REGULATION, PUBLIC POLICY, AND INVESTMENT IN COMMUNICATIONS INFRASTRUCTURE*

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Revised Draft
April 2, 2009

* Earlier versions of this paper were presented at the NGI Foundation conference "Networks for a Brighter Future," Rotterdam, The Netherlands, November 10-12, 2008 and at the 40th Annual Regulatory Policy Conference of the Institute of Public Utilities in Williamsburg, VA, December 11, 2008.

Abstract

Regulation and other forms of public policy toward infrastructure industries were and are designed to support the necessary large-scale investment. Throughout history, with few exceptions, rather pragmatic approaches guided policies. A more rigorous lens was only applied more recently although it often focused on narrow aspects of regulation. In contrast, this paper attempts to develop a broader, integrated framework to analyze the effects of regulatory and other public policy choices on sector investment. During the past decades, regulation has gradually abandoned instruments that allowed regulators to influence investment decisions directly. Presently used forms of wholesale regulation such as unbundling and network neutrality requirements work indirectly, creating complex and sometimes contradictory incentives for the affected stakeholders. Regulation cannot anymore "control" investment. Rather it functions as a "tuning variable" that influences the level and the structure of investment activity in various direct and indirect, often non-linear ways. Fiscal and monetary policy instruments also can be used to influence investment choices but they have their own advantages and disadvantages and do not work under all conditions. Due to the multi-faceted effects of regulatory measures, fiscal and monetary policy is preferable to regulatory measures to create short term economic stimulus. Whereas the overall effects of a combination of regulatory and other public policy measures on communications sector investment levels and structure are difficult to predict, basic guidelines for the design of a coherent approach can be specified.

Keywords: Network investment, innovation, regulation, public policy

JEL classification: L96, L51, L52

1. Introduction

Regulation has important repercussions for investment and innovation in communication industries. Retail and wholesale regulation affect investment decisions not only of the regulated firms but also those of their unregulated competitors. Unbundling rules, for example, have implications for incumbents and new competitors. Regulation also shapes, moreover, investment decisions in complementary markets. Rules governing access of content providers to network platforms, for instance, affect investment decisions in both markets. A full assessment of the implications of regulation on investment therefore has to capture its effects on the information and communication technology (ICT) value net as a whole and not only on the firms subject to regulatory constraints and obligations. Due to the many feedbacks in the increasingly complicated ICT value net, this is a challenging, but not impossible, undertaking. With governments and regulators worldwide designing the contours of the legal and regulatory frameworks governing next-generation networks, an in-depth examination of the effects of alternative regulatory instruments on the level and structure of investment decisions is timely. It is also urgent as an increasing number of governments plan to launch public spending programs, some earmarked to boost the deployment of advanced communications, in response to the economic recession.

The significant investment requirements of infrastructure industries were one of the reasons for government intervention beginning in the nineteenth century. Government ownership and the regulation of private enterprises by specialized commissions emerged as the principal institutional responses. In some countries, government operated communication services from the beginning, in others they were initially operated by private firms that were later nationalized or subjected to regulation. Whereas one system or the other dominated in most nations, other institutional forms often co-existed with them, including cooperatives and ownership by public sector organizations other than the national government such as cities, municipalities, and provinces (Bauer forthcoming). Government intervention was frequently driven by pragmatic motives such as poor performance of service providers. The importance of infrastructure services to society

and the durability of plant, which required long-term planning horizons rarely chosen in market environments, were additional factors that eventually led to government involvement. Gradually, consensus emerged that the prevalence of high economies of scale and scope rendered these industries "natural" monopolies that were better organized as exclusive franchises to avoid wasteful duplication of resources. The conditions for infrastructure investment were, therefore, at the cradle of modern regulation. Nonetheless, the relations between regulation, investment and innovation were, for a long time, not examined in detail but treated rather pragmatically. There is a risk that in the rush to revitalize economic growth and boost innovation rash decisions based on incomplete models of the drivers of investment and innovation are made. With the transition to advanced communication networks requiring large amounts capital to either upgrade or replace the existing infrastructure, it is particularly pressing to understand the effects of regulatory choices on the level and structure of investment.

This paper is an attempt to review the state of the art and provide additional elements of a dynamic approach. The following section two provides a brief historical overview of different takes on the interaction of regulation and investment. Section three discusses the factors shaping investment decisions at the firm level and section four uses this framework to clarify the multiple paths through which regulation affects investment decisions. More detailed theoretical and empirical evidence on the effects of wholesale regulation and of potential rules governing the vertical relations between platforms and content providers is examined in sections five and six. Section seven discusses the possible role of other forms of public policy, including tax incentives and subsidies in supporting infrastructure investment. Conclusions for the U.S. debate are drawn in sections eight and nine. Section eight briefly reviews whether the U.S. indeed has a broadband policy problem. Section nine explores the relative advantages and disadvantages of alternative regulatory and public policy instruments. Examples and empirical evidence from the U.S. and the European Union are used throughout the paper to illustrate and substantiate the arguments. Key lessons for public policy conclude the paper.

2. A brief historical synopsis

External regulation and government ownership were historically the principal approaches to facilitate large-scale investment. Regulation by specialized commissions was long accepted as a workable institutional arrangement designed to balance the financing needs of private utilities with the interests of consumers in affordable, reliable service and with the interests of society at large in reaching ubiquitous access to infrastructure services. The historical system of rate-base rate-of-return regulation (ROR) can thus be seen as an explicit transparent institutional arrangement to reconcile conflicting private and public objectives. Most countries outside North America entrusted the supply of infrastructure services to state-owned enterprises. Investment decisions were strongly influenced by overarching socio-economic policy goals, such as anti-cyclical stabilization of employment or support for regional economic development (Thiemeyer 1983). These objectives were translated into corporate goals with mechanisms that were less transparent than external regulation. Typically, ownership rights gave government limited ability to shape management decisions in ways compatible with broader societal objectives. Both institutional arrangements face different kinds of principal agent problems (Aharoni 1986; Laffont and Tirole 1993). For example, asymmetrical information rendered regulators vulnerable to capture by special interest groups; on the other hand, the combination of regulatory and operational functions in one unit or frequent discretionary intervention from multiple stakeholders, as was typical for state-owner firms, created biased incentives to shield incumbents from competition. Nonetheless, both approaches were deemed workable until the late part of the twentieth century.

Beginning in the late 1960s in North America and in the late 1970s in other parts of the world, these prototypical systems were gradually transformed through the triple forces of liberalization, privatization, and regulatory reform. Interestingly, with regard to investment incentives, the reasons for reform were almost diametrically opposed. The North American system was in part reformed in response to the critique by Averch and Johnson (1962) that ROR provided incentives for sub-optimally high wasteful investment.

In contrast, publicly owned systems were in part reformed to relieve the investment constraints of the state that impeded urgent infrastructure expansion. During the 1980s and 1990s, telecommunications sector organization increasingly looked alike: more private sector participation, easier market entry, and independent regulation. In the 1980s, price cap regulation was first introduced in England as a retail regulatory tool that supposedly avoided many of the negative aspects of ROR (OECD 1994). The U.S., concerned about the relatively low level of network infrastructure investment (NTIA 1991), also migrated from ROR to price caps, initially at the federal and later at the state level. During a transition period, hybrid earnings-sharing plans, combining features of rate-of-return and price cap regulation were popular. These plans often contained contingency provisions for infrastructure expansion. However, because of the perceived negative efficiency incentives of such plans, they were gradually replaced with pure price cap plans, which were also typical for most other countries (Xavier 1995). Empirical research and practical experience quickly showed that the effect of price caps on investment had been overestimated and misjudged (Sappington and Weisman 1996; Ai and Sappington 2002; Vogelsang 2002). Where investment activity increased, it was mostly in productivity-enhancing process innovations but not necessarily in infrastructure expansion.

By the mid-1990s, policy makers started to believe that due to technical and economic changes competition in retail voice and data markets could be achieved provided that wholesale regulation neutralized control of the incumbent over bottleneck facilities. Retail competition was seen as the main driver of efficiency improvements and accelerated investment. As retail prices were successively deregulated, new forms of wholesale regulation were introduced. The ladder-of-investment framework (Cave 2006) became widely accepted as an explicit or tacit blueprint to design regulatory intervention: new market entrants would initially purchase services from incumbent operators and gradually migrate from services- to facilities-based competition. Consequently, the ladder-of-investment framework suggested mandatory resale and unbundling as appropriate policies to facilitate this transition. In the wake of the Telecommunications Act of 1996, the U.S. Federal Communications Commission (FCC), in addition to resale,

introduced stringent unbundling rules for local loops in 1996 and for broadband access in 1999 (Bauer 2005). A few years into the new approach, empirical evidence was decidedly mixed. It showed that the model had some merits but there were also many situations in which actual investment behavior of incumbents and new entrants was not well described by the model. In a complicated process of court challenges to regulatory decisions, by 2003 the very aggressive U.S. local loop unbundling regime had been eased and brought closer in line with international practice. One key argument in the process of paring back stringent unbundling requirements − in particular the unbundled network element platform (UNE-P) − was the negative effect of these rules on facilities investment.

In the U.S. debate, this claim was raised even more forcefully in the regulatory procedures defining the policy framework for broadband access networks. Here the argument focused on the substantial network upgrades and new investment needs of next-generation access and backbone networks. By 2007, in contrast to policy in most other countries, U.S. regulators and courts had freed broadband access markets from unbundling requirements. After a prolonged court battle, cable modem service was declared a largely unregulated information service in 2005 and DSL followed soon thereafter. In 2007, wireless broadband and broadband over powerline (BPL) were also declared information services. In special access markets, the FCC established a geographically differentiated framework that retained common carrier obligations (such as non-discriminatory treatment of competitors) in areas that did not meet certain market structure criteria, intended to capture the presence of workable competition but relieved incumbent service providers from these requirements in all other markets. No other country has yet adopted a similarly radical course of deregulation. The European Union, which had prescribed local loop unbundling only in 1999, continued to use its three-part test to assess the competitive structure of a market on a going-forward basis. According to this test, ex ante regulation is warranted if (1) a market is characterized by high and durable barriers to entry, (2) no increase in competition is foreseeable, and (3) competition law is not suited to deal with these issues. Vogelsang (2008) maintains that the third part of this test is rarely examined in detail. Like voice access markets,

broadband access was seen by many national regulatory authorities (NRAs) as a market with significant market power and hence subject to ex ante regulatory remedies. Such remedies typically encompass resale, non-discriminatory access obligations, and various forms of unbundling (e.g., local loop unbundling and bitstream access or comparable products).

Decades of regulatory convergence were, therefore, superseded by renewed divergence between the U.S. and many of its peer nations in the regulation of next-generation networks and services. However, the debate did not stop there but it shifted from a focus on horizontal access to network facilities to a broader discussion of the rules that ought to govern the horizontal and vertical relationships between the players in the next-generation service value net. In parallel to its deregulation of broadband access networks, the FCC had issued a legally non-binding declaration affirming its determination to safeguard the open nature of the Internet (FCC 2005). Concerns that the abandonment of common carrier rules for broadband access would lead to new forms of discrimination, a diffuse yet fierce debate on network neutrality ensued. A large part of the debate focused on the implications of network neutrality requirements on investment incentives in network infrastructure and services. The initial skirmish of proponents of different black-and-white scenarios was gradually replaced by more nuanced explorations of alternative forms of network management and their possible implications for investment. Given the highly interconnected value network of advanced ICT, developing a full understanding of different specifications of governance mechanisms, spanning a wide range between the complete absence of regulatory ex ante intervention to relatively strict and detailed regulation, turned out to be much more daunting than suggested by pundits and is still a work in progress (Bauer and DeMaagd 2008).

In contrast, while details are still being discussed in the ongoing 2007 Communications Review, there are indications that the European Union might take a pro-regulatory turn in next-generation networks. Although the overall number of separate markets in which dominance is assessed was reduced from an unsustainable 18 to five, broadband access markets will remain a separate market. The potential pro-regulatory change is visible in

two measures that could easily increase the intensity of market intervention (1) the addition of structural separation between networks and services as a new ex ante remedy; and (2) advice by the Commission to National Regulatory Agencies (NRAs) to take additional risk premiums for next-generation network infrastructure into account when setting wholesale prices. This leaves regulators in the uncomfortable position of evaluating the investment risk of innovative technology, but it is seen as a mechanism to strengthen the investment incentives of operators. Of the countries that have concluded their SMP assessment, a majority have found a dominant supplier in broadband access and are in the process of adopting ex ante regulatory remedies. On the other hand, several countries, including France, Spain, and Austria, have moved to geographically differentiated regulation to better reflect the spatial nature of competition. As broadband access remains under regulation, the debate on network neutrality in the EU is presently much weaker (Valcke, Hou et al. 2008).

The successive regulatory regimes reviewed in the preceding paragraphs were all adopted under the premise that they would facilitate investment in network infrastructure. Similarly, the new principal paradigms, the more market-based U.S. approach and the pro-regulatory European model are branded as means to accelerate investment. In part these alternative policy approaches can be explained by the differences in the status quo in the two regions. Most importantly, the market structure in the U.S. can be regarded as a duopoly plus competitive fringe, whereas in many European nations it remains to be a monopoly plus a competitive fringe (Noam 2006). However, neither the historical models nor the present approaches were or are rooted in a fully explicated microeconomic theory of investment. The need for such a dynamic theory of regulation has been recognized by several authors (Gayle and Weisman 2007; Bauer and Bohlin 2008) but it is not yet fully developed. The next section will outline basic contours of such an approach.

3. Factors influencing investment decisions at the firm level

With the exception of direct government investment, public policy and regulation can affect investment and innovation decisions via supply-side and demand-side means. Natural starting points for an examination of the effects of regulation on investment are therefore individual agents. Companies make their investment decisions by examining the expected revenues and costs during the estimated lifetime of a project as well as the option values associated with a particular decision. Historically, investment theory focused on the first aspect. The most widely used approach was the net present value (NPV) model. Cash flows over the life of the project *T*, including initial investment outlays R_0 and any remaining value at the end of the period are discounted to the point in time when an investment decision has to be made. The discount rate *i* reflects the opportunity cost of the investment and the perceived risk of the project, which is affected by the time preference and risk attitude of the investors. Overall project risk is influenced by industry conditions, including the competitive landscape, knowledge about consumer demand, and the stability of government policy. It is sometimes approximated by the weighted average cost of capital (WACC) of the firm modified for other risk factors. A positive NPV indicates that a project is profitable over its estimated lifetime and is therefore economically viable.

$$NPV = -R_0 + \sum_{t=1}^{T} \frac{R_t}{(1+i)^t} \qquad (1)$$

NPV	Net present value (at point t=0)
R_0	Initial investment at time t=0
R_t	Cash flow (inflow minus outflow of funds) at time t=1, …, T
i	Discount rate

The NPV approach offers a useful framework under relatively simple conditions, for example, if a decision is a one-time event and the only choices are to either go ahead with a project or not do it at all. However, it provides an incomplete decision-making framework if firms have other options available, such as postponing or re-scaling an

investment. Moreover, the standard NPV models is more appropriate under conditions of risk than under conditions of uncertainty, a situation in which decision makers do either not know the relevant future events or are not able to assign even subjective probabilities to the occurrence of an event. These shortcomings were reduced by the real options theory of investment (Dixit and Pindyck 1994; Trigeorgis 1995; Alleman and Noam 1999; Smit and Trigeorgis 2005). In a dynamic and uncertain environment, management will flexibly respond to changing circumstances. The NPV model assumes that an investor possesses all the relevant information, can develop a most likely scenario for a project and faces a decision between committing to this investment, and not making it at all. In contrast, the real options approach takes alternative strategies that are available to management into account, such as waiting until more information about relevant market developments is revealed, delaying an investment to a later period, investing at a different pace, scaling operations up or down, and the option to modify the input combination. Real options theory does not entirely replace but rather augments the NPV model by pricing these options explicitly. In the formulation of Trigeorgis (1999, p. 4) this can be expressed as follows:

$$ENPV = NPV + V_m \qquad (2)$$

ENPV	Expanded (strategic) net present value (at point t=0)
NPV	Static (passive) net present value of expected cash flows (at point t=0)
V_m	Value of options from active management, m=1 … M

The expanded (strategic) net present value of a project is derived as the traditional (static, passive) NPV modified for the option value of active management decisions m $(m \subset M)$. Aspects of real options theory have been used in capital budgeting for a long time but it was formulated coherently only beginning in the late 1970s. It treats real investments with the tools of pricing financial options. For example, the opportunity to expand the exiting broadband network to a specific location is similar to a call option, in that it gives the firm an opportunity but not an obligation to invest. On the other hand, abandoning an already started expansion is similar to a call option in that it gives the right but not the obligation to sell an asset. Financial pricing techniques can be used to evaluate these

alternative strategies. Given the broad spectrum of strategic choices that is typically open to management, a correspondingly wide variety of real options exists (see Trigeorgis 1999, for a detailed discussion). Various techniques have been developed for valuing real options, including analytical methods or numerical approaches although the stochastic nature of the problem and the high dimensionality of the options space may make valuation a challenging task.

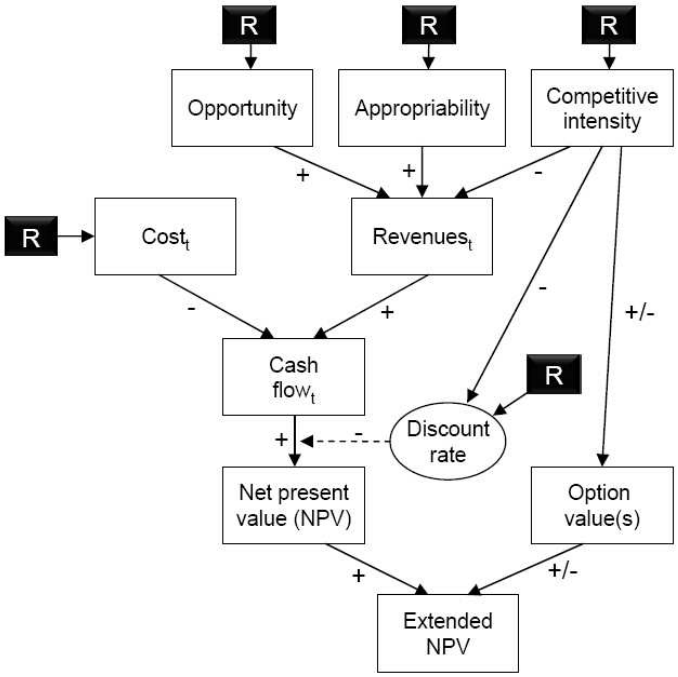
From a strategic point of view, three aspects of investment decisions are important for their real options treatment. It is, firstly, important whether a real option is proprietary or shared. A project and the corresponding real option is proprietary if the firm's decision as to whether and when to invest is unaffected by the decisions of other players, in particular competitors and government. An investment protected by intellectual property rights or otherwise difficult to duplicate may be proprietary. An option is shared if other players also hold a right to exercise and can take away all or part of the option. For example, competitors of the public sector may also considering investment in a local broadband network. Compared to proprietary options, shared investment options suffer from a competitive loss (Trigeorgis 1999, p. 21). Secondly, an investment decision may not be valuable in and of itself, but it may be a prerequisite for subsequent investment opportunities. In such cases of "project compoundedness" (Trigeorgis 1999, p. 21), the exercise of an option has another option as a payoff. Even if the direct cash flow of the initial project is negative, it may be economically rational to commit if it is a precondition to secure future investment opportunities. The third aspect relates to the urgency of a decision. Some investment opportunities expire and therefore require immediate action whereas others may be deferred. For instance, bidding for an incumbent service provider during privatization may offer only a short window of opportunity to develop presence in a specific geographic market.

4. Public policy and investment

Regulatory and other public policy decisions affect ICT investment decisions directly or indirectly via the factors that influence expected cash flows of projects and option values

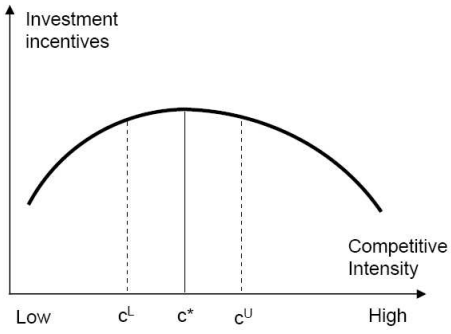
of management decisions. For example, network roll-out requirements, as are common in wireless communications, have a direct effect on investment whereas licensing decisions affecting the number of competitors in a market segment exert an indirect effect. This section expands the microeconomic investment models from the prior section with an explicit consideration of the multiple ways in which public policy influences investment choices. Figure 1 is a representation of the variables that influence investment decisions of an individual firm as seen from an expanded NPV perspective. Regulatory measures interact with this system in multiple ways and the net effect on investment decisions by the private sector is mediated by several trade offs and non-linear feedbacks. Recent theoretical and empirical research has deepened our understanding of these interactions but significant knowledge gaps continue to exist. As the factors in this system change continuously, the traditional ceteris paribus approach, in which changes in policy are examined assuming all else remains unaltered, may be of limited value. Nonetheless, for the time being, the effects of different regulatory choices will be explored using this methodological assumption.

Figure 1: Intervention points of policy and regulation in the investment calculus



To develop a full understanding of the transmission mechanisms of regulatory choices to investment decisions, the extended NPV investment calculus has to be expanded further. Cash flow is determined by the costs and revenues during the period under consideration. The expected revenues of an investment project are, in turn, affected by the technical and economic opportunities of generating revenues in a particular market segment, the appropriability of revenues and profits from a particular project, and the competitive pressure to invest. The existing opportunities are, first, influenced by factors on the demand side, such as consumer preferences, but also by the technological capabilities of network platforms and services, which are to a certain degree external to the regulated firm. The second factor, appropriability, refers to the ability of a firm to extract sufficient revenues from the market to recover its costs and an adequate risk premium. Appropriability is negatively related to the competitive intensity of the market environment: a monopoly market offers the strongest opportunities to appropriate rents whereas a perfectly competitive market does fully eliminate it (or limits it to very brief periods).

Figure 2: Competitive intensity and investment incentives



The third factor influencing future revenues is competition from other service providers. In contrast to appropriability, the incentive to invest and innovate to defend revenues against competitive threats increases with the intensity of competition. As a result of these two contrary factors, the relation between the intensity of competition and the incentive to invest and/or innovate resembles an inverted u-shape. It is lowest for highly concentrated and highly competitive markets and highest in between. The exact shape of the relation depends on specific industry characteristics, such as the magnitude of

economies of scale and scope (Aghion, Bloom et al. 2005; Friederiszick and Röller 2006). Figure 2 provides a stylized picture of this relation. Its gradient and the locus of the maximum investment and innovation incentive (c*) are dependent on the specific circumstances of an industry. Unbundling and network neutrality rules in addition to economic factors such as economies of scale, height of entry barriers, and the number of competitors affect it. Either factor is sufficient to create high competitive intensity: if the number of competitors in the market is low, for example, stringent regulation that reduces market entry barriers may nonetheless create high competitive intensity. While it may not be possible to fine-tune the system to c* it seems more feasible to keep it within the band c^L and c^U.

During the period of detailed retail price control, regulation affected many of these parameters directly, often starting from the firm's investment plans. Under rate-of-return regulation, for example, regulators would set prices subject to a firm's investment plans, its cost of capital and its operating expenses. In the present regulatory environment, regulation affects investment decisions much more indirectly. Figure 1 depicts the ENPV model from the perspective of a firm and indicates the intervention points of regulatory and public policy measures and Table 1 provides additional detail on forms of intervention. Price cap retail regulation, where it continues to be used, influences the appropriability or revenues and profits but is much less constraining than traditional rate regulation. As broadband communication services are typically not subject to retail price regulation, this effect of regulation is presently probably quite negligible.

Much more important are the effects of regulation on wholesale markets, including regulatory measures that affect the horizontal structure of markets and newer forms that shape the vertical structure of markets. Traditional forms of wholesale regulation, such as unbundling or interconnection requirements, influence the competitive intensity of the market and indirectly shape the investment decisions of both incumbent suppliers and new entrants. Similarly, regulations affecting the vertical structure of markets also affect investment choices of all market participants. The competitive intensity of the market influences the appropriability conditions, the pressure to invest, the level of uncertainty

and hence the discount rate, and the option values of different management strategies. The net effect of wholesale regulation on investment is critical to understand the overall impact of regulatory choices.

Table 1: Public policy instruments affecting investment incentives

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

Other forms of regulatory and public intervention may directly influence investment decisions. For example, network deployment requirements as they are often specified in the licenses of wireless service providers have a direct impact on the path of investment choices. Common carrier requirements provide an indirect mechanism to coax a supplier into expanding network capacity in response to demand. However, the ability of regulators to achieve this outcome was much more effective under rate-of-return (ROR) than any other type of regulatory regime. Under ROR regulation, a used and useful standard was applied to network investment and the regulatory method, albeit cumbersome and plagued by problems of asymmetric information and other weaknesses facilitated the financing of the required investments. The move to price cap regulation and later full deregulation has reduced the ability of regulators to coax suppliers into

committing to specific investment strategies. Such commitments were sometimes extracted in a tit-for-tat process, side-agreements to price cap plans, in which suppliers promised a certain amount of investment in return for being freed from ROR regulation. Many of these plans were not realized as promised but regulators had not retained any effective instrument to remedy the situation.

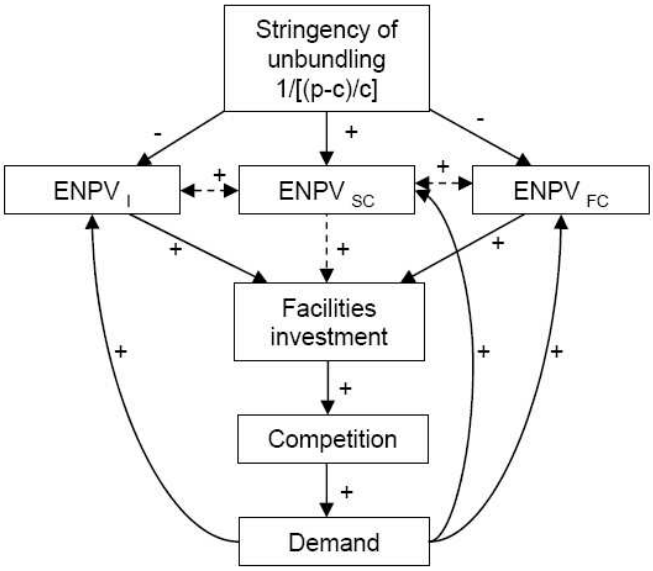
Under retail price deregulation investment is predominantly market-driven. As incumbent service providers are exposed to intensifying competition, common carriage obligations become instable. Regulatory influence on investment decisions is essentially curtailed to forms of universal service funding and indirect measures that affect the ENPV of projects. The void can, to a certain degree, be filled with other policy instruments, such as tax credits, accelerated depreciation, subsidies, and more direct involvement of the public sector. This may take a range of forms with different degrees of involvement. In a minimal scenario, the public sector may create demand-pull by deliberately using e-government or other services as a demand driver. It could serve as an anchor tenant of infrastructure investment (as is the case in some municipal wireless projects). The public sector could facilitate demand aggregation or assume a proactive role in organizing infrastructure projects, for example, by coordinating investment (issuing a request for proposals, arranging a financing model for private investors, etc.). In the most involved form, the public sector could directly invest in infrastructure and own and operate it.

5. Regulation, competitive intensity, and investment

The vast majority of presently used regulatory instruments, most importantly unbundling, other forms of access regulation, and interconnection obligations, affect investment decisions by influencing the competitive intensity of a market segment. In the U.S., predecessors of unbundling have been used since the 1980s (Noam 2001). In its current form unbundling was introduced explicitly with the Telecommunications Act of 1996 (TA 96) in the U.S. The European Union introduced unbundling as a remedy in 1999 and

many other countries established unbundling rules in attempts to facilitate competition in local markets (OECD 2003). To understand the full impact of unbundling rules, one has to capture their effects on incumbents subject to unbundling, entrants whose entry costs are reduced by unbundled access, and the indirect effects on demand for telecommunication services (see Figure 3).

Figure 3: Unbundling and investment incentives



Unbundling has several conceptual roots. One is the essential facilities doctrine, which applies to situations in which an incumbent firm controls a facility that is indispensible (a "bottleneck") for a competitor seeking market access. The other is a view of investment in infrastructure as a stepwise process, as expressed in the ladder-of-investment (LoI) model briefly sketched in section two of this paper. According to the LoI approach, in industries with high sunk costs, new entrants will gradually migrate from service-based to facilities based entry. Unbundled access to network elements is the "rung" immediately after pure resale. It requires new entrants to invest in some complementary facilities without having to bear the burden of rolling out all the components of a network. The model predicts that, as a new entrant's customer base grows, facilities investment will increasingly replace unbundled access to the incumbent's network. In a dynamic

perspective, the model postulates several positive feedback loops that propel the transition from service-based to facilities-based competition.

The smaller the difference between the price for wholesale unbundled network access and the cost of providing these facilities, the lower are the costs of new market entrants. If p is the price of unbundled access and c the cost of providing the service, $1/[(p-c)/c]$ can be interpreted as a measure of the stringency of unbundling rules. It ranges from 1 for very stringent regulation (unbundled price set equal to cost) to a lower extreme of 0 for totally unconstrained pricing. New entrants will initially only invest modestly in complementary facilities to compete on a service basis. Increasing competitive pressure and slowly increasing new network investment from the new competitors eventually provide an incentive for the incumbent to improve its facilities. Moreover, as intensifying competition reduces the price for service, the market will grow and provide a further positive stimulus. Overall, a positive net effect on investment is derived from this analysis. However, its proponents often overlook an important negative feedback: a price close to incremental costs will also, ceteris paribus, weaken the incentives of the incumbent to invest. In such a comprehensive view, the net effect of unbundling on investment will therefore depend on the relative magnitude of these counteracting positive and negative effects. The strengths of these effects is, in turn, dependent on the overall sector conditions, in particular the risk associated with investment, the technology options available to incumbents and new market entrants, and the specific regulatory framework governing unbundling.

Other things equal, the regulatory framework not only affects the investment decisions of incumbents and new entrants, it also affects the structure of service- and facilities-based competition. Without having to decide which method is "correct" we can measure the "stringency" of unbundling regulation by how close to (or how far below) the cost of unbundled access is to the historical cost of providing the facility. Prices set on a forward-looking greenfield basis imply that regulation is rather stringent whereas the freedom to negotiate prices with competitors subject to regulatory intervention implies more light-handed regulation. From the perspective of the incumbent, more stringent

regulation reduces future cash flows derived from the facility. At the same time, it reduces the value of the option of investing in an expansion of the network (Pindyck 2007). Both effects reduce the $ENPV_I$ of any project and hence the investment incentive of the incumbent. In contrast, more stringent regulation improves the cash flow of any particular project for an entrant and it creates a valuable option in that the firm can postpone facilities-based investment until more market information becomes available. Both effects increase the $ENPV_E$ for the new entrant. The net effect on investment is therefore dependent on the relative elasticity of the investment decisions of incumbents and new entrants to the unbundling rules. However, regulation is not a zero-sum game, as both incumbents and new entrants may benefit from the market expansion effect (Waverman, Meschi et al. 2007).

In other words, regulation functions as a "tuning variable" in a dynamic system of interactions. In theory, several combinations of the relevant elasticities are possible leading either to a positive overall effect of stringent unbundling regulation or the opposite conclusion. The experience in the U.S. and in the EU can illustrate the main points. In the U.S. unbundling was introduced in the wake of the Telecommunications Act of 1996. Public policy moved from rather stringent unbundling rules for local loops and broadband to a regime that retained more relaxed unbundling requirements for local loops but eliminated unbundling for broadband altogether. Initially, the FCC chose a rather stringent approach to local loop unbundling: the TELRIC methodology generated prices for unbundled access that were close to cost; the introduction of the unbundled network element platform (UNE-P) offered new entrants a cheap platform that could be configured to offer service with minimal incremental investment. In 1999, unbundling requirements were introduced for broadband access. However, beginning in 2003, the FCC, in response to concern about the potential negative effects of its unbundling regime on sector investment, reduced the stringency of unbundling requirements. By 2005, local loop unbundling had been reduced to more traditional approaches also used by other countries. By 2007, broadband unbundling was fully eliminated and broadband access freed from regulation (see Bauer 2005; Bauer and Bohlin 2008 for a detailed discussion). In contrast, Europe introduced unbundling later but did not change its regime. Local loop

unbundling was adopted as a regulatory remedy in 1999 and broadband unbundling in 2003. Both local loop and broadband unbundling continue to be used by European regulators and will be taken over into the new regulatory framework adopted in the wake of the 2007 Communications Review. These differences between regions as well as the heterogeneity within the regions can be used to investigate the effects of unbundling empirically.

Several studies have examined the effects of unbundling empirically. The majority of studies focus on service penetration, for example, measures as broadband subscribers per 100 inhabitants, rather than investment. Examinations of broadband diffusion only allow an indirect understanding of the effects of regulation on investment as typically only a fraction of consumers in served areas will adopt broadband. Investigations of service adoption provide insights into investment but they confound supply- and demand-side effects. Unfortunately, due to data limitations this approach is often the only way to study the issue. Furthermore, most studies analyze first-round effects but only a handful takes dynamic feedbacks into account. With these caveats in mind, empirical studies of broadband diffusion consistently find that facilities-based intra-modal and inter-modal competition accelerate the diffusion of broadband (e.g., Distaso, Lupi et.al. (2006), Wallsten (2006)). The empirical evidence with regard to unbundling and broadband diffusion is less definite. 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 the OECD countries, differentiated between different forms of unbundling. He 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 et.al. (2006) found a strong positive effect of unbundling on broadband diffusion in the European Union.

A few newer studies address the issue of investment directly. Although their interest is in broadband investment, the studies typically utilize data for local loops (as a platform for DSL). Criterion Economics (2003) and London Economics/Price Waterhouse Coopers (2006) investigated the effects of regulation on investment at an aggregate level. The

former study found a negative effect of regulation on investment activity. The latter publication found a positive relation between the European regulatory approach and investment. However, the study was based on methodological choices that weaken the robustness of findings or which at least question the provided interpretation (see Frederiszick and Röller, 2007, for a detailed critique).

Table 2: U.S. broadband growth high-speed access lines before and after FCC deregulation measures

	Total growth 2001-2002 (before deregulation)	**Total growth 2004-2007** (after deregulation)	**Change before-after** (in percent)	**Change relative to cable** (percentage points)
ADSL	86.1	103.1	19.7	11.5
Cable	84.8	91.8	8.2	--
Fiber	56.5	180.4	219.0	210.8
Total wireline	85.1	97.9	15.0	6.8

Source FCC (2009), own calculations

A more direct, micro-analytical approach that avoids many of these problems was adopted by Waverman, Meschi et.al. (2007). The study, based upon data for 2002-2006 modified Crandall, Ingraham et.al. (2004) approach. The authors model the direct and indirect effects of unbundling as well as the effects of inter-model competition. A higher intensity of regulation of local loops was negatively correlated with investment in alternative network infrastructure. For example, a reduction of LLU prices by 10 percent coincided with an over-proportional reduction of investment in alternative facilities of 18 percent. Based on these findings, stringent access regulation cannot be seen as panacea to stimulate facilities-based competition in broadband markets. It may redirect market entry to service-based models and entail potentially high costs in the form of delayed facilities-based competition.

The limited evidence in the U.S. seems to be in line with these findings (see Table 2). A before-and-after test indicates a notable change in the structure of total growth of access lines added before and after the substantial regulatory relief measures were adopted in

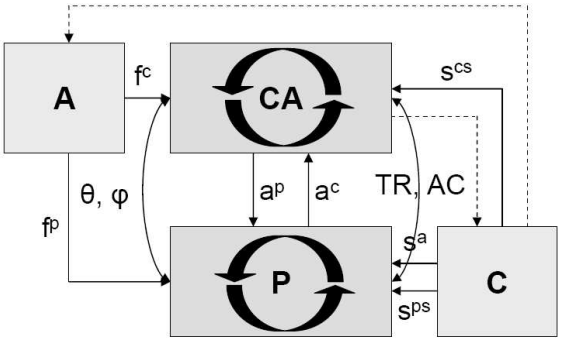
2003. As the cable modem regime did not change, the cable growth rate reflects the changing overall economic conditions and the demand for broadband. Therefore, it can be used as a crude benchmark against which the other two technologies are assessed. The CAGR of both ADSL and fiber exceed the number for cable although the increase was much more remarkable for fiber, as some of the investment activities of the telephone companies shifted from DSL to fiber platforms. The numbers are only proxy measures of investment as they do not reveal upgrade investments in existing networks, for example, the migration to DOCSIS 3.0 by many cable firms or upgrades of middle mile and backbone networks by telephone companies.

6. Network neutrality and investment incentives

In contrast to interconnection, access, and unbundling, which predominantly affect horizontal market relations, the issues raised in the network neutrality (or more recently "reasonable network management") debate predominantly affect vertical market relations. Nonetheless, for several reasons, these two sets of policy rules complement each other in the emerging environment. To see this more clearly, it is necessary to examine the competitive relations in next-generation networks. In these architectures general purpose platforms layers and application/services layers will be more distinct than in past networks, which were often engineered to provide specific (or a narrowly defined range of) services (OECD 2005; ITU 2007). While the physical networks are one platform, they are not necessarily the only one. In Web 2.0 and future Web 3.0 environments, the role of the platform could be played by organizers of a logical space, such as a social network or a content aggregator, rather than the physical transport infrastructure. Moreover, the system architecture might consist of several platforms: a physical transportation network, hardware platforms such as processors (Gawer and Cusumano 2002), and logical platforms that facilitate the creation of content and applications such as Google's Android mobile platform. In these multi-layer multi-platform environments, numerous complementary and substitutive relations co-exist. To simplify arguments, in

the following paragraphs we limit the discussion to network platforms and related applications and services.

Figure 4: The network neutrality problem



A …… Advertisers
CA …. Content/Application providers
P ……. Platform providers
s^a ….. Subscriber access prices to P
s^{ps} …. Subscriber service price to P
s^{cs} …. Subscriber service price to C/A

f^c, f^p … Advertising fees to C/A, P
a^p, a^c .. Platform/content access price
TR … Transaction costs
A … Adaptation costs
θ, φ … Complementarity coefficients

Source: Bauer (2007)

Applications and services are frequently complementary to networks as users will not subscribe to network platforms unless appealing content is available. In this case, the revenues and profits of a network platform provider will be dependent on their availability. Even a platform monopolist would not block or even deteriorate access to them. However, in an attempt to maximize profits, a monopolistic or dominant platform provider may try to extract rents from the complementary providers, possibly in return for some form of privileged access granted to the application provider. Even a competitive platform provider may try to extract some of the rents through forms of differentiation. It is not a priori clear whether platform operators might want to fully block applications, although they may have such an incentive in the case of high-bandwidth intensive applications if they cannot price accordingly. It is possible but unlikely that low bandwidth applications are blocked altogether.

The situation is different, however, in the case of substitutive products and services. This scenario is particularly relevant if the network platform is vertically integrated into services but the competing service provider does not own network facilities. It could also be the case, though, that an application provider offers functions that compete with functions also offered by the network platform. For example, an application provider could offer routing services in competition with a network platform operator. In these latter scenarios, a monopolistic platform operator many have strong incentives and the ability to sabotage competitors without own facilities. Even if competition existed between several platform providers, weak forms of sabotage might be feasible.

Network neutrality is subject to considerable debate in the U.S. where it is a response to the abandonment of common carriage rules for broadband access, which had provided one particular set of protections against discrimination and sabotage. At the end of 2008 it was less intense in other parts of the world which continue to rely on unbundling and other forms of non-discrimination obligations. However, due to the changes in the competitive landscape in next-generation networks, it will likely become a growing debate in other countries as well. The situation in the U.S. is further complicated by the artificial distinction between telecommunication services and information services that underpins communications law and FCC regulatory authority. This is not the place to review the multiple and far-ranging aspects of the network neutrality debate. Suffice it to say that the lack of an operational and shared understanding of the term "network neutrality" offers an opportunity for both proponents and opponents of public policy measures to present specific, often extreme, scenarios. Proponents of strong network neutrality rules argue, among other things, that deviations from the historical end-to-end model would not only impede innovation and investment but also endanger the democratic value of the internet as a public sphere securing free speech (Wu 2003; Frischmann 2005; Frieden 2006; Frieden 2007; Frischmann and Van Schewick 2007; Herman 2007; van Schewick 2007; Wu 2007). Opponents point out that network neutrality rules would diminish the incentives to invest in both network platforms and content as innovation and investment are fueled by the ability to differentiate and diversify (Thierer 2004; Yoo 2005; Dixon, Gifford et al. 2006; Hahn and Wallsten 2006).

As the debate is maturing, a growing number of more nuanced analyses help evaluate the key aspects of policy decisions as well as the advantages and disadvantages of specific approaches for the performance of the overall system. Clark (2005) and Felten (Felten 2006) have pointed out that the internet was never fully neutral and the difficulty of specifying rules that would preserve the benefits of diversity while not foregoing the benefits of openness. More recent papers have made attempts to model the underlying dynamic interrelations more explicitly. Bauer (2007) and Shrimali (2008) discuss the investment and innovation incentives in a vertically related market setting at a conceptual level. Bauer and DeMaagd (2008) further develop the approach using a game-theoretic model combined with a computational algorithm to find solutions to the optimization problem. They find that non-discrimination rules under certain conditions increase the profits of the network provider but no general pattern of abuse emerges in the absence of such rules. Choi and Kim (2008) develop an analytical model of the dynamic investment problem and come to the conclusion that network neutrality rules may provide positive investment incentives to Internet Service Providers. Similarly differentiated findings by Hermalin and Katz (2007), Economides (2008), Economides and Tåg (2007), and Kocsics and Bijl (2007) suggest that no simple and clear cut set of network neutrality rules exists that holds for all market conditions.

In the framework proposed in this paper, the effect of network neutrality rules on the investment calculus of individual firms, and to a certain degree the overall sector pattern, can be studied through an integrated analytical lens. Investment and innovation are, first and foremost, affected by the competitive conditions, the technological opportunities, and the appropriability of temporary rents in the respective layer of the industry. In vertically related markets with complementarities, the investment and innovation activity on each layer is, furthermore, influenced by investment and innovation activity in the complementary layer. This is where network neutrality rules come into play. Like in the case of unbundling, the range of possible non-discrimination rules can be ranked from very strict to very light-handed. For example, a rule requiring that every bit be treated alike would be rather stringent whereas a rule allowing differentiation of network

services as long as they do not violate antitrust laws would be very lenient. Non-discrimination rules affect the overall investment and innovation dynamics of the value network in three ways: (1) via charges that the players may assess, (2) the transaction costs of getting access, and (3) adaptation costs, in particular of content and applications to networks. Players on the related layers are affected in different ways.

Other things equal, it is most likely that non-discrimination rules, like competitive intensity to which they are similar, will reduce network providers' cash flows and the option value of investing in infrastructure, although the effect will depend in the stringency of these rules. On the other hand, such rules, because they reduce transaction and adaptation costs, they will increase the cash flows of content and application service providers. These effects will most likely also increase the option value of remaining a services provider. If network neutrality rules also reduce the ability of network providers to price differentiate, they may reduce the costs of access to network platforms for some providers. If these conditions hold, network neutrality rules will likely shift the threshold of projects that will be pursued by content and application service providers outward. In that sense, they will facilitate experimentation and innovation. However, unless regulated access fees are set at zero, it may well be that non-discrimination rules increase access charges for content providers, who otherwise may have benefited from lower or even zero negotiated fees. In this latter case, overall innovation activity might even suffer. The overall innovation rate may also suffer if network neutrality rules impede beneficial forms of network differentiation that might spur innovation at the content and application layer. For example, the success of an application may be dependent on network services that guarantee certain technical features. Some of these features might be realized on the edge of the network but some may require differentiation that reaches deeper into the network architecture.

Thus, the net effect of non-discrimination rules on investment and innovation activity is difficult if not impossible to predict. However, partial relations can be identified. 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 greater innovation potential than the network platform layer and complementarities are weak, then policies that foster players on that layer may be more desirable and vice versa. If complementarities are strong, then a balanced approach will contribute to greater overall welfare. However, in that case all but myopic service providers will realize their interdependence and act accordingly. All this is mediated by the competitive intensity on each layer, which, as discussed in the previous section, forms an inverted U-shaped relation to the strength of the innovation and investment incentives. If competition is below the critical threshold, increasing competitive intensity will have positive effects. If it is above the critical threshold, further increases in competitive intensity will reduce incentives to invest and innovate. This critical threshold is probably at different points for network platforms, service-based competitors, and content. It is most likely lower for network platform providers and higher for service and application providers. The net effect is further influenced by the sensitivity of investment and innovation on each layer on transaction costs and adaptation costs.

Table 3: Platform competition and vertical relations

Platform market structure	**Competitive relation**	
	Complements	Substitutes
Monopoly or dominant firm	Rent extraction	Rent extraction, sabotage
Differentiated competition	Weak rent extraction	Weak rent extraction, weak sabotage

In the complementarity scenario non-discrimination rules seem most justified if there is persistent abuse of market power at one or multiple layers. In that case, the incentive to innovate is relatively low and the ability to extract rents high. However, in a dynamic market like ICT in which a continuous technology race takes place, this is most likely only the case if the number of effective competitors is close to monopoly or if a small number of players tacitly collude. In all other cases, effective safeguards against competitive abuses will most likely suffice and stringent ex ante network neutrality rules may have unintended negative consequences on innovation and investment. On the other

hand, if the ability to differentiate fully forecloses access to a relatively open network access platform, the long tail of innovation experiments, that is potentially valuable projects with a low or unknown chance of succeeding, may be crowded out. It seems that network neutrality rules are an expensive way of fixing that problem and other rules may suffice to retain this innovation dynamics. One way of preserving it is a requirement to maintain a general open network access layer. Another one is institutional competition between different platform models, for example, if public sector agencies, non-profit organizations, or cooperatives allow such open access. Innovative services could use these spaces to experiment even if not all of the population can be reached at once. Should a promising project emerge it could migrate to other network platforms. The case for network neutrality provisions is much stronger in the case of substitute services, where stronger incentives to sabotage and exclude may exist. Ex post policy measures such as antitrust enforcement may be too slow to prevent such behavior.

7. Fiscal, monetary, and other public policy measures

Regulatory and legal policy measures have great influence on investment and innovation decisions but they are not the only instruments available to government. A range of other fiscal and monetary measures to influence private sector investment and innovation is at its disposal. Supply-side measures include tax credits for investment and innovation expenditures, accelerated depreciation, measures that lower interest rates and hence the cost of capital, and subsidies. Demand-side instruments encompass tax credits, subsidies, and voucher programs that benefit households and individuals as well as measures by government agencies that boost demand for ICT. Whether any of these measures has the desired effect on investment and innovation depends on the design of the policy instrument and its context. For example, the effect of fiscal measures that reduce the tax burden of companies depends on factors such as the corporate tax rate, the ability to carry forward losses, and the extent to which investment decisions are driven by profits (that is, internally generated funds). Likewise, monetary measures that work via the interest rate will critically depend on the sensitivity of investment decisions to external funding

conditions in general and the cost of capital in particular, investor expectations, and demand conditions. Depending on these details, a measure may be effective or not. The appropriateness of a measure will also be influenced by the prevailing economic situation. If the overall economic situation is poor and the public sector in danger of running a significant budget deficit, off-budget measures such as investment tax credits may be easier to realize than subsidies or public investment. An assessment of alternative policy instruments will have to judge the ability of an instrument to achieve a certain objective, the efficiency of reaching this goal, and the administrative cost of the program.

The main government instruments available to influence investment and innovation indirectly through the tax system are tax credits, accelerated depreciation, and other tax provisions that reduce the cost of an investment project. Tax credits are typically awarded as percentage of a qualifying type of investment or expenditure, for example, capital investment or expenditure for research and development. These credits can be used to reduce the corporate tax owed by a company (or the income tax owed by its owners). Their effect depends to a large degree on the details of the program. Investment tax credits can be granted on a general basis or for specific qualifying investments, say in designated geographic zones or for specific purposes such as high-speed broadband access. Such credits reduce the cost of investment for firms that owe income taxes. Accelerated depreciation essentially shifts a tax liability to a later period in time. Depending on future investment choices and the future profitability of the firm, accelerated depreciation may lead to a permanent or only a temporary tax savings. It will lead to a permanent saving if the firm continues to invest and to expand or if it experiences losses in the future (so that the shifted tax burden does not materialize). If the firm reduces investment or stops to invest altogether in future periods, the savings realized through accelerated depreciation is equal to the interest saved on the "tax loan" corresponding to the initial tax savings.

Both tax credits and accelerated depreciation can achieve the goal of boosting investment. However, they differ in their effectiveness and administrative simplicity. As companies owe more taxes in the upswing of the business cycle, tax credits are inherently pro-

cyclical. For the same reason, tax credits will tend to favor large established firms over start-ups. This undesirable feature can be mitigated somewhat by allowing unused credits or losses to be carried forward. Moreover, a tax credit program faces the challenge of avoiding bandwagon effects, that is, the use of tax credits for investment that would have happened regardless. In that case, funds would simply be redistributed from the public to the private sector without any net addition to investment. This raises the larger and complicated question of the incidence of tax credits, that is, who benefits and who bears the burden of the credit.

To avoid some of these undesirable effects, tax credits can be made contingent on meeting certain criteria, including proof that the expenditure is incremental, investment in a specific geographic region, into a specific type of project, and so forth. All these contingencies increase the precision of the instrument but at the expense of administrative simplicity. For all these reasons, researchers have raised some theoretical doubts about tax credits. For example, Huffman (2007) suggests that the welfare effects of capital taxes (and hence of capital tax credits) may be negligible and that a research subsidy of the same magnitude would have a larger growth effect on the economy. Goolsbee (1998) showed that tax credits often do not benefit the investing firm but the firms producing capital goods (depending on their capacity utilization). Nonetheless, empirical studies indicate that investment tax credits do have a positive effect on investment (e.g., Chirinko and Wilson 2006). With the exception of the concern about the incidence of costs and benefits, all the possible problems affecting tax credits also apply to accelerated depreciation. One important feature of both measures is that they can be used on a short notice and designed to sunset after a specified period. In that case, the value of the option to wait is reduced and the incentive to invest earlier increased. Unlike income tax benefits to individuals that have a stronger effect if they are permanent, investment tax credits have stronger effects if they are temporary.

Tax credits and accelerated depreciation reduce the cost of internal financing of investment and innovation. Another way for government to influence investment is via the external cost of funds, predominantly through policies affecting interest rates. This

may be achieved at the macroeconomic level via monetary policy efforts intended to reduce overall interest rate levels or be more targeted to specific industries, regions, or types of investments. A broad spectrum of measures is at the disposal of government, ranging from deductions for interest, subsidies for interest payments, and loan guarantees. All these measures reduce the cost of external financing and therefore increase cash flows from an investment project. Like in the case of tax credits, reductions in the level of interest rates may trigger bandwagon effects and not stimulate any additional investment. However, they can be used in a rather targeted way and may therefore be effective in achieving specific public policy goals, such as investment in a particular region. Moreover, guarantees might be effective tools during a credit crunch period. On the other hand, such instruments carry a higher administrative burden than tax credits and may take some time to implement.

A third option for the public sector is to take a more direct and proactive role, either by coordinating infrastructure investment or by investing directly. Many communities have taken a leadership role in the deployment of wireless broadband services (and fewer in wireline broadband) but, so far, with relatively mixed financial success. Several models are utilized across the U.S.: communities that coordinate deployment but did not plan to provide any subsidy; communities that support the projects with demand-side measures, such as serving as an anchor tenant; communities that subsidize networks and services, often to provide public services; and direct public investment (see also the detailed discussion by Huang 2008). The experience of the past few years seems to suggest that models that aim at full community coverage are financially not sustainable without some form of subsidy. This may change with next generations of wireless technologies, such as WiMax, that have more advantageous cost characteristics. Providing some form of public subsidy may be justified if public services are provided. In fact, the public sector could use an investment calculus that takes externalities into account. Such externalities are not part of private EPNV calculations unless they are internalized, for example, using a subsidy. A public sector agency could directly operate using such a broader social assessment of the value of an investment (a "social ENPV" or SENPV). Moreover, it could operate open wholesale platforms, thus providing a valuable institutional

alternative that might curb private providers' ability to extract excessive rent from non-network-based players. In practice, given the tight financial constraints of the federal and subsidiary governments, direct public sector involvement is currently a strategy facing serious constraints.

8. Does the U.S. have a broadband problem?

It has become commonplace to lament the poor broadband performance of the U.S. compared to peer nations. There is some truth to the story: during most of the twentieth century the U.S. could boast one of the most efficient, widely available, and affordable telecommunications infrastructures. Only very few countries, such as Sweden, could measure up to its performance. Toward the end of that century, the relative positions started to shift. The U.S. lost its leadership in wireless communications to Europe and later to South Korea and Japan. However, this loss was not permanent and by the early twenty-first century U.S. consumers benefited if not from the technically most advanced so from the lowest priced mobile services, at least for heavier users (Bauer and Kim 2009). Several factors had contributed to this time pattern, including the availability of an efficient wireline telephone network that delayed the incentive to switch to wireless; the decision to allow standards competition, which slowed the roll-out of networks; and catching-up by other nations.

In broadband, East Asian and a few European nations also are ahead of the U.S. Even more than mobile communications, fixed broadband is a diverse technology and has many performance attributes. The most widely used metric of broadband subscribers per 100 inhabitants is distorted as it does not correct for varying household sizes across countries. But even if household penetration and other metrics such as average advertised download speeds and prices are taken into account, the U.S. does usually not rank better than five based on OECD statistics (OECD, 2008). In approaches that try to assess the availability and use of advanced infrastructure in a comprehensive fashion, the U.S. does even worse when the ITU Digital Opportunities Index (DOI) is used (ITU

2007). However, it does much better in the World Economic Forum's Network Readiness Index (World Economic Forum 2007), where it ranks number four. In the Economist Intelligence Unit's E-Readiness Index the U.S. even holds to top position (EUI 2008). The Phoenix Center estimated a best-practice frontier by correcting for factors that influence the relative position of nations in a cross-national comparison (Ford, Koutsky and Spiwak, 2007). In this analysis, the U.S. is close to where is should be, given income, population density, education levels and other explanatory variables, not necessarily an outstanding performance.

Table 4: U.S. standing in international broadband rankings

Organization	**Metric**	**U.S. rank**
OECD	Broadband connections per 100 inhabitants (June 2008)	15
	Net addition of broadband access lines June 2007-June 2008	12
	Price range for broadband access (June 2008)	5
	Average advertised download speed (June 2008)	14
	Percentage of fiber connections in total broadband (2008)	9
ITU	Digital Opportunities Index (DOI) (2007)	20
World Economic Forum	Network Readiness Index (NRI) (2008)	4
Economist Intelligence Unit (EIU)	E-Readiness Index (ERI) (2008)	1

Several authors have suggested that the U.S. position might be a temporary phenomenon. Bauer (2006) concluded that it was too early to diagnose a structural U.S. broadband deficit. Bauer (2008) focusing on investment activity also concluded that U.S. telecommunications companies in recent years have been investing in networks at a pace that is superior to European and Asian counterparts. Eisenach (2008, p. 10) examined real investment in communications equipment, which includes network investment. After a peak during the IT bubble in 2000, investment decreased until 2003 and picked up again after the change in unbundling rules, almost reaching the earlier high point. Whereas such aggregate figures cannot establish a causal effect between unbundling policy and investment, they indicate a relatively robust level of investment by the private

sector. On the other hand, they do not justify a leap of faith that the U.S. will close the gap without supportive public policy.

Given the fact that broadband access prices in the U.S. are relatively low compared to other nations and that broadband deployment is such that more than 90% of households could be served, one has to ask whether there are demand-side reasons that contribute to the rate of broadband diffusion. Several demand-side factors could be at play. Survey results from the Pew Internet and American Life Project indicate that a considerable share of the U.S. population continues to be content with dial-up service, which, after all, is available at zero incremental cost. Moreover, it could be a lack of availability of complementary equipment such as computers or other access devices that slows down diffusion. Lastly, it could be a matter of education and poor digital literacy.

Whereas the network roll-out data shows steady growth, it is insufficient to conclude that the U.S. would not be better off with a broadband policy other than the present strong reliance on market forces. Three main reasons can be put forward in favor of a national broadband policy. First, in a market-driven roll-out of advanced networks, the sheer size and geographic diversity of the nation will create imbalances between urban and rural areas, to which investment will only be directed later in the deployment cycle (see Bauer, Kim, and Wildman 2003). In as far as broadband access is seen as an essential infrastructure service, such disparities, even if temporary, may be unacceptable and amplify regional inequalities. Second, bringing commercial service providers to a specific market may suffer from a demand aggregation problem if total demand by all relevant users is not expressed simultaneously. In that case, suppliers may not perceive an area as commercially appealing even it total demand would be considered as sufficient if it were articulated at once. Third, in the presence of public good effects, such as beneficial positive externalities of the availability of broadband on education or public safety, private demand, even if successfully aggregated, will not reflect the true social benefits of rolling out networks and services to areas. The first is a case of market insufficiency, the second and third scenarios are forms of market failure.

Overall, the empirical evidence does not suggest that the U.S. faces an immediate broadband *crisis*. It is also clear, on the other hand, that other countries have been able to achieve faster diffusion of broadband service. However, despite a plethora of suggestions and claims, it is not self-evident that the position of the country could be lastingly improved by public policy. Different supply and demand-side courses of action are available whose pros and cons are outlined in the next section.

9. Charting and evaluating different courses of action

In a dynamic perspective, the interaction of policy design with decentralized investment decisions of market players and other stakeholders in the ICT value net has to be understood. Alternative policy choices will prod the system in different directions and these effects of regulation may be analyzed systematically. It may not be possible to predict the exact outcomes but only to establish a correspondence between policy measures and ranges of likely outcomes. Because many trade-offs exist, a "best" course of action that dominates all other solutions, may not exist. From the study of other dynamic systems it is known that different legal and regulatory choices, while they result in diverging system trajectories, sometimes yield broadly comparable aggregate performance, a phenomenon sometimes referred to as "functional equivalence" (Ropohl 1999; Rodrik 2007). Alternatively, they may produce unique developmental paths over time, often associated with specific trade-offs. For example, regulatory choices that support a higher rate of entrepreneurship and innovation might go hand in hand with a more turbulent sector evolution but it may not be possible to have both dynamic entrepreneurship and calm economic development. A decision for one approach or another requires a normative criterion, such as a dynamic social welfare function, that allows valuing the institutional arrangements (in case of functional equivalence) or the anticipated outcomes.

It is important to consider policy measures primarily motivated by reinvigorating economic growth separately from those that are intended to solve perceived long-term

structural broadband policy problems, even if selected instruments may be able to address both sets of concerns. The economic crisis requires swift and immediate action. Regulatory instruments, including the promulgation of more specific network neutrality rules or universal service policies that also support broadband access, will need some time for deliberation. Moreover, as the discussion in sections five and six above has illustrated, they generally have differential effects on stakeholders with ambiguous overall effects on investment and innovation. It is unlikely that these ambiguities can be resolved without further empirical evidence. The best strategy at this point would therefore be to renew a generic statement in favor of open networks and to strengthen the ability of antitrust and regulatory agencies to monitor sector evolution and act quickly if problems become visible. Such a process could be modeled after the mediation and dispute resolution procedure used to settle interconnection conflicts. Should the process turn out to be insufficient, additional measures might be developed on a less strained schedule. To stimulate investment in infrastructure, applications and services, legislative measures seem more appropriate given the urgent nature of the response. Of the instruments reviewed in section seven, investment tax credits, tax credits for research and development expenditures, and possibly accelerated depreciation will spur investment indirectly via the associated tax savings. The dependence on taxes has certain disadvantages, some of which may be overcome with appropriate designs. Other disadvantages may only be overcome with alternative instruments.

Indirect instruments, as discussed in section eight, are working through a reduction of the tax burden of a company. Not only may they suffer from bandwagon effects, they also may create a bias in favor of already established, profitable companies. To avoid such downsides, such provisions could be adopted with conditions. Unfortunately, if they are granted subject to certain conditions, the administrative complexity of the program is increased, a trade-off that needs to be carefully balanced. Moreover, negotiating contingencies may delay legislative adoption of any specific measure. A possible pragmatic compromise would be to grant investment tax credits only for investment exceeding a certain percentage of past levels, as suggested by (Atkinson, Castro et al. 2009) and to tie them to investment in certain regions. If more specific conditions are

deemed appropriate, two criteria seem most operational and are proposed in recent legislative initiatives: location and access speed. Defining the qualifying criteria introduces a considerable level of discretion and it is necessary to be clear about the underlying rationales and motives. Should investment be channeled to a certain region because the associated positive externalities are higher than in other regions? Is the main reason to avoid digital and economic inequality? Or is it a mix of distributional and efficiency arguments? Such incentives may be more compelling for equity than for efficiency reasons. Similar arguments hold for incentives tied to speed. Should an absolute threshold be established (e.g., 10 Mbps or 45 Mbps download speed with corresponding upload speeds) or an increase over the status quo?

In principle, differentiated self-selection incentives could be designed that give suppliers a trade-off between different levels of incentives and the qualifying types of investments. Higher investment credits could, for example be granted for more rural areas or higher access speeds. In either case, such contingent forms of support reduce the cost of investment and hence increase present and future cash flows. They most likely change the pattern and timeline of investment, may lead to a reallocation of investment expenses, but do not necessarily lead to an increase of the overall investment volume. General tax credits or forms of accelerated depreciation for broadband investment, especially if they are only granted for incremental capital expenditures, are less prone to suffer from these potential problems. Similarly, geographic restrictions make less sense for research and development tax credits. Instruments that utilize the tax system have several possible disadvantages. First, as suppliers tend to owe higher taxes during and upswing, they tend to be pro-cyclical. Moreover, they may be more attractive for already established firms than for start-up companies. These disadvantages can be overcome to a certain degree if the tax code allows carrying losses forward.

An alternative to such indirect policy instruments are subsidies to suppliers. These can come in the form of direct payments equivalent to part of the capital expense, low-cost loans, and loan guarantees. The latter instruments seem particularly fitting during a period of a credit crunch. Like tax incentives, these instruments reduce the cost of an

investment project and hence increase its ENPV, other things equal. Direct subsidies have the advantage that they can be made contingent on a range of criteria that allow fine-tuning them to a broad range of situations and objectives. Such criteria may include location and speed as discussed earlier but they may also specify the platform to be used (wireline or wireless) or the size of the supplier, for example, by limiting subsidies to small and medium-sized firms. Given recurring concerns about possible dominance of the broadband access market by cable and phone companies, this may be a feasible measure to strengthen the competitive fringe of the access duopoly. Such measures could also be designed to facilitate alleviation of special access bottlenecks that seem to exist in certain markets, judging from the incomplete information available (Wallsten 2007; Blohm and Loube 2009). On the other hand, the more finely grained the criteria for awarding such subsidies the higher the administrative burden associated with administering the program and the slower its implementation. Moreover, more specific criteria also increase the possible allocative distortions introduced by the measures. If quick stimulus is desired, a subsidy program may have to rely on simple, easily verifiable criteria. It would make most sense if it were available on a competitively and technologically neutral basis and did not discriminate between providers. Like tax-based incentives, such programs may cause bandwagon effects, that is, subsidize investments that might have taken place anyway. Restricting the subsidies to incremental investments might be an appropriate way to overcome this problem.

Direct public sector investment is a third principal option. Even after the abolition of state-owned enterprises, a fair number of countries have used public investment to complement or accelerate private investment. South Korea, Denmark, and Sweden (as the U.S. in the 1960s and 1970s) have invested in public backbone networks. State-owned utilities in energy and transportation have been used to roll-out network capacity. The return of the state is most visible, however, at the local and state level. A growing number of communities are actively involved in the deployment of (mostly wireless) broadband access network. At the same time, there is considerable resistance against such a role for the public sector. In the U.S. several state legislatures have adopted measures to prohibit or at least curtail public investment on the grounds of allegedly

Table 3: Effects of regulation and public policy on next-generation network investment (first-round ceteris paribus effects)

	Platforms			**Content applications**			
				Platform dependent		**Platform independent**	
	Incumbent	**Service entrant**	**Facilities entrant**	**Complement**	**Substitute**	**Complement**	**Substitute**
Horizontal access							
Local loop unbundling	–	+	–	+	+	NA	NA
Unbundled platform	–	+	–	+	+	NA	NA
Bitstream access	–	+	–	+	+	NA	NA
Competitive intensity (see Figure 2)	if $c<c^*$ + if $c>c^*$ –	if $c<c^*$ + if $c>c^*$ –	if $c<c^*$ + if $c>c^*$ –	if $c<c^*$ + if $c>c^*$ –	if $c<c^*$ + if $c>c^*$ –	if $c<c^*$ + if $c>c^*$ –	if $c<c^*$ + if $c>c^*$ –
Vertical access							
Non-discrimination	–	–	–	–	+	+	+
Reduction of transaction costs	+	+	+	+	+	+	+
Reduction of adaptation costs	+	+	+	+	+	+	+
Other policies							
Investment tax credits	+	+	+	+	+	+	+
Subsidies	+	+	+	+	+	+	+
Demand stimulus	+	+	+	+	+	+	+
Public ownership	–	+	–	+	+	+	+

unfair competitive advantages for the public sector (e.g., tax exemptions or free access to rights of way). These are not principal arguments against public involvement as any existing competitive distortions could be eliminated by appropriate legal and regulatory action. At the same time the public sector can adopt a societal perspective by taking external effects into account and adopting a longer time horizon (a lower discount rate) when assessing future benefits and costs.

To conclude this section, a few remarks on the employment effects of alternative measures seem to be appropriate as this is of core interest in the present discussion over economic stimulus and the possible contribution of next-generation communications investment. Incremental infrastructure investment has direct effects on employment in the sectors that produce and install equipment and operate networks and services. It also has indirect effects as the additional income is spent in turn. These multiplier effects vary depending on the economic sector to which the first-round effects go. In an overall stimulus packet, the magnitude of multiplier effects is an important consideration when determining the structure of a program. However, other considerations are also relevant. Multiplier effects are mort relevant if a sector and the related sectors have unused capacity available or are able to expand capacity quickly without inflationary and crowding out effects. If this is not the case, the actual multiplier effect will be below the theoretical one. Several studies also take additional employment effects into account. For example, Crandall and Jackson (2001) and Atkinson, Castro et.al. (2009) attribute "induced" employment resulting from the enabling effects of communications infrastructure on existing and emerging economic activities.

These effects constitute positive externalities of infrastructure investment. Although the argument is economically elegant, it is also incomplete. To estimate a true induced employment effect, not only such positive externalities but also potential negative ones would have to be considered. The spectrum of possible negative effects of increased use of ICT is broad. It may include jobs losses due to increased productivity; the loss of local and regional jobs due to e-commerce and the associated centralization of economic activity in a few hub locations; and the outsourcing of jobs to overseas locations. It may

include more complicated effects as well. For example, there is evidence that the recent financial crisis was deepened by the easy availability of online banking, instant fund transfers, and the related global web of interdependencies. This raises the tricky question of whether job losses in the wake of the crisis could be regarded as a negative externality of ICT. In any case, these examples of possible negative employment externalities illustrate the upward bias that is introduced in attributing only positive induced jobs. Unless a net effect that properly accounts for positive and negative induced employment effects can be determined it is prudent to not inflate job estimates with only positive induced numbers. Rather, the focus should remain on direct and multiplier effects.

10. Conclusions

The effects of regulation and public policy on communications infrastructure have been a central concern since the introduction of regulation at the end of the nineteenth century. Nonetheless, its effects have not been fully explored beyond a relatively pragmatic level. This paper first provided a brief historic review of the frames used to theorize the relation between public policy and investment. Noticing the lack of an explicit micro-foundation for these frames, the next sections developed an enhanced net present value model of a firm's investment decision and examined the various ways in which regulatory and public policy measures affect it. In the present open market environment, the effects of regulatory instruments on regulated and unregulated firms in the multi-layer ICT value net have to be understood. The two most important regulatory dimensions are provisions governing horizontal network access (unbundling and equivalent requirements) and vertical network access (currently conducted under the terms network neutrality and network management).

Regulatory instruments are best seen as "tuning" variables in a dynamic adaptive system. Specific choices not only affect the overall level of investment in regulated and unregulated market segments, they also influence the structure of investment and the amounts invested by different types of firms (e.g., incumbents, new facilities-based

market entrants, platform operators, or content providers). These effects are non-linear and not yet fully understood. However, both horizontal and vertical regulatory instruments probably are in an inverted U-shaped relation to overall investment. Regulation can be too loose but also too stringent. In the first case, overall investment and innovation are dampened due to excessive market power of the dominant firm(s). In the latter scenario, investment and innovation are dampened due to excessive competition and the insufficient ability of firms to appropriate rents sufficient to compensate investment and innovation risks. Ideally, regulation would remain in a target zone that avoids either extreme.

In vertical relations the potential problems are less acute in case of complementary services than in the case of substitutes, which creates stronger incentives for dominant firms to sabotage their competitors. These non-linear relations are highly complex and no simple rules are known that would cope with the potential problems without introducing others. Therefore, the best way forward might be a strengthening of the authority and capability of regulatory agencies to detect abuses and act swiftly to eliminate them. Such powers could be enhanced by a mediating role for regulatory commissions in contract negotiations. Furthermore, requiring the provision of an open access tier, possibly modeled after the C-Band in the 700 MHz wireless auction, could have beneficial implications to keep a continuous flow of high risk-low-probability-of-success innovations. On the other hand, such provisions will also weaken the incentive of network operators to invest (both by reducing the ability to appropriate temporary rents and by increasing regulatory uncertainty and hence the discount rate applied to future cash flows).

Other forms of public policy, such as tax incentives, subsidies, and direct public investment are effective tools but each has their advantages and disadvantages. If regulatory choices are flawed, for example, by inadvertently setting sub-optimally low investment incentives, these alternative policy instruments can compensate for them. Ideally, however, they would be used to strengthen the pro-investment incentives created by the design of regulation. These additional public policy instruments are more

appropriate than regulatory tools to create short-term stimulus. They are also better suited to internalize positive external effects and base local investment decisions on the social rather than the private extended net present value. An expansionary program would best use a mix of instruments, including tax credits, subsidies, loan guarantees, and direct public investment. Conditioning these instruments to certain geographical areas and access technologies will likely reduce the stimulus impact and may have other undesirable long-term consequences. As the meaningfulness of such policies will depend on a careful analysis of the specific circumstances, they are less suited as stimulus instruments and would better be developed as medium- and long-term structural policies. If such measures are deemed of high priority, a compromise approach would be to grant higher tax credits or other incentives for designated rural areas, for example, areas that are presently unserved. Such a slower approach would allow addressing demand-side issues and other possible causes of slow broadband diffusion in a more systematic manner. As time is of essence to provide a counter-cyclical investment stimulus, primary attention in the short run would ideally be focused on non-regulatory public policy measures. A re-calibration of horizontal and vertical regulatory arrangements, if deemed necessary, could then be addressed with greater caution as is required by the risks inherent in getting these policies wrong.

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