Public and Private Investments in Regulated Network Industries: Coordination and Competition Issues*

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Abstract

This paper analyzes the relationship between a national regulator, an incumbent and a local government in a context where investment in a new network has to be undertaken. In the light of the recent debates on the competition between private firms and local governments, we analyze the limits to be put on the local public intervention in these markets. We show that banning local government intervention can be welfare-enhancing either in the presence inter-districts externality or with asymmetric information or in case of conflicting objectives between the regulator and local governments.

1 Introduction

While network industries are subject to competition by now, public intervention remains common, be it in the form of access regulation or universal service obli-

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gations to name but a few. Moreover, private actors in these industries must undertake substantial long-term infrastructure investments in order to gain a competitive edge over their rivals by offering higher-quality services to customers. The profitability of these investments may be affected by other variables, though. First, as hinted previously, new infrastructure networks, which typically involve a long-term planing of coverage deployment, may be regulated by a national authority. Second, public investment may limit the profitability of private investment. Local or regional authorities may indeed consider preemptive investment schemes to foster the delivery of new services. This paper analyzes such a three-way interaction between a national regulator, private actors and a local government, in a context where both the private sector and the local government may invest in a new infrastructure network.

The telecommunication industry is the sector where our analysis is the most relevant.[1] Indeed, next generation access networks will allow to reach higher delivering speeds than ADSL2+ or cable technologies. Despite the uncertainty surrounding the demand for these new services, many decision-makers foresee in these investments a profound impact on the broadband market, but also on society.[2] Investment costs for the deployment of these networks and the upgrading of the existing network are substantial, though, and entail some risks for private actors. In this context, some local public authorities or regional development agencies have decided to build their own infrastructure in order to boost the delivery of new services to their constituencies.

This behavior has been put into scrutiny both in the USA and in Europe. In the United States, the controversy over the possibility to ban public intervention has led more than 10 States to ban -partially or completely- municipal intervention.[3] In Europe, the 2009 Guidelines issued by the European Commission (see EC (2009)) acknowledged the problem created by national or local government interventions in telecommunication markets. It claims that "it must be ensured that State aid does not crowd out market initiative in the broadband sector. [State intervention] could affect investment already made by broadband operators on market terms and significantly undermine the incentives of market operators to invest in the first place." Even if the few evidence for the USA (see Hauge, Jamison, and Gentry (2008)) suggest that private and public investment are more comple-

[1] Note that other sectors such as transportation can also suffer from the same problem. Indeed, private firms may compete with public ones for managing competing airports or ferry lines.

[2] See OFCOM (2007) for instance.

[3] There is also a controversy on the cost of national regulation. See Jamison and Sichter (2010) for the case of the telecommunication industry in the USA.

mentary than substitutes, the debate is far from being settled. Our paper aims at exploring some of the theoretical arguments in favor or against a regulation over public intervention.

To this purpose, we build a canonical model of the relationship between a national regulator, a local government and a private actor. The national territory is divided into 'districts', which differ by the level of demand for new services and the cost of building a new network.

An incumbent operator contemplates the decision whether to invest in a new infrastructure in each district. Such an infrastructure can be rented to a competitive fringe of operators to provide services to customers. For the incumbent to be willing to invest, some access markup is needed to cover the investment cost. The national regulator is in charge of regulating the access to the incumbent's network.

The local government can decide to develop its own network infrastructure, in which case it decides the terms of access to the local network. This government is interested in the welfare of its constituency and, in particular, can use local public funds to finance the network, as opposed to the regulator. We assume that the local government is a priori less efficient than the incumbent in building the new network, but since the former can use public funds it may also set a lower access charge on its network, thereby improving customers' surplus.

The sequence of decisions is as follows. First, the regulator sets the access charge which applies to the incumbent's network on the national territory. Second, the incumbent decides whether to invest or not. Third, the local government may invest in, and decide the terms of access to, a local network. Our goal is to determine the optimal regulatory regime, that is, whether the local government should be allowed to or banned from investing in a public network.[4]

Assume in a first step a setting with only one district and assume that the local government's investment cost is publicly known. Then, we show that one should always allow the local government to invest. Indeed, under complete information, the incumbent can perfectly anticipate the local government's decision and there is no inefficient duplication. The regulator, in turn, can set a regulated access tariff which leaves the incumbent with no extra profit, implying that the local government's objective becomes aligned with the regulator's. In a nutshell, delegation of the investment decision has no social costs in this setting.

Consider now a multi-district situation with externalities across districts. Two

[4]In our companion paper (Jullien, Pouyet, and Sand-Zantman (2009)) we investigate the possibility that the local government reaches a contractual agreement with the incumbent, including subsidies, a possibility which is not allowed here.

types of externalities can be envisioned. First, cost externality through scale effect may make it less costly for the incumbent to deploy investment over the whole territory. Second, demand externality may arise due to either network effects or the mobility of consumers. In these settings, allowing duplication has some costs and may be banned in some circumstances.

We then turn our attention to a situation in which neither the national regulator nor the incumbent are informed about the local government's investment cost. Hence, the incumbent cannot perfectly foresee when it will be duplicated and is thus exposed to a risk. In this context, duplication is no longer always efficient and the regulator faces two options. A ban on duplication removes the duplication risk faced by the incumbent, but does not allow to benefit from reduced access tariff when the local government invests. By contrast, allowing duplication forces the regulator to increase the regulated access price so as to compensate the incumbent from the duplication risk. We show that if private investment is profitable, then a ban on duplication is socially optimal.

We finally discuss several situations where conflicting objectives between the regulator and the local government have a bite. We show that the presence of divergent objectives between these two agents may induce excessive public investment. This calls for adding regulatory tools (such as, for instance, a price-floor or a reimbursement policy) and we study the impact of these instruments. At last, we analyze the regulatory commitment issue and show that, under symmetric information, a ban on duplication is time-consistent whereas a policy allowing duplication may not be.

Our paper belongs to the theoretical literature on regulation in network industries (see Laffont and Tirole (2001) for instance). Our main departure is to focus on the interaction between a regulator and a local government, each having specific attributes; hence, our paper is also related to the literature on the provision of local public goods. A few articles have discussed the regulation process when different market structures are possible. In this literature, the standard trade-off is between granting access to the essential facility at a low price (or promoting competition at the upstream level) and recouping the cost of investment. For example, Dana and Spier (1994) made one of the first contributions where the modes of production and the market structure are endogenous. Even closer to our paper is Caillaud and Tirole (2004) who highlight a conflict between social optimality and financial viability. We also have a similar conflict, but the potential competitor is a local public agency. Moreover, we analyze the role of a national regulator in mitigating this risk by choosing the regulation rules.

The key ingredients of our model are exposed in Section 2. Section 3 analyzes the benchmark case of complete information. Section 4 studies the multi-district case and the impact of externality across districts on the desirability to ban duplication. Section 5 focuses on the duplication risk that arises when the incumbent lacks some information about, and cannot predict, the local government's intervention. Section 6 discusses several problems originating from the conflicting objectives between the national regulator and local governments. Section 7 concludes.

2 Model

There is one representative geographical zone, called the 'district', characterized by its level of demand for broadband services denoted by θ.

Customers located on the district may benefit from a new service provided by a set of identical firms. The provision of this service requires access to an up-to-date network. An incumbent operator, denoted by I, has the possibility to upgrade its existing network at a cost $c > 0$ to allow the provision of the service.[5]

Access to the infrastructure network is set on a nondiscriminatory basis and the unit price is denoted by a. Service providers are assumed to behave competitively with a constant marginal cost normalized to zero, so that the final price p they charge to customers is always equal to the access charge: $p = a$. The demand is then $\theta D(a)$ and we assume $D(0) > 0$. The corresponding consumers surplus is denoted by $\theta W(a)$, with $W'(a) = -D(a)$. Let $\varepsilon(a) = -aD'(a)/D(a)$ be the price elasticity of the demand. We assume that $\varepsilon(.)$ is increasing and $\varepsilon(0) = 0$. As it will always be optimal to set the price below the monopoly level, we restrict attention to access prices a such that $\varepsilon(a) \leq 1$.

Access to the incumbent network is regulated. The regulator R is in charge of the pricing of the access to the existing network and commits to an access charge $a = r$ prior to the decision of the incumbent to upgrade or not. Note that this administrative body has no taxation power. Note also that the rule set by the regulator must apply in all districts. Even if there are cases where regulatory rules are tailored for specific districts, especially in the USA, it seems more common that general rules are set at the national level on a uniform basis, especially when there are cross-district externalities.

[5]This cost may depend on the observable characteristics of the district such as its density for example.

Instead of relying on the incumbent, a local government L, representing the constituency of the district, may decide to build its own network. L's cost is given by k and is distributed on $[\underline{k}, +\infty)$, according to a strictly positive density $f(.)$ and cumulative distribution function $F(.)$. We assume that $\underline{k} \geq c$ to account both for the specific ability of the incumbent and the cost of distortionary taxation since this government has taxation power that he may use to finance the infrastructure. The local government's objective is to maximize the welfare of its constituency. Even if local governments can intervene in many ways in markets (see Gillet, Lehr, and Osorio (2004)), we focus on its role of infrastructure developer and financier, assuming that the rulemaking activities are managed by the national regulator.

The network built by L is not subject to the access regulation that applies to I's network. However, in order to focus on the most relevant cases, we assume (without loss of generality) that L does not implement an access price higher than the regulated access price. If both the incumbent and the local government build an upgraded network, there is Bertrand competition on the wholesale market for access.

Events unfold as follows. First, regulator R decides on the price r for the access to the incumbent's network. Second, the value of k is realized. Third, incumbent operator I decides whether to upgrade its network. Fourth, local government L decides whether to build a competing network. If it does, then it can decide the terms of access to the local public network newly built. If it does not, then broadband services might be provided using the already existing network at the access price r decided by the regulator R.

The local government is thus allowed to intervene and to duplicate the investment of I or to invest when I fails to do so. We refer to this regime as the regime D (for duplication or duopoly). We will compare that scenario with two other possible regulatory regimes.

In regime L, the incumbent is not investing (because either regulation forbids investment or r is low enough to discourage it) and L decides to provide the service locally or not. Regime M (for monopoly) emerges when the local government is not allowed to duplicate the infrastructure. In this case, the local government is allowed to invest in a network only if the incumbent has not.[6]

[6] An alternative would be to forbid completely the intervention of L but this would be dominated by regime M since investment by I would be the same, but L would invest less.

3 Benchmark

As a preliminary step, consider a single district and assume that the incumbent's and the local government's investment costs are publicly known.

Let us first analyze the investment decisions by the incumbent and the local government.[7] At the last stage of the game, L decides whether to duplicate the network. Obviously, that decision depends on the choice made by I at the previous stage. If I has not upgraded the network, then L decides to build its own network if, and only if:

$$\max_{a \leq r} \theta W(a) + \theta a D(a) - k \geq 0. \tag{1}$$

The left-hand side of (1) is the welfare of the local government when it upgrades the network, and sets optimally the access price for that network.[8] The optimal access price is thus equal to nil. Hence, condition (1) can then be rewritten as $\theta \geq \frac{k}{W(0)}$.

If I has upgraded the network, then the local government is willing to duplicate the network if, and only if:

$$\max_{a \leq r} \theta W(a) + \theta a D(a) - k \geq \theta W(r). \tag{2}$$

The difference with inequality (1) is the gain for the local government if it decides not to intervene and contents itself with broadband services being provided to its local constituency at final price r. Simple manipulations allow to rewrite inequality (2) as:

$$k \leq \hat{k}_\theta(r) = \theta[W(0) - W(r)].$$

Let us now turn on to the decision faced by the local incumbent at the second stage of the game. The incumbent is not willing to undertake the upgrading if it expects to make losses from such a decision. Negative profits arise either because the level of demand for broadband services is too low to cover the fixed cost of the upgrading, or because the local government decides later on to bypass the incumbent's network. Therefore, I invests provided that:

$$\frac{c}{rD(r)} \leq \theta \leq \frac{k}{W(0) - W(r)}. \tag{3}$$

[7]Note that in this single-district setting, the government can be either central or local.

[8]That welfare is the sum of customers' surplus and the access revenues generated by the local public network, minus the fixed cost of duplication k; it does not account for the incumbent's profit.

Situations in which the incumbent never invests (either because it is not economically viable or because the incumbent expects to be duplicated by the local government) are of limited interested. Therefore, we focus on cases in which inequality (3) is satisfied. It can be shown that condition (3) holds for some values of the access price r set by the regulator and of the demand parameter θ if $k > c$, a condition which always holds in our model.

Social efficiency solves the following trade-off. The incumbent is more efficient than the local government to build the infrastructure. However, as opposed to the local government, the regulator cannot use taxation to finance the investment and must distort the access price away from the marginal cost of access.

In a regime where the incumbent invests, the access price r_{bb} implemented by the regulator is such that the incumbent exactly breaks even, or $\theta r_{bb} D(r_{bb}) = c$. Welfare is thus equal to: $\theta W(r_{bb})$. If, by contrast, the regulator lets the local government undertake the investment, L implements an access price which maximizes the welfare of its constituency only, which as we have seen, leads to a nil access price. Welfare is thus equal to: $\theta W(0) - k$.

Therefore, the first-best investment rule is as follows: the incumbent invests at a regulated access price r_{bb} if and only if $k \geq \hat{k}_\theta(r_{bb})$; otherwise, the local government invests and sets a nil access price on the new infrastructure.

In this framework where all the relevant information is available to all the actors, there are various ways to implement the first-best allocation. For instance, the regulator can dictate which party has to undertake the investment. Or, R can let the local government decide who has to make the investment (but R keeps the power to set the access price if the incumbent builds the infrastructure).

Alternatively, suppose that R provides the incumbent with the incentives to invest by setting an access price equal to r_{bb}, and allows the local government to duplicate the incumbent's network. It is straightforward that this regulation triggers the socially optimal investment choice at equilibrium of our game, i.e. regime D implements the first-best. By contrast, both regime M (which bans duplication) and regime L (which prevents investment by the incumbent) are suboptimal under complete information.

This benchmark is summarized as follows.

Conclusion 1 *With complete information and only one district, allowing duplication (i.e. regime D) implements the social optimum. The optimal regulated access price is r_{bb} and the incumbent invests iff $k \geq \hat{k}_\theta(r_{bb})$.*

Key to the second part of Conclusion 1 are the facts that, first, under complete information L's intervention is perfectly anticipated by I and R and, second, that R sets an access charge which leaves no profit to the incumbent so that L's and R's objectives become perfectly aligned. The same conclusion would obviously obtain with more than one district, provided that the regulator is able to charge different access prices in districts with different characteristics.

In a context where the regulator's information is limited, these results are preserved provided that (i) the incumbent and the local government share the same information at their decision nodes and (ii) the regulator and the local government maximize consumers welfare. Indeed, as long as the incumbent and the local government share the same information, any duplication will be perfectly anticipated by the incumbent and no duplication will occur at equilibrium. Moreover, as long as the regulator and the local government share the same objective, the latter's decision to invest or not will be optimal. Therefore, allowing duplication is still optimal in this context.

4 Multiple districts and externality effects

Presentation. In this section, we consider the case of multiple districts but we work under the assumption of a unique access charge nationwide. Indeed, the common practice, in particular for broadband access, is to have a unique access charge across all districts, referred to as a universal service obligation. One may also justify the assumption of a unique regulated access price by the fact that the regulator does not know the precise conditions in all districts (at least *ex-ante* at the time the regulation is decided) and must base its decision on prior and general knowledge.

Notice first that since local conditions (costs or demand) differ from one district to another, the choice of regulated price may either deter private firms from investing or provide a strictly positive profit in the districts with a low cost or a high demand.

In this multi-district framework, we will study the impact of several types of externality on the desirability to ban duplication. To discuss these issues, we consider the case of two districts, 1 and 2. Each district i is characterized by parameters θ_i and c_i where c_i is interpreted as the cost for the incumbent to develop the infrastructure in district i alone. We assume that the demand-adjusted cost is larger in district 1 than in district 2: $c_2/\theta_2 \leq c_1/\theta_1$.

To simplify matters we focus on the externality exerted by duplication in district 2 on district 1 by assuming that there is no local government in district 1 that can invest in infrastructure. Parameter k denotes then the cost for the local government to build the infrastructure in district 2. Moreover we assume that the regulator maximizes total consumers surplus; this allows to focus on inefficiencies not related to conflicting objectives between the regulator and the local authorities as a whole.[9] The timing is as follows: the regulator chooses an access price r; the incumbent decides whether to upgrade the network in each district; then the local government in district 2 decides to invest or not in the infrastructure.

Case with no externality. In this first case, the incumbent's decisions to build the infrastructure in each district are taken independently. More precisely, in regime M, the incumbent invests in district i if and only if:

$$\theta_i r D(r) - c_i \geq 0. \tag{4}$$

Since $c_2/\theta_2 \leq c_1/\theta_1$, the smallest regulated charge r_M inducing investment in both districts is the solution of:

$$r_M D(r_M) = \frac{c_1}{\theta_1}.$$

Consider now regime D. Duplication occurs at $r = r_M$ if and only if $k < \theta_2[W(0) - W(r_M)] = \hat{k}_{\theta_2}$. This decision rule is exactly the one that would be chosen by a regulator maximizing consumers surplus. Anticipating this behavior, the incumbent will only invest on district 2 when $k \geq \hat{k}_{\theta_2}$ but this will have no impact on its investment decision in district 1. This results can easily be extended to the case of n districts and to the case where the risk of duplication concerns also district 1. Therefore, in a multi-district framework with no externality, there is no reason to ban duplication.

Cost externality. In some cases, duplication may prevent the incumbent from exploiting scale economy at the level of the national territory, thereby creating inefficiencies. It was assumed so far that the cost of providing the infrastructure is fixed in each district. In practice, though, there are common fixed costs in deploying infrastructures. To illustrate this effect, we extend the previous case to introduce a technological externality. Formally, we assume that c_i is the cost of developing the infrastructure in district i only, while $c_1 + c_2 - \delta$ is the cost of

[9]Section 6 looks at the polar case where the regulator aims to maximize social surplus

developing the infrastructure in both districts. Thus, δ can be seen as a common fixed cost.

Consider first regime M. Then, the incumbent builds the infrastructure in both districts if:

$$\begin{aligned}
(\theta_1+\theta_2)\,rD(r)-(c_1+c_2-\delta) &\geq 0,\\
\theta_1 rD(r)-(c_1-\delta) &\geq 0,\\
\theta_2 rD(r)-(c_2-\delta) &\geq 0.
\end{aligned}$$

The smallest regulated access charge r_M is now solution of:

$$r_M D(r_M)=\max\left\{\frac{c_1-\delta}{\theta_1},\frac{c_1+c_2-\delta}{\theta_1+\theta_2}\right\}<\frac{c_1}{\theta_1}.$$

Note that the access charge r_M is decreasing with the level of cost externality δ.

Consider the case of regime D. Duplication occurs at $r=r_M$ if

$$k<\theta_2\left[W(0)-W(r_M(\delta))\right]=\hat{k}_{\theta_2}(\delta).$$

When this is the case, the regulator needs to set a price $r=r_D>r_M$ such that $\theta_1 r_D D(r_D)=c_1$ to induce investment in district 1. Thus, duplication forces to raise the price in district 1 to compensate for the foregone scale economies.

Duplication is efficient if: $\theta_1 W(r_D)+\theta_2 W(0)-k>(\theta_1+\theta_2)W(r_M)$. Thus, duplication should be forbidden when: $\hat{k}_{\theta_2}(\delta)-\theta_1\left[W(r_M)-W(r_D)\right]<k<\hat{k}_{\theta_2}(\delta)$.

Since r_M decreases with δ, an increase in the cost externality has two impacts. First, from an *ex-ante* point of view, it decreases the incentive to duplicate since $\hat{k}_{\theta_2}(\delta)$ decreases with δ. Second, the range of k with inefficient duplication increases since $\theta_1\left[W(r_D)-W(r_M)\right]$ increases. Therefore, in the case of cost externality, it may be optimal to ban duplication and this ban is all the more beneficial that the externality is large.

Demand externality. Demand externality is another reason that may induce the legislator to ban duplication. Two different sources of demand externality can be envisioned: network externality and competition between districts for mobile consumers. Let us study these two cases in turn.

To consider the case of network externality, we slightly change the two-district framework by assuming that consumers in district 1 benefit from the fact that district 2's consumers are served by the same firm as themselves. Formally, we assume that the net consumer surplus in district 1 is given by:

- $(\theta_1+\hat{\theta})W(r)$ if the incumbent is the provider in the second district;
- $\theta_1 W(r)$ if the second district market is served by the local government.

This case coincides exactly with the case of cost externality studied above. Indeed, when duplication is not allowed -in regime M-, the incumbent builds the infrastructure in both districts if:

$$\begin{aligned}(\theta_1+\hat{\theta}+\theta_2)rD(r)-(c_1+c_2) &\geq 0,\\ (\theta_1+\hat{\theta})rD(r)-c_1 &\geq 0,\\ (\theta_2+\hat{\theta})rD(r)-c_2 &\geq 0.\end{aligned}$$

The smallest regulated access charge r_M is now solution of:

$$r_M D(r_M)=\max\left\{\frac{c_1}{\theta_1+\hat{\theta}},\frac{c_1+c_2}{\theta_1+\hat{\theta}+\theta_2}\right\}<\frac{c_1}{\theta_1}.$$

In this case, the access charge r_M is decreasing with the level of network externality $\hat{\theta}$.

Consider the case of regime D. Duplication occurs at $r=r_M$ if

$$k<\theta_2\left[W(0)-W\left(r_M(\hat{\theta})\right)\right]=\hat{k}_{\theta_2}(\hat{\theta}).$$

When this is the case, the regulator needs to set a price $r=r_D>r_M$ such that $\theta_1 r_D D(r_D)=c_1$ to induce investment in district 1. Thus, duplication forces to raise again the price in district 1 to compensate for the foregone network externality and it should be forbidden when: $\hat{k}_{\theta_2}(\hat{\theta})+\theta_1\left[W(r_D)-W(r_M)\right]<k<\hat{k}_{\theta_2}(\hat{\theta})$. Therefore, in the case of network externality, it may be optimal to ban duplication.

To study the case of district competition with mobile agents we amend our framework by assuming that $\hat{\theta}$ represents a mass of mobile agents, either wealthy consumers or firms, who choose their location according to the proposals made by the districts. We assume that those agents are initially located in district 1 and that the mobile agents cannot modify the ranking of the cost/demand ratio across districts, i.e. $c_2/\theta_2\leq c_1/(\theta_1+\hat{\theta})\leq c_1/\theta_1$.

Note that the local government in district 2 maximizes the surplus of the initial population in its own district. More precisely, it considers only the immobile agents even if, *ex-post*, mobile agents turn out to settle in district 2.[10] In the

[10] This assumption builds on the fact the local government is a representative (possibly elected) of the inhabitants of the district, and, therefore, is subject to the influence of the agents living in the district at the moment of making choices.

absence of any mobility, the local government would choose a price equal to zero for the use of the infrastructure in case of duplication. But this would not deter the incumbent from investing in district 1 since the price ensuring budget-balance would not change. In case of mobility, the consumers leaving district 1 would drive up the price in this district. Note that the price in district 2 may be above zero in order to increase local revenues to a lesser extent than the regulated price that prevails in district 1 however. As in the case of network externality, this mobility will induce an inefficiency in the duplication decision.

We summarize this discussion as follows:

Conclusion 2 *Cost or demand externalities may justify a ban on duplication.*

5 Duplication risk and risk premium

This section is devoted to the analysis of our game taking into account some asymmetries of information between the incumbent and the local government. More precisely, the informational gap is now between, on one side, the regulator and the incumbent, and, on the other side, the local government since we assume that only L knows its investment cost k.[11] In this section, we keep on assuming that the level of demand θ is public information.

The crucial difference between this informational setting and the one developed in the previous sections is that, now, the incumbent cannot perfectly foresee the local government's duplication decision. Duplication may then arise with a strictly positive probability at equilibrium, leading the regulator to compensate the incumbent for this risk in order to stimulate private investment.

When $k \leq \hat{k}_\theta(r)$, the local government bypasses the existing network and builds its own public network. Assuming duplication is authorized, the regulator has two options: trigger investment by the incumbent firm, or not.

In the first case, define the access price r_D such that the incumbent is just indifferent between building a network or not, that is:

$$\left[1 - F(\hat{k}_\theta(r_D))\right] \theta r_D D(r_D) = c.$$

The regulator then sets $r = r_D$ to induce investment. Of course r_D may not exist, in which case the regime with duplication is equivalent to regime L since the

[11] Superior information of the incumbent, for instance on the level of demand, would not invalidate our results.

incumbent is deterred from investing. The choice is thus between regime M and regime L. Regime M then dominates if:

$$\theta W(r_{bb}) > \mathbb{E}\{\max(\theta W(0) - k, 0)\}.$$

To focus on the interesting cases, we assume from now on that r_D exists. Then under the regime D, the regulated access charge that maximizes welfare with private investment is r_D. Expected welfare in the regime with duplication and $r = r_D$ writes as follows:

$$\begin{aligned} W_D &= \int_{\underline{k}}^{\hat{k}_\theta(r_D)} [\theta W(0) - k - c]\, dF(k) + \int_{\hat{k}_\theta(r_D)}^{+\infty} [\theta W(r_D) + \theta r_D D(r_D) - c]\, dF(k), \\ &= \int_{\underline{k}}^{\hat{k}_\theta(r_D)} [\theta W(0) - k]\, dF(k) + \int_{\hat{k}_\theta(r_D)}^{+\infty} \theta W(r_D) dF(k). \end{aligned}$$

Another option is to deter the incumbent from investing by setting too low an access price (for instance $r < r_D$); only the local government does invest, provided its cost parameter is sufficiently low, or, formally, when $k \leq \theta W(0)$. Expected welfare in that case can thus be written as follows: $W_L = \int_{\underline{k}}^{\theta W(0)} [\theta W(0) - k]\, dF(k)$.

Interestingly, the comparison of the two regulatory policies turns out to be unambiguous:

Lemma 1 *Assume that there is asymmetric information on the local government's cost parameter only and that r_D exists. Then regime D with $r = r_D$ dominates regime L.*

Proof. Suppose r_D exists and rewrite W_D as follows:

$$\begin{aligned} W_D &= \int_{\underline{k}}^{\hat{k}_\theta(r_D)} [\theta W(0) - k]\, dF(k) + \int_{\hat{k}_\theta(r_D)}^{+\infty} \theta W(r_D) dF(k), \\ &= W_L + \int_{\hat{k}_\theta(r_D)}^{\theta W(0)} [\theta W(r_D) - \theta W(0) + k]\, dF(k) + \int_{\theta W(0)}^{+\infty} \theta W(r_D) dF(k). \end{aligned}$$

Obviously, the second integral in the last expression is positive. Notice also that, for any r, $\hat{k}_\theta(r) \leq \theta W(0)$ and that $\hat{k}_\theta(r) \leq k \leq \theta W(0)$ is equivalent to $\theta[W(0) - W(r)] \leq k \leq \theta W(0)$. Therefore, the first integral is also positive. We thus conclude that $W_D > W_L$. ■

The next step is to determine when it is optimal to ban the intervention of the local government (regime M). Obviously, there is a trade-off. On the one hand, the intervention of the local government arises provided that its cost parameter is not too high and allows to benefit from a reduced final price. On the other hand, since the incumbent can no longer perfectly anticipate the local government's *ex-post* intervention due to asymmetric information, the incumbent's *ex-ante* incentive to invest weakens, thereby forcing the regulator to increase the access price.

Formally, if there is a ban on the intervention by the local government, the regulator provides the incumbent with the incentives to upgrade the network by setting the access price $r_M = r_{bb}$ (such that $\theta r_{bb} D(r_{bb}) - c = 0$). Expected welfare is thus given by: $W_M = \theta W(r_{bb})$.

Comparing W_M and W_D, we obtain the following result:

Lemma 2 *Assume that there is asymmetric information on the local government's cost parameter only and that r_D exists. Then it is preferable to ban duplication and induce investment by the incumbent, i.e. regime M dominates regime D.*

Proof. See Appendix. ■

Lemma 2 states that when the incumbent invests and there is some duplication, it would be better to simply induce investment with no duplication. The result is due to the fact that inducing the incumbent to invest requires compensating it for the risk of duplication by raising the access charge. Compared to setting r_{bb} with no duplication, the increase in access charge offsets any benefits that may arise from the local government's intervention.

As opposed to the previous case of symmetric information, duplication is not always efficient because $r_D > r_{bb}$. There exists a range of cost k where duplication occurs while it would be more efficient to let the incumbent invest but with the break-even access charge r_{bb}.

Conclusion 3 *When there is asymmetric information on the local government's cost parameter only, then the regime with duplication is dominated by a regime without duplication.*

In real-life situations, the areas on which duplication occurs are not exactly the same as the ones covered by private investment. Therefore, local government intervention may improve global coverage. There would then be a trade-off between increased coverage and a rise in the *ex-ante* regulated tariff.

6 Divergent objectives

General analysis. Divergence of objectives between the regulator and the local government occurs when the regulator accounts for the welfare of some agents that are outside the jurisdiction of the local government. As discussed above, this occurs when there are externalities between districts. This is also the case when R accounts for the private sector's profit. To discuss this issue we consider a district in a multi-district context and assume that the regulated access charge r does not depend on the level of demand θ that prevails in this particular district. We assume also that the incumbent knows k, that there is no externality and we consider a district where the profit $\theta rD(r) - c$ is positive.

Let us assume that R maximizes total welfare, i.e. the sum of consumer surplus and profit. There may then be a conflict of objective as L duplicates when $k < \hat{k}_\theta(\theta) = \theta[W(0) - W(r)]$ while from a total welfare perspective this is efficient only if $\theta W(0) - k \geq \theta W(r) + \theta rD(r) - c$ or $k < \hat{k}_\theta(\theta) - [\theta rD(r) - c]$.

If the local governments cost were observable *ex-ante*[12] by the regulator, then R simply has to establish an *ex-ante* list of the districts were duplication is allowed or not. The incumbent then refrains from investing in those cases where it anticipates that the local government will duplicate. Symmetric information between R and I implies that no inefficient duplication arises at equilibrium. For a given access tariff r, this *ex-ante* rule implements the optimal outcome.

In many cases, though, the regulator lacks such a knowledge about k. Then allowing duplication results in inefficient duplication whenever k lies between $\hat{k}_\theta(\theta) - [\theta rD(r) - c]$ and $\hat{k}_\theta(\theta)$. In this case, only inefficient duplication can occur so that a ban on duplication is optimal if the expected welfare gain conditional on duplication occurring is less that the profit. This writes as

$$\hat{k}_\theta(r) - \mathbb{E}\left\{k \mid \hat{k}_\theta(r) > k\right\} < \theta rD(r) - c \tag{5}$$

Conclusion 4 *Assume I and L share the same information. From a total welfare perspective, allowing duplication (regime D) induces excessive public investment. A ban on duplication is not optimal if the incumbent's profit is small.*

Thus, duplication should be allowed only in districts with low demand or large cost.

[12]That is, before the investment decision by the incumbent.

Constraining local governments' intervention. Faced with the difficulty of predicting the level of k, the regulator may try to use alternative instruments to curb local activism. We consider here two types of intervention: price-floor and compensation.

Suppose that if duplication arises, then the regulator can impose a price-floor on the local government's network: that is, the price to access L's infrastructure cannot be lower than $l \leq r$.[13] Thus, the incumbent decides to invest as long as it expects not to be duplicated and the local government duplicates when $k \leq \theta[W(l) + lD(l) - W(r)]$. Expected welfare is thus given by:

$$\tilde{W}(r,l) = \int_{\underline{k}}^{\theta[W(l)+lD(l)-W(r)]} [\theta W(l) + \theta lD(l) - k]\, dF(k) + \int_{\theta[W(l)+lD(l)-W(r)]}^{+\infty} [\theta W(r) + \theta rD(r) - c]\, dF(k).$$

Starting from regime D, implementing a small price-floor is optimal if:

$$\frac{\partial \tilde{W}}{\partial l}(r, l=0) \propto \theta rD(r) - c - \frac{F(\hat{k}_\theta(r))}{f(\hat{k}_\theta(r))} > 0. \tag{6}$$

Imposing a price-floor has both a cost and a benefit. The cost is that the service is provided less efficiently by the local government when it invests and it is incurred with probability $F(\hat{k}_\theta)$. The benefit is that there is less inefficient public investment, where the level of inefficiency is of the order of I's profit and the marginal effect is captured by the density. A positive price floor is then optimal only if the inefficiency in investment decisions is large.[14] By contrast:

Conclusion 5 *Imposing a price-floor to local authorities is not optimal when the incumbent's profit from investing is small.*

Another possibility is to require that if the local government duplicates, it compensates the incumbent for its investment by reimbursing c. Thus, the incumbent decides to invest as long as it expects not to be duplicated and the local government duplicates when $k \leq \hat{k}_\theta(\theta) - c$. Expected welfare with reimbursement αc, $\alpha \in \{0,1\}$ is given by:

$$\tilde{W}(r,\alpha) = \int_{\underline{k}}^{\hat{k}_\theta(\theta)-\alpha c} [\theta W(0) - k]\, dF(k) + \int_{\hat{k}_\theta(\theta)-\alpha c}^{+\infty} [\theta W(r) + \theta rD(r) - c]\, dF(k).$$

[13] As it should be clear, a price-cap has no bite in our context.

[14] The condition (6) is sufficient if the hazard rate $F(.)/f(.)$ is increasing.

Starting from regime D, implementing a full reimbursement policy is optimal if $\tilde{W}(r,\alpha=1)-\tilde{W}(r,\alpha=0)>0$ which can be written as:

$$\hat{k}_\theta(r)-\mathbb{E}\left\{k \mid k\in\left[\hat{k}_\theta(r)-c,\hat{k}_\theta(r)\right]\right\}<\theta rD(r)-c. \tag{7}$$

Condition (7) shows that when the regulated access price leaves the incumbent with no profit, then a reimbursement policy is not warranted. A regime with authorization of duplication is optimal in that case.

Complications arise when the regulated access tariff departs from this break-even point. For a district with a large demand, so that the incumbent profit tends to be large in that district, a reimbursement rule tends to be optimal.

Conclusion 6 *Imposing a full reimbursement policy is not optimal when the incumbent's profit from investing is small.*

Commitment issues. One issue with policy constraining *ex-ante* the local government is that the regulator may lack the commitment power to implement it *ex-post*, once the incumbent has sunk the investment cost. To discuss this issue without excessive technicalities, let us assume that R knows the cost k. Then R optimally bans duplication and the incumbent invests when

$$\hat{k}_\theta(r)-k<\theta rD(r)-c \tag{8}$$

Suppose that L knows that R is not consistent over time. Then, after the firm has invested, the local government may ask the regulator to change the rule. On regards of such a request, R would reconsider the policy and allow the duplication only if the welfare gain is positive. At this stage the cost c is sunk by the firm so that R would remove the ban if $\theta W(0)-k>\theta W(r)+\theta rD(r)$, or $k<\hat{k}_\theta(r)-\theta rD(r)$. But this cannot be the case under Condition (8) since c is positive. Thus R would always refuse to renegotiate a ban with L.

However the alternative scenario where the regulator could impose a ban *ex-post* could occur, although this seems less credible. Indeed suppose that despite the fact that duplication is allowed and $k<\hat{k}_\theta(r)-\theta rD(r)+c$, the firm invests and then asks the regulator to impose a ban on duplication. Again the request is made once the cost c is sunk. Thus R would be willing to impose the ban if $k>\hat{k}_\theta(r)-\theta rD(r)$. Thus for k in the interval $\left(\hat{k}_\theta(r)-\theta rD(r),\hat{k}_\theta(r)-\theta rD(r)+c\right)$ the policy would be revised *ex-post* and duplication would be banned. Thus:

Conclusion 7 *Under symmetric information, a ban on duplication is time-consistent, but a policy allowing duplication may not be.*

Notice that this implies that without commitment and with a sophisticated firm able to manipulate the policy making process, there will be an excessive level of investment by the firm and insufficient intervention by the local government.

7 Conclusion

Investment by local governments may help fostering the fast development of new telecommunication infrastructures and reaching a large coverage of population. As such it may be an important element of public policies aiming at reducing the potential gap between highly competitive zones and less competitive ones. Still, public policy should guard itself from potential crowding out of efficient private investment, which may occur when public investment is not restricted to areas where private investment is deficient.

Our paper helps understanding the issues at stake by focusing on situations where conditions for competition are not met, but it is not obvious whether a regulated private monopoly dominates a local public investment.Thus our conclusions are valid in such grey areas where competition is not effective enough.

We identify three key dimensions that should be considered with special attention when designing rules governing the intervention of local authorities. First the impact of inter-district externalities when the regulator chooses uniform rules independent of the local conditions (as demand and costs). Second, the risk born by private investors, that may refrain them from investing in the context of uncertainty. Costly *ex-ante* weakening of regulation is then required to restore investment incentives. Our results suggest that when this is the sole distortion, the benefits of local intervention do not outweigh the cost of lenient regulation. Last, other issues relate to differences between the motives of the local authorities and the social welfare and the lack of commitment power of the national regulator.

In discussing these issues we ignored political economy or prestige considerations that may lead politicians to invest excessively in advanced technologies at the expense of less rewarding but more useful local goods. Our discussion of the regulation with conflicting objectives doesn't clearly support banning duplication but rather suggests that some form of control and limits on local public intervention may help improve efficiency.

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Appendix

Proof of Lemma 2.

Note first that if there is no investment in regime D, banning duplication has no effect since the regulatory choice is only between allowing the incumbent to invest with no duplication, or no investment by the incumbent and investment by the local government. Assume from now on that there is investment in regime D.

One has to show that $W_M - W_D$ is always positive when duplication arises with a strictly positive probability under regime D. We have:

$$K(c) = W_M - W_D = \theta W(r_{bb}) - \left[\int_{\underline{k}}^{\hat{k}_\theta(r_D)} [\theta W(0) - k]\, dF(k) + \int_{\hat{k}_\theta(r_D)}^{+\infty} \theta W(r_D) dF(k) \right].$$

Note first that when $c = 0$, then $r_D = r_{bb} = 0$ and $\hat{k}_\theta(r_D) = 0$. Therefore, $K(0) = 0$.

Now let us differentiate $K(.)$ with respect to c:

$$K'(c) = -\theta D(r_{bb}) \frac{\partial r_{bb}}{\partial c} + \theta D(r_D) \frac{\partial r_D}{\partial c} \left[1 - F(\hat{k}_\theta(r_D))\right].$$

Remark that r_{bb} and r_D are increasing functions of c. Let us consider first the definition of r_{bb}. It is the smallest solution of the following relationship: $\theta r_{bb} D(r_{bb}) - c = 0$. It exists for c less than the monopoly profit. Using the implicit function theorem, it is therefore direct to conclude that:

$$\frac{\partial r_{bb}}{\partial c} = \frac{1}{\theta[D(r_{bb}) + r_{bb} D'(r_{bb})]} > 0,$$

since $r_{bb} \leq a_m = \arg\max_a aD(a)$.

Similarly, r_D is defined as the smallest solution of: $[1 - F(\hat{k}_\theta(r_D)]\theta r_D D(r_D) - c = 0$. Since for $c = 0$ the solution is $r_D = 0$, and using a continuity argument, there are solutions to the previous equation for small c and a straightforward argument shows that the smallest one is increasing with c. Notice that r_{bb} exists if r_D exists.

There may be upward discontinuities of r_D. At such point $K(.)$ has an upward discontinuity. Now, where r_D is continuous, it is differentiable and the derivative of the gross profit function is increasing (since $a_D \leq a_m$). More precisely, we have:

$$\frac{\partial r_D}{\partial c} = \frac{1}{\theta \left[D(r_D)(1 - F(\hat{k}_\theta(r_D))) + r_D \frac{\partial}{\partial r} \left(D(r)(1 - F(\hat{k}_\theta(r)) \right) \Big|_{r=r_D} \right]} > 0.$$

We can now rewrite the expression for $K'(c)$ as follows:

$$K'(c) = \frac{-D(r_{bb})}{D(r_{bb}) + r_{bb} D'(r_{bb})} + \frac{D(r_D)(1 - F(\hat{k}_\theta))}{D(r_D)(1 - F(\hat{k}_\theta(r_D))) + r_D \frac{\partial}{\partial r} (D(r) \left(1 - F(\hat{k}_\theta(r))\right)) \Big|_{r=r_D}}.$$

Now, using the positivity of the denominator, we can state that:

$$\begin{aligned}
K'(c) \geq 0 \quad &\Leftrightarrow \quad \frac{D(r_{bb}) + r_{bb} D'(r_{bb})}{D(r_{bb})} \geq \frac{D(r_D)(1 - F(\hat{k}_\theta(r_D))) + r_D \frac{\partial}{\partial r} \left(D(r) \, (1 - F(\hat{k}_\theta(r))) \right)\big|_{r=r_D}}{D(r_D)(1 - F(\hat{k}_\theta(r_D)))}, \\
&\Leftrightarrow \quad 1 - \varepsilon(r_{bb}) \geq 1 + \frac{\partial}{\partial r} \left(D(r)(1 - F(\hat{k}_\theta(r))) \right)\big|_{r=r_D} \frac{r_D}{D(r_D)(1 - F(\hat{k}_\theta(r_D)))}, \\
&\Leftrightarrow \quad -\varepsilon(r_{bb}) \geq \frac{r_D \left[D'(r_D)(1 - F(\hat{k}_\theta(r_D))) + D(r_D) \frac{\partial}{\partial r} \left(1 - F(\hat{k}_\theta(r_D)) \right)\big|_{r=r_D} \right]}{D(r_D)(1 - F(\hat{k}_\theta(r_D)))}, \\
&\Leftrightarrow \quad -\varepsilon(r_{bb}) \geq -\varepsilon(r_D) + r_D \frac{\frac{\partial}{\partial r} \left(1 - F(\hat{k}_\theta(r)) \right)\big|_{r=r_D}}{(1 - F(\hat{k}_\theta(r_D)))}.
\end{aligned}$$

Since $r_{bb} \leq r_D$ and $\varepsilon(.)$ is increasing, $-\varepsilon(r_{bb}) \geq -\varepsilon(r_D)$. Moreover:

$$\frac{\partial}{\partial r} \left(1 - F(\hat{k}_\theta(r)) \right)\big|_{r=r_D} = -\frac{d\hat{k}_\theta}{\partial r}(r_D) f(\hat{k}_\theta(r_D)) = -\theta D(r_D) f(\hat{k}_\theta(r_D)) \leq 0.$$

So $K'(c) \geq 0$ when r_D is continuous. Thus $K(c)$ is non-decreasing with c. Using the fact that $K(0) = 0$, we obtain that $K(c)$ is non-negative on its domain.