A growing number of countries are reexamining telecommunications policies in search of approaches that better support investment and innovation in advanced communication networks and services. In addition to regulatory instruments, a broad range of fiscal and industrial policy measures are being revitalized. These instruments affect regulated and unregulated firms in the ICT ecosystem in multifaceted ways and sometimes have counterintuitive effects on aggregate performance. The design of policies is further complicated by trade-offs between short-term and long-term policy objectives. This article examines individual and joint effects of regulatory and other policy instruments on the investment incentives in advanced communications. It conceptualizes governance as a problem of “tuning” a highly dynamic, adaptive system. Alternative consistent combinations of regulation and public policy are feasible but they have different implications for sector outcomes, most importantly the balance between static and dynamic performance.
heavily on unfettered market forces. Accelerated by the economic downturn of 2008, a growing number of countries are reconsidering such forms of state intervention. For example, Australia has announced plans for a nationwide public–private broadband backbone project. The American Recovery and Reinvestment Act (ARRA) of 2009 dedicated US$7.2 billion of funding to broadband access in unserved and underserved regions of the country. Likewise, the European Economic Recovery Plan (EERP) of 2008 included dedicated funding for high-speed broadband access. Several European nations, including the UK and France, have announced the use of public funds to invest in ICT infrastructure. This is a considerable shift in the thrust of public policy which, during the preceding decades, had predominantly been concerned with the 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, a policy vision that is reassessed in the present rebalancing.

During the transition from monopoly to competition, regulatory policy was developed contingent upon the prevailing, historical market structure. This was a sensible approach and resulted in the development of an elaborate toolkit appropriate to facilitate the transition. However, the design of investment and innovation incentives in next-generation networks differs in three important ways from the past. First, communications have evolved from a monopoly environment to an ecosystem of multiple regulated and unregulated players (Fransman, 2007). Public policy design has to pay much closer attention than in the past to the direct and indirect effects on all these players and not only on those subject to regulation. Second, new forms of inter-modal competition and cooperation are pervasive. Competitive relations between players coexist with strong complementarity relations, resulting in highly complex and dynamic market processes (Brandenburger & Nalebuff, 1996; Farrell & Weiser, 2003) for which ex ante regulatory rules may be difficult to devise. Third, a significant portion of the new infrastructure has to be built, either by upgrading the existing networks or by rolling out new networks. The total cost of upgrading the US infrastructure to ultrabroadband, for example, has been estimated to US$350 billion, more than seven times the 2007 total private sector investment in information and communication technology. Given these challenges, regulation will have to carefully consider its implications for the investment and innovation decisions that shape the future development of the sector. Regulation and public policy therefore have to be understood as both endogenous responses to the existing sector conditions and past performance as well as exogenous forces shaping the future of the sector. They are exogenous in as far as policy-makers have some discretion as to how interventions in the marketplace are designed. Under conditions of uncertainty, the extent and form of policy discretion will be influenced by the overarching national and regional guiding vision for the sector. Regulation and public policy are also exogenous in an inter-temporal perspective: measures in period t influence forward-looking investment and innovation decisions and therefore shape market structure in future periods t+n.

Despite the importance of regulation for dynamic sector efficiency, until recently the relations between regulation, investment and innovation were rarely examined by researchers and treated pragmatically by regulators. Joseph Schumpeter was very critical of regulatory policy designed to mimic the outcomes of perfectly competitive markets (Bauer, 1997) but his critique was disregarded. Among the few papers that analyzed the effects of regulatory choices on investment and innovation in a rigorous framework are Averch and Johnson’s analysis of the effects of rate of return regulation on the capital intensity of the regulated firm (Averch & Johnson, 1962) and Bailey’s paper on regulation and innovation (Bailey, 1974). In practice, successive generations of regulation, including rate-of-return regulation, price caps and other forms of performance-based regulation, and the subsequent shift from retail to wholesale regulation were all seen as means to sustain investment and innovation. In every instance, initial enthusiasm for the advantages of the approach faded as some of the disadvantages also became apparent (Ai & Sappington, 2002; Phillips, 2002; Sappington & Weisman, 1996; Vogelsang, 2002). Valletti (2003, p. 671) noted that “there is no developed analysis of the linkage between access pricing and incentives to invest.” With the high investment needs of next-generation networks, the dynamic implications of regulation have received increased attention (e.g., de Bijl & Peitz, 2008; Gayle & Weisman, 2007; Prieger, 2002). In a comprehensive survey of this growing body of research, Cambini and Jiang (2009) concluded that the findings are heterogeneous and that further research will be necessary to address contested issues.

This article aims at contributing to the theoretical and practical policy discussions in two ways. At a conceptual level, it proposes a framework for the design of regulation and the evaluation of the implications of regulatory choices on investment and innovation in the communication industries. In technologically dynamic sectors, these two aspects of intertemporal decisions are closely intertwined: investment will often be in new generations of technology and innovations require investment in R&D as well as in the commercialization of products and services (Friederiszick & Röller, 2006). Building on the notion of ICT as an ecosystem (Fransman, 2007), the paper systematically explores the effects of different regulatory choices on static and dynamic sector performance and the likely trade-offs between them. The approach allows a more systematic assessment of the ways in which regulatory and other public policy instruments affect the investment and innovation incentives of regulated and unregulated players in the ICT ecosystem. It allows a clearer view of the potential trade-offs between different objectives and the effects of different policy choices on individual firms and aggregate sector performance.

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At a practical level, the article aims at sensitizing policy makers to the challenges of coordinating alternative sets of policies to find an overall consistent approach. Due to the high degree of interdependence in advanced communication systems, regulation resembles a set of “tuning” parameters more than a set of “controls”. Consequently, there is not just one “best” choice; rather, regulation deliberately or tacitly sets the ICT ecosystem on alternative paths characterized by specific performance metrics and trade-offs. Section 2 discusses the factors shaping investment decisions at the firm level and clarifies the multiple paths through which regulation affects investment decisions. Sections 3–5 examine horizontal and vertical regulation as well as other public policies. Empirical contributions are re-examined in the light of this conceptual framework in Section 6. Basic guidelines for policy are suggested in Section 7, followed by some concluding reflections.

2. Regulation, competition, and investment decisions

In contrast to the rather hierarchical network architectures and market organization of traditional telecommunications, advanced communication networks and services require the cooperation of many players. In this ecosystem, regulated and unregulated network operators, equipment manufacturers, software vendors, application and content providers, portals, search engines, and many others coexist. Independently of whether these firms are regulated or not, they will decide level and structure of investment and innovation activities by examining expected revenues and costs over the estimated lifetime of a project. Investors and innovators are therefore influenced by supply and demand conditions in the relevant markets. The consequences of regulatory choices on investment and innovation of groups of players and the sector as a whole can be analyzed systematically by examining their influence on the factors relevant for investment decisions. Under conditions of uncertainty, firms will pursue investment opportunities as long as their net present value (NPV), modified for the option values associated with alternative business strategies, is positive (Alleman & Noam, 1999; Dixit & Pindyck, 1994; Smit & Trigeorgis, 2005; Trigeorgis, 1995). For each firm in the ICT ecosystem, the expanded (strategic) NPV of a project is derived as the traditional (static, passive) NPV modified for the option value of active management decisions \( m \) \((m \in M)\), with \( M \) the set of available strategies. Following the formulation of Trigeorgis (1999, p. 4) this can be expressed as follows:

\[
ENPV = NPV + V_m = \sum_{t=0}^{T} \frac{R_t}{(1+i)^t} + V_m
\]

where \( ENPV \) is the expanded (strategic) net present value (at point \( t=0 \)); \( NPV \), the static (passive) NPV of expected cash flows (at point \( t=0 \)); \( R_0 \) the initial investment at time \( t=0 \); \( R_t \) the cash flow (inflows minus outflows of funds) at time \( t=1, \ldots, T \); \( i \) the discount rate; \( V_m \) the value of options from active management, \( m = 1, \ldots, M \).

Regulatory and public policy measures affect investment and innovation decisions of firms because they modify one or more of the factors in the investment calculus. Some forms of regulation such as general interconnection or interoperability obligations, affect all players but more typical regulatory interventions are targeted to specific players (often those with market power) and hence exert differential effects on regulated and unregulated firms. To understand the consequences of regulation on the level and structure of investment, its effects on the variables that determine cash flows in future periods and the option values of strategic management choices need to be examined (see Fig. 1). Other things being equal, cash flows vary positively with the existing market opportunities and the appropriability of revenues and profits but negatively with the competitive intensity of the industry segment and the costs of providing service. The option value of a particular investment strategy, for example of going ahead with a project, depends on several factors, most importantly the competitive intensity of the industry and regulatory choices.

![Fig. 1. Effects of regulation on investment calculus of firms.](Image)
Unbundling, open access, network neutrality, and other forms of regulation affect investment and innovation through multiple channels (see Table 1). As will be discussed, the strength of these effects depends on the status quo of the industry and the specific design of the regulatory instruments. Stringent unbundling, for example, will constrain the opportunities of players with the unbundling obligation to appropriate profits from an investment. Other things being equal, this will reduce the ENPV and hence the incentive to invest in facilities. At the same time, unbundling reduces the entry cost of new and potential competitors and will therefore, other things being equal, have a positive effect on complementary investment of service-based entrants. Unbundling, furthermore, creates options to postpone facilities investment for both incumbent players and new entrants, which also influence the ENPV of any particular project. Other measures influence market opportunities, appropriability, and the discount rate.

Regulatory choices are one important determinant of the competitive intensity of different segments of the ICT ecosystem. In a dynamic perspective, competitive intensity is of great relevance for the level and structure of investment and innovation that will emerge in an industry. The relation between the intensity of competition and the innovation rate in a market is particularly important in the context of next-generation networks. Innovation research suggests that both markets with too little and markets with too much competition may generate weak innovation performance (see Fig. 2). Schumpeter (1942) asserted that temporary market power allowed firms to appropriate risk premiums that, in turn, were required to assume innovation risks. Subsequent technology and innovation research (e.g., Kamien & Schwartz, 1982; Sutton, 1998) also detected a non-linear relation between market power and innovation. Consequently, especially in industries with significant sunk costs, loose oligopoly rather than perfect competition or monopoly was seen as most conducive to investment and innovations. Aghion Bloom, Blundell, Griffith, & Howitt (2005) suggested an alternative explanation of this inverted U-shaped relation between competitive intensity and investment and innovation incentives. Unless firms in monopolistic markets are protected by high entry barriers, entry by new firms will increase investment and innovation. On the other hand, if competition gets too intense, firms will increase investment in differentiated products.

### Table 1

<table>
<thead>
<tr>
<th>Intervention point</th>
<th>Regulation</th>
<th>Public policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competitive intensity</td>
<td>Licensing conditions</td>
<td>Antitrust enforcement</td>
</tr>
<tr>
<td></td>
<td>Unbundling, open access</td>
<td></td>
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<tr>
<td></td>
<td>Network neutrality</td>
<td></td>
</tr>
<tr>
<td>Opportunity</td>
<td>Line-of-business restrictions</td>
<td>General business climate</td>
</tr>
<tr>
<td>Appropriability</td>
<td>Profit regulation</td>
<td>Patent and copyright provisions</td>
</tr>
<tr>
<td></td>
<td>Retail price regulation</td>
<td>Antitrust provisions</td>
</tr>
<tr>
<td></td>
<td>Non-discrimination requirements</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>Quality-of-service requirements</td>
<td>Tax policy (investment tax credits, depreciation, carry-over of losses)</td>
</tr>
<tr>
<td></td>
<td>Unbundling, open access</td>
<td>Subsidies</td>
</tr>
<tr>
<td></td>
<td>Network neutrality</td>
<td></td>
</tr>
<tr>
<td>Discount rate</td>
<td>Stability of regulation</td>
<td>General business climate</td>
</tr>
<tr>
<td>Option value(s)</td>
<td>Unbundling, open access</td>
<td>General business climate</td>
</tr>
<tr>
<td></td>
<td>Network neutrality</td>
<td>Patent and copyright provisions</td>
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</table>

Fig. 2. Competitive intensity and investment/innovation incentives.
and services to weaken competitive pressures. A third explanation in high-tech industries is that coordination and cooperation requirements between suppliers can best be undertaken if competition is neither too weak nor too intense.

The empirical shape of this relation for the next generation network (NGN) value net is not known and will only be revealed over time. Given this lack of knowledge, it seems impossible to design regulatory policies that maximize investment and innovation incentives. It is less demanding, however, and within the reach of practical policy to keep the system within reasonable upper and lower bounds of desirable investment and innovation incentives. From this vantage point, the task of regulation is to prevent the competitive intensity of the system from falling below a threshold $c_L$ where dynamic performance deteriorates. At the same time, regulation needs to avoid pushing competitive intensity above a level $c_U$ where dynamic performance also deteriorates. In contrast to a situation with too little competition, a situation in which regulation enforces too much competition will reduce investment and innovation incentives but result in lower prices for consumers. Keeping a market between these two thresholds is probably best achieved in a combination of ex ante safeguards and ex post intervention, which jointly allow adapting regulation to the dynamic performance of the ICT ecosystem.

3. Horizontal regulation

Access to rights of way, collocation, interconnection, unbundling, resale, provisions governing number portability, and to a certain degree licensing policies influence investment and innovation predominantly by affecting the structure and competitive intensity of network platform markets. These arrangements govern transactions between different facilities and service-based network operators. They are important tools to harness the benefits of seamless communication services but also to level the competitive playing field. By standardizing important transactions between players, they also reduce transaction costs. Use of these horizontal regulatory instruments expanded greatly during the transition from monopoly to a more competitive market organization. In next-generation environments, some of the traditional instruments are technically not feasible but similar specifications are available. For example, in fiber networks, corresponding regulatory instruments include access to ducts and dark fiber, collocation at various locations (e.g., in street cabinets, optical distribution frames, or core metropolitan locations), full and sub-loop unbundling, and bitstream access (Elixmann, Dragan, Neumann, & Plückebaum, 2008). In both traditional and next-generation networks a range of more or less stringent options for the governance of horizontal relations between players exists.

Stringency is determined by the scope of horizontal regulatory provisions, the process of negotiating them, and the pricing of services. Interconnection, for instance, could be left to negotiations between the players, left to negotiations with recourse to a regulatory agency, or be strictly regulated at prices and conditions favorable to the firm seeking to interconnect. Unbundled access could be left to market negotiations, left to negotiations with recourse to a regulatory agency, or regulated at more or less favorable conditions to the firm seeking access. Furthermore, the scope of rights and obligations can vary quite substantially. Asymmetric regulation affects stakeholders (e.g., incumbents, new entrants, facilities-based suppliers, and non-facilities-based service providers) in different ways. In most cases, the goal of regulation is to optimize the performance of the entire market segment, not of an individual company. Therefore, in order to design effective policy, direct and indirect effects on regulated and unregulated players need to be considered.

Horizontal regulatory measures are well-grounded in theoretical frameworks. For example, interconnection provisions are typically justified as efforts to capture the benefits of network effects and to neutralize market power. Likewise, unbundling has several conceptual roots, including the essential facilities doctrine and the ladder-of-investment (LoI) model of investment (Cave, 2006). These foundations rarely predetermine a single "best" way of implementing a measure but leave degrees of freedom for regulation. This is desirable for several reasons. First, it allows regulation to be fine-tuned to the specific technological, economic, and political context. Regulators are, second, able to tune instruments to balance different and possibly conflicting objectives, most importantly short-term static and long-term dynamic aspects of efficiency. Third, regulatory diversity also facilitates institutional learning processes as comparisons generate insights into the advantages and disadvantages of approaches.

Effects of unbundling choices on investment can be modeled using the framework presented in the previous section. If $p_u$ is the price of unbundled access and $c$ the cost of providing the service, the mark-up of prices over cost $m_u = (p_u - c)/c$ can be interpreted as a measure of the "stringency" of unbundling rules. A lower or even negative mark-up signals more stringent unbundling regulation and vice versa. The smaller the difference between the price for wholesale unbundled network access and the cost of providing these facilities, the lower are the start-up costs of new market entrants. The overall effect of unbundling rules on investment depends on the relative magnitude of three countering factors: (1) the responsiveness of new entrants to the stringency of unbundling; (2) their effect on incumbents; and (3) their indirect effect on market demand. Furthermore, it makes a difference whether unbundling policies apply only to existing facilities or whether they also apply to new investments.

More stringent unbundling regulation will increase the incentives of competitors to compete on a service-basis and only invest modestly in the necessary complementary facilities. Moreover, if such favorable conditions remain in place for
prolonged periods of time, incentives to migrate to facilities investment will be lowered. Incumbent service providers will operate under two conflicting incentives. Competitive pressure from the new entrant may, other things equal, trigger higher investment in response to the entrant. This desirable incentive is, however, counteracted if stringent unbundling mandates that any network upgrade will have to be shared with competitors. Such a provision increases the value of the option to postpone investment in facilities for new entrants and decreases the option of investing for an incumbent service provider (Pindyck, 2007), resulting, ceteris paribus, in lower investment. On the other hand, both new entrants and incumbents will invest more if competition, via lower prices and increased quality differentiation, results in accelerated market growth and hence market opportunities.

The net effect of unbundling on sector investment depends on the relative magnitude of these counteracting forces. The chain of causality differs between situations in which existing facilities are subjected to unbundling and situations where unbundling is applied to forthcoming investment. In either case the interaction between the competitive structure of the market and the stringency of unbundling rules is critical. In the first case, an unbundling measure of given stringency will more likely have the desired net effect if the market is highly concentrated to begin with. It will be much weaker or possibly negative if the market was oligopolistic or “workably” competitive. However, unbundling is a matter of degree. Carefully applied to a concentrated market, it may increase the incentive to invest. On the other hand, even starting from a dominated market, overly stringent unbundling may backfire by pushing the market beyond the threshold \( c^U \) where investment incentives again start to decline. The strengths of these effects are mediated by the overall sector conditions, in particular the risk associated with investment and the technology options available to incumbents and new players. Higher risk, for example, will increase the value of the option to delay facilities investment by new entrants and thus, other things equal, result in more service-based competition.

The analysis has to be augmented if such requirements are imposed on facilities that have not yet been built. In this case a focus on existing technology and existing market structures misses a key aspect of infrastructure competition and may generate negative incentives for investment and innovation. Competition is better modeled as a technology race to build networks, a race that is affected by horizontal regulatory rules (Faulhaber & Hogendorn, 2000; Valletti, 2003; Woroch, 2002). Next-generation access networks are not only local but also spatially differentiated markets. Given the high investment requirements, it is unlikely that one firm has sufficient resources to invest simultaneously in ubiquitous coverage across an entire nation. Thus, in the absence of unbundling rules, the likelihood that multiple investors will initiate projects in different locations is increased. Whereas this may not initially lead to parallel investment in any location, a diverse market structure may emerge with alternative providers co-existing in sufficient proximity to exert credible competitive threat.

The modularity of advanced communication technology further facilitates this development, in particular, if safeguards are in place allowing access to backhaul and interconnection to backbone networks. In contrast, if stringent unbundling requirements are in place, for example, by making a menu of choices available that includes various forms of local loop unbundling, smaller investors that might have deployed infrastructure now have an attractive option to wait. At the same time, suppliers bound by the unbundling obligations would forego a similar option to wait by investing early. The overall effect is a lower investment level in the market. The strength of this effect is dependent on the stringency of the unbundling requirements and mediated by factors such as the anticipated market growth. Symmetric unbundling rules will ameliorate these undesirable effects.

Unbundling not only influences the overall investment rate in a market, it also affects the mix of facilities-based and services-based competition that will emerge. Where the combination of market structure and unbundling pushes the market too far toward high competitive intensity, the overall investment rate will be lower and accompanied by a higher share of service-based competition. Less stringent unbundling will set the market on a course with a higher investment rate and a lower share of services-based competition. The first scenario will likely have higher short-term benefits for consumers (but require prolonged regulatory intervention) whereas the latter one will probably yield higher consumer benefits in the long run in the form of improvements in the quality/price ratio.

4. Vertical regulation

The factors influencing performance dynamics, and in particular investment and innovation, in vertically related markets are complex. Not only are they shaped by the conditions in each layer of the value network, they are also affected by the relations between players on separate layers. An analysis of competitive relations is further complicated by the fact that some players may only be present on a single layer while others are vertically integrated with a presence across layers. Vertical regulation structures the rights and obligations that govern interactions between players at different layers in the ICT value net and therefore influence overall performance. The design of vertical rules is at the heart of the “network neutrality” debate that has engulfed the US and is also gaining momentum in other countries. The current policy debate blends interrelated issues: (1) concern about the potential abuse of market power, in particular by vertically integrated players; and (2) concern about the regulatory framework that best facilitates dynamic efficiency.

Clark (1961) pointed out that in real world markets the conditions of perfect competition are often violated. Despite such imperfections, markets may be “workably” competitive and yield satisfactory performance.

On October 22, 2009, the FCC adopted a notice of Proposed Rulemaking seeking public input on draft rules to preserve the free and open Internet. See In the Matter of Preserving the Open Internet; Broadband Industry Practices, WC Docket no. 07-52; GN Docket no. 09-191.
On both counts, claims and counter claims are far-ranging and a detailed discussion and critique would exceed the scope of this paper (see Bauer & DeMaagd, 2008 for a review of the arguments). Pundits who are mainly concerned about conditions conducive to innovation in content and applications emphasize the importance of network neutrality to maximize innovation (Herman, 2007; Windhausen, 2006; Wu, 2003). On the other hand, experts who focus on network infrastructure investment argue that such rules would choke network investment and innovation (Hahn & Wallsten, 2006; Yoo, 2005). Both groups make good points but each position emphasizes a special case. Moreover, like unbundling, vertical rules are flexible. At one extreme is an approach that would leave all negotiations to market players and on the other the stringent regulation of prices and conditions. In between is a broad range of non-discrimination obligations of varying stringency. For example, a rule allowing differentiation of network services as long as they do not violate antitrust laws would be very lenient. An arrangement requiring structural separation or a rule requiring that every bit be treated alike would be rather stringent. Recent research has therefore moved beyond early claims and begun to examine the effects of vertical rules on the dynamic interdependencies between networks and applications. The findings are often more cautious recommendations for public policy than found in the world of advocacy (Peha, Lehr, & Wilkie, 2007). Vertical regulation is not a new phenomenon and earlier forms may offer valuable insights. Examples include rules granting access to content providers to cable distribution platforms, rules prohibiting exclusive contracts between cable systems and vertically integrated content providers (e.g., sports broadcasting, popular entertainment programs), mandatory openness provisions in mobile networks, functional or structural separation between networks and services, and common carriage obligations (although their historical roots are not related to vertical regulatory concerns). Despite the wide and repeated use of vertical regulation, its conceptual foundations are not as fully developed as the underpinnings of horizontal regulation. Such a framework will have to identify the core issues embedded in vertical regulatory problems and generalize them. The following paragraphs provide a first sketch (see Bauer, 2009a for a more detailed discussion).

Investment and innovation activities of the players at the platform and content layers are, first and foremost, affected by the competitive conditions, the technological opportunities, and the appropriability of temporary rents that prevail in the respective layer (which are also influenced by horizontal regulation). Both platforms and applications are heterogeneous so that a range of economic conditions will characterize different market segments. For example, the sunk costs of wireless and wire-line networks differ and within these categories alternative network architectures imply different cost structures; likewise, some applications will only require limited research and development efforts whereas others carry significant sunk costs. Different types of innovations require a commensurate chance to appropriate a sufficient risk premium. Innovations with low sunk costs will probably be most stimulated by fierce competitive conditions; on the other hand, innovations associated with high sunk costs will require some form of temporary market power to generate an adequate risk premium and will therefore not be forthcoming if the market is too competitive.

Vertical rules affect the overall investment and innovation dynamics of this ecosystem in several ways: (1) by delineating the permissible scope of business operations; (2) by constraining the charges and service conditions that the players may negotiate for access to their platforms, applications, or content; and (3) by influencing the transaction costs of network operators and content provider of gaining access to complementary layers. Vertical regulation could, first, constrain or even prohibit the vertical integration of players, both from network operators into content but also in the other direction. Technological change, such as deep packet inspection or proprietary search algorithms, has expanded the means of players to tacitly disadvantage or sabotage competitors. Whether and which form of vertical separation (accounting, functional, structural) is the correct regulatory response depends on the level of economies of scope between layers that are forsaken. Such a measure is potentially less costly, if such economies are low, for example, because platforms and applications are independent and the transaction costs of coordinating are low. This may be the case for some applications but does not hold for others, which require specific platform features. Therefore, imposing a general vertical separation rule has potentially high costs. To preserve the working of markets, it will likely suffice to prevent exclusivity agreements between vertically integrated firms, as this has been done in the US cable television industry.6

In other instances players at different layers will offer complementary services. Unless they are myopic or poorly informed, players will recognize their interdependence and make their services available to complementors. However, in an attempt to realize temporary innovation rents, each player will try to capture part of the rent of the other player(s), for example, by charging for access. If a market segment is concentrated, the players will have higher bargaining power to extract rents from complementary players operating in more competitive circumstances. Often, but not necessarily, the player with more bargaining power will be a network operator controlling access to customers. Rents extracted by other players could reduce innovation activity as projects that do not generate sufficient surplus may no longer be pursued. However, this is not necessarily the case as the complementor may differentiate access fees and may set some at zero. Furthermore, several remedies exist that do not require the regulation of charges and service conditions. One is the codification of a consumer right to get access to any application of their choice as, for example, expressed in the FCC’s Open Internet declaration (FCC, 2005) and subsequent case law, in particular the Comcast decision of 2008. Another option is to impose an obligation on ISPs to make one open service tier (possibly of a certain quality) available. Another alternative is...

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6 An example illustrating that vertical exclusivity agreements can pose serious barriers to competition is mobile TV in South Korea (where terrestrial broadcasters do not have to make content available to satellite-based mobile TV service providers). On the other hand, vertical separation between content and platforms also has a poor track record, as evidenced by the history of cable television in Germany.
the facilitation of institutional competition so that networks following different approaches co-exist. This is an important but often overlooked function of non-profit, cooperative, and publicly owned networks. If they operate under voluntary open access guarantees, they can provide an experimental environment for innovative applications.

Vertical regulation also affects players’ transaction costs, including the costs of negotiating, monitoring and enforcing access agreements, but also the costs of adapting applications and services to differently configured network platforms. Such transaction costs potentially affect platform-dependent applications and services more strongly than platform-independent ones. With the differentiation of network platforms increasing fragmentation might result so that the costs of adapting to different platforms may increase for all players. This would have similar effects as a charge assessed by a network operator and reduce the number of innovation projects that may be pursued. Werbach (in press) has proposed a general interoperability obligation as a sufficient condition to achieve many of the goals that network neutrality could reach. Details could then be left to industry standardization bodies and other forms of self- and co-regulation.

5. Non-regulatory public policy

With the exception of US and Canada, government regulation of telecommunications by specialized agencies was established during the past three decades. Prior to the emergence of the “regulatory state”, government ownership had been the main vehicle to pursue infrastructure goals but this approach was seen as wanting beginning in the 1980s. Inefficiencies of many (but not all) state-owned enterprises, financial constraints of the public sector during the 1980s that slowed large-scale infrastructure investment, and a general belief in a reduced role of government, all contributed to the stronger reliance on private sector participation. Despite the emerging strong trust in liberalization, privatization, and regulation, the traditional roles of the state as owner, operator, and facilitator were not fully abandoned (Bauer, 2009b; Cava-Ferreruela & Alabau-Muñoz, 2006; European Commission, 2004). It continued to play a role in areas where private infrastructure investment was not forthcoming or emerged slower than anticipated. Moreover, broadband networks have public good aspects that may not be realized by market players unless some form of public intervention provides the right incentives (Bauer, Gai, Kim, Muth, & Wildman, 2002; Picot & Wernick, 2007; Teppayayon & Bohlin, 2009).

Numerous municipal WiFi projects and fewer, but highly visible, fiber projects (e.g., in Amsterdam and Stockholm) are examples of local communities acting to accelerate access to advanced communications. In an increasing number of countries (e.g., in UK and the US) government is again becoming involved by granting subsidies and tax breaks to service providers in an effort to expand the network to previously unserved or underserved areas (OECD, 2008). In other cases (e.g., Australia), state investment in an advanced infrastructure may also be an unintended effect of forward-looking unbundling requirements, which may delay investment of incumbents and entrants. These ongoing initiatives were given new urgency by the economic downturn of 2008, which is straining private sector investment in NGN. Governments worldwide crafted broadband plans in a hurry to pursue two distinct purposes: short-term stimulus to an ailing economy and longer-term structural issues of rolling out ubiquitous infrastructures. Although this is not the place to review these initiatives in detail, it is important to briefly examine their interaction with horizontal and vertical regulation.

Non-regulatory government policies are designed to affect the investment incentives of market players. The most important supply-side tools are tax credits for investment and innovation expenditures, accelerated depreciation, subsidies, and measures that lower interest rates and hence the cost of capital. Demand-side instruments encompass tax credits, subsidies, and voucher programs that benefit households and individuals as well as measures by government agencies that boost ICT demand. Properly designed, all these measures are capable of achieving the desired expansionary effect on investment and innovation in NGN networks. Unlike regulatory measures that are often applied only to players with market power, non-regulatory tools are usually applied symmetrically so that their effect is easier to assess a priori. Nonetheless, the specific conditions and the context in which these instruments are applied matter. Tax credits and accelerated forms of depreciation, for example, may be more advantageous for established firms, as opposed to start-ups that might not yet be profitable and do not owe taxes. However, this could be overcome if companies can carry losses forward to mitigate future tax payments. Therefore, whether any of these measures has the desired effect on investment and innovation depends on the specific design of the policy instrument and the situation of the targeted organizations and individuals (see Bauer, 2009a for a more detailed discussion).

Another option for the public sector is to take a more direct and proactive role, either by coordinating infrastructure investment or by investing directly. Numerous projects at the municipal, regional, and national level are operational or in the planning stage (e.g., Gillett Lehr, & Osorio, 2004, 2006). Several models are utilized: public sector agencies that coordinate deployment but do not provide any subsidy; initiatives that support the projects with demand-side measures, such as serving as an anchor tenant; public subsidies for networks and services, often to provide public services; and direct public investment (Huang, 2008). The experience of the past few years seems to suggest that projects aiming at full community coverage are financially not sustainable without some form of subsidy. This may change with next generations of technologies, such as WiMax, that allow coverage of wider areas in a more cost-effective way. Moreover, public subsidies may be efficient if public goods are provided that would otherwise not be forthcoming from markets or communal initiatives.

The public sector could use an investment calculus that takes externalities and public good effects into account. Positive or negative externalities are not part of private ENPV calculations unless they are “internalized,” for example, by granting
subsidies or assessing taxes. A public sector agency could apply such a broader assessment of the value of an investment (a “social ENPV” or SENPV) in deciding on direct public investment. Publicly owned networks could be operated as open wholesale platforms, providing an institutional alternative that might curb private providers’ ability to extract excessive rents from non-network-based players. Despite these possible advantages, any state investment raises crowding-out concerns, the displacement of private by public investment with a negligible effect on the overall investment volume. In practice, given the tight financial constraints of national and local governments, direct public sector involvement faces serious limitations.

The interaction of alternative public policies with horizontal and vertical regulation will depend on their design details. Taken by themselves, tax credits and subsidies will have positive effects on investment and innovation. It is more difficult to ascertain the effects of hybrid measures that combine both regulatory and non-regulatory instruments. The recent broadband stimulus plan in the US, for example, blends expansionary fiscal with potentially constraining regulatory instruments. Part of the funding to unserved and underserved areas requires recipients to grant open access to their networks. This particular combination juxtaposes a positive (subsidy) with a negative (open access) incentive, leaving the overall effect on an individual provider ambiguous. In response, several large service providers announced that they would not compete for program funds. Most of the funds will therefore go to smaller local and regional firms. This may in turn accelerate the investment plans of incumbent service providers with a presence in adjacent areas (as the presence of a new competitor reduces the value of their option to wait to enter the new market).

Moreover, the institutional diversity resulting from the selectively applied openness conditions may have beneficial effects (Ostrom, 2005). If increased openness indeed attracts services and applications that are not available in the absence of such openness, it may set a precedent that other suppliers have to follow. A similar argument holds for direct public investment. The first-round direct effect of such investment on private facilities investment is most likely negative. However, if public investment reduces the value of an option to wait for private investors it may actually accelerate their investment plans in subsequent periods. Similarly, it may facilitate complementary investment if a public project eases bottlenecks, for example, by increasing competition in backhaul services.

6. Empirical evidence

Although NGN raise several unique and new issues, policy makers can and should be informed by the experience with earlier generations of technology and of other countries as long as lessons are drawn carefully and with caution (Rose, 1991). Research has made considerable progress during the past decade. Cambini and Jiang (2009) provide an excellent survey of the theoretical and empirical literature on regulation and investment. The authors conclude that the findings are heterogeneous and that further research is needed. Some of the heterogeneity may be related to the fact that studies of different generations of technology (telephone, broadband) are discussed jointly. Studies of the diffusion of broadband (which is the joint outcome of supply and demand-side factors) and those focusing more narrowly on investment and the supply-side of the market might also warrant separate examination. The effects of policies such as unbundling, for example, are, moreover, contingent upon the structure of the industry to which they are applied and the stringency of the adopted measures, which is, to some degree, in the discretion of the regulator. Empirical studies often do not disentangle the interaction between these factors. Lastly, much of the research is rooted in equilibrium models, which have difficulties capturing the dynamic interdependencies in advanced communication environments. One promising avenue that might help overcome these challenges is the use of simulation models or experimental approaches. Early attempts have allowed interesting insights into the dynamic interactions in stylized models (Bauer & DeMaagd, 2008; Beltrán & Sharkey, 2009; Bykowsky Olson, & Sharkey, 2008; de Bijl & Peitz, 2002, 2004; Mandy & Sharkey, 2004).

Using a dynamic lens, the available empirical evidence regarding horizontal and vertical regulation is largely consistent with the framework presented in Sections 3 and 4. Horizontal and vertical regulation are not either-or, dichotomous means of intervention, but rather can be employed in a gradated manner. Alternative designs have different effects on the overall investment and innovation rate, the mix of facilities and service-based competition, and the short- and long-term consequences for sector performance. A full review of the literature from this vantage point would exceed the scope of this paper and more selected hints must suffice. Few empirical studies have examined the effects of horizontal regulation on investment or innovation directly. Focusing on US wire centers, Gabel and Huang (2008) found that a higher markup was associated with higher rates of innovation in services geared to business users. Waverman, Meschi, Reillier, and Dasgupta (2007), using European data for 2002–2006, found that a higher intensity of regulation of local loops was negatively correlated with investment in alternative network infrastructure. Lastly, in a recent study of the effects of unbundling on fiber deployment, Wallsten and Hausladen (2009) also detected a negative effect of unbundling.

More studies use service diffusion as an independent variable and therefore only allow indirect conclusions on the effects of unbundling on investment. Bauer, Kim and Wildman (2003) in an early empirical study of the effects of unbundling on broadband diffusion in OECD countries, could not find a significant effect. Wallsten (2006), also in a study of OECD countries, differentiated between different forms of unbundling. Wallsten found a negative influence of sub-loop unbundling but a positive effect of local loop unbundling. Bitstream access did not have positive or negative effects. On the other hand Distaso, Lupi, & Manenti (2006) found a strong positive effect of unbundling on broadband diffusion in the European Union. However, as predicted by our conceptual analysis, the acceleration of diffusion facilitated by more
stringent unbundling coincided with a much higher share of service-based competition in the access markets (see also Kittl, Lundborg, & Ruhle, 2006).

Due to the forward-looking nature of the network neutrality debate only limited and mostly anecdotal empirical evidence is available that is insufficient to test competing claims. Like in the case of horizontal regulation, lessons may be drawn from comparable earlier experience, the few cases on the record, and simulation studies. Given space limitations, only the most important findings can be reviewed here. Research on the effects of functional and structural separation as a safeguard in telecommunications does, overall, not provide a strong endorsement of the approach. Crandall and Sidak (2002), Zhou (2003), and Xavier and Ypsilanti (2004) are skeptical in their assessments. US experience with the break-up of AT&T also did not provide compelling evidence as to the efficiency gains from separation. Rather, subsequent regulatory proceedings and the research literature highlighted regulatory cost, transaction costs associated with the coordination and contracts between separated businesses (Cave & Doyle, 2007), and opportunity costs due to lost economies of scale. Nonetheless, vertically integrated firms have incentives to discriminate and to exclude competitors that are not vertically integrated. However, except in rare circumstances, vigorous antitrust enforcement and constraints on vertical exclusive contracts as discussed in the previous section seem to be appropriate responses.

The literature addressing the second set of vertical regulations, non-discrimination rules, is at an early stage and findings are diverse. Choi and Kim (2008) in a game-theoretic model showed that investment in network infrastructure may increase under network neutrality rules. Economides and Tagger (2007) studied the question within a two-sided market framework and came to the conclusion that under monopoly and duopoly conditions the purely unregulated market outcome reduces surplus compared to a non-discrimination rule that sets access prices to networks at zero. Bauer and DeMaaagd (2008), combining game-theory with a numerical simulation model, found that under the chosen parameter constellation network operators did not benefit from differentiation but content providers did. Beltrán and Sharkey (2009) also use a computer simulation to solve a duopoly game among network providers and calculate social surplus under several scenarios with similar results for scenarios with and without regulation. These initial findings suggest that non-discrimination safeguards have benefits for sector performance but they are too tentative to support strong ex ante network neutrality rules.

Although there is no shortage of case studies of industrial policy measures in telecommunications and qualitative assessments as to how it might have affected broadband diffusion and investment, the quantitative empirical evidence is relatively scant. Numerous qualitative studies have examined the role of the state in using public policy to facilitate the deployment of advanced communications infrastructures. These contributions highlight the success of countries with a tradition of state-private sector cooperation, including Japan, South Korea, the European Nordic countries, and the Netherlands (de Bijl & Peitz, 2008; Falch & Henten, 2000; Fransman, 2006; Frieden, 2005; Lee & Chan-Olmsted, 2004; Picot & Wernick, 2007). Empirical research also affirms the positive effects of tax credits but often comes to a more nuanced assessment of subsidies as they may have happened regardless (Chrinko & Wilson, 2006).

With regard to possible crowding-out effects, Hauge, Jamison, and Gentry (2008) found that in the US the vast majority of municipal projects complement rather than crowd out private investment. Laroze, Gregg, Strover, Straubhaar, and Inagaki (2008) found anecdotal evidence of a crowding-in effect: incumbent service providers accelerated their investment plans once a subsidized or publicly owned provider entered a local market. Likewise, Ford (2007), in a study of Florida municipal electric utilities that also supply communications services found that the investment stimulation effect outweighed crowding-out. In these cases, public policy seems to fill gaps left by private market forces, often in smaller communities or thinly populated areas. This is less self-evident in cases where the public sector plans to invest in core network infrastructure. Nonetheless, the crowding-out of private investment may be mitigated by stimulating institutional competition with its positive impact on investment and innovation.

7. Tuning the NGN system

The enormous diversity of the next-generation value network and its dynamic evolution complicates finding consistent policies. Most likely, as in highly dynamic interrelated systems, alternative coherent combinations of horizontal regulation, vertical regulation, and other public policy measures exist. At the same time, these consistent combinations are not equivalent but have different consequences for the performance characteristics of the system. In particular, trade-offs between static efficiency (e.g., in the form of lower prices in the short run) and dynamic efficiency (e.g., improvements in the price/quality ratio in the medium and long-run), may exist. Public policy and regulation would benefit from a more explicit account of the existing trade-offs as this allows more rational and deliberate choices for policies going forward. To this end, it will be necessary to know the effects of individual regulatory and public policy instruments on the investment proclivity of the different stakeholders in the ICT ecosystem. Moreover, knowledge of the indirect effects of such measures would be desirable, although this will often be only possible ex post (Cave, 2009).

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7 Similar policy discussions took place in other network industries, for example, in electricity. Assessing this experience, Howell, Meade, and O’Connor (2009) also conclude that the transaction costs of coordination outweigh the potential benefits of structural separation.
Table 2 summarizes in a nutshell the first-round effects of selected horizontal and vertical regulatory instruments and of public policy measures. The signs indicate the direction of the relation between more stringent versions of an instrument and the investment and innovation incentives of the stakeholders listed in the top row. A positive sign indicates that more stringent measures will increase (i.e., regulatory stringency and investment incentive move in parallel), and a negative sign that they will decrease investment incentives (i.e., regulatory stringency and investment incentive are in an inverse relation). For example, incumbent network operator’s investment incentives are negatively affected by a policy requiring them to make unbundled access available to their competitors; on the other hand the incentives of service-based network operators to invest in complementary facilities are improved. The table entries are the most likely effects holding other factors (hypothetically) constant. Read across columns it is apparent that only a few measures—in particular, vertical measures that reduce transaction costs, tax credits and subsidies—affect the investment incentives of all stakeholders positively and therefore allow a priori conclusions as to the total effect on the ICT ecosystem. Read along rows, the table shows that different regulatory and policy measures affect investment incentives in positive and negative ways. Different instruments may serve as substitutes for each other. For example, public investment may compensate negative investment incentives on incumbents from stringent unbundling obligations. Whereas such a combination may achieve a high level of investment, it also leads to a different mix of private and public players in the broadband market. Care is needed in combining different measures as poorly designed interventions may neutralize each other.

The effect of most instruments on aggregate performance, therefore, depends on a complicated web of positive and negative effects on market players. Knowledge of the direction of the effects is important but only a first step. Additional information as to the relative strength of the effects on different players will be relevant. This will depend on the existing market structure, the specific design of the regulatory instruments, and other national and local conditions, such as the ability of government to orchestrate private sector investment through the pronouncement of national policies, which will differ across nations and cultures. Moreover, knowledge of the indirect effects would be desirable. For example, under certain conditions, even if it initially reduces the investment incentives of incumbent players, unbundling might trigger the virtuous cycle described in the ladder of investment model: service based entry will stimulate price competition and accelerate demand growth which will in turn trigger increased investment (Cave, 2006; Waverman et al., 2007). At present, no systematic tool is available to assess indirect effects. Probably the best approach would be adaptive regulation: a monitoring of the outcomes of policies and regular adjustments of policy.8

Despite these multiple contingencies, the question arises as to whether scenarios can be identified under which specific horizontal and vertical regulatory measures are more likely to enhance investment and innovation. An inter-temporal view and the recognition of the endogeneity of market structure on regulatory decisions calls for an inclusive, forward-looking, and dynamic view of competition. Rather than designing regulation as an instrument to mimic static competitive equilibrium it should prevent the system from deteriorating below the threshold where reduced competitive intensity is accompanied by reduced investment and innovation activity. At the same time, it must avoid increasing the competitive intensity above the threshold where dynamic efficiency also deteriorates. This is probably best achieved in a gradated, adaptive regulatory approach that: (1) is responsive to the status quo ante; and (2) establishes forward-looking boundary

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8 The regular reviews of the European Union and comparative benchmarking among nations are steps in that direction.
conditions that will keep the system in a desirable performance zone. The proposed adaptive regulatory model further expands these suggestions and generalizes them into a broader framework. The following paragraphs sketch important choices and trade-offs faced by policy-makers.

Forms of horizontal regulation are most appropriate in cases of existing facilities and where a very strong case can be made that duplication is severely limited due to economic or other constraints. Access to rights of way (e.g., ducts, poles, and conduits), existing loops, and collocation may be candidates. The appropriate intensity of horizontal intervention is dependent on the status quo, expectations as to available and emerging alternative access options, and the overall regulatory guiding vision. If the goal is a transition to facilities-based competition, the stringency of measures should be relaxed over time with the eventual goal of phasing-out unbundling altogether. In the case of investment in network expansion and upgrades ex ante horizontal access regulation risks reducing investment by all market players: investors with high risk aversion or fewer financial resources will be tempted to wait until they get access and firms with available resources will delay investment. Such a stalemate can be mitigated by appropriate pricing of unbundled access although this requires the evaluation of investment risk by regulators and continued regulatory intervention, which has its own potentially serious disadvantages. In both scenarios (existing and new infrastructure), overly stringent and permanent unbundling is likely to reduce investment incentives and result in a higher share of customers served by service-based competitors. More intense service competition may, however, go hand in hand with lower prices in the short-run and hence a faster service diffusion. At the same time, the industry may invest less on a per capita basis and consumers may consequently experience slower improvements of the price/quality ratio over time.

In case of vertical regulation, the number of contingencies is even greater than in the case of horizontal regulation. The net effect depends, first, on the relative contribution to welfare at the network versus the content and application layer and the relative strength of the complementarities between the layers. If the content and application layer has a significantly greater innovation potential than the network platform layer and complementarities are weak, then vertical policies that foster players on that layer (e.g., strict non-discrimination rules) may be more desirable. The opposite will hold if only weak complementarities exist and stronger welfare gains can be expected from the platform layer. This is the less likely scenario but may apply during the initial roll-out phase of next-generation networks. If complementarities are strong, an approach that safeguards against structural abuses of market power along the lines discussed earlier, for example, by placing limits on exclusion, requiring open access lanes, and introducing consumer rights will likely strengthen the dynamic performance of the system. The intensity of competition has effects not only on the performance of players on each layer but also on investment and innovation activity in the entire interrelated system.

Given the complexity of these interactions, it is therefore unlikely that one approach can be designed that optimizes system performance across all scenarios. Public policy can overcome this seeming quandary by: (1) making policy choices contingent upon the status quo in the market as well as the expected further development of competition; (2) deliberately choosing an approach that achieves the desired balance between short-term and long-term goals; and (3) providing for continuous monitoring and periodic fine-tuning of the selected course of action. As different means of regulation and other forms of public policy interact and sometimes contradict each other, it is important to design a consistent approach. In such an overall design, horizontal and vertical regulatory measures as well as public policy, contrary to widespread belief, are complementary to each other, each targeted to specific performance aspects of the value network.

After a period of regulatory convergence, during the past decade individual countries and regions have positioned themselves differently by adopting diverging combinations of policy instruments. In an international comparison, three groups seem to emerge. Countries with a tradition of strong state coordination of the economy such as South Korea, Japan, and the Nordic countries, have relied on a combination of instruments that uses stringent unbundling with various forms of public policy directed to accelerate sector investment. Japan and South Korea did not introduce unbundling until after large network deployments had happened. Nordic countries introduced unbundling sooner but relied more strongly on local and municipal funding for infrastructure roll out. Many European nations, synchronized by Europe-wide policies and initiatives, have emphasized unbundling and market entry with the goal of reducing prices for consumers. This strategy has been very successful and has contributed to a rapid diffusion of broadband and a closing of the historical gap to the US. However, it has shifted the pattern of market entry to services competition and resulted in lower facilities investment per capita with potential problems for the roll-out of next-generation networks (Huigen & Cave, 2008; Ruhle & Reichl, 2009). Recent changes in the European approach to NGNs, in particular the consideration of periods of limited regulation and risk-adjusted contracts for unbundled access reflect this concern. In contrast to the other regions and countries, the US since 2003 had essentially eliminated unbundling requirements and adopted a bold market-driven approach. Unlike the other regions, the US does not have a strong tradition of government coordination and funding of ICT infrastructure. Preliminary data seem to suggest that the US approach has succeeded in generating high rates of infrastructure investment but it has gone hand in hand with higher prices and a slower diffusion of service, in particular to rural areas where the investment case is very weak. Given its strong reliance on unregulated markets during the past few years, US policy has failed to address this form of market deficiency. Recognizing these trade-offs gives countries and regions an opportunity to...
recalibrate their approach. However, not all policies are fully portable across nations and regions, as their success and failure may be contingent upon specific institutional and socio-cultural conditions.

8. Conclusions

Designing a governance framework for NGNs raises complicated horizontal and vertical regulatory issues. Due to the high level of interdependence between stakeholders in the different segments of the value network, good governance needs to be cognizant of and take into account the effects of regulatory choices not only on the regulated entity and the regulated market segment but also their repercussions for unregulated firms and services. Advanced communication systems are dynamically evolving systems. Regulation interacts with this dynamic development. Traditional regulatory approaches sought to find a "best" policy contingent on an examination of the existing market structure. In a dynamic setting, it is also necessary to take the effects of current regulatory choices on investment and innovation choices and hence future industry structures into account. As in other dynamic systems, alternative development paths are feasible for next-generation networks, each with unique performance characteristics that reflect the trade-offs implied by regulatory choices.

A more stringent regulatory approach will—other things equal—set the system on a course with swifter entry by service-based competitors; higher short-term benefits for consumers; but an overall lower level of investment into networks and services. A governance regime with less stringent regulatory intervention will most likely generate more competitive turbulence; a lower rate of service-based entry; but also a higher rate of innovation and investment as well as the associated longer-term user benefits. In the former approach, the system will require prolonged regulatory intervention. At the same time, long-term benefits for consumers from improvements in the price-quality relation of services will likely be lower (or will require additional regulatory intervention). Some of these performance differences may be compensated by complementary public policies, including tax incentives for investment in facilities and R&D, subsidies, and the promotion of institutional competition between networks organized according to different levels of openness. As some policy choices counteract others, the consistence of the approach is important for overall performance. This requires coordination between policy-making agencies that traditionally have not collaborated on a regular basis, including regulatory agencies, legislators in charge of tax policy, and departments in charge of educational policies, to name but a few. Moreover, it may require collaboration between agencies at different levels of the governance structure (federal, state, and local). Although consistent policy design is challenging, it has the potential to result in better approaches to the governance of advanced communications.

The presented view of regulation goes beyond the social engineering approach that currently dominates regulation and emphasizes that public policy and regulation have more degrees of freedom than often realized in the research literature. Practical policy has been more pragmatic and essentially proceeded on a trial-and-error basis. The framework developed in this article can provide a basis for the development of integrative policy models that might allow the simulation of alternative paths of actions and help reduce poorly designed policies. Absent such models, the integrative and dynamic approach should still be useful in the development of consistent policies by encouraging policy-makers and analysts to systematically examine the direct and indirect, short-term and long-term effects of policy choices on the interconnected ICT ecosystem.

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