Delta'(r)<0$;
- reduces the loss resulting from duplication if $r$ is medium – if $r\in\left]\frac{1}{4};\frac{2}{5}\right]$, then $\Delta\leq 0$ and $\Delta'(r)>0$;
- increases the gain resulting from duplication if $r$ is high – if $r\in\left]\frac{2}{5};\frac{1}{2}\right[$, then $\Delta>0$ and $\Delta'(r)>0$.

Finally, as the second-order condition is satisfied ($\left.\frac{\partial^2 W_3}{\partial r^2}\right|_{R=0}=\frac{1}{162\theta}(-480r^2+498r-148)<0$), the optimal access price is such that $\left.\frac{\partial W_3}{\partial r}\right|_{R=0}=0$, i.e. such that $\left.\frac{\partial W_1}{\partial r}\right|_{R=0}=-\frac{d\Delta(r)}{dr}$. For the access price $r_1^*$ that maximizes welfare when only SBC is possible, we find that any additional increase in the access price would reduce the loss associated with duplication ($\frac{d\Delta(r_1^*)}{dr}>0$). As a consequence, the access price $r_3^*$ that maximizes welfare under competition for rolling out new infrastructures is higher than $r_1^*$. This result is illustrated in Figure 2, and can be summarized as follows.

**Proposition 2.** *The linear access price that maximizes welfare is higher when duplication is feasible than when only service-based competition is possible.*

*Proof.* $\frac{d\Delta(\frac{1}{4})}{dr}=0$, and $\left.\frac{\partial W_1}{\partial r}\right|_{R=0}>0$ in $r=\frac{1}{4}$. As a consequence, $r_1^*>\frac{1}{4}$ and $\frac{d\Delta(r_1^*)}{dr}>0$. Since $\left.\frac{\partial^2 W_1}{\partial r^2}\right|_{R=0}<0$, $r_3^*$ such that $\left.\frac{\partial W_1}{\partial r}\right|_{R=0}=-\frac{d\Delta(r_3^*)}{dr}$ is higher than $r_1^*$ (see Figure 2). □

## 6.2. Two-part tariff

Does the introduction of a positive flat fee $R$ improve welfare? On the one hand, any increase in $R$ expands coverage, which in turn improves welfare (see Section 4). On the other hand, any increase in $R$ raises the number of locations where duplication takes place, which in turn reduces welfare (see Section 5). The social benefit from covering one additional location is higher than the loss from duplicating the infrastructure in one additional location: For any variable part $r>0$, $W_{I,N}(r)-W_{N,N}>W_{I,I}-W_{N,I}(r)$. Moreover, any increase in $R$ results in the same expansion of coverage and of duplication: From Definition 1, $\frac{\partial\Pi_{I,N}}{\partial R}=\frac{\partial\left[\Pi_{I,I}-\Pi_{N,I}\right]}{\partial R}=\frac{1}{\theta}$. As a consequence, raising $R$ always increases welfare and the optimal flat part is $R_3^{**}=\pi_{N,I}(r)$. Formally – from Equation 5 –, $\frac{\partial W_3}{\partial R}=\frac{1}{\theta}\left(\Pi_{I,I}-\Pi_{N,I}-(W_{I,I}-W_{I,N}(r))\right)+\frac{1}{\theta}\left(W_{I,N}(r)-\Pi_{I,N}\right)>0$.

When the flat part is set at its optimal level, we find $W_3 = \frac{1}{162\theta}(3r^3 - 8r^2 + 2r + 11)$, which is maximized for $r = \frac{8}{9} - \frac{1}{9}\sqrt{46}$. As in the case of a linear tariff – and for the same reasons –, the variable part is higher than when only SBC is feasible. As in Section 4 – and for the same reasons –, the variable part is lower with than without a flat part. These results can be summarized as follows.

**Proposition 3.** *Under competition for rolling out new infrastructures, it is optimal to set the flat part as high as possible, and to set the variable part above marginal cost.*

# 7. Conclusion

While most of the existing work on access regulation and welfare has focused on the flat part of the access fee, we have studied more in detail the optimal variable part and its interaction with the flat part. The specificity of the variable part is that it determines at the same time the private incentives to build an infrastructure and to bypass, and the social benefits from these investments.

Our model confirms the intuition that a two-part tariff induces higher welfare than a linear access price. It also indicates that the introduction of a strictly positive flat fee reduces the optimal variable fee. However, when the access price is a two-part tariff, the latter is not always cost-oriented. In fact, we found that the variable part of a two-part access price should be cost-oriented when only service-based competition is feasible, but should be above marginal cost when facilities-based competition is possible. Interestingly, this results occurs although there is always too much duplication. This is explained by the fact that raising the access price reduces welfare under service-based competition and makes duplication more socially desirable, which in turn improves welfare.

In this paper, we addressed the issue of the optimal variable access fee in a model of geographical coverage. It should be noted that this type of model ignores an important feature of competition for rolling out new infrastructures: the fact that firms may implement preemption strategies. Although the papers based on the concept of investment rivalry take these strategies into account, the main issues addressed by this literature are the existence of a first-best and the optimal flat fee. It would be relevant to analyze what should be the variable part of the access price when regulating the flat part is not enough the reach the socially optimal investment timing.

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