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Platforms, systems competition, and innovation: Reassessing the foundations of communications policy

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ABSTRACT

Focusing on the effects of policy on investment and innovation this paper examines whether the conceptual foundations of sector regulation are aligned with the current technological and economic conditions of advanced communications. One conclusion is that the prevailing theories and practices are only adequate if the policy challenge can be reasonably approximated as a static or steady-state problem but they may have serious shortcomings if this is not possible. The article proceeds with a review and critical examination of two approaches that could augment or possibly replace the traditional approach under conditions of dynamic competition—the theory of platform markets and systems approaches. Both frameworks model aspects of competition in interconnected systems in more detail and offer novel insights to inform communications policy in an era of continuous change. Nonetheless, important theoretical and implementation gaps remain that will require additional efforts by researchers and practitioners.

1. Introduction

This article explores the implications of the changed economic and technological conditions of information and communication industries for communications policy. Particularly the plasticity and generativity of digital production technologies raise interesting new challenges. A growing body of research on network industries suggests that to be effective policy needs to be aligned with the technological conditions of the system to be governed (see Künneke, Groenewegen, & Ménard, 2010). It is therefore rational for policy makers to review whether and how sector governance should be adapted to better support investment and innovation in the digital economy. While traditional goals such as universality of access, affordable prices, and high reliability continue to be important, supporting investment and innovation has moved to the forefront of the policy agenda. Yet knowledge of the conditions that facilitate investment and innovation in technologically dynamic sectors is less robust than our understanding of the prerequisites of efficient regulation under static or steady-state technology. Recent efforts to develop better models of how regulation affects innovation are promising, especially if they are combined with theories that grasp the dynamic aspects of innovation better than mainstream regulatory theory.

The increased reliance on IP networking and the Internet requires reconciling two different yet complementary realms of governance—traditional telecommunications sector regulation and Internet governance—a task fraught with considerable tensions (Mueller & Van Eeten, 2013). Whereas government policy is promulgated and implemented in formal and often

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hierarchical procedures, Internet governance relies on a mix of formal and non-formal multi-stakeholder settings with participants, rules of engagement, and powers of enforcement that are different from and sometimes orthogonal to traditional government regulation. Much of regulatory theory and practice originates in monopoly regulation and in problems associated with the transition from monopoly to a more open market environment. Internet governance cannot yet refer to a comparable standard body of normative foundations. Much of it is rooted in a strong trust that networked coordination is workable for a wide array of governance tasks (Mueller, 2010). Although there is a track record in support of this premise, the conditions under which network governance is effective and principles of how it can best be organized are not fully explored and continue to evolve.

Three interwoven developments during the past decades have fundamentally altered production and use of Internet-based services. One trajectory is the evolution of communication networks from specialized infrastructures to general purpose platforms capable of supporting a broad range of applications and services. A second development is increased and ubiquitous connectivity at increasing speeds in combination with more powerful fixed and mobile devices. The third element is advances in computing power and the adoption of modular system architectures. Taken together, these developments have greatly increased the plasticity and generativity of digital production technology. Plasticity allows the production of digital services and applications with multiple factor combinations at often radically different costs (e.g., online video via best-effort Internet connections, peer-to-peer communications (P2P), and content delivery networks (CDNs)). With few exceptions, most products and services can be produced with alternative technologies but in a digital environment such flexibility abounds. The resulting greater plasticity allows new, non-traditional players to enter the market and hence significantly alters patterns of competition. Generativity refers to the greatly expanded space of innovation opportunities opened up by digital technology and the accelerated pace at which it is being explored. It also has direct consequences for the intensity and dynamics of competition.

These changes have greatly altered and will further influence investment and innovation in the ICT sector. They have also affected the technical and business relations in the advanced information and communication system. Public policy—despite efforts to adapt to the new industry structure—continues to be largely based on conceptual models and practices that were developed under different economic conditions. Periodic mismatches between the economic and technological basis of a sector and the principles informing its governance are to be expected in a dynamically evolving industry. An increasing number of policy-makers and academics are concerned about this incongruity as it may result in erroneous public policy choices (e.g., Ballon & Heesvelde, 2011; Bauer & Bohlin, 2008; Serentschy, 2013; Whitt, 2007; Yoo, 2012). Despite the widely shared sentiment that a new round of reforms is needed, considerable differences exist among stakeholders in the diagnosis of the most pressing issues and the appropriate courses of action. Some experts find strong reasons for less regulation and stronger reliance on decentralized market coordination (e.g., Eisenach, 2012; Yoo, 2012) but others identify a need for continued and new forms of interventions in response to the logic of the digital economy (e.g., Bourreau, Cambini, & Hoernig, 2012; Cherry, 2007; Crawford, 2013; Noam, 2010; Wu, 2003).

The main objective of this paper is a review and critical evaluation of the conceptual and practical foundations of public policies, paying special attention to the facilitation of network investment and innovation in advanced communications. We focus on two promising approaches—the theory of platform markets and systems approaches—to assess their potential contribution to the development of a forward-looking framework for ICT governance. To set the stage, section two discusses potential mismatches between the structure and functioning of advanced communication systems and the prevailing paradigm of regulation. Given the importance of multi-sided market relations, section three discusses the notion and regulatory implications of competition in platform markets. Section four revisits the interaction of competition, regulation and innovation from a dynamic system perspective. General implications for the design of a governance framework capable of supporting investment and innovation processes are explored in section five. Specific lessons for communications policy are addressed in section six before the most relevant points are reiterated in the concluding remarks.

2. Reassessing the conceptual foundations of regulation

During the past three decades, in response to national and regional contexts, regulatory practices have been primarily designed and refined to address problems of market failure and deficiencies. The institutional and regulatory reforms put in place since the 1980s have helped unleash and accelerate the innovative power of digital technology. Even though many utopian and visionary expectations were not fulfilled, substantial improvements in metrics such as access and usage, prices, and the number and diversity of available applications and services are observable (Cowhey & Aronson, 2009; OECD, 2013). These observations suggest that the policy model, under the specific industry conditions, helped move the system toward higher performance compared to the prior monopolistic sector organization. The continuing changes in the technological and economic sector conditions beg the question whether this post-monopoly regulatory paradigm continues to be appropriate. Particularly four areas may require reconsideration: the static nature of regulatory theory, the insufficient attention to interdependencies in the ICT system, the assumption of costless regulation, and the endogeneity and co-evolution of regulation and performance.

Regulatory theory has undoubtedly made significant advances during the past decades. The influx of game theory, stronger reliance on formal models, and richer empirical data have added rigor and deepened the understanding of good regulation. At the same time, the theoretical and practical underpinnings of regulation continue to be rooted in static equilibrium models of the economy, with many of its principles derived from the theory of optimal monopoly regulation.

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Classical treatises on regulation typically assumed that the technology and cost conditions of the regulated firm were known and that an optimal intervention could be designed by a benevolent regulator (Berg & Tschirhart, 1988; Kahn, 1970/1971; Phillips, 1965; Spulber, 1989; Train, 1991). Recognition of the problem of asymmetric information and strategic behavior of players resulted in a sophisticated literature on mechanism design and incentive regulation (Hurwicz & Reiter, 2006; Maskin, 2008). Despite these efforts, the legacy of static monopoly regulation reverberates in core aspects, such as the focus on monopolistic market segments and the determination of regulated prices based on long-run incremental costs. Furthermore regulation continues to be conceptualized as a substitute for market forces where competition fails, often approximated by the equilibrium conditions in a perfectly competitive market. This widely shared framing of the nature of regulation impedes the development of a broader perspective of governance as a prerequisite of coordination in highly differentiated socio-technical systems like ICT.

In defense of this mainstream approach one has to recognize that a static, equilibrium-oriented approach is not necessarily erroneous. Whether it is an appropriate abstraction and simplification depends on the character of the system to be represented. If technological and economic change is slow or proceeding along a steady state, an equilibrium model may be a good approximation. Because it is well known and analytically tractable, it can help guide policy choices. However, if a system such as the Internet evolves in dynamic, non-linear fashion, using a static model will be inadequate. The likelihood of erroneous recommendations will be higher in more dynamic and volatile systems. Limited efforts to include the importance of technological change and innovation into the standard approach were made in models of dynamic optimization (e.g., Berg & Tschirhart, 1988). While welcome, these efforts did not build on an explicit theory of the innovation process. Rather, innovation was taken into account implicitly, e.g., as a change in the production function.

A second area in which current regulatory theory and practice fall short of the new reality of ICT markets is the incomplete consideration of the increasing interconnectedness and interrelatedness of advanced communications. Economic theory is not insensitive to these linkages: competition as rivalry, game theoretic models of strategic interactions, notions of substitutability and complementarity of products, and concepts such as externalities and spill-overs all recognize forms of interdependencies. Most recently, new tools emerging from network science have started to pay direct attention to interdependencies among players (Easley & Kleinberg, 2010). Several authors also have suggested that notions from innovation economics or the theory of complex adaptive systems can help provide an appropriate framework (Atkinson & Ezell, 2012; Cherry, 2007; Whitt & Schultze, 2009). Although some of these concepts enjoy increasing traction, they have not yet been employed to develop a systematic instrumental theory of network governance in which the potential direct and indirect effects of intervention are systematically examined and taken into account. This is not necessarily wrong if a problem can be isolated and feedbacks are negligible or weak. Even in highly interconnected systems, not everything is connected with everything else (Bunge, 2000). However, in cases where such effects are relevant, present regulatory theory risks to offer misleading guidance.

A third shortcoming of much of mainstream regulatory economics is the widespread (often tacit) assumption that regulation is costless and efficient. This is a modern version of the public interest theory of regulation, which has been challenged by political-economic theories of regulation since the 1960s. As a theoretical abstraction, this assumption may be justifiable. However, it becomes a problem when policy recommendations are directly derived from a formal model based on the premise. A pragmatic and practical theory of regulation will need to take several types of costs into account. One source of costs that has received most attention is problems associated with asymmetric and incomplete information. Another source is the fact that regulation takes place in an institutional environment that imposes certain feasibility constraints (e.g., certain procedural and majority requirements). Coordination among actors may be time-consuming and not all theoretically imaginable solutions may be practically feasible once political and institutional conditions, such as the presence of veto players that can block a change, are taken into account (Tsebelis, 2002). Consequently, changing status quo ante arrangements is typically afflicted with non-trivial costs that should only be incurred if the expected benefits outweigh them.

Fourth, regulatory decisions are designed to reshape the incentives of players to invest and innovate. In this sense governance choices will become embedded in the material and knowledge base of the ICT system. If changing the existing infrastructure, applications and services is afflicted with switching costs, systems will have to overcome problems of path dependency. How constraining the historical path is will depend on the magnitude of costs to alter it. If these costs are high, lock-in may occur or changes will take some time to unfold in a gradual fashion. Regulatory and other policy changes therefore will have to yield benefits that are larger than the aggregated switching costs. Not only may this be difficult to assess, benefits and costs will often be asymmetrically distributed. Consequently, considerable resistance will be exerted by stakeholders who benefit from the status quo but might lose under alternative sets of rules. Theoretical welfare economics suggests the application of some form of compensation principle (e.g., the Kaldor–Hicks approach) in such situations but the practical implementation may be complicated. Communications policy is rife with such distributional conflicts, including recently debates over unbundling (pitching incumbent network operators against newer entrants) and net neutrality (pitching network operators against content providers).

These arguments suggest that much of current regulatory theory can be considered as a special case of a more general theory of governance of a dynamic adaptive system. Public policy would be improved by asking explicitly whether the static, equilibrium-based approach is appropriate to address an issue. If the potential errors introduced by a static equilibrium framework, the incomplete consideration of interdependencies, and the abstraction from the costs of regulation raise concerns, alternative approaches ought to be considered and a determination has to be made whether they can yield

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superior guidance. The following sections examine two frameworks—the economics of platform markets and systems approaches—that can help overcome some of these limitations.

3. Competition and innovation in platform markets

The theory of platform markets directs attention to the interdependencies among players. Public policy can gain insights in three areas: a better understanding of the effects of structural forms of regulation, the need to broaden the perspective beyond a single side of the market, and a clearer view of the potential costs of asymmetric regulation. The relevance of two- and multi-sided market relations has been recognized for some time (Baxter, 1983; Rosse, 1970) but it is only during the past decade that analytical models are being developed that start to capture their multi-faceted nature more fully. Within the research on platforms, two principal approaches can be differentiated. The management literature looks at platforms as "technological foundations upon which other products, services, and systems are built" (Gawer & Cusumano, 2002). This technological perspective is related to but not identical with definitions that emphasize the economic features of platforms as linking different sides of a market (Rysman, 2009).

A technology-centric view starts from the realization that important high-tech industries, including computing and telecommunications, have adopted modular technological architectures since the 1960s to facilitate coordination between increasing numbers of components. Platforms enable the assembly of complementary modules into the systems needed to create value. In a complex socio-technical system such as ICT, multiple platforms co-exist. Semiconductors enable operating systems, which in turn function as platforms for applications and services. Physical communication networks serve as platforms for information transportation services, which in turn enable applications and services. Likewise, mobile devices can be seen as platforms that enable mobile data communications and the multitude of applications and services built on them. Some platforms are sufficiently flexible to support a wide range of complementary modular technologies and services. Hence they are examples of general purpose technologies (Bresnahan & Trajtenberg, 1995; Helpman, 1998) with a high generative potential (Zittrain, 2008).

Economic models of platform markets recognize these characteristic technological features but broaden the perspective. A particularly compelling definition of multi-sided platforms (MSPs) is provided by Hagiu and Wright (2011, p. 1) who view them as "an organization that creates value primarily by enabling direct interactions between two (or more) distinct types of affiliated customers." Although there is some variation in what are considered the key economic attributes of platform markets, all contributors conceptualize platform markets (often also referred to as two- or multi-sided markets) as special type of intermediation. Early contributions emphasized the presence of direct and indirect network effects between the market sides (Armstrong, 2006; Evans & Schmalensee, 2007; Rochet & Tirole, 2003) but more recent papers point out that such network effects, while often present, are not a necessary condition for an intermediary to be a platform (Hagiu & Wright, 2011). One important economic function of platforms is to reduce transaction costs between participants on different market sides. Where externalities are present, platforms can facilitate internalizing them. In this sense, platforms are institutional arrangements to help overcome forms of market failure and obstacles to market transactions.

A first benefit of a platform perspective is a fresh take on forms of structural regulation. Since the shift from retail to wholesale regulation that started during the 1990s, network operators have typically been treated as input providers. This is evidenced in measures such as the vertical separation of networks and services (Cave, 2006), MVNO and other open platform requirements (Banerjee & Dippon, 2009), and net neutrality (Bauer & Obar, 2014). The economics of platform markets clarifies that input provision is but one type of intermediation in network markets besides operating as a reseller and a multi-sided platform (Hagiu & Wright, 2011). Resellers operate between sellers and buyers so that only indirect transactions between these players take place. Input providers serve only one customer group, they are a one-sided platform. All three organizational arrangements are pervasive in advanced information and communication systems. Given plasticity of the production technology, providers may operate as hybrid organizations that act as multi-sided platforms for part of their operations but resellers or input providers in others. For example, cable service providers act as retailers when selling programming, as platforms in their Internet access services, and possibly as input providers of connectivity to wholesale customers.

In an unregulated market environment, management can choose the form of intermediation that is most profitable. However, structural forms of regulation limit these options and therefore constrain the ability of firms to pursue certain types of business innovation. Platform economics suggests that the welfare effects of such an intervention need to be assessed by looking at its broader impact on the value network and especially the potential costs of eliminating business innovation experiments. In dynamic technology markets, regulatory interventions that limit the scope of organizational innovation deserve particular scrutiny as they undermine the experimental process underlying innovation. Hence, vertical separation may have negative effects on network operators' innovation decisions and may also impede coordination and knowledge transfer with application and content providers. Both effects may result in lowered innovation activity. This is not to say that there may not be scenarios where such approaches are warranted. The economics of platform competition provides a more appropriate framework to assess the costs and benefits of such measures.

A second lesson for regulation emanates from the explicit analysis of interdependent markets offered by platform economics. Multi-sided platform players optimize profits by looking at all related market sides simultaneously. Given the pervasive presence of high fixed and low incremental costs, platforms will need to differentiate service quality and prices. Unlike in textbook competitive markets, prices in multi-sided platform markets will typically not be in a well-defined

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relationship with the incremental costs. Platform providers may charge prices from both market sides or only from one side. Consequently, mark-ups and profit margins may vary considerably. Regulatory policies constraining the ability of platform providers to vary and optimize prices across all market sides, such as a prohibition of certain types of pricing plans like data caps, will affect experimentation, innovation, and potential efficiency gains associated with platform markets. Not surprisingly, most contributions to the economics of network neutrality find that some form of differentiation is beneficial for static and dynamic efficiency (Krämer, Wiewiorra, & Weinhardt, 2013). Platform economics also suggests a different perspective on the pricing of access and of unbundled network elements. If a network operates as a platform, the prevailing approach of pricing such services at retail-minus-direct costs or at some form of long-run incremental cost basis may be inappropriate. Thus, regulatory policy designed by looking only at one market will typically be flawed (Eisenach, 2012; Evans, 2012).

A third lesson for public policy is related to the asymmetric treatment of players with market power. Since firms in platform markets are subject to threats from a wider range of players, a strong market position is more vulnerable and contestable than in other settings. Nonetheless, one cannot derive from platform economics that markets always work. Even though it may be more difficult to assess accurately, market power continues to be an issue (Evans & Schmalensee, 2007). Because of the historically constrained remit of regulation, it focuses on market power in access markets. In the broader ICT system, market power may reside in complementary markets as well, including search and access to content. Although these activities are subject to competition law, this bifurcated approach creates an asymmetry among players that does not have a strong rationale in economic theory (Eisenach, 2012). In dynamically evolving markets, a more symmetric approach will often be superior. However, this does not necessarily imply that regulation should be replaced with antitrust oversight as many have asserted, but it could also call for the expansion of regulation so that all players in a certain type of activity are covered.

Innovation in platform markets unfolds in interplay between innovation at the platform level and innovation in the related market sides. Digital technology is malleable so that some innovation is possible independent of advances in complementary activities. Consequently, innovation in interdependent areas can evolve in asynchronous fashion, with one segment temporarily taking a lead over others. For example, developers can unilaterally explore a vast design space associated with a given network platform. Similarly, network operators have incentives to upgrade the platform without fully knowing future demand and the direction and attractiveness of complementary innovations. Nonetheless, plasticity has bounds; platforms and affiliated market sides need to move in compatible ways lest the risk increases that lack of innovation in one area constrains innovation opportunities in related areas. In unregulated market environments, many of the required coordination tasks can be achieved by decentralized decisions and negotiations. This process may not always be smooth and may go hand in hand with waste in the form of transaction costs and unsuccessful innovation attempts. Despite such transaction costs, it will often work better than alternatives. However, sometimes a decentralized process fails to reach efficient coordination or it collapses altogether. This is more likely in cases of coupled radical innovations. Thus, innovation research continues to emphasize that there is a potential role for the public sector to facilitate and coordinate large-scale, systemic innovation processes (Bauer, Lang, & Schneider, 2012).

4. Competition and innovation in a systemic perspective

The theory of platform markets refocuses the analyst to new forms of intermediation in digital markets. However, competitive interactions often have broader scope and the relations between players are more multifaceted and indirect. Studying innovation processes, Fransman (2010) speaks of "symbiotic" relations among the players in the different layers of the advanced ICT system. These pervasive interdependencies have prompted researchers and stakeholders to increasingly refer to an "ecosystem" when describing ICT (Fransman, 2010; Longstaff, 2002; Whitt & Schultze, 2009). Adopting a system-theoretic framework offers additional insights for the design of public policy. The main strength of this approach is an emphasis on four aspects of dynamic systems that are incompletely addressed in the ICT literature: systemic interrelatedness that goes beyond complementarity and substitutability, attention to complex patterns of feedback and non-linear developments, awareness that important performance characteristics of the ICT system are emergent properties that cannot easily be traced back to a micro-level of decision-making, and the existence of multiple dynamic equilibria of such systems. Moreover, the framework builds a bridge to recent notions of digital innovation as continuing experimental learning process (Antonelli, 2008; Bauer, 2012; Brynjolfsson, 2011).

Going beyond platform economics, an ecosystem perspective provides, first, a novel framework for the analysis of the multi-faceted value network of advanced information technologies. That economic relations in markets are more diverse than suggested by traditional competitive analysis has been recognized for a long time by institutional economists. Only during the past two decades have these insights been absorbed into the mainstream of managerial economics and game theory, as evidenced by notions such as co-opetition (Brandenburger & Nalebuff, 1996), disruptive competition (Christensen, 1997), as well as models of structural holes and niche competition (Burt, 1992; Kim & Mauborgne, 2005). An ecosystem approach widens the lens beyond these more differentiated accounts to other forms of symbiotic interdependencies (Fransman, 2012; Longstaff, 2002). These have been studied in great detail in biological ecosystems but can also be found in socio-technical systems. Players can be in *mutual* relations that benefit all of them, in *commensal* relations where one player benefits without harming others, in *amensal* relations whereby one is harmed whereas the other is unaffected, and in *parasitic* relations in which one player wins at the expense of another. An interesting insight from the analysis of ecosystems

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is that all these relations, as long as they are within acceptable boundaries contribute to the working and improvements in fitness of the system as a whole. By analogy, this suggests that diversity of institutional arrangements is a form of higher-level competition that allows learning about their efficiency implications and is hence beneficial to the working of socio-technical systems and needs to be supported by appropriate institutional design.

System perspectives, second, direct the analyst's attention to non-linear processes, which are often the outcome of indirect feedback effects that amplify and accelerate or reduce and slow down processes. Non-linear diffusion processes have been widely used to study the effects of policy decisions on the speed of broadband adoption (Gruber & Koutroumpis, 2013; Lee, Marcu, & Lee, 2011). But other forms of non-linearities are relevant as well and observable in highly connected network industries. Many features of the Internet, such as the number of links associated with a node (degree), the messages sent by nodes, and the revenues associated with digital products follow power law distributions. Information, both desirable and malicious, spreads in non-linear fashion through networks with such characteristics (Barrat, Barthélemy, & Vespignani, 2008; Easley & Kleinberg, 2010; Pastor-Satorras, Vázquez, & Vespignani, 2001; Pastor-Satorras & Vespignani, 2004; Van Mieghem, Omic, & Kooij, 2009). Information cascades and messages or products "gone viral" are other examples of such processes.

In a highly interconnected system, any regulatory or governance action will have indirect effects in addition to the direct effects. The sign of these indirect feedbacks will often deviate from that of the direct effects. For example, unbundling measures will increase the incentive of new entrants to invest in complementary assets (but not necessarily core network assets) and reduce the incentive of incumbents to invest in network upgrades. Moreover, the strength of these effects will depend on the details of regulation. The overall net effect is therefore dependent on whether the direct and roundabout positive or negative effects are stronger. Examining the European telecom market, Grajek and Röller (2012) found evidence that the negative effects on investment were stronger than the positive effects. Overall, unbundling reduced infrastructure investment in the aggregate. Similar positive and negative effects exist with regard to the decision to migrate from copper loops to fiber networks (Bourreau et al., 2012). Bauer (2010b) showed that this is a generic feature of interrelated systems. Regulators and other policy makers face the challenge to develop an appropriate understanding of the magnitudes of direct and indirect, positive and negative effects when calibrating decisions, no small task in systems with many interdependencies.

Third, in dynamic, highly connected systems such as the Internet, performance characteristics measured at an aggregate level are emergent outcomes of myriad interactions of agents. Whereas traditional economics has sought to provide a micro-foundation for macroeconomic processes by building theories around representative agents, an ecosystem approach explicitly recognizes the heterogeneity of players and their differential capabilities to interpret their environment and respond to it. Agents seek to maximize their own "fitness," a general metric expressing how well they do relative to other agents given a specific environment. Adaptive and other evolutionary learning strategies are employed to increase agents' "fitness". Moreover, under certain circumstances, decision-making by decentralized yet interrelated agents—termed "patching" by Stuart Kauffman (1993)—may be a good mechanism to improve the performance of the system overall (e.g., Cherry, 2007; Post & Johnson, 1998; Teske, 1995). How well agents do will typically only be revealed ex post when the implications of having adopted a specific course of action will become apparent. As species in ecosystems optimize fitness relative to their environment, evolutionary processes do not necessarily lead to performance improvements relative to an absolute goal (e.g., welfare maximization). Furthermore, evolutionary economic processes are not necessarily associated with improvements (Nelson & Winter, 1982). In fact, they can be associated with overall deterioration if the environmental conditions nudge the system in that direction (Hodgson & Knudsen, 2006, 2010). One critical role of public policy then is to design an environment in which evolutionary processes driving agent fitness are aligned with performance improvements of the system overall. The specific attributes of a framework that achieves this alignment are not fully understood.[1]

Fourth, dynamic systems typically are characterized by multiple equilibria (Day, 1999; Rosser, 1999). The existence of multiple equilibria is well-known from game theory. In systems theory constellations toward which a system converges are termed "attractors". Such positions may be stable or they may be unstable ("strange"), in which case a system may oscillate around multiple states (Room, 2011). By analogy, this suggests that the quest for a best practice regulatory approach in ICT may be somewhat elusive, as different constellations of environmental conditions, players, and their interaction will likely result in distinct equilibria with different performance characteristics. International comparisons reveal abundant empirical evidence of multiple stable combinations of policy choices and their different performance implications. For example, the European regulatory framework with its stronger reliance on unbundling for access networks seems to have helped accelerate the diffusion of broadband within a generation of technologies but slowed network upgrades to next generations. In contrast, the US system with a lower degree of regulatory intervention has experienced higher rates of investment in network upgrades but the rollout is strongly driven by commercial appeal and adoption in some areas has been slower than anticipated (see Bauer, 2013 for a more detailed comparison).

Schneider (2001), in a pioneering study, applied an evolutionary framework to the historical transformation of telecommunications during the twentieth century. In his analysis, monopoly and regulated competition are alternative attractors but the study does not examine the co-existence of attractors in different countries and regions. Recent

[1] Unregulated market coordination is one example of such a framework but it falls short of many of the coordination tasks that need to be achieved in advanced communication systems.

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observations suggest distinct characteristics of models adopted in the US, Europe, and Asian countries. A critical question for policy makers is whether their actions are limited to affecting performance within the vicinity of the prevailing equilibrium or whether they can orchestrate all the necessary steps to move the system to a different attractor with more desirable performance features. Forcing such a transition with strong interventions affecting the entire system (e.g., a radical redesign of the legal and regulatory framework of communications) may be a strategy with largely unknown outcomes. To avoid the high risks of unanticipated consequences from system-wide policy interventions, Bunge (2000) suggested to test such policies locally if this is feasible.

5. General implications for regulation and governance

Interest in the implications for ICT governance of the economics of platform markets and the more general ecosystem approach developed in several, largely separate discourses, since the late 1990s. These discussions have started to reveal important consequences for regulatory policy in general and an innovation-oriented ICT policy in specific, although many details remain to be worked out. Recent evolutionary views of innovation as an experimentation and learning process and the insight that interrelated forms of innovation flourish under different regulatory and market conditions have raised the question of how good regulation and governance can be designed and implemented. From an examination of the lessons that can be derived from the economics of platforms and of ecosystems, important strengths and weaknesses of these alternatives to traditional regulatory economics have become visible (see Table 1). This section will briefly review the main points of this discussion. Although the explanatory frameworks are distinct, many of the policy recommendations point in similar directions and are largely consistent.

Interestingly, policy repercussions following from the economics of platforms were first explored by legal and communication scholars. Starting point of these analyses was the convergence discussion of the 1990s, which pointed to the potential costs of sector-specific legal and regulatory frameworks that were at odds with digital communications and the gradual migration to IP-based networks (Baldwin, Mcvoy, & Steinfield, 1996; Latzer, 2009). Many experts concluded that communications law and regulation would best respond with a horizontal, layered framework that was technologically, competitively and provider neutral (Werbach, 2002). This approach was based on specific assumptions of how communications technology would develop that have only partially turned out to be true. Although the three neutrality principles are in many ways superior to the historical technology- and market segment-specific regulatory framework, the ICT system has evolved further toward diversified, multiple horizontal and vertical arrangements.

Although constituting the core of the Internet, the open layered architecture is overlaid by specialized networks and services. The more endemic legal and regulatory challenge in this environment of convergence is the coordination of regulation, antitrust, and intellectual property rights law (Weiser, 2002; Whitt, 2007). Both antitrust and intellectual property law recognize that temporary market power may be beneficial to innovation. Regulation, however, continues to focus on the presence of market power as a criterion for ex ante intervention. Although some efforts are visible to differentiate desirable from undesirable forms of market power (e.g., in the revisions of US unbundling regulation, in the EU approach to delineate areas in which ex ante regulation is permitted), regulatory practice follows a much more rudimentary approach than antitrust and intellectual property law.

Early discussions were based on notions of information platforms as enablers of complementary services and innovations. During the past decade, insights from the more specific economics of platforms also were absorbed into regulatory analyses. Farrell and Weiser (2003) focused on the vertical relations in the ICT system, explaining that platform operators have incentives to allow open access to providers of complementary services because they enhance the value of

Table 1
Frameworks for the design of ICT governance.

	Economics of regulation	Economics of platforms	Economics of ecosystems
Foundations	Industrial organization, institutional economics	Industrial organization	Innovation economics, complex adaptive systems theory
Modeling assumptions	Representative agents, optimal choices, information constraints, equilibrium	Representative agents, interdependencies, optimal choices, information constraints, equilibrium	Heterogeneous agents, incomplete information, optimization of fitness relative to environment, emergent properties at system level
Relevance	Static or steady-state technology, repeated actions in stable environment	Interdependent agents, optimization in a context of multiple market and non-market relations	Dynamically evolving system, rapid and non-linear change, complexity
Strengths	Formal models, need to make assumptions transparent	Analysis of interdependencies in digital markets	Strong mathematical foundations, general dynamic theory of systems behavior
Weaknesses	To keep models tractable, assumptions may be overly simple	Difficulty of dealing with more general, dynamic forms of interdependencies	Difficult to validate models, tendency to use in metaphorical form
Practical applicability to ICT governance	Comprehensive set of practical tools and best practices, embedded in current knowledge base of regulators	Some experience in antitrust cases, limited application in regulation, modest knowledge base among practitioners	Applied as metaphors, experiments with agent-based and computational modeling, limited knowledge base in regulatory practice

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their access services, an effect that the authors label Internalization of Complementary Externalities (ICE). In many situations, ICE will therefore align the incentives of vertically related players in platform markets. However, Farrell and Weiser also note a number or exceptions in which this alignment is interrupted and policy intervention may be warranted, e.g. where a complementary service is also a substitute for a service offered by the network platform.

Starting from the economics of platforms and the dynamic and systemic nature of competition in markets with modular architectures, Eisenach (2012) concludes that there is no defensible reason for ex ante regulation of broadband services and ex post antitrust scrutiny of information technology services. While correct in many ways, the conclusion seems overly broad as the existence of interdependencies per se is not sufficient to establish sole reliance on antitrust. Some intermediate role for regulation may be justifiable, although it will often be advantageous to apply it symmetrically to all players. Moreover, properly designed regulation will have to take the interdependencies between players into account and assess the effects of a possible intervention on all interrelated market segments rather than just one market relation (Beltrán, 2012; Evans & Schmalensee, 2007).

Adding to earlier contributions to the theory of complex adaptive systems, Bauer (2004), Cherry (2007) and Whitt (2007) started to derive specific implications for policy. Cherry reiterates Kauffman's point that decentralized experimentation can be utilized by a higher-level policy maker to enact superior policies. Such experimentation can occur across nations or within nations (or one regulatory environment). Both are, to some degree, now regularly utilized to adapt and improve regulatory arrangements as policy-makers and other stakeholders are able to compare approaches and outcomes (even though deriving clear conclusions is not an easy task). Institutional diversity within a nation allows to experiment with different implementations (as has historically been done in the US at the state level, e.g. Teske, 1995), again facilitating an institutional learning process. Whitt develops specific guidelines for regulatory action based on a framework denoted "emergence economics" that draws from a diverse body of contributions in innovation economics, the theory of complex adaptive systems, and the literature on ecosystems. He recommends nine principles for adaptive policy-making, which ought to be cautious, macroscopic, incremental, experimental, contextual, flexible, provisional, accountable, and sustainable (Whitt, 2007, pp. 495). Adaptive policy should be enabling rather than "dictating", which can be achieved by measures that support innovation and choice, foster institutional and infrastructure connectivity, build incentives and trust, and transparency and accountability (Whitt, 2007, pp. 573).

6. Lessons for communications regulation

These are pertinent and interesting recommendations but the economics of platforms and a systemic approach offer additional insights for communications policy. As is to be expected in new areas of inquiry, they remain relatively abstract and generic, with details of implementation not yet worked out. With regard to proposals for adaptive regulation, one concern is that many policies cannot be changed continuously in response to the state of the system, even if this might be the appropriate strategy. Actors whose decisions were shaped by past regulatory choices may face considerable adaptation costs so that new initiatives often face resistance unless there is a way to pay off players who suffer costs and other disadvantages. Moreover, regulation itself is a process that is time-consuming and costly. Apart from the inertia of changing existing rules, it cannot be taken for granted that stakeholders will agree on the right course of action. Thus, policy-makers may not be in a position to implement sophisticated and precise analytical recommendations for dynamic regulation. This is true for government regulation but also for other forms of coordination, including forms of multi-stakeholder governance.

A first additional lesson from both the economics of platforms and ecosystem approaches is that public policy makers need to take interdependencies explicitly into account. However, even in highly connected systems not everything is connected to everything else in equally strong ways (Bunge, 2000). Only where indirect and feedback effects are strong, focusing on one element (e.g., unbundled local loops, an API) may lead to erroneous policy interventions. Where such links are weak, a more narrowly construed approach may be appropriate. Therefore, a first step in the process of policy design is to identify the relevant interdependencies. Some subsystems of players or some performance metrics could be more strongly interrelated than others. For example, in information security, some vulnerabilities (e.g., untargeted attacks) depend on the weakest player (node) whereas others (e.g., targeted attacks) will depend on the efforts of an individual player (node) (Varian, 2004). Likewise, the literature on local loop unbundling suggests that well-intended policies that do not take broader effects on investment and innovation of all players into account risk to inadvertently suppress them (Grajek & Röller, 2012).

Platform economics and an ecosystem perspective, secondly, reveal that advanced communication systems consist of multiple interrelated platforms. In such systems, network effects and spill-overs are pervasive. While this does not imply, as some have suggested, that any form of regulation should be replaced by antitrust oversight, it is a strong argument in favor of symmetric treatment of all players. Where potentially distorting market power prevails or where it is abused, be it in network access, operating systems, restrictively held patents, or content, it may need to be addressed. Sole reliance on competition law may be insufficient to tune this system to peak performance as the discovery process used by antitrust enforcement often is slow and burdensome. Therefore, an approach may be superior in which overarching goals of communications policy are established as a basis for regulatory enforcement ex post (Yoo, 2012). Regulation is invoked if violations of the principles have occurred. Because guidelines are in place, action can take place quickly. At the same time, these guidelines provide focal points that align actors' actions and business strategies with the overarching goals of the policy framework.

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This policy design is fully in line with the most important, third, lesson from ecosystem approaches: that players seek to improve their fitness relative to their environment. Whether the overall system performance will increase or not therefore depends to a high degree on this environment and the incentives it provides. Some dimensions of this environment can be designed by society, other aspects are endogenous to player interaction, and yet others are external and hence beyond the control of policy-makers. An ecosystem approach therefore focuses our attention on the constitution of markets and non-market activities. The importance of the overarching "order" in which economic transactions take place has been sensed and analyzed by authors such diverse as Smith (1759), Hayek (1960), Eucken (1950), and constitutional economists such as Vanberg (2001). It is also a recurring theme in institutional economics (Groenewegen, Spithoven, & van den Berg, 2010). All these approaches have in common that they recognize that markets do not exist in a vacuum but that they are embedded in an institutional fabric of voluntary and collectively agreed arrangements. Actors pursue their goals within the framework of these rules, which therefore are of immediate consequences for the overall performance of the system.

This fundamental insight reveals that much of the current policy debates and implementation, which narrowly construe regulation, may miss the point. What is needed is a rethinking of the broader, overarching framework of advanced communication markets that reflects their new technological and economic conditions as well as foundational values and concerns. Admittedly, given the constraints of successful legislative action, overarching reforms will be difficult. Yet, it may be possible to address and design such broader principles in a more piecemeal fashion. Such an approach also allows overcoming the difficulties, mentioned in the previous section, of adaptive regulation. Rather than envisioning regulation as a continuously adapting form of public intervention—an utterly idealistic vision of how regulation could function—one could embed important principles of organizing the information and communications infrastructure in the legal and regulatory environment of markets. A precondition for such an approach is the establishment of the overarching principles that should guide communications.

Defining them is inherently a political process that ought to involve a broad set of stakeholders interacting in multiple settings from voluntary networks to multi-stakeholder settings to traditional government institutions. The specific content of these principles may vary between nations and regions and not all of it may be universally achievable. There are some common elements, though, at least among nations with a strong belief in human and individual rights: freedom of expression, conditions that allow innovation in networks and services, openness of communication systems and flows, interoperability, ubiquitous access to networks, services, and devices, and some inalienable user rights (e.g., the right to access legal content of their choice). A challenge will be to pursue these goals simultaneously by coordinating policy instruments. For example, Bauer and Obar (2014) analyze how political and economic objectives can be pursued with combinations of policy instruments.

This leads to a fourth novel conclusion. Complex interdependent systems typically are not only coordinated by one mechanism. Most well-working biological and socio-economic ecosystems are best described as a panarchy: "an interlinked system of systems in which hierarchical and non-hierarchical elements are linked in continual motion of innovation, growth, adaptation, and renewal" (Gunderson & Holling, 2002). If this also holds for socio-technical systems, it suggests that a robust governance system might be one that combines multiple institutional forms, including multi-stakeholder approaches, spontaneous forms of voluntary coordination, and also traditional government regulation, each in areas where they are most appropriate. Consequently, despite its current appeal, multi-stakeholderism is not a privileged, best mechanism to address all governance issues that arise in advanced communications (Bauer, 2006; Latzer, Just, Saurwein, & Slominski, 2003). Market power, cybersecurity, universal service, and numbering each will best be addressed in different institutional arrangements. Likewise, institutional diversity facilitates evolutionary learning processes. For example, the coexistence of commercial and not-for profit access networks, one driven by profit motives the other by a broader set of public interest goals, allows a comparison of the implications of these institutional arrangements for performance that could not be realized otherwise. Hence, the analysis of ecosystems suggests advantages of a diverse multi-institutional environment. Coexistence and rivalry between institutional arrangements, much like competition and co-opetition in the market place, is a powerful arrangement for learning and adaptation. In this sense, it can be considered a meta-level precondition to high performance in complex socio-technical systems that is superior to efforts aiming at finding a "best" single institutional arrangement (Jessop, 2002).

A final lesson from platform economics and system approaches is that public policy interacts and co-evolves with other factors in ways that often cannot be fully anticipated but whose effects only can be discerned after the fact. National and regional policy-makers regularly make seemingly rational decisions that turn out to be wrong in hindsight. Consequently, nations and regions may experience long periods of weak performance that may be difficult and costly to overcome. For example, in the US, divestiture of AT&T took place along local-long distance market boundaries that were not sustainable. The country spent more than a decade to allow firms to reintegrate, at considerable resource cost to the economy and possibly the temporary loss of leadership in communications markets. Of course, it is an idle exercise to speculate how things could have evolved differently. Many European countries are stuck in a situation, induced by prior regulatory choices, in which investment in next generation networks and technologies is weak. On the other hand, Japan, which invested early and swiftly in fiber optical technology, may suffer from the problem of being a "leader without followers" at the expense of considerable direct and indirect economic cost (Kushida, 2011).

Although poor policy choices cannot be fully avoided, their effects could be mitigated if policy analysts were to more systematically use techniques that can help identify and avoid undesirable outcomes. Techniques that can be employed to this end in advance of an action include scenario building, the use of computational methods to explore alternative courses

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of action, pattern forecasts based on big data analytical methods, and the systematic learning from experiences in other countries and regions (Bauer, 2010a; DeMaagd & Bauer, 2011; Room, 2011). It would help if policy analysts were to explicitly seek to identify potentially harmful feedbacks and explore more systematically things that could go wrong. All these exercises could contribute to more resilient policy design (De Vries, 2011). Moreover, in a dynamic adaptive system regular collection of metrics and their systematic and continuous analysis gain in importance (Napoli & Seaton, 2006). Unfortunately, the collection of data that would allow thorough evaluation of policies is too often seen as a waste of resources and an additional burden. This is a regrettable situation as it complicates and even undermines learning from experience. Data harvested from the networks might in future be able to generate some of the needed information but additional monitoring and review is indispensable.

7. Conclusion

This paper has raised more questions than can be answered given our present state of knowledge on the governance of dynamic socio-technical systems. Changes that have unfolded in the past decades have altered the economic characteristics of the ICT system, often in conflicting directions. Modular digital technology has expanded the space for innovation opportunities, as continuous experiments can contribute to steady improvements of products and services. Many modular innovations can be carried out with modest resources by small and medium-sized firms. At the same time, innovations that require coordination of a complicated value network and high investment upfront have also grown in importance. Consequently, innovations that reduce the inherent economies of scale and scope of networked technologies go hand in hand with innovations that generate considerable economies of scale and scope, resulting in high market concentration in important segments (Noam, 2009). Furthermore, the fusion of computing and connectivity has resulted in a production technology of high plasticity and generativity that has changed the dynamics of competition.

Traditional regulatory analysis captures these features only in an incomplete fashion. Much of regulatory economics continues to be based on a static equilibrium analysis, often focused on narrowly defined markets. This is not necessarily wrong if interdependencies among players are weak and the technological conditions are either static or steady state. If this is not the case, the recommendations based on traditional regulatory analysis may be misleading. The economics of platform markets helps overcome some of these problems by encouraging the analyst to take the relevant interdependencies among players connected by a platform into account. The further-reaching ecosystem approach pays attention to broader interdependencies that affect the nature and intensity of competition. It also recognizes explicitly that in a dynamic, interdependent system regulation does not fully control outcomes and often may have unintended, positive or negative, consequences. Furthermore, an ecosystem approach sharpens the view for the multitude of mechanisms that are in place to govern such dynamic systems.

Both approaches yield strong arguments in favor of adaptive governance, in which continuous monitoring of outcomes is used to fine-tune policy. One such policy approach is competition and antitrust supervision. However, sole reliance on antitrust overlooks that competition takes place within an institutional framework that influences outcomes. Recognizing this point squarely focuses communications policy on re-thinking the overarching principles that should govern private and public ordering. As in the past, interoperability, interconnection, universality, and user rights will most likely be important components but they will have to be re-conceptualized for the new environment. Given the massively computer-mediated nature of advanced communications policy can take lessons from the governance of other ecosystems. One important insight is that the overall system benefits from allowing multiple institutional arrangements to coexist, as this will facilitate higher-level learning process and enhance resilience. Neither the theory of platform markets nor the ecosystem approach has yet resulted in a set of practical guidelines that could be implemented without further work by regulatory agencies. Yet they offer alternatives to the prevailing regulatory mainstream and, with additional effort, promise to inform governance frameworks that are in line with the conditions prevailing in advanced communication systems.

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