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# Old technology upgrades, innovation, and competition in vertically differentiated markets

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ABSTRACT

In this paper we study how the migration from an old to a new technology is affected by the access price to the old technology, when it is set after investments have taken place. We show that both the incumbent and the regulator are willing to set a very high access price to accelerate consumers' migration to the new technology. When the quality of the old technology is exogenous and the entrant dominates investment in the new technology, the old technology is completely switched off in equilibrium. On the other hand, when the incumbent dominates investment, the old technology persists. When the incumbent can decide on an endogenous upgrade of the old technology, the migration to the new technology is slowed down, and the entrant might be foreclosed.



## 1. Introduction

In network industries, infrastructure investments are necessary to maintain or improve the quality of services provided to consumers. Such investments can involve either upgrades of the old generation network or the deployment of new infrastructures, i.e., next generation networks. For example, in the European telecommunications industry operators have started to invest in high-speed fiber next generation access networks to replace the old legacy copper networks. At the same time, some historical telecom operators are planning to introduce a new technology, called "vectoring," which will allow them to upgrade copper networks to provide higher speeds for Internet access.[2]

As network infrastructures are expected to be a strong contributor to economic activity and growth,[3] a fast transition from old network technologies to new ones is a key challenge for policy makers. For example, the European Commission has set up a "Digital Agenda 2020" with very

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[1] The views and opinions expressed herein are solely those of the author and do not necessarily reflect those of the Autorità per le garanzie nelle comunicazioni.

[2] Fiber networks provide a higher speed than the standard DSL broadband technology. Vectoring is an engineering technique that enables traditional copper lines to achieve speeds that are close to the theoretical limits, and therefore also close to the speed of first-generation fiber networks. For vectoring to be effective, however, all copper lines in the relevant area have to be under the control of a single provider, which implies that vectoring is not compatible with sub-loop unbundling, a wholesale service mandated by several European National Regulatory Agencies.

[3] See Czernich et al. (2011) for empirical evidence that the diffusion of broadband has a positive impact on growth.

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ambitious objectives for the migration of consumers from standard broadband (based on the old generation copper network) to very-high speed broadband (based on next generation fiber networks).[4] A relevant and important question is then which type of regulatory intervention could accelerate the transition.

The migration from an old to a new network technology can indeed be a slow process, due in particular to the large investments necessary to deploy next generation networks, and to the competition on the consumers' side between the two technologies, when they coexist in a transitory phase. Access regulations, which oblige the owner of the legacy network to provide access to competitors at a given price, can affect both investment incentives and the competition between the old and the new technologies, and hence shape the transition process.

In this paper we study how the terms of access to the old generation network affect the competition between the old and the new generation networks in the retail market, and thus the migration from the old to the new technology. This question is of particular relevance in European telecoms, where some of the alternative operators investing in fiber lease access to the legacy copper network of incumbent operators.[5]

Aside from access obligations, we also consider two other forms of regulatory intervention: (i) switching off the old generation network after the new network has been deployed and (ii) allowing or forbidding an upgrade of the old generation network. Switching off the old network forces consumer migration to the new network, and thereby reinforces firms' incentives to invest in next generation networks. In Australia, for example, a public company (NBN Co) is rolling out a national fiber infrastructure and has started a countdown for the switch-off of the old copper network. The European Commission also sees a switch-off of the copper network as a means of providing proper investment incentives to operators.[6] An upgrade of the old generation network is likely to have one of two contrasting effects on investment incentives. It could either slow down the transition because of the tougher competition between the old and the new technologies after the upgrade, or alternatively, spur investment because operators wish to escape the competition from the old technology. It is therefore not surprising that in most European countries regulators are still wondering whether they should authorize the vectoring technology.[7]

We then investigate the two following questions. First, if a switch off of the old generation network is socially desirable, can it be achieved by the market players without any regulatory intervention, or is a formal switch-off by the regulatory authority necessary? Second, should the regulator allow the owner of the legacy network to upgrade it?

In the stream of literature which studies the interplay between regulation and investment in network industries (see Cambini and Jiang (2009) and Vogelsang (2013) for recent surveys), the new technology always replaces the old one. Some papers analyze investment by an incumbent firm only, which can upgrade its old network (e.g., see Foros (2004), Kotakorpi (2006), etc.). Others focus on entrants' incentives to bypass the old network by investing in a new alternative infrastructure (e.g., see Bourreau and Doğan (2005, 2006), Avenali et al. (2010), Klumpp and Su (2010), etc.). Finally, some authors analyze investment races where firms compete to deploy new infrastructures, which completely replace the old ones (e.g., Gans (2001), Hori and Mizuno (2006), Vareda and Hoernig (2010), etc.). In all these studies, consumers cannot choose between the old and the new technology, and as a result the migration issue is absent.

We depart from this standard set-up by building a framework where two firms, an incumbent which owns the legacy old generation network (OGN), and an entrant that leases access to the OGN, can invest to roll out next generation networks (NGN) in order to offer multiple vertically differentiated services based on the old and the new technologies. The migration from the old technology to the new ones is endogenous to consumers' decisions. It depends on firms' pricing decisions, their initial investment decisions, and the upgrade of the OGN.[8]

We start by analyzing a benchmark with a monopoly provider of OGN and/or NGN services. We show that, given the demand and cost structure of our model, it is profit and welfare maximizing to supply only NGN services. Hence, consistent with policy makers' position in favor of fiber networks, a full migration to NGN is socially desirable.

We proceed by analyzing investments in a duopolistic context, when the OGN cannot be upgraded. The incumbent and an entrant initially decide on the quality of their next generation networks (NGNs). Once investments have been made, the access charge to the OGN is set by either the incumbent or the regulator. Finally, firms compete with vertically-differentiated multiple products.

Therefore, we assume that the incumbent and the regulator cannot commit ex-ante to an access price to the OGN. Consequently, they cannot influence investment decisions directly with the access price. However, they can influence the consumers' choices at the retail level, when both the OGN and the NGN services are available, which affects indirectly investment incentives.

Our results are as follows (see also the summary Table 1 below). The game has two equilibria: a leapfrogging

[4] The European Commission's objective is that half of European households subscribe to a broadband offer above 100 Mbps by 2020.

[5] Our approach is less relevant in other markets (such as the US market), where the alternative operators investing in fiber do not lease access to the legacy copper network, but rather use cable or electricity infrastructures.

[6] For example, European Commission Vice-President Neelie Kroes declared that "the gradual switch-off of copper could reduce the cost to such a degree that new fiber investments break even in under 10 years. And thus align the interests of investors and long-term financing providers." (See: Investing in digital networks: a bridge to Europe's future, 3 October 2011, http://europa.eu/rapid/press-release_SPEECH-11-623_en.htm). However, to date, in Europe, there is no example of copper switch-off.

[7] The only two European regulators that have withdrawn the sub-loop unbundling obligation to allow the deployment of vectoring are those of Belgium and Ireland, but other NRAs are also considering the possibility of at least partially removing this obligation.

[8] Our model captures the actual situation in several European countries, such as France, Italy, Denmark and Finland, among others, where there are two (or more) competing fiber (FTTH) networks, and where incumbent operators are upgrading their copper infrastructures to VDSL2/vectoring in order to provide FTTC services.