Regulation and Investment in Telecom Network Infrastructure Facilities: The Recent Developments and Debates

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Abstract. The regulation has the greatest role in forcing the introduction and the establishment of competition in the fixed telecom markets by facilitating the entrants' access conditions to the incumbent's infrastructure facilities (the local loop). Recently, the sole way to ensure the development of telecom industry consists to promote innovation and investment in network infrastructure technologies. This paper provides a critical review of both recent theoretical and empirical literature that address the issues of regulation on innovation and investment in the fixed telecommunication infrastructures.

Keywords: bottleneck, access regulation policies, investment in network upgrade, service-based competition, facility-based competition.

1 Introduction

The ultimate aim of regulation is to achieve the goal of ensuring effective competition in whole telecom markets (Oldale and Padilla 2004). There are two forms of competition: (1) the service-based competition, in which entrants provide their end-user services using the existent facilities of the historical integrated monopoly (the incumbent), and (2) the facility-based competition, in which entrants provide their services using their own network infrastructures. The later form of competition is argued to lead to more rapid development of telecom markets by fostering innovation and reducing the need to regulation. But, the facility-based entry is impeded by the high investment costs (the sunk costs of building the telecom network infrastructures). This explains why the regulators in a number of countries are turned to promote the service-

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based competition rather than the facility-based competition, by requiring regulatory access policies generally in detriment of incumbent but in favor of the entrants[1]. In the short run, service-based competition reduces prices and enhances consumer welfares by eliminating progressively the discriminatory behaviors of the significant market power firms and inciting operators to use the network infrastructures in efficient manner in order to reduce their costs (cost reduction). In the long-term, service based competition may reduce or even impede innovation in telecom industry by discouraging investment in network infrastructure facilities. Therefore, the regulation-investment relationship is complex when considering both short and long terms (static and dynamic). Literature on one-way access points out on the trade-off (dilemma) between static and dynamic efficiency. Recent contributions investigate this issue by focusing on the question of impacts of access regulation on innovation in telecom industry.

The aim of this paper is to survey the recent theoretical and empirical contributions on one- way access literature that focus on the impacts of access regulation on investment in new telecom infrastructure technologies (broadband technologies).

Given the extensive literature on this question, there are some researches that have interested in reviewing this literature. The most recent and complete survey on the relationship between regulation and investment is given by Cambini and Jiang (2009). These authors conclude that the impact of regulation on investment is ambiguous and further research is necessary to understand this relationship. In this paper, we seek to extend the proposal of Cambini and Jiang (2009) by focusing on recent contributions on this question and also giving more detailed analysis for the individual impacts of specific regulatory policies such as the vertical separation of the integrated incumbent on investment in new technologies.

The rest of this paper is organized as follows. In section 2, we review the theoretical works that investigate the regulation-investment relationship. In section 3, we survey the empirical literatures on this question. Section 4 concludes.

2 Regulation and investment: a theoretical literature review

Regulation should simultaneously accomplish the following objectives to permit the development of telecom industry. First, regulation should promote competition in order to reduce prices and thereby enhance consumer welfare. Second, regulation should ensure efficient entry, promote investment in network upgrade by incumbent and incite entrant to build its own network facili-

[1] See Ben Dkhil (2014 a) for a review and classification of these reforms.

ties when it is socially optimal to do in order to enhance quality of end-user services and thereby enhance consumer welfare (Cave and Doyle 1994)[2].

Literature shows that there are conflicts between these objectives when considering both short and long terms. In particular, a number of researches point out on the regulation-investment dilemma (e.g., Laffont and Tirole 2000; Bourreau, Dogan and Manant 2010) suggesting that there is a trade-off between statistic efficiency and dynamic efficiency: access regulation has the advantage of promoting service-based competition and therefore increases consumer surplus and reduces prices in the short run (static efficiency). But, it discourages the infrastructure investments by entrants (facility-based entry) and the existent infrastructure owner (the incumbent), which delays and impedes the innovation and reduces service differentiations and consumer surplus leading to delay the development of telecom markets in the long term (dynamic efficiency)[3]. Indeed, for incumbent, a stringent access regulation may reduce its access revenue and therefore reduce its investment incitation, while for entrants, benefits earned from service based competition (experiences, market shares) may exceed gain generating from constructing new infrastructures in presence of access regulation and the high investment costs. These entrants' benefits due to service-based competition represent opportunity costs that lead to replacement effect to facility based entry in favor to service-based entry (Bourreau, Dogan and Manant 2010).

2.1 The impact of access regulation on incumbent's investment incentives in network upgrade

The relationship between access price regulation and investment is a subject of debate across previous studies. Obviously, as noted by Chang, Koski and Majumdar (2003), this relationship can be seen in two different manners leading to two opposite results. On the one hand, access price regulation undermines telecom investment by reducing directly access surplus of infrastructure owners through requiring lower access price. On the other hand, access price regulation promotes telecom investment as follows: requiring lower ac-

[2] Cave and Doyle (1994) note "There are three main aims in setting access charges":
-"The promotion of an efficient (static) level and structure of access prices".
- "The attainment of dynamic efficiency through efficient entry and investment decisions. "
-" To allow the incumbent to make a sufficient return to sustain the cost of social obligations. "

[3] Laffont and Tirole (2000) note that "There is in general a trade-off between promoting competition to increase social welfare once the infrastructure is in place and encouraging the incumbent to invest and maintain the infrastructure. That is, regulators must encourage entry without expropriating incumbents.", p.7; and that « There is then a trade-off between two considerations: "ex post efficiency," which goes in the direction of fostering competition through access beyond the level that would be spontaneously permitted by the bottleneck owner, and "ex ante efficiency," which suggests giving the bottleneck owner flexibility in exploiting the bottleneck.", p.137. Bourreau, Dogan, and Manant (2010) also note that: "Regulators therefore face a trade-off: while service-based entry promotes competition in the short-run, the full benefits of competition would be achieved in the longer-run only with facility-based entry to the market", p. 683; and that "the trade-off between service-based competition and facility-based competition, i.e., ensuring that favorable conditions for the former does not hinder the latter", p. 684.

cess price leads to lower prices for end-users services which rise consumer surplus and increases demand for retail services (enhancement of volume of calls and connectivity, etc.). This, in turn, leads to increase access surplus of network owners, which spur investment in telecom infrastructures. Therefore, the variation of demand in retail segment affects incumbent's investment decision because it affects its profits. In imperfect markets where products are not homogenous (i.e. vertically or/and horizontally differentiated), the prices and thereby demand are different from those in perfect markets. Some papers have studied the case where incumbent and its rivals provide homogenous services (e.g., Sarmento and Brandão 2007). Others have focused on the case where retail services are differentiated (e.g., Foros 2004; Kotakorpi 2006; Brito, Pereira and Vareda 2010).

Further, the timing when regulator can intervene to set the access price also affects the investment decision of the incumbent firm. In particular literature distinguishes two cases of timing of regulatory intervention to regulate the access price: (1) Ex-post regulatory intervention (No credible commitment): In this approach, the access price is assumed to be fixed by the regulatory authorities after the investment decision. (2) Ex ante regulatory intervention (Credible regulatory commitment) under which the access price is assumed to be fixed by the regulatory authorities prior to the incumbent's investment decision. Under this assumption, the regulator is supposed to have certain ability to make an ex ante credible commitment.

Recent contributions also have analyzed the impact of access price on both retail competition and incumbent's investment considering two different cases of industry configurations: vertical integration versus vertical separation of the monopolist provider of essential input (access service). In the case of vertical integration, the monopolist provider of the essential input (the incumbent) also operates in the competitive market by providing the final service while in the case of vertical separation (ownership separation), the monopolist network provider is forced to only operate in wholesale segment and, therefore, it is prohibited by authority to provide the end user service[4].

All these studies model the different interactions and strategies followed by the actors in these related markets (incumbent, entrant(s), consumers and regulator) using the game theory. Under different market circumstances (homogenous vs differentiated final services, ex ante vs ex poste regulation, vertical integration vs vertical separation of the incumbent firm, etc.) results and conclusions may differ from one study to another. Nevertheless, it is always possible to draw some policy lessons. We present first the main studies that consider only the case of vertical integration of the incumbent firm. Second, we review the literature that compares vertical integration to vertical separation.

[4] In some countries, incumbents have chosen to apply voluntary this measure of vertical separation. This case is not the focus here.

2.1.1 The impact of the access pricing on investment and competition: The case of vertical integration of the incumbent firm

Foros (2004) considers an integrated monopolist network provider and an independent retailer competing "à la Cournot" and having different abilities to provide value-added services in the competitive segment using the same input (the network access service). He considers two cases of access pricing: the unregulated case versus the access regulation without commitment. He shows that in unregulated case the integrated firm chooses an access price over the marginal cost of the network access provision to foreclose the market while the regulator sets the access price at/ or close to the marginal costs. He demonstrates that under the latter case, the consumer and the total welfare may be reduced under some properties on investment costs and the integrated network provider chooses the over-investment strategy to foreclose the market when it has the highest ability to provide value added services (low spillover effect) while it has no incentive to invest in network quality upgrade when it provides retail service with value added quite similar to the one offered by its rival.

Kotakorpi (2006) finds quite similar results. He considers an integrated monopolist network provider and a rival fringe[5] competing "à la Cournot" and providing vertically differentiated services. He shows that when access is regulated (without commitment), the socially optimal access price should be equal to the marginal cost of the network provision. Compared to the unregulated case, the integrated firm's investment incentives are reduced, the under-investment problem (i.e. relatively to the social optimum level) is worsened and the foreclosure may occur in the case of high investment spillovers (i.e. a high positive effect of investment on the competitors' demand). However, in the absence of access regulation, low investment spillover undermines investment in network upgrade and may lead the network provider to foreclosure the market by setting too high access price.

Mizuno and Yoshino (2012) also consider a setting similar to Foros (2004) but focus on the case where the investment spillover is low. They show that when the access price is determined by the regulator after the investment decision (access regulation without commitment), the integrated network provider uses the investment strategy to deviate the access price from its socially optimal level (the marginal cost). In particular, it under-invests (over-invests) in order to force the regulator to set the access price below (over) the marginal cost if the investment cost is low (high).

Sarmento and Brandão (2007) consider a different setting. They consider an integrated network provider and an independent rival competing "à la Stackelberg" and providing homogenous retail services. They compare three alternative ways to set the access price for the network access service: (1) the unregulated access price (2) the cost-based regulation (3) the retail-minus regulation.

[5] Group of independent rivals that have same costs and demand functions and therefore they have same prices and qualities.

Their main findings are the following. First, regulation prevents foreclosure. Second, the level of investment under deregulation policies is higher than that under the access regulation policies. Third, the retail-minus regulation permits better outcomes in term of consumer welfare and investment incentives in network upgrade than the cost based regulation.

All these papers study the investment incentives if the regulator sets the access price after the investment decision (no-commitment credible regime). Vareda (2010) and Brito, Pereira and Vareda (2010) also investigate the case where the regulator has the ability to set the access price before the investment decision (commitment credible regime). In particular, Brito, Pereira and Vareda (2010) consider an integrated incumbent and an independent entrant competing with horizontally differentiated services. They study whether the two-part access charge[6] may solve the trade-off between static and dynamic efficiency. They show that when the investment cost is low relatively to the incumbent's profits earned from investments, the socially optimal access price coincides with the marginal cost of the network provision and the regulator uses the access fee to promote investment. In this case, the trade-off between competition and investment is solved. However, when investment cost is too high, the investment even if occurs is not socially desirable while for intermediate value of investment costs, the trade-off is not solved: to induce investment, regulator must set an access price over the marginal cost which leads to foreclosure. These results are the same under access regulation with and without commitment when investment cost is low or high.

Vareda (2010) assumes that the integrated incumbent and the separate entrant offer vertically differentiated services and that there are two complement kinds of investment in network infrastructures: (1) quality-upgrade (2) cost-reduction. He shows that the higher the ability of the regulator to make a credible commitment in access price before investment decision, the higher the integrated network provider's investment incentives. He also demonstrates that the investment in network quality upgrade (cost reduction) is increasing (decreasing) in the access charge when investment cost is too high. Otherwise, the higher the access price the higher the investment incentive.

The first lesson that we can draw from these different contributions is that when the monopolist network provider is vertically integrated and therefore operates in the competitive segment, access regulation is necessary to avoid foreclosure and ensure competition. The second lesson is that access regulation may discourage investment in network upgrade when the access price is fixed at marginal cost of the network provision because in this case the fixed cost incurred by the incumbent is not covered. The third lesson is that when spillover effect is small, the integrated network provider over-invests relatively to the social optimum and may use this over-investment strategy to

[6] All papers reviewed in this paper consider linear access price except this paper that assumes two part access tariffs, which consist on the linear access tariff majored by a fixed fee.

foreclose the market if the access price is regulated. Therefore, it seems from these different contributions that the trade-off between competition and investment is still unsolved.

2.1.2 The impact of the access pricing on investment and competition: Vertical separation versus Vertical integration of the incumbent firm

When there are conflicting regulatory targets, it may be insufficient to use a sole policy tool (the access price) (Laffont and Tirole 2000, p.125). As we can see from previous paragraph, access price regulation shows many limitations to solve the trade-off between static and dynamic efficiency. As a remedy, the regulators have recently turned from a regime that controls the behavior of incumbent to a regime that seeks to modify the incitation of incumbent through requiring additional regulatory tools that reduce or even remove the motivation of the network owner to discriminate entrants (Bijl 2005). Precisely, policy makers and even certain academics suggest separating the activities that remain dominated by the natural monopoly properties (the network access provision) from competitive activities (provision of end user services) to help to achieve these conflicting regulatory goals (promoting both competition and investment). In particular, this solution is first applied in the USA since 1984 to the incumbent operator AT&T leading to the creation of separated providers: seven Regional Bell Operating Companies (RBOCs) that provide only local loop access services, and competitive carriers that provide only long distance and international services. Another famous example of separation applied in most countries is the ADSL local loop which is generally owned by the historical telecom monopoly that only provides access service to the Internet Service Providers (ISPs) that in turn only sell end user services (internet connection). However, the debate about the role of such practice in promoting both competition and investment is recently revived and intensified specially in Europe and OECD countries. The OECD recommendation of 2001 proposes different separation models that can be ranged from less to most intensive policy as follows: (1) Accounting separation which consists to create separate accounts for wholesale and retail services (2) behavioral or virtual separation (e.g. functional separation or operational separation) which is a moderate policy that consists in creating separate divisions for wholesale and retail services in the firm owned by the vertically integrated network provider. (3) The full structural separation which consists in creating separate ownerships for wholesale and retail activities. This recommendation was followed by series of reports published by OECD in 2003, 2006 and 2011[7]. Conclusion reached by the authors of these reports states that there is no universal industry structure that is convenient to all countries, and therefore, the regulator in a given country

[7] See (OECD, 2001, 2003b, 2006, 2011 a).

should evaluate and balance between costs and benefits of such practice before deciding the implementation of the separation policy. European Commission (EC) seems to have a quite similar position. In its access directive 2009/140/EC, EC recommends to regulators to force separation as the last solution in the case where other policy tools (e.g. access price regulation) fail to eliminate the discriminatory behavior of the integrated network provider.

Structural separation is recently a subject of extensive debates across academic literature. Economic researches point to the difficulties to conclude about its effects on telecom industry. In particular, there is no consensus about the importance of its costs and benefits in term of competition and investment. A number of authors (e.g., Cave 2006 b; Bijl 2005; Cave adn Doyle 2007) argue that structural separation by prohibiting the incumbent from operating in retail segment avoids foreclosure and therefore promotes competition and increase consumers' welfare. According to these authors, vertically separated network provider has neither incitation nor ability to discriminate retailers. Precisely, vertical separation removes anti-competitive behavior usually practiced by the vertically integrated incumbent against its rivals in retail segment that consists in providing the access service at high price (price discrimination) or degrade the quality of the access service delivered to its competitors (non-price discrimination). Further, when the incumbent is vertically integrated, these discriminations are vertically transmitted from wholesale market to retail market by rising end-user prices and reducing quality of competitors' retail services. Therefore, another benefit of separation is that there is no need for retail regulation.

Crandall and Sidak (2002) and Crandall, Eisenach and Litan (2010) support the view that vertical integration structure is more appropriate for telecom industry. In particular, these authors argue that requiring separation leads to losses of economies of vertical integration (economies of scope and scale, economies of costs of coordination between wholesale and retail activities). Indeed, according to these authors, first the telecom network infrastructures are highly significant and irrecoverable. Thus, the vertical integration permits more gain in terms of economies of scope and scale. Second, the telecom network infrastructures present a high degree of asset specificity: these infrastructures are costly and only designated to provide telecommunication services in a specific area[8] and thereby vertical integration is more convenient. Third, telecom industry is characterized by rapid technology and demand changes. This raises risk and uncertainty about market conditions, and thereby, generates important costs of coordination between wholesale and retail activities if these activities are negotiated between independent firms compared to the case where these activities are accomplished in a same vertically integrated company. The first argument is based on the concept of the natural monopoly and its related notion of the sub-additively of the cost production function introduced by Baumol (1977). The two later arguments come from the developments of

[8] i.e. these infrastructures (local loop networks) cannot be used in other sector.

the transaction cost theory that is originally funded by the paper of Ronald Coase (Coase 1937) and then reformulated and developed by Oliver Williamson (Williamson 1985)[9]. Coase (1937) points out on the failure of traditional conception on the economic system that considers that the sole way to allocate and organize the economic activities is the market through the price mechanism. He says that this conception ignores the costs of market transaction exchanges due to incomplete information and uncertainty (e.g., costs of determination of relevant prices, costs of negotiations and conclusions of contracts between partners in the market). He considers the firm as an alternative organization of economic activities that co-ordinates and allocates economic activities through the called "managerial" or "co-ordinating function of the entrepreneur". However, according to Coase (1937), the return of this managerial function is decreasing with the size of the firm which may lead to waste of resources when an extra transaction is internalized (made in the firm). Therefore, the decision of internalization or externalization of an extra transaction by a firm should be based on comparison of costs of market transaction (costs of externalization) with the costs uncured by the firm if it internalizes this transaction (costs of internalization). The contributions of Williamson (1985) can be summarized in three main issues. First, Williamson (1985) adds various forms of contracts between partners as another alternative ways to market and firm to organize economic transactions. Second, he show that in reality that contracts between partners are incompletes and thereby generate costs of coordination given the characteristic of human behaviors which consist on opportunism and the limited rationality. Third, he identifies three sources of transaction costs: asset specificity, uncertainty and frequency of transaction and states that the vertical integration is the best organization when the degree of uncertainty, transaction frequency and asset specificity are high. Crandall and Sidak (2002) note that these sources of transaction costs correspond "plainly" to the telecommunications industry. The strong interdependency between retail and wholesale activities conjugated with complexity and uncertainty of telecom market conditions lead to incomplete contracts between the separated providers of wholesale and retail activities which imply important contracting costs and therefore vertical integration is more appropriate to spur innovation in telecom industry because communication and coordination is ensured along different production stages in the same company.

As responses to these critiques, Cave and Doyle (2007) say that these arguments funded on transaction costs are unrealistic. In practice, the wholesale prices are controlled by regulator and the problem of difficulties to contract between separated wholesale and retail providers mentioned above can be solved by an appropriate regulatory intervention (e.g. price cap regulation). Further, these authors argue that the overall benefits of separation from com-

[9] See Crandall, Eisenach and Litan (2010); Gonçalves and Nascimento (2010) and Howell, Meade and O'Connor (2010) for further developments about arguments for and against vertical separation in telecom industry and their associated theoretical foundations.

petition are high relatively to costs of such measure. Cave (2006 b) seems to take more careful position. He says that regulator must proceed to benefit-cost analysis before requiring specific form of separation to the incumbent while Bijl (2005) recommends separation only after ensuring that there is an effective bottleneck (essential facilities) that "cannot be replicated due to significant sunk costs [10]. In line with these suggestions, Gonçalves and Nascimento (2010) propose a guideline for regulators before deciding to whether mandate or not vertical separation which take into considerations many aspects including costs and benefits of separation, degree of market power of access service provider, the degree of complementarities between access and retail services and the strategic actions of different actors in telecom markets (providers, end-users and regulators).

Some studies model interactions between players in telecom industries using the game theory and considering both cases of industry structure: vertical separation versus vertical integration in order to compare costs and benefits of separation in term of competition and investment. Brito, Poreira and Vareda (2011b) focus on impact of vertical separation on welfare and non-price discrimination (i.e. quality degradation of the network access service provided by incumbent). They assume retail competition with horizontally and vertically differentiated services. They find that vertical separation reduces non-price discrimination but it does not necessarily avoid it, and its impact on welfare is negative or ambiguous. Based on this last study, Brito, Pereira, and Vareda (2011) controverts the European Commission assertion that says that vertical separation avoids discrimination in the retail market. Sarmento and Brandào (2009) assume retail competition with homogenous products. They show that under vertical separation, there is no foreclosure in the retail market, but that the access regulation is necessary to stimulate investment when the retailers jointly do not have a high capacity to transform the quality access upgrades into cost reductions. Furthermore, Sarmento (2011) shows that the optimal level of investment decreases with vertical separation under both deregulation and the cost based regulation regimes.

It seems that neither benefits nor costs of separation policies are simple to evaluate. Therefore, the regulators face a delicate task. The debate persists since the trade-off between static and dynamic efficiency is still unsolved.

2.2 The impact of access regulation on entrant's investment in network facilities

These studies usually assume that incumbent cannot invest in new technologies because of the high sunk costs that result from its previous investment in local loop or because of regulatory obligations (e.g., Bourreau and Dogan 2006). These contributions come as critiques of the ladder of investment para-

[10] In fact, technologies changes modify the notion of replication by reducing substantially the costs of these technologies.

digm which suggests an original regulatory schema for access price adjustments over time that permits to promote service-based competition in the short term and investment by entrant in more long term. The next paragraphs describe this regulatory schema and review main associated critiques.

2.2.1 2.2.1 The "theory" of the Ladder of investment ("the stepping stone theory"): as a regulatory remedy to the competition-investment trade-off

The "Ladder of Investment" (LoI) (or the so-called Stepping Stone) theory is suggested by Martin Cave in 2001 to European regulatory authorities as a remedy to the competition-investment dilemma, and then developed and detailed in series of works (Cave and Prosperetti 2001; Cave and Vogelsang 2003; Cave 2006 a, 2010). Since its apparition, it is the subject of an important debate across both academic theoretical and empirical studies and the regulatory reports[11].

LoI can be defined as an incentive dynamic regulatory process for one-way access. Initially, entry is encouraged by facilitating the access to incumbent facilities. Then, the entrants will be progressively forced to create their own network facilities as soon as their market shares increase and incertitude related to market conditions decreases. During this regulatory process, the entrants benefit from various levels of access conditions to incumbent's network facilities. These access conditions must be "deteriorated" over time using appropriate regulatory tools in a way that entrants will be forced to gradually roll out their own essential network infrastructures[12]. Cave (2006 a) mainly proposes two regulatory alternative tools: (1) dynamic pricing policy that consists in increasing access pricing over time or (2) Making a credible regulatory commitment to suspend access regulation in a certain date ("sunset clause") after ensuring service based entry. LoI approach, therefore, suggests reducing over time the replacement effect between the service-based entry and facility based entry using these appropriate access regulatory tools in order to force the passage to the facility based competition after certain date from imposing service based competition. According to this approach, the service based competition must be used just by regulators as a "stepping stone" to develop facility -based competition in the long term by helping entrants to acquire market shares and experiences that reduce their incertitude about demands and costs before incurring high infrastructure investment costs (the stepping stone effect). The success of LoI process requires that this stepping stone effect of the service based competition dominates its replacement effect. Martin Cave uses "the investment ladder" metaphor, where the different stages of the so-called "investment ladder" corresponds to ascendant levels of network invest-

[11] See Bourreau, Dogan and Manant (2010, 2011) for extensive review and consistent critiques for LoI approaches.

[12] The entrants are encouraged to "climb the investment ladder" as the regulator.

ment that entrants will be forced to "reach" over time as responses to modification of incumbent's network access conditions due to these incentive dynamic regulatory tools (see Figure 1).

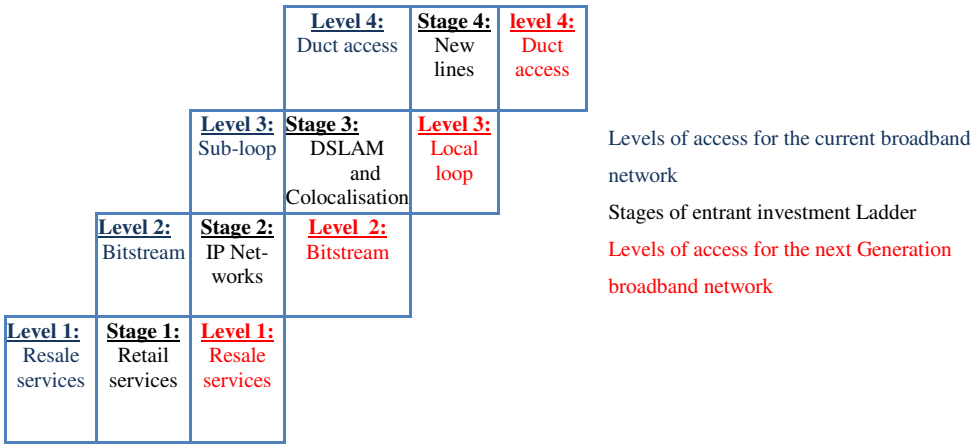

Fig. 1. Example of the LoI[13].

2.2.2 The critiques of the Ladder of Investment paradigm

Despite the absence of any theoretical economic foundations for this approach, European regulatory authorities highlight the implementation of LoI approach arguing that this regulatory process is the best solution to the competition-investment dilemma. It suggests a practical regulatory method that promotes service-based competition in the short run in order to achieve the ultimate regulatory objective which consists in establishing facility based competition (Bourreau, Dogan and Manant 2010)

However, Cave (2006 a) confesses that the success of the implementation of LoI is constraint by number of delicate clauses including the abilities of the regulator to (1) intervene in appropriate date with appropriate policies in different "stages of the investment ladder" and (2) make a credible commitment to these regulatory interventions, which require complete information about market conditions (costs and demands). This supposes that the regulator also has the ability to range different components of network infrastructures (the local loops) from least to most replicable with respect to entrants. However, the identification of degree of replication for given components of networks is difficult because the notion of replication changes over time and depends on several factors (economies of scale and scope, sunk costs, market technology conditions, entrant experiences, etc.). This particular question of the ability of regulatory authorities to make a credible commitment and related information-

[13] The rungs corresponding to different levels of access for current and next generation broadband networks (see, Cave (2006 a, p.84) and Bourreau, Dogan and Manant (2011)).

al problems are considered by Oldale and Padilla (2004) the main reproaches of the LoI approach.

The other consistent critiques against this theory concern mainly the LoI regulatory tools and its hypothesis. They come from results of the dynamic theoretical models based on the game theory provided by Bourreau and Dogan (2006), Bourreau and Drouard (2010), Avenali, Matteucci and Reverberi (2010), Bourreau, Dogan and Manant (2010, 2011).

Results obtained by Bourreau and Dogan (2006) dispute the LoI regulatory tools (the dynamic pricing rule and the sunset clauses). These authors model the setting where entrant can lease the existent local loop of the incumbent (service-based competition phase) before building new infrastructures (facilities based competition phase). Under the main assumptions that only entrant can invest in new technologies while the incumbent is prohibited to invest in these technologies, that the cost of its adoption is decreasing over time, that the quality of retail services are vertically and horizontally differentiated and that only the quality of service provided by entrant depends on the quality of new technology adopted, authors find that the regulator should set a cost-based access price during the phase of service-based competition to maximize the consumer welfare and also the sunset clauses regulatory tool suggested by the LOI do not lead to achieve the facilities based competition because after suspending access price regulation, the incumbent will protect its position as monopoly in wholesale segment by lowering the access price in order to increase the opportunity cost of technology adoption by entrant and therefore reduce the incitation of this later to build new infrastructures.

The model of Avenali, Matteucci and Reverberi (2010) is close to the setting of Bourreau and Dogan (2006) but it proposes two main extensions. First, authors consider that the service based competition phase is an essential step for entrant to acquire reputation and brand loyalty and therefore they relax the assumption that investment cost of alternative technologies adoption is decreasing over time. Second, authors test the fact that whether the LOI paradigm is robust to regulatory commitment problem (i.e. the case in which regulator can lift its commitment to suspend access price regulation at certain date after introducing the service based competition (incredible regulatory commitment). Authors show that a dynamic access pricing policy that consists in raising the access charge over time is necessary to promote efficient investment by entrant but it suggests asymmetric regulation that consists in seting different access charges to entrants that enter at different dates. Further authors demonstrate that sunset clauses delay the facilities-based competition.

Results of the models, suggested by Bourreau and Drouard (2010), show that the stepping stone hypothesis is not always valid. Authors consider the cases where entrant can use the existent infrastructure of the incumbent or enter with its own network facilities. In the first case, the market share of entrant is assumed increasing with its experience that it acquire gradually over time, the quality of service provided by entrant is assumed initially lower than the

one offered by incumbent and then it increases over time, the cost of adoption of new technologies is supposed decreasing over time and only entrant can invest in new technologies. Under these conditions, authors find that the service-based competition does not always serve as a stepping stone for facilities-based competition because the entrant may delay the step of facilities-based competition by prolonging the service-based competition step in order to benefit more from market experience. Authors also show that in the setting where entrant and incumbent compete "à la Cournot" by providing vertically differentiated services and when the market experience acquired by entrant depends on access price, a dynamic access pricing policy that consists to rise the access price over time does not always lead to accelerate the adoption of new technologies by entrant as advocated by LoI paradigm.

2.3 The impact of access regulation on both incumbent's and entrant's investment

In our knowledge, until this date there are few papers that have been interested to study the impact of access regulation on the investment incitation in the context of one way access considering more realistic setting where both incumbent and entrant can invest in new technologies. In this paragraph, we summarize the main finding of two relevant contributions.

Vareda (2011) addresses this issue. He considers a vertically integrated network provider (the incumbent) that faces an independent entrant in retail market. Given the access price regulation to incumbent network and the investment amount decided by the later, the entrant has two options: enter the market using facilities of incumbent (service-based entry) or building its own infrastructures (facility-based entry). He shows that the incumbent's investment in quality upgrade delays the entrant's investment. In contrast, the incumbent's investment increases with the entrant's incitation to build its own infrastructures. He finds that access price regulation has ambiguous effects on both incumbent's investment and the decision of entrant to build its own facilities. He finally demonstrates that cost based price regulation is not always optimal when entrant benefits from a rise of its market shares or investment cost reduction during the phase of service-based competition.

Manenti and Scialà (2013) also investigate the case where entrant has two options that consist in entering market with or without building its own facilities. However, they assume that the firms compete "à la Cournot" with vertically differentiated services and the investment is assumed to have positive effect on demand for retail service (positive spillover effect). Authors also consider three ways to determine the access price: (1) unregulated access price (2) the regulator sets the access price after observing the investment behavior of both firms (access price regulation without commitment) (3) the regulator sets the access price before observing investment behavior of both firms (access price regulation with commitment). Authors find the following results. In

unregulated case, the incumbent forecloses the market by setting high access price, and the facility based entry is possible, but it may be inefficient. The access regulation may discourage facility based competition at the date when this later kind of entry is socially optimal. This reduction in the social welfare, due to service based entry instead of facility based entry, is the highest in the case of access regulation without commitment.

To summarize, the theoretical investigations tend to point out on the negative effect on access price regulation on investment incentives. Next, we present the main finding of the empirical literature on the regulation-investment relationship.

3 Regulation and investment: an empirical literature review

Using different econometric techniques, measures, variables, models and different samples covering different regions and different time series, earlier studies reach different conclusions. We classify these studies following the measurements of the regulation used. First, we survey the empirical works that use aggregated and disaggregated measurements of regulation reforms (access pricing methods, unbundling policies, separation policies and others).

Second, we review the studies that measure regulation by its market outcomes including mainly measurements of degree of privatization or market competition.

3.1 The impacts of the regulation through aggregated and disaggregated measurements of reforms

Recent papers have been interested to study the direct (the stricter) impacts of the regulation reforms on telecom infrastructure investment. Most of these studies are focused on the specific individual effects of one or two reforms rather than studying the global joint impact of the telecom regulatory reforms. However, as pointed out by Bauer (2010), the impact of a requirement of a given policy in a given country during a period of time, in general, is affected by other regulation policies mandated that may in turn have effects on driving or impeding telecom innovation. Therefore, we think that it is important to study both individual and joint effects of the regulation policies to better understand how regulation may affect telecom infrastructure investments in order to help policy makers to choose the most appropriate combination of policies and thereby determine the best regulatory intervention that can drive the development of the telecom industry in the best possible way. Nevertheless, there are difficulties to collect complete data for all or the most important telecom regulation reforms adopted in a given period of time for certain countries to construct a more complete analysis where several reforms are considered in the same empirical model. In our knowledge, the unique paper that studies the global effect of telecom regulation reforms on innovation is the

one of Bauer and Shim (2012). This last study uses an overall regulation index that adds 41 indicators. Each one corresponds to an individual measure of a specific regulatory reform introduced in telecom industry including accounting and vertical separation, infrastructure sharing, the three kinds of local loop unbundling (full local loop unbundling, bitstream, sub-loop), access pricing regimes and others. These indicators are in general binary variables, each one takes a value of "1" if the correspondent regulatory reform is required by law in a given country and year. This index (known as Plaut Economics Regulation Index) is computed for 32 countries (27 European and 5 others including Australia, Japan, Singapore, Switzerland and USA) over the period of 1997-2010 by a group of experts and academics (Zenhäusern et al.)[14].

Based on this measure of telecom regulation and using the difference Generalized Methods of Moments (GMM)[15] as estimation method, Bauer and Shim (2012) conclude that regulation negatively affects innovation measured by the number of secure services or fixed broadband subscriptions. Authors also find that the dynamic effect of innovation is positive and strongly significant and the regulation-innovation relationship is non-linear. They also examine separately the joint impacts of both price and entry regulation reforms.

3.1.1 Access price regulation and investment

Bauer and Shim (2012) find that access price regulation (as proxy by a measure that aggregates scores of price policies that concern both retail and wholesale services) undermines innovation in telecom sector.

Distaso, Lupi and Maneuti (2005) also find that a stringent access pricing policy that consists to set lower access unbundling price promotes broadband diffusion in 14 European countries during the period from 2000 until 2004.

Considering the case of 41 local telephone companies operating in USA over a period of 5 years from 1994 to 1998, Chang, Koski and Majundar (2003) estimate two relations. In the first model, the investment in infrastructure is measured by the share of a given company in fiber-optic (expressed in kilo miles). In the second model, investment is proxy by digital lines share. Including different controls such as number of competitors, firm size and others and considering a Generalized Least Squares (GLS) as estimation method in order to deal with a number of technical problems of data such as the heteroskedastic and autocorrelated errors, Chang, Koski and Majumdar (2003) find that interconnection charge (expressed in minutes), which is the main measure of access price regulation used in their study, affects negatively both measures of telecom investment considered (fiber-optic share and digital line share). Authors therefore conclude that lower access price increases invest-

[14] See Zenhäusern et al. (2007, 2012 a, 2012 b) for further details about the methodology of coding and calculation of this index.

[15] This advanced econometric method is used mainly to deal with the problem of reverse causality between regulation and investment (i.e. regulation affects investment that in turn affects the former).

ment in new telecom technologies and give the following explanation: lower access price leads to more connectivity to networks and more service differentiations, which imply more revenues for operators (cash flow). This, in turn, permits to enhance level of investment in both fiber-optic and digital technologies. In the second part of their paper, Chang, Koski and Majumdar (2003) analyze yearly data coming mainly from OECD telecommunication database 1999 and European inter-connect Atlas that consists in information about interconnection regimes implemented (FDC, LRIC and Cost-based)[16] in 14 European countries in the period 1993-1997. Authors deduce that both FDC and LRIC models do not spur investment in new infrastructures. Analyzing levels of interconnection charges and investment, authors conclude that in the European countries, where the level of interconnection charges exceeds the European average, the level of investment is the highest. According to Chang, Koski and Majumdar (2003), this result, that contrasts with their finding for the case of the USA is due mainly to the facts that the implementation of these methods of access pricing is recent in Europe compared to the case of USA and that the body of regulation authorities in USA exercise its missions in more independent way than in Europe.

Waverman et al. (2007) construct an annual unbalanced panel data covering about 27 European countries during the 2002-2006 period. Combining data for prices of local loop unbundling, market shares of different technologies (cable, DSL[17], Fiber) and using Seemingly Unrelated Regressions (SUR) which permit to control for reverse causalities, authors show that stringent access price regulation policy measured by lower unbundling price may promote broadband diffusion through increasing intra-platform competition via traditional platform technology(copper lines) but can lead to decrease in the total broadband penetration if the subscriptions via alternative platforms are still relatively low.

Seo and Shin (2011) consider a balanced panel composed of 25 local Exchange Companies in the USA during the period from 1988 to 1998. They find that lighter access price regulation which consists in requiring price cap method for access charge increases productivity growth in the USA telecom industry.

Although some exceptions (i.e. Waverman et al. (2007) , and Chang, Koski and Majumdar (2003) for Europe case during the 1993-1997 period), it seems that there is a consensus across the studies cited above around the following conclusion. A stringent access pricing policy (requiring lower access prices based on the FDC or LRIC models), reduces telecom innovation. However, a lighter access pricing policy (e.g., requiring price cap regime) spurs innovation.

[16] FDC: Fully Distributed costs and LRIC: Long Run Incremental costs (see chapter 1 for further details about these access pricing models).
[17] Digital Subscriber lines.

3.1.2 Entry regulation and investment

Few papers study the global joint effect of entry regulation reforms. In particular, Friederiszick, Grajek and Röller (2008) ; Grajek and Röller (2012) and Bauer and Shim (2012) use the Plaut Economics sub-indice that aggregates measures of entry regulation reforms (i.e. unbundling policies, line sharing, separation policies and number of licenses[18]) and find that entry regulation impedes telecom innovation.

Friederiszick, Grajek and Röller (2008) consider an annual panel data composed from 200 operators (grouped as incumbents versus entrants and mobile versus fixed lines operators) covering 30 European countries for a period of 10 years from 1997 to 2006. Using both OLS and 2SLS as estimators of the effect of entry regulation on infrastructure investment, authors conclude that entry regulation do not affect investment in mobile sector, but it discourages entrant's infrastructure investment and has no impact on incumbent's infrastructure investment in fixed line sector. The major contributions of this study is that it uses data performance (infrastructure investment) disaggregated by kind of operator (incumbent versus entrant) and by type of telecom sector (mobile versus fixed).

Grajek and Röller (2012) use a part of dataset constructed by Friederiszick, Grajek and Röller (2008) and estimate separate equations[19] using both OLS and 2SLS methods with robust standard errors in order to study the strategic interaction between different actors in telecom markets (i.e. regulator, incumbent and entrants) and suggesting therefore an empirical investigation of competition-investment dilemma. Authors conclude that entry regulation have negative impact on investment. Their results reveal that there are commitment regulatory problems (i.e. the higher the incumbent's investment, the higher the regulation intensity). Grajek and Röller (2012) also find that there is a complementary strategy between incumbent and entrants: an increase in entrant's investment due to low entry regulation intensity leads to increase incumbent's investment.

Friederiszick, Grajek and Röller (2008) and Grajek and Röller (2012) take also into account the reverse causality between regulation and investment, the dynamic effect of infrastructure investment, and control for autocorrelation problems of errors terms. However, these studies ignore the non-linear regulation-investment relationship. Furthermore, they do not take into account the effects of other telecom regulatory reforms such as price regulation that affect investment in telecom industry. They do not study also the individual effects

[18] This last measure concerns mobile sector.

[19] The first equation explain entry regulation intensity as function of entrants' infrastructure investment, incumbent's infrastructure investment and other controls including per capita GDP and dummy variable that takes a value of "1" if there are no entrant in a given national market. The second equation explains incumbent's infrastructure investment as function of regulation, entrants' infrastructure investment and the controls. The third equation explains entrants' investment as function of entry regulation and incumbent's investment.

of entry regulation reforms (e.g. the individual effect of unbundling or the one of separation).

- **Impacts of unbundling policies**

Some empirical studies find that unbundling policies have no effect or a negative effect on investment in telecom infrastructures. Bacache, Bourreau and Gaudin (2013) test whether the unbundling policies can stimulate broadband investment by entrants. The ultimate objective of their study is to find if there is an empirical support for the Ladder of Investment Approach. To this end, authors construct data for 15 countries, which are member of European Commission, covering a period of 17 semesters from July 2002 to July 2010. They consider different specifications where the number of broadband lines owned by entrants is regressed on the number of local loop unbundling or bit-stream lines managed by entrants and some control variables such as a measure of income level (the GDP), population and level of competition proxy by market share of incumbent in mobile telephone market. In certain specifications, authors also include another measure of regulation policy as an interacted term with unbundling policy measure considered. This consists in an index, computed by Plaut Economy, which captures the regulatory intensity in telecom industry. Bacache, Bourreau and Gaudin (2013) conclude that there is no support for the Ladder of investment approach because the service-based competition promoted by requiring unbundling policies does not contribute to stimulate entrants to construct their own broadband lines. In this study, the difference GMM estimator with time fixed effects is used in order to take into account the reverse causality between regulation and the telecom performance measure considered (the number of broadband lines owned by entrants).

Applying the simple Ordinary Least Squares (OLS) method with and without fixed effects to panel composed from 30 OECD countries over 5 years from 1999 to 2003, Wallsten (2006) finds quite similar results. In particular, he concludes that a lighter unbundling policy which consists in requiring the full local loop unbundling or bit-stream access has no impact on broadband penetration, while more extensive unbundling policy (sub-loop access) negatively affects broadband deployment. Crandall, Eisenach and Ingraham (2013) study effects of both unbundling policy and line sharing requirement on broadband penetration. Their study concerns 28 OECD countries covering a period of 10 years from 2001 to 2010. Results of different specifications using robust least square estimator show that unbundling of copper loops lines has no impact or a negative impact (in some regressions) on broadband penetration suggesting that unbundling undermine investments in new telecom infrastructures. In the rest of this study, authors deduce from analyzing the differences between unbundling of fiber lines and unbundling of copper lines that unbundling of fiber platforms also impede NGN investments.

Nardatto, Valleti and Verboven (2014) focus on the case of United Kingdom (UK). They construct detailed quarterly data for a panel covering the in-

cumbent and about 5000 "local exchange" LE companies in UK during a period of 17 quarters from December 2005 to December 2009. Authors consider two telecom performance indicators, which consist on broadband penetration and broadband speed and different explanatory variables including the regulatory measures which are the different measures of unbundling policies (dummy that takes value of 1 if LLU policy is introduced in UK, number of LE that use LLU lines), the percentage of incumbent's Bitstream lines relatively to total lines and the percentage of cable lines[20]. Other explanatory variables of both broadband penetration and broadband speed are included as controls such as income level (the GDP), ages and urban population. Authors also run different static and dynamic regressions using various estimators: simple fixed effect estimator and the system GMM. They conclude that intra-platform competition through LLU lines do not increase broadband penetration but it strongly increases broadband speed (quality of end users services) when entrants has more ability to differentiate their retail services than the incumbent. In contrast, the inter-platform competition (measured by number of cables) fosters both broadband penetration and speeds.

This result is contrasted by the finding of Gruber and Koutroumpis (2012). Precisely, in this last study, authors conclude that full unbundling increases broadband adoption. They use more advanced econometric methods (Instrumental variables techniques), that control for reverse causality between regulation and broadband penetration and consider a panel data composed of 167 developed and developing countries from 2000 to 2010.

Similar results are obtained by Martha (2005). In particular, results for both logit and OLS regressions for about 100 developed and developing countries in year 2001 show that unbundling policy improves broadband availability and the positive effects of this policy are more important in middle-income countries. Therefore, Martha (2005) recommends to regulators authorities of less developed countries to require unbundling policy and encourage competition in order to foster broadband adoption. Martha (2005) also shows that there are other factors that affect significantly the broadband access and explain the disparities between countries. In particular, income level, population size, education, price of computer, content (proxy by "number of domain name servers registered"), monthly price that end user pays to access to the internet, and competition[21] affects positively the percentage of population that have broadband access.

[20] The cable lines are a technology (platform) alternative to main and traditional technology used, which are the DSL networks (unbundling, bitstream, etc.). Therefore, considering number of bitstream lines measure in addition to the number of LLU lines measure in a same model imply that authors aim at study intra-platform competition (i.e. competition between firms using a same networks or platform (DSL) also called services-based competition). Adding the percentage of cable lines as another variable in a same model means that authors also aim at study the impact of inter-platform competition (i.e. competition between platforms called also facilities based competition or known also as intermodal competition.

[21] Competition, privatization and unbundling are Dummies variables.

Grosso (2006) considers a yearly panel data covering 30 OECD countries from 2001 to 2004 and estimates generalized least squares multiple regression, in which the logarithm of broadband subscribers per 100 people is a function of a dummy for local loop unbundling implementation, the logarithm of the broadband subscribers per 100 people lagged by one-year to take into account the dynamic effect of broadband penetration, and a set of controls that are the Herfindahl-Hirschman index measuring broadband market concentration, the GDP per capita, and the fixed Internet penetration. Grosso (2006) finds that unbundling policy increases broadband penetration. He justifies this result as follows: unbundling policy reduces entry costs and therefore fosters competition and reduces prices of end users services, which increases demand for broadband services.

In sum, results of these studies are heterogeneous and led to opposite conclusions about the role of unbundling policies to drive or impede investment in new infrastructures.

- **Impacts of separation policies**

There are few empirical studies that address the issue of the effects of separation policies on investment in telecom infrastructures despite the great debate across the theoretical academic and non-academic studies.

Bruno (2012) collects yearly data for a panel composed from 14 European incumbent firms (3 separated operators plus 11 integrated operators[22]) operating in fixed telecom lines during the period from 2005 to 2010. For each company, author combines data including the total operational cost, the number of wholesale access lines which sum both narrow and broadband lines and the number of retail lines (the narrow band lines offered to end-users). Using a non-parametric econometric method, author computes efficiency scores for each incumbent operator in order to study the effects of introduction of functional separation in terms of loss of economies due to vertical telecom structure. Through the comparison of scores of separated and integrated incumbents, author finds that separated incumbents show more efficiency in terms of economies of costs than the integrated operators. According to Bruno (2012), this may be due to several factors including that the implementation of functional separation increases competition and therefore encourages incumbents to enhance their efficiency and performance. However, considering more advanced services (broadband services), the efficiency level of separated incumbents decreases because the provision of advanced services require a freely

[22] The separated operators (with associated country) are Telecom Italia (Italy), TeliaSonera (Sweden) and British Telecom (UK). The integrated operators (with associated country) are Telefonia (Spain), France Telecom (France), Deutsche Telecom (Germany), OTE (Greece), TEO (Lithuania), Belgacom (Belgium), Eirecom (Ireland), Polish Telecom(Poland), Telecom Austria (Austria), Portugal Telecom (Portugal) & KPN (Netherlands).

circulation of information across units, which is more likely to be produced in the case of integrated structure rather than separation one[23].

Viani (2006) studies the impacts of vertical separation on the use of both international and local fixed telephony and then he address their effects on the price of local fixed telephony. He collects data for a panel composed from 67 countries that have privatized their telecom main operator (the incumbent) over the period from 1984 to 2003. Using robust fixed effect models clustering on countries, author finds that vertically separating the incumbent operator[24] from the international telephony segment has significant negative effect on both the expansion of international telephony[25] and the expansion of local fixed telephony[26]. He also shows that the vertical separation of the incumbent operators increases the price of the local fixed telephony.

In conclusion, these studies also reach opposite conclusion about the impact of separation policies on telecom industry performance.

3.2 The impacts of the regulation through measurements of market competition

Earlier empirical studies and even a number of recent researches have analyzed the effects on telecom infrastructure investment of the regulation through its market outcomes[27] such as measures of competition or others (i.e. privatization) rather than studying the stricter impacts of regulation reforms. In fact, regulation aims at encouraging entry to telecom markets by requiring obligations to incumbent in order to reduce its market power. Therefore, competition can be seen as a direct market outcome of different telecom regulation reforms. This may justify why some organizations such as OECD and even some empirical academic studies use indicators of competition such as market shares of operators or a number of firms operating in a given telecom segment instead of using direct indicators of telecom regulatory reforms. This common "belief" on the evident positive link between regulation and competition reflect in fact a conviction of policy makers that competition is a driver of growth ("laissez faire"). Gilbert (2006) says that: "The actions of the U.S. antitrust enforcement agencies reflect a judgment that competition is a spur for innovation."[28] The same idea is shared by Bauer (2010) who reviews and

[23] See Bruno (2012) for further explanation.

[24] The vertical separation policy is measured by a dummy variable that takes 1 if there are vertical separation between the incumbent and the international service operator.

[25] The expansion of international telephony is measured by the "number of outgoing international minutes per person".

[26] The expansion of local fixed telephony is measured by "the country's fixed telephone lines in service per person".

[27] i.e. these studies do not use direct measures of regulation but use measures of effects of regulation on telecom market in term of competition (number of competitors, market share of providers) or measure of privatization.

[28] Gilbert, R. (2006): "Looking for Mr. Schumpeter: Where Are We in the Competition-Innovation Debate?" Innovation Policy and the Economy 6, p. 161.

comments the implications of policy instruments in term of telecom investment. He notes: "(…) regulatory measures required to facilitate the transition from monopoly to an open market environment. These reforms were based on the strong belief that competitive market organization would best support investment and innovation"[29].

These studies that we will survey in the next paragraphs also reach opposite conclusions. Precisely, estimating linear models, some works find that regulation has no effect or a negative effect on investment in telecom infrastructures while others find positive relationship (see the paragraph 3.2.1). However, the studies that consider non-linear models demonstrate that the relationship between regulation (proxy by a measurement of market competition) and telecom innovation[30] (as proxy by amounts of investment in telecom infrastructures or broadband penetration) is more complex: it is an inverted-U relationship (paragraph 3.2.2).

3.2.1 Competition and telecom innovation: as a linear relationship

Boylaud and Nicoletti (2000) is a study "sponsored" by OECD[31]. This paper study the impacts of both competition and privatization on industry performances in three telecom segments: domestic and international fixed and mobile telephony services using panel data covering 23 OECD countries over the period from 1991 to 1997 and considering both fixed and random effects models. Authors conclude that competition (measured by the number of competitors, the share of new entrants or the number of years to introduction of market competition) increases productivity and service quality levels and reduces prices of end-users services. Results of this study also show that privatization has no effects on quality and prices of end-users services and "surprisingly" affects negatively the productivity.

Li and Xu (2004) construct data for a panel composed from 177 countries over 1990-2001 period. Their study investigates the impacts of privatization and competition on telecom performances measured in several ways (telecom investment per capita, price of three minute local call, labor productivity, etc.). Competition is measured as follows: it takes value of "0" when both fixed and mobile segments are monopolistic, "1" where there is one competitor in fixed or mobile segments and "2 where there is a competition in both fixed and mobile markets. Full privatization is dummy that takes "1" for year and country

[29] Bauer, J. (2010): "Regulation, public policy, and investment in communications infrastructure." Telecommunication Policy 34, p.66.

[30] Innovation refers to "changes in the functionality of products and processes" (Stoneman 2008, p. 2). Investment in telecom infrastructures such as broadband networks is seen as innovation because it permits to change the production process of services and leads to innovative services (see Bauer and Shim 2012). Therefore, we use investment in infrastructures or broadband deployment to mean innovation in telecom industry.

[31] FCC (2009) is a survey for empirical works. It criticizes the empirical studies that are sponsored by some organizations.

that privatizes a part or entire telecom operators. Partial privatization takes "1" if the state ownership remains dominant. Using also different estimators (Fixed effects and two least square estimators with fixed effects) and trying different specifications, authors conclude both full privatization and competition considerably ameliorate the telecom performances while partial privatization has no effects. Results also show that complementarity between privatization and competition improves the telecom performances.

Alesina et al. (2005) study the impacts of regulation reforms on investment for 21 OECD countries over the 1975-1998 period. Data cover seven non-manufacturing industries including post and telecommunications[32]. They use the GMM estimator that controls for sector and country effects. Regulation reforms are computed as indexes that incorporate market shares of entrants to measure entry (competition) and market shares of government in incumbent operator as measurement of privatization. Their results show that both competition and privatization spur investment.

London Economics (2006) is a report sponsored by the European Commission. This study investigates the relationship between telecom investment made by an operator (entrant or incumbent) proxy by tangible fixed assets and the regulatory index computed by OECD (or ECTA in other specifications[33]) using data for about 25 European countries over the 2001-2004 period and considering robust fixed effects models. Results show that high regulation intensity promotes investment in telecom infrastructures.

Djiofack-Zebaze and Keck (2009) study effects of competition and liberalization on telecom performances considering three telecom segments (fixed, mobile and international telephony) in 177 countries (including 45 Sub-Saharan Africa countries) over 7 years from 1997 to 2003. Measurements of competition, liberalization and regulation reforms consist in score for market structure (monopoly, duopoly or more than two operators), numbers of years from introduction of competition, dummy to measure degree of independence of regulatory authorities, numbers of years from instauration of independent regulatory agency, adoption of GATS[34] and WTO commitments. Using different specifications and econometric methods (GMM, 2SLS, 3SLS, OLS and GLS), authors find positive correlation between liberalization and telecom performances measured by price of end-user services or number of subscriptions.

Bouckaert, Dijk and Frank (2010) consider panel data composed of 20 OECD countries for a period of 17 quarters from December 2003 to March 2008. Using simple fixed effects estimator, they regress the total broadband subscriptions on three competition variables which are the Herfindahl index-

[32] The post and telecommunications was considered a same industry before 1998 in most countries.
[33] These indexes incorporate mainly measures of market shares of different telecom providers.
[34] Country makes commitment to open to foreign competition.

es[35] for respectively the inter-platform competition, the services-based intra-platform competition and the facilities-based intra-platform competition. The control variables used in this study are the following: the average price of broadband connection, average speed of broadband connection, population dispersion, population density, GDP[36], and Personal Computers penetration. Regarding the relation between access regulation (imposed to incumbent firm) and these competition variables, Bouckaert, Dijk and Frank (2010) say that a "strength" access regulation (e.g., low access unbundling price) leads to more services-based competition (i.e. low Herfindahl index for services-based competition) and vice versa. However, a "weaker" access regulation (e.g., high access unbundling price) leads to weaker facilities-based competition (i.e. high Herfindahl index for facilities-based competition). They reach the following conclusions. The facilities-based competition promotes broadband deployment, while the service-based competition discourages investment by incumbent and does not encourage investment by entrant sufficiently. Therefore entry regulation does not serve as "stepping stone" to facilities-based competition. In other words, Bouckaert, Dijk and Frank (2010) show that an extensive access regulation undermines broadband deployment. We consider that the main limits of their study are that it ignores reverse causality between regulation and broadband deployment and uses inappropriate estimator method to estimate a dynamic specification.

Distaso, Lupi and Maneuti (2005) find quite similar results. Precisely, using both theoretical and empirical models, authors show that competition in DSL market does not significantly influence broadband investment but competition between different platforms (DSL, fiber and cables) spur broadband deployment. This study is conducted considering unbalanced panel composed of 14 European countries during 15 quarters from November 2000 to April 2004, and using three estimators (fixed effects, random effects and method of instrumental variables). Data set combine both competition data (Herfindahl indexes)[37] and values of access prices.

Gruber and Koutroumpis (2012) also combine direct measures of regulation (full unbundling policy) and measures of competition (Herfindahl indexes for inter-platform and intra-platform competition) but find opposite results. Considering panel composed from 167 developed and developing countries over the period from 2000 to 2010, using 2SLS estimator that deals with reverse

[35] The Herfindahl index is a measure of degree of concentration in a given market. The higher the Herfindahl index, the lower the degree of competition in this market. It is computed by adding squares of market shares. The Herfindahl index for inter-platform competition adds the square of DSL market share and the square of non-DSL market share. The Herfindahl indexes for services- based intra-platform competition adds the square of retail market share of incumbent and the square of market share of alternative DSL operators while The Herfindahl index for facilities-based intra-platform competition adds the square of wholesale market share of incumbent and the square of market share of alternative DSL operators in wholesale segment.

[36] A measure of national income is the Gross Domestic Product per capita (GDP).

[37] In this study, only competition variables are instrumented.

causality between regulation and broadband diffusion measure and controlling for country and year fixed effects, authors show that the competition between firms (intra-platform) that use DSL technology of incumbent substantially increases broadband adoption while the inter-platform competition has little positive impact on broadband diffusion.

Quite similar results were obtained by Denni and Gruber (2006) where the authors focused on the case of U.S Federal States during the period from June 1999 to June 2004. In this study, different estimation methods are used (Fixed effects, Random effects, First Difference Instrumental variable estimator and Fixed effects GLS estimator). Authors find that both inter- and intra-platform competition increase broadband diffusion but inter-platform competition has the great impact.

3.2.2 Competition and innovation: an Inverted-U relationship

According to our researches, only three empirical works (Heimeshoff 2007; Briglauer, Ecker and Gugler 2013; and Li 2008) are used non-linear models to estimate the relationship between competition and telecom innovation[38]. These works find that this relationship is an inverted U shape. Economic literature provides both theoretical and empirical supports for this result.

- **The inverted U-relationship between Competition and innovation in economic literature: foundations and explanations**

The relationship between competition and innovation is a subject of controversial debate across economic literature. In particular, Schumpeter (1943) criticizes the Adam Smith's conception of the "invisible hand" that considers the competitive markets as the best organization structure for economic activities. He argues that monopoly rents give firms more incitation to innovate, and therefore, monopoly structures are more appropriate to generate economic growth through innovation. Several studies support the Schumpeter's argument and demonstrate that competition has a negative impact on innovation (e.g., Greenstein and Ramsey 1998; Culbertson and Mueller 1985; Aghion and Howitt 1992) while others find that competition spurs innovation (e.g., Arrow 1962; Nickell 1996)[39].

Aghion et al. (2005) show that these opposite results are due to the use of linear models to specify the relationship between competition and innovation. They demonstrate that this relationship is in fact more complex. In particular, their theoretical model predicts that the overall effect of competition on inno-

[38] Telecom innovation in empirical studies is proxy by amount of investment in telecom infrastructures (see for e.g., Friederiszick, Grajek and Röller 2008; Grajek and Röller 2012; Heimeshoff 2007). It is also proxy by other measures (e.g., the broadband penetration, the number of lines of fiber-optics...).

[39] See Gilbert (2006) for an extensive literature review for competition-innovation debate. See also Loury (1979); Aghion et al. (2005) and Hashmi (2011).

vation is an inverted U-shape. Their empirical investigation applied to unbalanced panel composed from 311 manufacturing firms in the United Kingdom during the 1973-1994 period using non-linear estimator confirms their theoretical predictions. Several recent empirical studies on competition and innovation support the original finding of Aghion et al. (2005)[40] (e.g., Innui, Kawakami and Miyagawa 2008; Hashmi 2011; Goettler and Gordon 2014).

Aghion et al. (2005) and Aghion, Akcigit and Howitt (2013) interpret this overall effect (the inverted U-shape) as the "composition effect" of the two opposite traditional extreme effects of competition, Escape versus Schumpeterian effects.

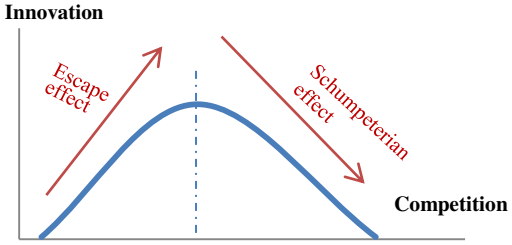

Fig.2. Competition and Innovation: an Inverted-U relationship

Figure 2 ullustrates this issue. In particular, the increasing part of the U-curve shows the escape effect of competition, under which rivals are assumed to escape from competition by innovation in order to restore a part of their historical monopoly profits. Therefore, innovation is fostered for relatively low degree of competition. After a given certain level of competition (saturation point), the Schumpeterian effect will dominate because for relatively high degree of competition, rents earned from innovation are not high enough to cover the costs of investment incurred by firms.

However, considering a two stage game where it is assumed that a duopoly competing "à la Cournot" and providing differentiated products, Sacco and Schmutzier (2011) demonstrate that this inverted U-shape relationship between competition and innovation is only conceivable when firm investing in the cost reduction is more efficient than its rivals. However, this relation is negative when the firm that invests is less efficient than its competitors.

Competition and telecom innovation: a non-linear relationship

The few studies that investigate the linkage between competition and innovation in telecommunication sector support this result on inverted U relationship. Among that, we review the following works.

[40] This paper is cited in most studies as the first work that suggests an inverted-U relationship between competition and innovation. Hashmi (2011) cites others previous studies (e.g., Scherer 1967; Mukoyama 2003) where this U-relationship was hinted.

Heimeshoff (2007) investigates the impact of competition measured by an indicator of market shares computed by OECD on telecom investment using an annual panel data covering 30 OECD countries over the period from 1990 to 2003. Using the first-difference GMM estimator two-step, the author finds that competition-telecom investment is an inverted-U relationship.

Briglauer, Ecker and Gugler (2013) also use the difference GMM estimator but without fixed time effects and other estimation methods including the GMM-system, bias-corrected LSDV estimator and simple fixed effect estimator. They consider dynamic non-linear regressions, in which the number of fiber lines normalized to population depends on a measurement of service-based competition, two measurements of facilities-based competition and some control variables such as per capita GDP, population, annual labor cost, number of Internet users and ICT technologies normalized by income level. The service-based competition is measured by the percentage of unbundling broadband lines while the facilities-based competition is measured by the percentage of cable and DSL lines controlled by entrants and the percentage of subscribers of 3G Internet services. Panel data used in this study are unbalanced and concern 27 European countries for a period of 7 years from 2005 to 2011. Authors draw the following conclusions: The relationship between facilities-based competition and fiber technology deployment is an inverted-U shape while the service-based competition undermines investment in this technology.

Li (2008) collects data on penetration, privatization, number of operator in mobile sector[41], information on dependency of regulators on mobile sector for a panel composed of 29 OECD countries over the period from 1991 to 2006. Estimating dynamic non-linear regressions using difference GMM and 2SLS methods where mobile penetration is expressed as function on number of operators in mobile sectors and dummies variables for mainly privatization and dependency of regulation agencies and controls such as GDP and population, the author finds an inverted-U shape between the measurement of new entry in mobile sector (number of actual operators) and the number of subscriptions per 100 habitants.

Ben Dkhil (2014 b) constructed an annual panel data for 105 developed and developing countries covering the period of eight years from 2004 to 2011. Data are collected from various sources including mainly regulatory databases of the ITU and different publications (laws, decrees, reports, etc.) mainly coming from the NRAs and OECD reports. Regulatory data information collected include the access pricing policies, the separation policies (accounting separation and functional or structural separations), the unbundling policies (full local loop unbundling, Bitstream, sub-loop and line sharing) and other regulatory reforms including the incumbent's obligations to make public the access

[41] This current literature survey focus on the fixed segment of telecom industry but we include this study on mobile sector given the limited numbers of empirical works in telecom industry that find an inverted –U shape relationship between competition & innovation.

conditions (prices and agreements), whether the incumbent is privatized, and whether the regulatory authority is autonomous in its decision (i.e. whether it has an independent regulatory body). Using this information and following the methodology of Zenhäeusern et al. (2007, 2012 a, 2012 b), we construct an indicator for each regulatory reform which is a binary variable that takes the value of one if the corresponding regulation is required by law in a given country and year and zero otherwise , a measure for access price policies and another for entry regulation policies by adding the indicators of corresponding reforms, and an overall measure that aggregates the indicators for all reforms considered in this study. Therefore, these aggregated measurements measure the intensity of regulation required to dominant operator (the incumbent) (see Ben Dkhil (2014 a).

In addition to usual estimators (the Ordinary Least Squares (OLS) and the robust Fixed Effects (FE) estimator), we use the Instrumental Variables (IV) and the Generalized Methods of Moments (GMM), including the Two Stage Least Square with Fixed Effects (FE-2SLS), Two-Step Generalized Method of Moments with Fixed effect (FE-2S-GMM) and GMM Continuously Updated Estimator (FE-GMM-CUE) robust to heteroskedastic and autocorrelated errors. We take into account several considerations: the non-linearity of the regulation-broadband deployment relationship, the dynamic process of the broadband deployment and the unobserved heterogeneities across individuals (i.e. countries) and time period (i.e. years) by adding the fixed effects. These IV& GMM permit to overcome problems of omitted explanatory variables, error in measurements, as well as, the reverse causality between regulation and broadband deployment (the regulatory commitment problem) . In our knowledge, our study is the sole that uses the FE-GMM-CUE to estimate the regulation-telecom investment relationship. It is also the first that suggests more completed analysis, by studying both the individual and the global effects of the most applied regulatory reforms on investment in both developed and developing countries across the world .

As regards to results, we obtain an original finding about the global effect of regulation . In particular, we show that the regulation-investment relationship is an inverted U shape in the developed world, while it takes a U form in the developing countries . This means that in the developed countries, a low level of regulation spurs innovation in telecom industry, while a high level of regulation undermines telecom investment. However, in developing countries, regulation has a strict negative impact on telecom innovation. The differences in issues of regulation on telecom innovation between developed and developing countries may be due to the fact that in general, the existent fixed infrastructures in poor countries are not already sufficiently developed compared to those in the richer world. Basing on this last result, we suggest the following policy recommendation: the government in developing countries should immediately encourage facility-based entry by reducing or even stopping regulation.

Our results concerning the individual and the joint effects of the regulatory reforms provide more support for the inverted U shape relationship. In particular, our findings show that requiring an extensive unbundling policy (sub-loop access) or the most stringent separation policies (operational, functional or structural separation) undermines broadband investment, while a less intensive unbundling (full unbundling or bitstream) or a moderate separation policy (accounting separation) increases broadband deployment. However, our results for the impact of access price regulation show that the higher the intensity of the control of access price is, the lower the broadband deployment is. Precisely, in the absence of access price regulation (no control), the broadband deployment is the highest. A moderate access pricing regime, that offers a certain access margin for incumbent firm such as price cap or retail minus, permits to reach better results in term of telecom innovation than stringent access pricing policies (the cost-based models). Most of these results about the issues of the individual reforms confirm both the previous empirical and theoretical findings including our results of the theoretical investigation provided in chapter 3, among that, the findings that the structural separation and access price regulation undermines investment and innovation in the telecommunication infrastructures.

We show further that both the Gross Domestic product (the GDP) and the population size contribute to explain broadband deployment. In particular, we find that a 10% increase in GDP per capita (population size) leads to an average increase of broadband deployment by around 14% (12.1%). This result confirms most previous empirical studies.

4 Concluding Remarks

In this paper, we reviewed selected theoretical and empirical works that investigates access regulation-investment relationship in telecom industry and the key related debate. After the introduction of competition in fixed telecom service markets, regulation remains necessary to supervise and facilitate the entrants' access conditions to the existent network infrastructure facilities (the local loop) which remain exclusively owned by the historical monopoly (the incumbent) in most countries over the world. These facilities constitute an essential input to provide end-user services (e.g., Internet connection, long distance telephone service, etc.). Access regulation (i.e., access pricing, unbundling and/or separation policies) raises questions about its impacts on investment in new network infrastructures across both theoretical and empirical studies.

Literature points out on the difficulty to solve the trade-off between the static regulatory goal, that consists in promoting competition (leads to service-based competition), and the dynamic regulatory goal that consists in spuring innovation by both incumbent (upgrading the existent network infrastructures)

and entrants (building new infrastructures which leads to facility-based competition) (Laffont and Tirole 2000; Bourreau, Dogan and Manant 2010).

Under different assumptions on costs, demand and access pricing (homogenous versus differentiated services, deregulation versus ex ante regulation/ ex poste regulation, etc.) , interactions between different market players (incumbent, entrants, consumers and regulator) modeled using the game theory leads to various conclusions, although it is always possible to draw some policy lessons. In particular, a common result of this theoretical literature is that unregulated access price leads to foreclosure but implies better results in term of investment compared to the regulation case (e.g., Foros 2004; Kotakorpi 2006; Sarmento and Brandão 2007).

In the last decade, much of the debate is focused on two main questions. The first one concerns the requirement of the structural separation policy to the vertically integrated incumbent and its implications in term of consumer welfare and incumbent's investment in new technologies. The second key question concerns whether the ladder of investment approach is a solution to the trade-off between competition and investment. The literature gives different answers to these questions but the trade-off is still unsolved, and therefore, further theoretical researchs are required to overcome and understand this access problem. In chapter 3, we suggest a theoretical investigation based on more realistic assumptions compared to previous theoretical works.

Previous empirical researchs also fail to give final answer to impacts of access regulation on investment. This was the conclusion of many researchs that have surveyed the empirical works addressing this question in telecom industry. Heterogeneous empirical methodologies (different measures of regulatory variables, various measures of innovation in telecom network infrastructures, different control variables, different sample covering various time periods and regions and different econometric specifications and methods) leads also to opposite results, and therefore ambiguous conclusion. Obviously, consistent data and robust methods to overcome many technical aspects and to take into account many particular considerations (i.e. reverse causalities between regulation and investment, heteroskedastic and autocorrelated errors, dynamic process of telecom investment, etc.) , as pointed by Cambini and Jiang (2009); Friederiszick, Grajek and Röller (2008) and FCC (2009), are necessary to understand the regulation-investment relationship.

Further, in our survey, we classified empirical works by type of regulation (access price policy, separation and unbundling policies) to determine the particular effect of each reform required in telecom industry. We also classified these works following the regulatory measurements and specifications of the regulation- investment relationship (linear versus non-linear models). These classifications lead to the following additional remarks:

- First, it seems that the intensity of regulation plays an important role. In particular, regarding the impact of the access price regulation, our survey permits to draw the following conclusion: a stringent access price regulation

that consists to set lower access prices (cost-based approaches such as FDC or LRIC) undermines investment while a less intense access price policy such as requiring price cap model spurs innovation. However, the impacts of the unbundling as well as the separation policies are still ambiguous. In fact, there is no work that studies the individual effect of various levels of unbundling or separation policies, except Wallsten (2006). This latter author, indeed, studies the impact of different forms of local loop unbundling, and reaches an original conclusion. In particular, Wallsten (2006) concludes that a less intense unbundling policy which consist to require full local loop unbundling or bit-stream access has no impact on broadband penetration, while more stringent unbundling policy (sub-loop access) negatively affects broadband deployment.

- Second, the specification of the regulation-investment relationship also plays an important role. Few works use non-linear models to specify the regulation-investment relationship but consider measurements of market outcome (measures of level of competition). They show that this relationship is more complex: it is an inverted-U shape. This confirms the recent finding of both theoretical and empirical researches on the relationship between competition and innovation in the economic literature (see for e.g., Aghion et al. (2005), Innui, Kawakami and Miyagawa 2008; Hashmi 2011; Goettler and Gordon 2014). According to Aghion et al. (2005), the failure of the previous economic studies to reach common conclusion is due to the fact that these works use simple linear models to specify a complex relationship. However, although the obvious positive relationship between competition and regulation, Bauer and Shim (2012) find a non-invested U shape using a measure aggregating scores and dummies that measure regulation reforms. They suggest a strict negative impact of regulation on investment. In our knowledge, this is the unique paper, in which a non-linear model is estimated using direct measurements of regulation reforms rather than market outcome measurements such as competition. We have many reproaches to this study that concern mainly three points: the econometric method, the sample, and the interpretation given by authors for some of their results). We will provide further details about these in chapter 4.

In our paper ((Ben Dkhil (2014 a)), we show that the relationship between regulation and investment is an inverted U shape in rich countries, but it takes a U form in poor countries. This means that in rich countries, a less restrictive regulatory policy spurs broadband deployment, while a stringent policy intervention discourages innovation in telecom industry. However, in poor countries, the regulation has a strict negative impact on broadband deployment.

Concerning the individual impacts of the access regulatory reforms, our empirical results give more support for the inverted U shape relationship. In particular, we find that requiring an extensive unbundling policy (sub-loop access) impedes investment, while a lighter unbundling regulatory policies such as the full local loop unbundling, bit-stream or line sharing drives innovation. In the same way, requiring extensive separation policies (operational, functional or full structural separation) undermines broadband investment, while a

moderate separation policy (accounting separation) spurs broadband deployment. Our results of both theoretical and empirical investigations support the findings of the related previous works that access price regulation and the full structural separation requirement undermine investment in the telecommunication infrastructures.

However, this study has a number of limitations we first do not use a disaggregated measure for broadband deployment by type of operator (incumbent/ entrant). Second, given the non-availability of amounts of investment in fiber or broadband technologies, we use like the majority of studies the broadband penetration which may not reflect exactly the level of investment in these technologies. Additional researches are, therefore, required to further understand the regulation-investment relationship.

5 Appendix: Regulation and telecom innovation: A summary of selected empirical works

Table 1. Impacts of access pricing policies

Study	Samples	Econometric methods	Measures of telecom innovation (performances)	Measures of regulatory variable	Results and our remarks
Chang, Koski and Majumdar (2003)	1/ 41 local operators in USA (1994-1998) (annual panel data)	GLS[1] (to control for heteroskedasticity and autocorrelated erros) (static linear models)	Share in fiber-optic / Share in digital lines	access charge (in dollars per minute)	1/ USA (negative impact)
	2/ 14 EU countries 1993-1997 (annual data)	Simple analyze of data	Investment in telecom industry (ITU data)	Binaries variable for implementation of CB, FDC and LRIC models[2]	2/ Europe (no impact) (explanation of Chang et al.: The regulation is yet recent in Europe).
Distaso, Lupi and Maneuti, (2005)	14 EU countries 2000-2004 (quarterly data)	FR (with time fixed effects), RE and IV (one control variable is considered is endogenous).[3] (static linear models)	Broadband penetration	Access charge (the price of unbundled local loop)	Negative impact
Waverman, Meschi, Reillier and Dasgupta (2007)	27 EU Countries 2002-2006	SUR [4] (to control for reverse causalities between regulation and telecom innovation) (static linear model)	The broadband market shares of incumbent and competitors	Access charge (Price of local loop unbundling)	Negative impact
Seo and Shin (2011)	25 local companies in USA 1988-1998	OLS	Measure of Productivity growth change in telecom industry	Scores for regulatory regimes (price cap, rate of return,..)	Lighter access price policy that consist to price cap regulation increase per-

					formance of telecom industry
Bauer and Shim (2012)	32 developed countries (European, USA, Japan and others) 1997-2010 Annual data	Difference GMM (with standard errors)[5] (dynamic non-linear models)	Fixed Broadband penetration / Number of secure service	Sub-index that measure intensity of access price regulation [6]	Negative impact
Ben Dkhil (2014 b)	105 developed and developing countries	FE-GMM-CUE FE-2SLS FE-GMM-2step	Fixed Broadband penetration	Sub-index that measures the intensity of access price regulation computed by author as descripted in Ben Dkhil (2014 a)	A moderate access pricing regime (price cap or the retail minus) permits to reach better results in term of telecom innovation than adopting stringent access policies (the cost-based models such as LRIC or FDC)

Notes:

1. GLS: The Generalized Least Squares
2. CB: cost based that consists on the direct costs, FDC: fully distributed cost (direct and indirect costs), LRIC: long run incremental cost.
3. FE: fixed effects models, RE: Random effects models, IV: Instrumental Variable method.
4. SUR: Seemingly Unrelated Regressions
5. GMM: Generalized Method of moments is an advanced econometric models used by authors to control for reverse causality between access price regulation and innovation in telecom industry. Our reproach for this study that it ignores possibly problem of autocorrelation and heteroskedastic errors.
6. This sub-index is computed by Zenhäusern et al. (2007, 2012 a, 2012 b). It aggregate measures of regulatory price models adopted in a given countries for a given year. These measures are scores that associated as follows: no price control=0, price cap=0.5, FDC=0.8 and LRIC=1. LRIC therefore corresponds to the stringent regulatory access policy.

Table 2. Impacts of entry regulation

Study	**Samples**	**Econometric methods**	**Measures of telecom innovation (performances)**	**Measures of regulatory variable**	**Results**
Friederiszick, Grajek and Röller (2008)	200 operators (incumbent/ entrants and Fixed/mobile) in 30 European countries 1997-2006	OLS[1] and IV with robust standard errors (control for reverse causality between regulation and investment) **Dynamic linear** models)	Infrastructure investment	Sub-index that measure intensity of entry regulation policies[2]	Negative impact
Bauer and Shim (2012)	See table 1			Sub-index that measure intensity of entry regulation policies[3]	Negative impact
Grajek and	70 fixed opera-	OLS and IV	Infrastructure	Sub-index that	Negative impact on

Röller (2012)	tors in 20 European countries 1997-2006	with robust standard errors (control for reverse causality between regulation and investment) Dynamic **linear** models)	investment by incumbent Infrastructure investment by entrants	measure intensity of entry regulation policies	both entrant and incumbent investment.[4]
Ben Dkhil (2014 b)	105 developed and developing countries	FE-GMM-CUE FE-2SLS FE-GMM-2step	Fixed Broadband penetration	Sub-index that measures the intensity of entry regulation computed by author as descripted in Ben Dkhil (2014 a)	The relationship between Entry regulation and the fixed broadband subscription is an inverted U shape: A moderate entry regulation policy leads to better results in term of telecom innovation than adopting stringent entry regulation policy.

Notes:

1. OLS: Ordinary least squares.
2. This sub-index is computed by Zenhäusern et al. (2007).It aggregate binaries variables that take a value of "1" if the correspondent entry regulatory policy (unbundling, separation and others) is mandated in a given countries for a given year.
3. The same that used in Friederiszick, Grajek and Röller (2008) but updated to include data from 2007 to 2010 (see Zenhäusern et al. (2007, 2012 a, 2012 b).
4. This study is different from Friederiszick, Grajek and Röller (2008) although it uses the same data. It study suggests to analyze empirically the competition-investment dilemma of regulators in dynamic context by estimating separate equations to analyze the effects of decision made by two actors (may be entrant, incumbent or regulator) to decision made by the rest of market players in a given national market. Results show first that regulation measured by aggregate measure (summing dummies for accounting separation and unbundling reforms) have negative impact on investment made by both overall industry and individual operator (incumbent or entrant) investment. Second, the higher the incumbent's investment, the higher the regulation intensity (commitment problem). Third, authors show that there are a complementary strategy between incumbent and entrants (an increase in entrants' investment due to low regulation intensity leads to the increase of the incumbent's investment).

Table 3. Impacts of unbundling policies

Study	**Samples**	**Econometric methods**	**Measures of regulatory variable**	**Measures of telecom innovation (performances)**	**Results**
Martha (2005)	100 developed and developing countries Year 2001	OLS and Logit models (static linear models)	Unbundling (dummy variable) Competition (dummy) Privatization (dummy)	Broadband penetration	Positive impact of unbundling and competition and no effect for privatization The positive impact of unbundling in middle-income countries is the highest.
Grosso (2006)	30 OECD countries 2001-2004 Annual panel data	FE (dynamic linear specification)	Unbundling (dummy) Competition (market share of each firm in the industry)	Broadband penetration	Positive impact of unbundling policy and competition

Wallsten (2006)	30 OECD countries 1999-2003 Annual panel data	OLS and FE (static linear specifications)	Full local loop unbundling (LLU) (dummy) Sub-loop unbundling (dummy) Bitstream unbundling (dummy)	Broadband penetration	Lighter unbundling policies that consist to require full LLU of bitstream has no impact on broadband penetration while more intensive unbundling policies (sub-loop unbundling) affects negatively broadband deployment.
	29 OECD Year 2003	OLS (static linear specification)	Number of years of each unbundling policy implementation (and others)	Broadband Speeds in Mb/s	No impact of unbundling policies
Gruber and Koutroumpis (2012)	167developed and developing countries 2000-2010 Quarterly panel data	IV (2SLS with country and year dummies and standard errors) Static linear models	LLU policies (dummies) Measures of competition (see table)	Broadband penetration	Positive impact of unbundling policies
Baccache, Brourreau and Germain (2013)	15 European countries 2002-2010 Semester panel data	Difference GMM with time fixed effects (dynamic linear models)	Number of LLU lines controlled by entrants Number of bitstream lines controlled by entrants*	Number of broadband lines owned by entrants	Negative impact Conclusion of these authors: There is no support to ladder of investment approach. Indeed, the bitstream access (LLU) does not shown to serve as « a stepping stone » for entrant to construct its LLU lines (its broadband lines).
Nardatto, Valleti and Verboven (2014)	5000 local companies in UK 2005-2009 Quartly panel data	FE and System GMM (static and dynamic linear models)	LLU policy (dummy and number of companies that use LLU)	Broadband penetration/ Broadband speed	Unbundling does not increase significantly broadband penetration Positive impact on speeds (quality of retail service) when entrant differentiate its service relatively to incumbent
Ben Dkhil (2014 b)	105 developed and developing countries	FE-GMM-CUE FE-2SLS FE-GMM-2step	Fixed Broadband penetration	Binary variables that takes one if the unbundling policy is adopted	Positif impact of both full LLU and bitsream access on broadband adoption Negatif impact of subloop access on broadband adoption

Note: * In some specifications these variables are also interacted with the overall index of Plaut economy used by Bauer and Shim (2012) that measure the regulation intensity in telecom.

Table 4. Impacts of separation policies

Study	Samples	method	Measures of regulatory variable	Measures of telecom innovation (performances)	Results
Viani (2006)	67 countries 1984-2003 Annual panel data	Robust FE clustering on countries (static linear models)	Vertical separation of incumbent from international segment (dum-	Price of local fixed telephony "Outgoing international minutes per person"	Vertical separation has a ne impact on expansion of bot international telephone serv increases price of local tele service.

			my)	Number of use fixed lines in minutes per person	
Bruno (2012)	14 European operators (3 separated vs 11 integrated incumbents) 2005-2010	Data Envelop-ment Analysis (methods to estimate econ-omies of verti-cal integrations EVI)	efficiency scores measur-ing economies of vertical integration	Broadband lines	Vertically separated operat more efficient than vertical grated incumbents consider tional retail service (narrow lines) While for advanced retail s (broadband lines) efficienc rated firm decreases
Ben Dkhil (2014 b)	105 devel-oped and developing countries	FE-GMM-CUE FE-2SLS FE-GMM-2step	Fixed Broad-band penetra-tion	Binary variables that takes one if the separation policy is adopted	Positif impact of Accounting separation On broadband adoption Negatif impact of Functional separation on Broadband adoption

Table 4. Impacts of overall regulation

Study	**Samples**	**Econome-tric methods**	**Measures of telecom innovation**	**Measures of regula-tory variable**	**Results**
Bauer and Shim (2012)		See table 1		An overall index of Plaut Economy that measure the overall regulation intensity in telecom*	Negative impact on innovation
Ben Dkhil (2014 b)	105 devel-oped and developing countries	FE-GMM-CUE FE-2SLS FE-GMM-2step	Fixed Broad-band penetra-tion	Overall index for regulatory reforms re-quired in fixed telecommunica-tions computed by author as Ben Dkhil (2014 a)	In the developed coun-tries, the relationship between regulation and broadband adoption takes an inverted U form: a moderate regulation policy rises the broad-band adoption while a restrictive regulation policy reduces broadband adoption. In the developing coun-tries, this relation takes a U form which means a strict negative impact of regulation on broadband adoption.

Notes: * This index is an aggregation of 20 indices: indices measure price regulation, measures for entry regulation (i.e. unbundling, separation policies and others) and others. This indices are computed by Bauer and Shim (2012).

Table 5. Impacts of regulation through the market outcome measurements (non-linear specification)

Study	**Sample**	**Econometric methods**	**Measures of regula-tory variable**	**Measures of telecom inno-vation (per-formances)**	**Results**
Hei-meshoff (2007)	30 OECD countries 1990-2003 (yearly panel data)	First difference GMM estimator two step robust to heteroscedasticity and autocorrela-tion (dynamic non-linear specifica-tion)	OECD indexes meas-ure intensity of com-petition (market struc-ture)	Investment per capita	Inverted –U relationship be-tween competition and investment
Li (2008)	29 OECD	Difference GMM	Number of operators	Number of	Inverted-U rela-

	countries 1991-2005 Annual panel data	and 2SLS (dynamic non-linear models)	(measure of competition) Privatization (dummy) Independency of regulatory bodies (dummy)	subscriptions per 100 habitants	tionship between competition in mobile sector and number of subscription per 100 habitants
Briglauer, Ecker and Gugler (2013)	27 European countries 2005-2011	FE, Difference GMM and GMM-system (to control for reverse causalities)	Measure of service based competition (percentage of unbundling broadband lines) Measures of facilities based competition (Percentage of cable and DSL lines controlled by entrants/Percentage of subscriber of 3G service)	Number of fiber lines normalized to population	Inverted U-relationship between facilities based competition and fiber technology deployment Service based competition undermine investment

Table 6. Impacts of regulation through the market outcome measurements (linear specification)

Study	Sample	Econometric methods	Measures of telecom innovation (performances)	Measures of regulatory variable	Results
Boylaud and Nicoletti (2000)	23 OECD countries 1991-1997 (annual panel data)	FE and RE (static models)	Measures of service qualities ("call failure rate", "fault clearance rate", "answer seizure ratio") Measure of Productivity in telecom industry (ratio of number of main lines to total employment,..) Prices (tariffs of different final services)	Number of competitors Share of entrants Number of years of introduction of competition Index measures degree of state ownership Number of years since the first sale of part of public telecom monopoly firm	Competition increases productivity and service quality and reduces prices. Privatization has no effect on qualities and prices and negatively affects productivity.
Li and Xu (2004)	177 developed and developing countries 1990-2001	FE-robust 2SLS with fixed effects, clustering on countries (control for reverse causalities and autocorrelation and heteroscedastic errors) (static and dynamic specifications)	Telecom investment per capita Price of three minute local call Labor productivity	Scores for : Competition Partial privatization Full privatization	Full privatization and competition ameliorate telecom performance while partial privatization has no effect.
Alesina et al. (2005)	21 OECD countries 1975-1998	GMM with fixed effects (control for reverse causalties) (dynamic)	Investment (capital stock)	Indexes computed by authors incorporating market share of entrant to measure competition and share of government in incumbent's firm to measure privatization	Competition and privatization increase investment
Distaso,	14 Europe-	FE, RE and	Broadband penetration	Herfindahl index-	Inter-plaform

Lupi and Maneuti (2005)	an countries 2000-2004 Panel quarterly data	IV (control for reverse causalities) (static models)		es to measure inter-and intra-platform competition computed by authors Access prices	competition promotes broadband deployment while competition in the DSL market service has no significant effect.
London Economics (2006)	25 European countries 2001-2004 (annual panel data)	Robust FE	Tangible fixed assets of operator	OECD index or ECTA index	Positive impact of regulation on investment
Djiofack-Zebaze and Keck (2009)	177 countries (45 Sub-Saharan Africa and others) 1997-2003	OLS, GLS, 2SLS, 3SLS, GMM	Number of subscriptions and prices for end user service s (fixed, mobile , international telephony)	Liberalization (score for market structure) Dependency of regulatory bodies (dummy) Number of years from instauration of independent regulatory body , adoption of GATS and WTO commitment	Impact positive of regulation on telecom performance
Bouckaert, Dijk and Frank (2010)	20 OECD countries 2003-2008 (quarterly panel data)	FE (dynamic specifications)	Broadband penetration	Herfindahl indexes to measure inter-and intra-platform competition computed by authors	Service based competition discourages broadband deployment. (no support for the Lader of investment approach)
Gruber and Koutroumpis, (2012)	See table 3			Herfindahl indexes to measure inter-and intra-platform competition computed by authors.	Both service based competition and facility based competition increase broadband deployment but the facility based competition has the greatest impact.

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