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About CERRE

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1 Introduction

Digital connectivity plays a fundamental role in stimulating innovation and progress in all sectors of the economy. Especially now, in the context of the current Covid-19 crisis and the recovery plan, the continued development of network infrastructure and functionalities will be central to the success of the European economy.

To achieve widespread connectivity, significant investment is required in the telecommunications sector. Therefore, encouraging investment has become a central objective in recent reforms of the telecommunications regulatory framework and legislative initiatives.

To speed up the deployment of fixed and mobile very-high capacity networks[1] in what is now a liberalised and competitive sector, cooperation within the telecommunications sector and beyond (in the so-called industry 'verticals') is needed. At the same time, the separation of hardware and software in modern networks (e.g., via Software Defined Network technologies) increases the strategic independence of potential partners, making cooperation possibly less risky for competition.

More generally, cooperation between telecommunications operators for the roll-out of new infrastructure, the standardisation of network technologies (Open-RAN), or the development of cloud solutions can bring significant economic benefits to the society and the economy by allowing market players to reduce risks, share costs and pool different know-how.

Co-investment agreements for the deployment of ultrafast broadband fixed infrastructures have already been implemented in some European countries (e.g., in France, Italy, and Spain). Network sharing agreements are also prevalent in mobile markets. They can take different forms ranging from (passive) sharing of cell sites to (active) sharing of Radio Access Networks (RANs) and spectrum.[2]

From a public policy point of view, allowing for cooperation between competitors may involve trade-offs. On the one hand, cooperation allows operators to reduce risks and share costs, improving their ability to invest and innovate. On the other hand, there is the concern that cooperation may harm competition, e.g., by facilitating some form of collusion between firms, which could weaken incentives to invest.

In this Issue Paper, we review the potential pros and cons of allowing for infrastructure sharing between telecommunications operators, based on the relevant economic literature and previous research done at CERRE on co-investment and network sharing.[3]

The rest of this Issue Paper is organised as follows. In Section 2, we define infrastructure sharing and describe different possible operational models. In Section 3, we present the status of infrastructure sharing agreements in the European Union as of 2020. Finally, in Section 4, we discuss the possible pro- and anti-competitive effects of infrastructure sharing.

[1] Very-high capacity networks (VHCN) are either fiber networks (at least up to the distribution point) or networks capable of delivering the same performance in terms of download and upload speed, latency, etc. See, in particular, BEREC (2020a).
[2] More recently, a noticeable trend is to spin out tower assets into TowerCos, who/that? then try to increase sharing as "neutral hosts."
[3] See the CERRE reports on "Implementing co-investment and network sharing" (May 2020) and "Cooperation between firms to deploy very high capacity networks" (November 2020).

2 What is infrastructure sharing?

Infrastructure sharing occurs when two or more operators share network infrastructure and thus the costs associated with it.

For fixed networks, infrastructure sharing corresponds to *co-investment*. Operators typically share fiber-to-the-home (FTTH) or fiber-to-the-building (FTTB) network infrastructure to deliver ultrafast broadband services. They can share passive infrastructure, such as ducts or dark fibers, or active infrastructure, for example, when they share the whole network.

For mobile networks, infrastructure sharing corresponds to *network sharing*. As with fixed networks, network sharing agreements can concern both passive and active network elements. Passive sharing occurs when firms share passive network elements, such as mobile sites or masts. Active sharing occurs when they also share active (electronic) network elements, such as the radio access network (RAN sharing) or the whole network (national roaming).

In this note, we will use the generic term *infrastructure sharing* to designate sharing of either fixed or mobile network infrastructure. Therefore, infrastructure sharing encompasses both co-investment and network sharing.

Infrastructure sharing can happen to different degrees, depending on the network elements shared by the firms or the geographic scope of their cooperation. Of course, the cost savings achieved via infrastructure sharing depend on the degree of sharing, with a higher degree of sharing implying larger cost savings.

It also makes sense to distinguish between *ex-ante* and *ex-post* infrastructure sharing. *Ex-ante* sharing occurs before investments are made; this is the case for most fixed co-investment agreements. *Ex-post* sharing occurs after the investments have been made, for example, to consolidate existing networks. Infrastructure sharing is more likely to influence investment incentives when it takes place *ex-ante* than *ex-post*. However, the possibility to share infrastructure *ex-post* may lead to opportunistic behavior by potential co-investors, which could wait for all uncertainties to be resolved before entering (*ex-post*) a sharing agreement.[4]

We observe two types of operational models in Europe for infrastructure sharing (see Berkeley Research Group, 2017; CERRE, 2020a): cooperative arrangements (e.g., joint ventures) and contractual arrangements (e.g., reciprocal access or one-way sharing).

With a cooperative arrangement such as a joint venture, partners create a common entity (e.g., a special purpose vehicle), which manages the roll-out of their joint network and then maintains and operates the infrastructure. A joint venture requires a strong commitment from partners, as there are high costs of establishing, governing, and terminating the joint entity. However, it can give rise to significant synergies, for example, because each partner brings its know-how or because partners engage in joint procurement.

Contractual arrangements, such as reciprocal access (where each co-investor deploys its infrastructure and then grants access to it to its partners) or one-way sharing (where an operator invests in infrastructure and provides access to third-party operators through co-financing) are more flexible forms of organisation. They entail lower costs for partners than a cooperative arrangement for setting up, operating, and terminating the cooperation. The downside is that, as each operator deploys its infrastructure independently, the possible synergies are more limited.

Finally, infrastructure sharing can be mandated by regulation or be market-driven. For example, in France, the regulatory framework obliges investors to accept co-investment requests from third

[4] CERRE (2020a) discusses the problems raised by "late" co-investment.

parties in urban and suburban areas. In mobile markets, sharing masts and sites is mandatory in some European countries (e.g., Belgium, Spain, and Sweden) and encouraged in many others. However, market-driven infrastructure sharing agreements have arisen in many countries. Often (but not always), they aim to cover less densely populated areas. As discussed below, what motivates firms to engage in infrastructure sharing is the possibility of reducing their costs. Finally, the European Electronic Communications Code (EECC) views co-investment agreements as a substitute for significant market power (SMP) access regulation. Co-investment in the EECC is market-driven, but it can lead to complete deregulation under some conditions.

3 Infrastructure sharing in the European Union

3.1 Mobile network sharing

According to ETNO (2020), in 2019, there were between 1 and 3 network sharing agreements in all member states, half of them involving the sharing of RAN active equipment.

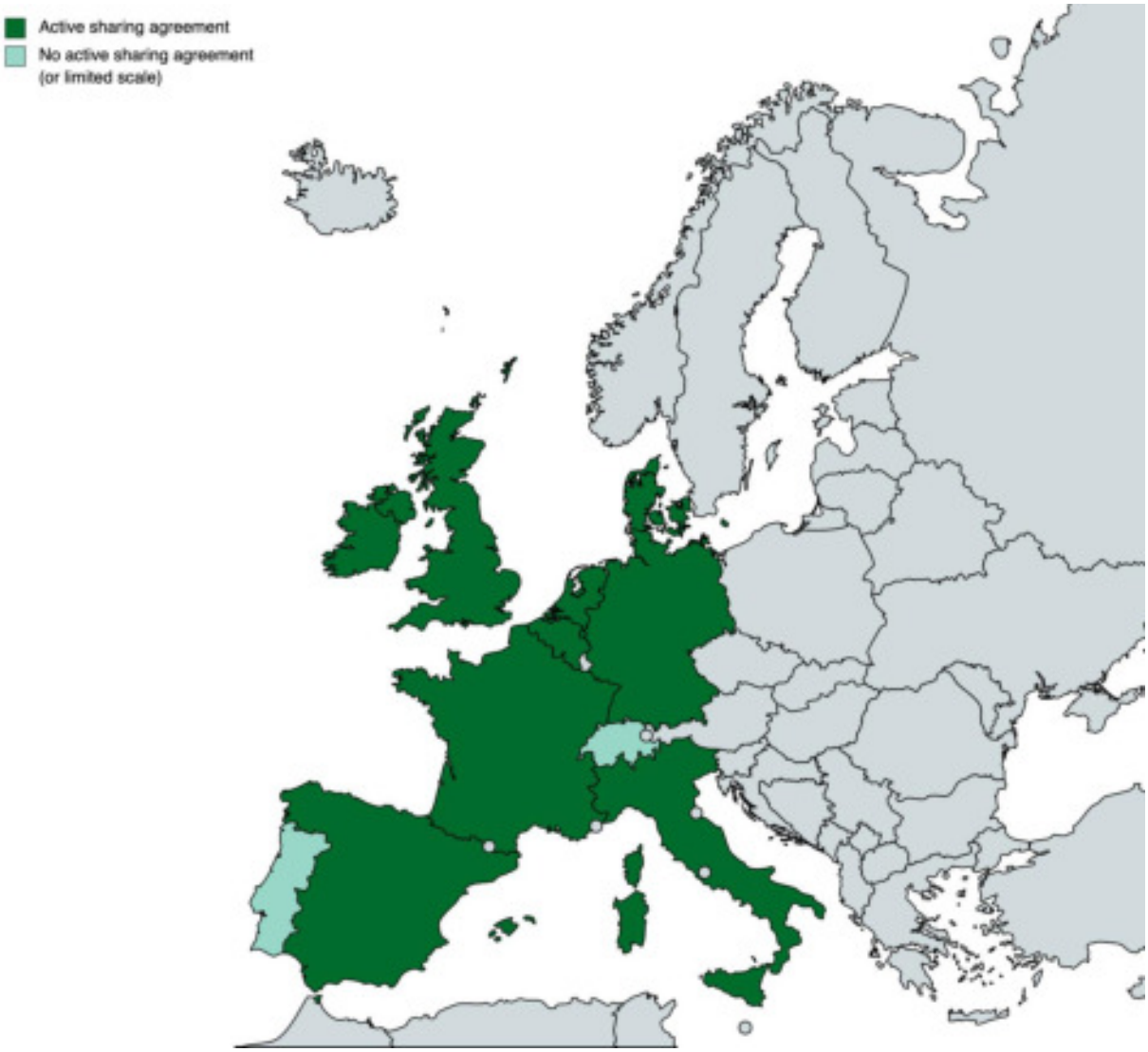
Passive sharing of sites and masts has a long tradition in Europe and is now widespread. In most countries, it is even mandated to reduce the environmental impact of network deployments. A recent trend is also to spin out tower assets into so-called TowerCos, active only upstream, which have the incentive to share their passive infrastructure to operators in a "neutral" (non-discriminatory) way.

Active sharing agreements are also in place in many countries. Figure 1 shows countries where an active sharing agreement can be observed as of 2020 according to the information that we collected in a previous CERRE report.[5] In most cases, these active sharing agreements correspond to RAN sharing, but in a few cases, they consist of nationwide roaming. Most active sharing agreements are based on commercial negotiations between market players and are not the result of regulatory obligations, according to BEREC (2018). Spectrum sharing is not allowed in most countries, with a few exceptions (e.g., Denmark and Finland).

[5] See "Implementing co-investment and network sharing" (May 2020): https://cerre.eu/publications/telecom-co-investment-network-sharing-study/ Note that the report does not cover all European member states, so the identification of network sharing agreements is not exhaustive.

Figure 1: Mobile active sharing agreements (2020)

Source of information: CERRE (2020a).



3.2 Fixed co-investment

Co-investment agreements for the deployment of fiber access networks are more recent than mobile network sharing agreements. In France, firms deploying a fiber network must accept co-investment requests from third parties. In very dense (urban) areas, sharing obligations concern only the final part of the network (in-building wiring).[6] In less dense (suburban) areas, the whole network should be opened to potential co-investors. In other countries (e.g., Italy, Portugal, Spain), commercial agreements for fiber infrastructure deployment have emerged. Co-investment agreements for the deployment between telecommunications operators and utility firms (e.g., energy) can be observed in some countries (e.g., Germany, Ireland).

[6] Note that access to in-building wiring can be requested by regulatory authorities under Article 61(3) of the EECC?

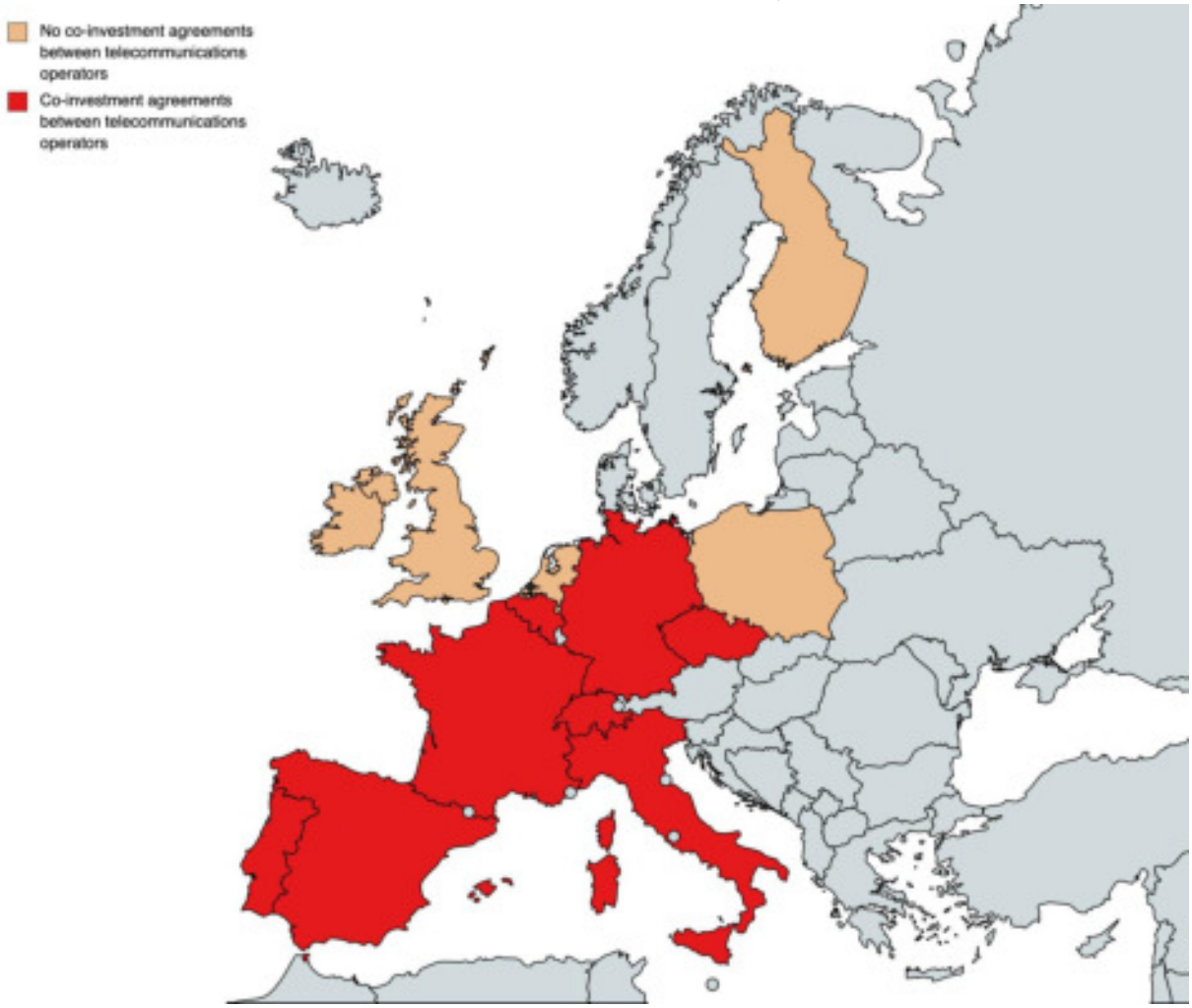
The EECC, which came into force in December 2018, contains various provisions regarding co-investment. Article 76 and the associated Annex IV provide incentives for co-investment by providing relief from ex-ante SMP regulation under some conditions. Since then, BEREC has published guidelines for a consistent application of these conditions (BEREC, 2020b).

In Italy, the incumbent operator, TIM, proposed the first co-investment offer under Article 76 through its subsidiary FiberCop. Potential co-investors can ask for access to the shared infrastructure via indefeasible rights of use (IRUs) or minimum purchase commitments, with also the possibility to become shareholders of FiberCop under certain conditions.

Figure 2 shows countries where fiber co-investment agreements between telecommunications operators can be observed as of 2021, according to Cullen International.[7]

Figure 2: Fiber co-investment agreements between telecommunications operators (2021)

Source of the information: Cullen International, October 2021.



[7] Note that in some countries, operators co-invest with utility companies. For example, in Ireland, Vodafone and the state-owned former electricity monopoly, ESB, established a joint venture in 2014 to deploy FTTH. In other countries (e.g., the Netherlands and Poland), some operators "co-invest" with pension funds or equity funds. However, in all these cases, the cooperation is not between telecommunications operators, which is our focus in this Issue Paper.

4 Pro and anti-competitive effects of infrastructure sharing

In general, cooperation between competitors at specific stages of the value chain, for R&D or environment protection for example, can benefit both companies and society. However, horizontal agreements can also raise concerns, as firms may end up coordinating in softening competition.

In this section, we discuss more specifically the possible pro- and anti-competitive effects of infrastructure sharing agreements between telecommunications network operators and how to design the agreement to mitigate anti-competitive effects.

4.1 Pro-competitive effects

Infrastructure sharing entails cost reductions, which may benefit consumers in terms of lower prices, a higher quality of service, and a wider variety of products and services available.[8]

Infrastructure sharing can reduce the fixed costs (CAPEX) of deploying or upgrading a network for an operator. These cost savings can benefit consumers when they translate into higher investment. For telecommunications infrastructure, the investment may take two main forms. First, operators may invest in expanding the coverage of their networks. This is particularly relevant for fixed networks (e.g., for the deployment of new fiber access networks) and new generations of mobile networks (e.g., 5G). Second, operators can invest in higher network quality (e.g., higher data speeds), for example, when they densify their mobile networks.

Infrastructure sharing may also reduce the variable costs (OPEX) of maintaining and operating a network that has already been deployed. Consumers benefit to the extent that the reduction of variable costs is passed through in terms of lower prices. In turn, the decrease in prices can influence operators' investment incentives, as we will discuss below.

The magnitude of the possible cost savings, and therefore, of the possible benefits for consumers of infrastructure sharing, will depend on various factors and, in particular, on the degree of sharing, with the idea that a higher degree of sharing may lead to more significant cost savings.[9]

When assessing the potential benefits of infrastructure sharing in terms of higher investment or lower prices, an essential step is defining the counterfactual: how would the market look without infrastructure sharing?

The first question is whether infrastructure sharing may allow competition to emerge, or instead, substitute for other forms of competition. In this spirit, BEREC (2019) proposes to assess active network sharing agreements in the mobile market according to the feasibility of infrastructure-based competition. In areas where infrastructure-based competition is deemed feasible, active network sharing should be restricted, as it may substitute for infrastructure-based competition, which is the preferred form of competition. Conversely, in areas where infrastructure-based competition cannot be reasonably achieved, infrastructure sharing should be encouraged. Indeed, in these areas, absent network sharing, competition is unlikely to emerge.[10]

[8] Our focus is on the possible benefits and costs of infrastructure sharing for competition. Infrastructure sharing may have other benefits and potential downsides, which are also relevant to society. For example, infrastructure sharing may have environmental benefits when firms share a common infrastructure rather than deploying their own. Conversely, infrastructure sharing may reduce network resilience. See OECD (2014) and BEREC (2019).

[9] For example, for mobile networks, active sharing corresponds to a higher degree of sharing than passive sharing, and BEREC (2019) states that "active sharing […] can achieve greater savings than passive sharing."

[10] Finally, BEREC (2019) notes that in areas where the feasibility of infrastructure-based competition is not "pre-determined," network-sharing agreements must be assessed on a case-by-case basis. Note that BEREC's report does not consider the specificities of 5G networks. The prospects for infrastructure-based competition may also differ for fixed and mobile networks.

Another defining feature of the counterfactual is whether an access obligation would apply to the firm deploying the infrastructure, absent infrastructure sharing. In the fixed market, it would be the case only if the operator has SMP. In the mobile market, the counterfactual would not involve any such access obligation (with the caveat that sharing towers are a common regulatory requirement).

Bourreau, Cambini and Hoernig (2018) study the impact of a co-investment agreement between an incumbent operator and a new entrant on prices and infrastructure deployment. They consider that in the counterfactual without co-investment, standard access obligations would be imposed on the incumbent, which corresponds to the scenario of an SMP fixed operator. This access obligation is lifted when co-investment is introduced. They show that, compared to the counterfactual with access, co-investment yields lower prices for consumers and stimulates investment in network coverage. Total coverage expands because, with co-investment, the incumbent operator becomes a monopoly in the costlier areas, which improves the profitability of investing in these areas.[11] Furthermore, consumers pay lower prices, as the implicit access price with co-investment is equal to marginal cost, which leads to lower prices than standard access. Therefore, consumers benefit in two ways from co-investment: network coverage is larger, and they pay lower prices.[12]

However, the impact of co-investment is different if the counterfactual does not involve any access obligations (i.e., the scenario of a non-SMP fixed operator). Using the same type of analysis done by Bourreau et al. (2018), one can show that co-investment does not affect total coverage. Indeed, in the costlier areas, only one operator finds it profitable to invest whether there is infrastructure sharing or not. However, the areas with competition between the incumbent and the entrant expand as co-investment allows entry. Therefore, consumers benefit from lower prices and broader choices in these competitive areas than in the counterfactual.

For mobile networks, absent infrastructure sharing, no access obligations would apply to the mobile network operators (MNOs). Besides, mobile markets are less concentrated than fixed markets. In each European market, there are typically 3 or 4 nationwide competing MNOs. Without infrastructure sharing, they would invest independently to expand and upgrade their networks.

Motta and Tarantino (2018) study the impact of a network sharing agreement between two (mobile) operators on prices and investment in an oligopolistic mobile market.[13] In their framework, the network sharing agreement corresponds to a joint venture. Thus, the two network-sharing partners coordinate their investment while competing in prices. Investment reduces operating costs, but it is equivalent to considering a quality investment. The authors show that the network sharing agreement leads to lower prices and higher investment than a counterfactual with independent investment. Therefore, consumer surplus increases. The mechanism is that network sharing leads to lower costs and thus, lower prices. In turn, firms sell larger quantities, which increases their incentive to invest in a higher quality of service.

Table 1 summarises the possible pro-competitive effects of infrastructure sharing discussed in this section.

An operator's decision to deploy its network in a given area may depend on the rivals' entry decisions for fixed networks and be, by comparison, hardly affected by the rivals' decisions for mobile networks.

[11] The authors assume that the operators can set different prices (or quality-adjusted prices) in different areas. Therefore, an operator can earn monopoly profits in the areas where it is the only provider.

[12] By contrast, the SMP operator does not necessarily gain from co-investment compared to the counterfactual with access. On the one hand, it can save investment costs via infrastructure sharing. On the other hand, competition is strengthened in the areas with co-investment. Therefore, the operator gains only if the cost savings exceed the profit loss.

[13] The analysis of network sharing agreements has been removed in the published version of the paper, Motta and Tarantino (2021).

Table 1: Pro-competitive effects of infrastructure sharing

Cost reductions entailed by infrastructure sharing		
Reduced deployment costs (CAPEX)	Reduced maintenance and operating costs (OPEX)	
Expected effect: higher investment	*Expected effect*: lower prices	
The impact of infrastructure sharing depends on counterfactual		
Fixed SMP: access obligations	*Fixed non-SMP*: no access obligations and monopoly	*Mobile*: no access and oligopoly
Possible impact based on literature review		
Larger total coverage Lower prices	Total coverage unaffected Lower prices	Higher quality investment Lower prices

4.2 Anti-competitive effects

Like any horizontal agreement, infrastructure sharing may have anti-competitive effects. Following OECD (2014), we distinguish between potential unilateral and coordinated effects of infrastructure sharing agreements.

4.1.1 Unilateral effects

First, infrastructure sharing agreements may entail unilateral effects:

- The partners may have the ability and the incentive to raise final prices and soften competition at the retail level by setting high internal or external access prices to the shared infrastructure.
- The partners' ability and unilateral incentives to compete and improve their services could be weakened. This may result from a lack of freedom for unilateral investment or wrong alignment between the parties when one partner can hold back the others.
- The partners may have the ability and the incentive to foreclose potential competitors from using their joint network, for example, by asking prohibitive access prices to outsiders. To the extent that infrastructure sharing allows firms to benefit from cost reductions, if some operators enter the agreement but not all, the latter could be at a cost disadvantage, weakening their competitive position if they are barred from participating.

4.1.2 Coordinated effects

Another significant concern is that infrastructure sharing may facilitate collusion between partners and thereby soften competition.

First, infrastructure sharing may facilitate *explicit collusion*. The necessary coordination on joint investment plans may facilitate information exchange between parties in other dimensions and help them coordinate their actions to soften competition at the retail level. For example, operators may be able to coordinate their marketing strategies to the detriment of consumers. They could also coordinate their technological choices, opting for lower network quality, or reduce investment, thereby increasing profits.

Second, infrastructure sharing may facilitate *tacit collusion*. The likelihood of tacit collusion to arise depends on firms' ability to (i) coordinate on a 'collusive' agreement, (ii) detect deviations from the

agreement, and (iii) punish these deviations. Therefore, the feasibility of tacit collusion depends on how competition between partners and non-partners works, which, in turn, can be influenced by the design of the infrastructure sharing agreement.

By sharing infrastructure, operators may end up with a very similar cost structure, which is expected to facilitate tacit collusion. For example, Miyagiwa (2009) shows that Research Joint Ventures (RJVs) tend to facilitate tacit collusion, compared to a benchmark with independent R&D, because cooperation in-process R&D yields symmetric costs for partners, whereas independent R&D results in asymmetric costs.

At the same time, infrastructure sharing may limit the possibilities of differentiation. Whereas we expect vertical differentiation to make collusion more difficult to sustain (as it creates an asymmetry between firms), the effect of horizontal differentiation is more ambiguous (Ivaldi et al., 2003). For example, Lambertini et al. (2002) compare the sustainability of collusion with an RJV and with independent R&D, assuming that forming RJV results in identical products for the participating firms. They find that, for this reason, an RJV makes collusion less likely to emerge than in the benchmark with independent R&D.

The overall effect of infrastructure sharing on the possibility of tacit collusion will thus depend on how the sharing agreement affects the commonality of costs and the possibilities of horizontal and vertical differentiation between partners.

The risk that an infrastructure sharing agreement facilitates (explicit or tacit) also depends on the technology and the market structure.

For example, policymakers consider that passive sharing does not raise any competition concerns because information exchange between parties is limited and sharing only passive network elements leaves each partner free to manage its network independently. By contrast, operators need to coordinate more when they share an active network (e.g., a radio access network, RAN), raising the types of concerns discussed above. Note, however, that the development of new network technologies, such as Software Driven Networking (SDN) or Network Function Virtualisation (NFV),[14] will allow network functionality and performance to be almost independent of the underlying infrastructure. The diffusion of these technologies may therefore alleviate the concerns raised by active sharing to some extent.

The possible coordinated effects of an infrastructure sharing agreement also depend on the market structure, such as the number of competitors outside the deal or its geographical scope. An agreement with a limited scope, in terms of geography or share of firms involved, will raise fewer concerns than an agreement with a broad scope.

Finally, anti-competitive effects exist only to the extent that they are not addressed contractually. We discuss below what should be the appropriate design of an infrastructure sharing agreement to mitigate these effects.

4.3 Design of infrastructure sharing agreements

The proper design of an infrastructure sharing agreement may address the concerns discussed above. Note that introducing appropriate contractual solutions can be done at the partners' initiative or be required by competition or regulatory authorities.

[14] SDN and NFV are network virtualisation technologies, allowing the separation of hardware and software in the network. Independent software-defined networks can then be run on the same (hardware) infrastructure.

Table 2 below summarises the possible contractual remedies that can mitigate the potential anti-competitive effects of infrastructure sharing agreements.[15]

Table 2: Contractual remedies to mitigate the potential anti-competitive effects of infrastructure sharing agreements

Unilateral effects	**Remedies**
Raising internal and/or external access prices to soften competition at the retail level	Regulatory oversight of access prices
Lack of freedom or incentive for differentiation or unilateral investment	Independence of each partner should be guaranteed (e.g., the right to unilaterally invest outside of the co-investment vehicle should be guaranteed)
Foreclosure: exclusion of third-party operators through entry deterring access conditions for non-partners	Wholesale access guaranteed. Exclusivity is limited to the minimum necessary
Coordinated effects	**Remedies**
Possibilities to implement explicit collusion, depending on the possibilities to exchange information and to coordinate on more than joint investment plans	Independence of partners should be guaranteed; information exchange should be limited to minimum necessary (e.g., via "clean teams" or some form of separation)
Possibilities to implement tacit collusion, depending on partners' ability to (i) coordinate on a 'collusive' agreement, (ii) detect deviations from the agreement, and (iii) punish deviations	

In the EECC, regulatory relief for SMP operators offering co-investment under Article 76 is subject to some conditions ensuring that the terms provided to potential co-investors "*favour sustainable competition in the long term*" (Annex IV(c)). These conditions are similar to the remedies outlined in Table 2 for potential unilateral effects, but with a stronger focus on the risks of foreclosure.

4.4 Empirical evidence

Since an infrastructure sharing agreement may have both pro- and anti-competitive effects, which depend on various factors, such as the counterfactual, the market structure, and the technology, the assessment should be done on a case-by-case basis. Empirical evidence on the impact of infrastructure sharing agreements can also be helpful to evaluate the overall effect. We review two recent empirical studies on the impact of (fixed) co-investment and (mobile) network sharing.

Aimene, Lebourges and Liang (2021) empirically study the impact of co-investment on FTTH adoption and local competition, using data on French municipalities located in suburban areas for the period 2015-2018. They find that co-investment is associated with a higher take-up of FTTH services and stronger competition in the local areas with co-investment. When co-investment occurs, the market share of the incumbent operator, Orange, decreases by 5.9%, compared to a similar area where Orange would operate alone. Aimene et al. (2021) study a situation that corresponds to

[15] See the CERRE report on "Implementing co-investment and network sharing" (May 2020) for more details.

the scenario of a "fixed SMP operator" in Table 1, since in the absence of co-investment, in France, the operator deploying its infrastructure has to offer standard wholesale access on a per-line basis. Their findings suggest that the pro-competitive effects of co-investment dominate any possible anti-competitive effects. Note, however, that co-investment is regulated in France.

Maier-Rigaud, Ivaldi and Heller (2020) provide empirical evidence on the impact on prices and investment of a network sharing agreement in the Czech Republic. First, using a difference-in-differences approach, they find that this network sharing agreement led to a significant reduction of prices of baskets of mobile services in the Czech Republic compared to a control group of other European countries. Second, using a structural model of demand and supply for mobile services, they find that the network sharing agreement has also led to lower costs and increased network quality. Maier-Rigaud et al. (2020) study a case corresponding to the last column in Table 1 where the counterfactual involves no access obligation and an oligopolistic market. Their empirical findings are consistent with the theoretical predictions of lower prices and increased investment, suggesting that the pro-competitive effects dominate any possible anti-competitive effects.

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