Governing the Mobile Broadband Ecosystem*

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**ABSTRACT**

The number of users accessing the Internet via mobile devices and mobile broadband is increasing rapidly. Keenly aware of the considerable economic and social effects of mobile broadband many countries are searching for policies that can boost their benefits for society. Designing such a framework is complicated by the dynamic technological change and pervasive interdependencies among players in the advanced mobile communication system. Established regulatory theory and practice may not provide reliable guidance because they are rooted in assumptions and conventions that do not appropriately reflect these new technological and economic conditions. Moreover, how government and non-government forms of coordination (“governance”) affect outcomes is complicated by the existence of non-linear direct and indirect effects whose net impact on performance is not well understood. This article explores these challenges conceptually and outlines a roadmap for rethinking the governance of mobile broadband.

Key words: Mobile broadband, Mobile Internet, General purpose technology, Innovation, Mobile broadband policy, Adaptive regulation

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I. INTRODUCTION

The Internet is increasingly accessed using mobile devices. In high income countries, fixed and mobile broadband are complementary access platforms for the majority of users. Mobile broadband is often the only available alternative in middle and low income countries given the lower cost of rolling out mobile networks and the poor development of previous generations of fixed infrastructure. In contrast to fixed broadband access, which is typically subscribed to at the household or firm level, mobile broadband is subscribed to by individuals. Keeping this difference in mind, the number of mobile broadband subscribers is the fastest growing segment of advanced communications markets. By 2015, there were 7 billion cellular subscribers worldwide, corresponding to an adoption rate of 96.8%. Globally, the number of mobile subscriptions exceeded the number of fixed subscriptions in 2007. By 2015, the mobile broadband adoption rate had reached 47.2% compared to a 10.8% penetration rate for fixed broadband (ITU, 2015). Predictions anticipate that by 2018 80% of the global population will have mobile broadband access (GSMA, 2013).

Despite staggering global and national growth rates there continue to be significant differences between countries. Among the 34 member nations of the Organisation for Economic Co-operation and Development (OECD), adoption by mid-2014 varied from 32.9 mobile broadband subscriptions per 100 inhabitants in Hungary to 131.6 per 100 inhabitants in Finland (OECD, 2015). Research on fixed broadband suggests that a multitude of factors influence broadband adoption, including the intensity of competition in the market, income, socio-demographic conditions, and public policy (Bouckaert, Van Dijk, & Verboven, 2010; Cambini & Jiang, 2009; Gruber & Koutroumpis, 2013). However, few studies are available that examine these factors for mobile broadband adoption and, given the different technological and market conditions, findings from fixed broadband probably cannot be directly applied without further examination. The importance of mobile broadband and its potential economic and social benefits raise the question of whether and how public policy can facilitate mobile broadband adoption and the innovation dynamics of the sector.

An answer to this question needs serious conceptual and empirical analysis. Broadband policy is strongly rooted in traditional concepts of industrial organization.
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and regulatory economics. Much of this work is based on game theoretical analyses of firm behavior and of the resulting equilibria in well-defined markets. Likewise, policy practice is based on conventions and uses historically tested instruments that originate in static economic theories of monopoly regulation. Policies based on these practices may or may not be appropriate for the current generations of technology given that mobile broadband markets are technologically dynamic, highly interrelated, non-linear, and systemic in nature. It is not entirely accidental that the Internet is governed by a very different set of bottom-up processes and organizations with rather limited government participation, often referred to as networked governance. The mobile Internet is likewise shaped by many such forms of non-government coordination. Reflecting these dual components of policy in the mobile Internet, this article uses the lens of governance theory, which encompasses both governmental and non-governmental forms of policy (Mueller, 2010; Mueller & Van Eeten, 2013). An assessment of prevailing governance and of available alternatives has to start with a fresh look at the characteristics of the mobile broadband ecosystem. A next step is a keen analysis of how the many policy instruments that are employed interact with this system and whether they can achieve the desired goals. From these insights it is possible to rethink the roles and instruments of mobile broadband policy.

To systematically discuss these issues, this article is structured as follows. The next section analyzes the economic and technical features of the modern mobile broadband system. Section three is dedicated to a discussion of the role of governance of the broadband system. Section four discusses principles of governance in the dynamic mobile broadband system, illustrated with the example of mobile network neutrality. Concluding thoughts and a recap of the main points are offered in section five.

II. THE MOBILE BROADBAND ECOSYSTEM

Due to the increasing reliance on digital technology, the value network of advanced communications looks very different from that of earlier services. Emerging at different points in time from the nineteenth to the second half of the twentieth century, broadcasting, telephony, cable TV, satellite communications, and mobile communications initially used specialized technologies, engineered and optimized
for narrow sets of communication purposes. The telephone system was built to provide high-quality voice communications. Thus it did not need more than narrow bandwidth in the access networks. Voice traffic was aggregated at higher levels of the system, such as the regional and national long distance networks, into higher capacity technologies including coax cables, microwave, and later fiber optical networks. Likewise, cable TV was initially engineered to optimize the one-way distribution of video from a headend to subscribers. It was from the beginning configured as a multi-channel—hence broadband—environment but early systems did not offer two-way communications capabilities. Given the low spectral efficiency of early generations of wireless communications, mobile services also were initially configured to support a narrow set of voice and very limited wireless data services. The same was true for other forms of communications, such as data communications (leased lines) and satellite communications. The value chain was largely linear in that a specific network and terminals supported specific services.

Two waves of convergence started to change this, driven by exponential performance improvements in digital technologies (captured in regularities such as “Moore’s Law” and “Cooper’s Law”) (Diamandis & Kotler, 2015). Beginning in the late 1960s with the emergence of data communications computing and telecommunications started to use similar digital core technologies in a broad range of new services often referred to as “telematics”. As the performance of semiconductors, computers, networks, storage, devices, and software further improved, all kinds of information from voice to audio to video also were increasingly processed in digital formats. Consequently, telematics and media started to integrate into what is sometimes referred to as “mediamatics” (T. F. Baldwin, McVoy, & Steinfeld, 1996; Latzer, 1997, 2009). These developments were accelerated by the gradual evolution of the Internet from a platform for scientists to a widely adopted communications infrastructure. Most of the traditional telecommunications technologies and the business and regulatory principles to govern them were developed in a top-down, government-led fashion nationally and internationally. In contrast, the Internet evolved in a bottom-up process from pragmatic decisions of computer scientists, engineers, and visionary innovators. As the Internet expanded worldwide, an increasing number of organizations were established to coordinate standards, protocols, numbering and address issues such as security, openness, and so forth. These include the Internet Corporation for Assigned Names and Numbers (ICANN), the Internet Engineering Task Force
(IETF), and global forums such as the World Summit on the Information Society (WSIS) and the Internet Governance Forum (IGF). Different from traditional institutions, such as national ministries of communications, national regulatory agencies (NRAs), and the International Telecommunication Union (ITU) these bodies have governed the Internet in a global, formally and non-formally networked, fashion largely outside of the forums dealing with traditional telecommunications regulation (Mueller, 2010). Only recently has the International Telecommunication Union (ITU) sought to reassert additional jurisdiction over Internet matters, an effort that has met considerable resistance from many countries.

**Figure 1** The mobile broadband ecosystem

The Internet offered a radically different and appealing technical solution to support a large range of digital communications processes and services. Key Internet technologies were deliberately developed as a set of open protocols and standards to allow communications across technologically heterogeneous physical networks. These efforts resulted in the Transmission Control Protocol/Internet Protocol (TCP/IP), which provides a logical layer that integrates the historically different telecommunications technologies into a network of networks, a seamless
all-IP communications infrastructure. Moreover, the modularity and layered architecture of the Internet in combination with the end-to-end principle has turned out to be a highly generative environment in which innovation flourishes (Van Schewick, 2010; Whitt, 2007; Whitt & Schultze, 2009). All-IP network infrastructure is a general purpose technology (GPT) (Bresnahan & Trajtenberg, 1995) on which a wide range of applications and services can be configured, typically at the upper layers of the Internet. Network infrastructure, devices, applications, and services evolve in a mutually enforcing cycle of enabling and constraining each other (Bauer & Shim, 2012).

Mobile broadband is part of that integrated communications infrastructure and needs to be analyzed in this broader context. This has several implications for the economic conditions of mobile broadband markets and how they can best be governed. A first important aspect is the many interdependencies that exist in this network of networks. Mobile broadband networks are in multiple complementarity and substitutability relations with fixed and other wireless platforms. In the core network, fixed and wireless platforms are largely complements, with wireless technologies increasingly used on the edges of the fixed networks, which will continue to serve as the workhorses of the Internet. In access networks, mobile and fixed platforms are substitutes for some users, uses, and locations in that mobile broadband is used instead of fixed broadband. For others, they are complements with strengths and weaknesses (e.g., ultra-high bandwidth of fixed networks, wider coverage and mobility of wireless networks).

In advanced communication systems there are also interdependencies with players in vertically related markets. For example, applications such as WhatsApp or Kakao that are configured at higher layers of the Internet and are offered on top of a broadband connection have become strong substitutes for mobile voice and text services. This has opened new and dynamic competitive relations between network operators that have to recover high network investment costs and app providers with much lower investment and operating cost, a situation that lends itself to forms of disruptive competition (Christensen, 1997; Christensen & Raynor, 2003). In many other cases, networks and applications are strong complements, linked in new economic relations among players that are often referred to as platform or multi-sided markets.

The management literature looks at platforms as ‘technological foundations upon which other products, services, and systems are built’ (Gawer & Cusumano,
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). From an economic perspective, multi-sided platforms (MSPs) can be seen as “an organization that creates value primarily by enabling direct interactions between two (or more) distinct types of affiliated customers” (Hagiu & Wright, 2011, p. 1). Although there is some variation in what are considered key economic attributes of platform markets, all contributors conceptualize platform markets as special type of intermediation. Often platform markets are characterized by the presence of direct and indirect network effects between the market sides (Armstrong, 2006; Evans & Schmalensee, 2007; Rochet & Tirole, 2003). An important economic function of platforms is to reduce transaction costs between participants in different market sides. Platforms, therefore, can be seen as institutional arrangements to help overcome forms of market failure and obstacles to market transactions.

Other economic features are also important and take on additional significance in light of these unique interdependencies. Mobile broadband networks require high initial investments but when deployed the maintenance and operational costs are relatively low and support multiple services. Consequently, they are characterized by high economies of scale and scope. Applications and services have similarly high upfront development cost but the incremental costs of serving additional subscribers are relatively low or even zero. Like at the network layer, economies of scale are pervasive although the gradient of the average cost curve is steeper and the required minimum efficient scale is lower for most applications and services than for networks. The effects of economies of scale and scope are further amplified by the presence of direct and indirect network effects, implying that the value of mobile broadband networks increases with the size of the user base. Direct network effects exist if the value of a service varies with the number of users; indirect network effects exist if the size of the user based positively affects the number and quality of complementary software and applications that are available.

Innovation in mobile broadband greatly benefits from the modularity of the employed technology. Modular design of technical systems seeks to reduce the interdependence of components so that they are only loosely coupled (Saltzer, Reed, & Clark, 1984). It allows individual components to be designed, produced, and possibly used independently (van Schewick 2010, p. 39). Together with layering and the end-to-end principle, modular technology greatly facilitates certain types of
innovation processes, as individual modules may be changed without having to alter the entire system. Modular innovation processes will often flourish in a competitive market environment (C. Y. Baldwin & Clark, 2000; Bourreau, Doğan, & Manant, 2007; Langlois, 2002). This is very visible in the mobile apps economy, where innovative software can be configured to reside on the edges of the network, thus avoiding time-consuming and potentially costly changes in the core of the network. All that needs to be known to an app developer is the application programming interface (API) to the operating system and the network. Interoperability and standardization therefore are critical for modular systems to work well. Not all innovation in the mobile broadband system or the Internet is modular. Systemic innovations such as the deployment of IPv6, the introduction of smart grid technology, or of mobile security may require more deliberate coordination processes than can be achieved by decentralized market forces and modular technology. Historically, such innovations required leadership by either government or other organizations (e.g., a network operators such as NTT DoCoMo for first generation mobile Internet, Apple for the iPhone, and Intel for WiFi) (Gawer & Cusumano, 2002; Mazzucato, 2013). A particular challenge for governance is therefore to balance incentives for different types of innovation processes (for a more detailed discussion see Bauer & Shim, 2012)

III. GOVERNANCE MECHANISMS FOR MOBILE BROADBAND

These economic features raise numerous theoretical and practical challenges for the effective governance of mobile broadband. First, the high technological dynamics of mobile broadband and the interrelatedness of advanced communications markets beg the question whether the prevailing theoretical models and practical conventions that inform public policy and regulation remain adequate. Second, much of regulatory theory focuses on controlling market power in retail and wholesale markets. Market power in dynamically evolving markets and multi-sided markets is exceptionally difficult to determine. Moreover, many policy issues arise because of the systemic nature of network effects and spill-overs in advanced communications and are only indirectly related to market power. Third, it is known from institutional economics that regulation often affects performance of a system
not via a single instrument but as a result of a specific constellation of regulatory interventions. Recent research suggests that often the right combination of policy instruments, coherence between technology and regulation, is more important that the type of policy instrument (Finger, Groenewegen, & Künneke, 2005; Künneke, Groenewegen, & Ménard, 2010). Empirical studies and regulatory practice typically focus on one instrument at a time and may hence overlook critical aspects of the ways in which policy interacts with outcomes. Fourth, most of the prevailing research tacitly assumes that regulation and governance are costless despite their direct and indirect costs, including costs of preparing information and costs of erroneous decisions (for a more detailed discussion of these issues see Bauer, 2014).

Regulatory theory and empirical research have undoubtedly made significant advances during the past decades. The influx of game theory, stronger reliance on formal models, explicit recognition of problems of asymmetric information, 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. In defense of the mainstream approach one has to recognize that a static 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 an acceptable approximation. Because it is well known and many of its aspects are analytically tractable, it can help guide policy choices. However, if the system to be governed evolves in a dynamic, non-linear fashion and if interdependencies are high, as is the case with mobile broadband, the prevailing static model may be inadequate.

Before we will look at several specific policy issues, it may be useful to take a quick inventory of the many types of policy intervention that are regularly employed to govern mobile broadband. Policy and regulation seek to affect performance such as coverage with mobile broadband, prices paid by different types of users, the rate of innovation in mobile devices, services and applications, and the broader overall benefits to important social areas such as health care, education, and care for the elderly. To this end, policy needs to alter the incentives of the players in the mobile ecosystem so that their decisions become better aligned with the goals to be pursued. It can do so by directing policies to the players on the
supply side of the market (including component manufacturers, network operators, device manufacturers, software and application developers, content providers) and/or to players on the demand side of the market (including business, government, and private users). As well, policy can seek to affect outcomes directly by prescribing certain performance goals (e.g., by regulating certain prices) and by facilitating transactions between players (e.g., establish open access obligations on network operators, promulgate standards, or require interconnection at transparent conditions) (see also Tsai, 2015).

Since the 1970s, it has become increasingly common to refer to these different modes of coordination in a socio-technical system as forms of “governance”, which therefore includes governmental and non-government instruments to coordinate a system. Table 1 provides additional information on the range of governance mechanisms that are widely used. They include top-down measures adopted by government bodies, voluntary agreements negotiated between players, and conventions that emerge from repeated interactions among the players. Many of these policies and instruments have fairly predictable consequences for the performance of the systems although much less is usually known about the specific effect sizes of policies (expressing essentially how a percentage change in an instrument affects an outcome metric). Given the many interdependencies, statements about relations between policies and effects refer to partial effects assuming that nothing else changes. For example, additional spectrum for mobile broadband will reduce the costs of deploying networks of a given capacity and should therefore have a positive effect on adoption and use. More electromagnetic spectrum can also be used to issue more licenses to increase the intensity of competition, which typically has beneficial effects for network coverage, prices, innovation, and quality of service such as access speeds. Or, to give a second example, spectrum trading allows network operators to make adjustments to market demands within the framework of a given allocation and should thus allow using spectrum in the most beneficial uses. Similarly, technologically neutral spectrum policy allows service providers to offer a broad range of voice and data services rather than only a narrow set of services (e.g., 2G or 3G). This allows flexible responses to market developments and to innovation opportunities and should therefore have positive effects on sector performance.

However, other interventions, such as open access provisions, wireless net neutrality, and universal service obligations, affect players asymmetrically. Often,
they affect them in opposite directions, providing positive incentives to some but negative incentives to other players. In addition, indirect effects may change the net effects of such opposing first-round relations. These effects are known from fixed broadband but have not been studied in great detail for mobile broadband (a first step in this direction is Tsai, 2015). One example that has been studied theoretically and empirically is unbundling provisions on fixed network operators. Network operators and new entrants work under conflicting incentives. Other things being equal, the more stringent unbundling obligations are, the more they decrease investment incentives for incumbent operators, because they are forced to make network services available to competitors. At the same time, they also decrease investment incentives for new entrants as they can obtain leased access at a lower cost than investing themselves. Theoretically, these decisions can be modeled as a multi-stage make or buy decision (see, for example, Bourreau & Doğan, 2006; Bourreau, Doğan, & Manant, 2010). However, these are only direct, first-round effects and a full analysis also needs to take indirect effects into account. For example, new entrants will invest in complementary technology and services and may increase the intensity of competition. In response, incumbents may strategically invest so that the overall effect after direct and indirect effects have played out will be a boost to network investment. Whether the positive or negative incentives dominate will depend on the magnitude of these direct and indirect effects, which will typically vary by location and nation.

**<Table 1> A synopsis of mobile broadband governance instruments**

<table>
<thead>
<tr>
<th>Area of intervention</th>
<th>Instruments</th>
<th>Implementation</th>
<th>Main effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectrum policy</td>
<td>Overall bandwidth</td>
<td>Administration, market mechanism</td>
<td>More bandwidth reduces the cost of deployment, allows licensing more operators to increase competition.</td>
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<tr>
<td></td>
<td>Frequency bands</td>
<td>Administration, market mechanism</td>
<td>Lower frequency bands have better propagation characteristics and therefore reduce cost of network deployment and operation.</td>
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<tr>
<td></td>
<td>Licensing</td>
<td>Administration, auctions, ownership</td>
<td>Market-based mechanisms guide assignment to best uses but may also increase costs of network deployment.</td>
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<tr>
<td>Spectrum trading</td>
<td>Secondary spectrum markets</td>
<td>Spectrum trading allows (limited) adaptations of frequency assignments in response to changing market conditions.</td>
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<tr>
<td>Technological neutrality</td>
<td>Flexible licensing</td>
<td>Technologically neutral licensing allows suppliers to use spectrum for multiple purposes in respond to market demand (rather than limiting a band for a certain use).</td>
<td></td>
</tr>
<tr>
<td>Competition</td>
<td>Number of licenses</td>
<td>Spectrum allocation and assignment</td>
<td>Although other factors are at play, the number and relative size of competitors in the market shapes the intensity of competition, which it positively related to many performance metrics</td>
</tr>
<tr>
<td>Competition policy</td>
<td>Competition policy; merger policy</td>
<td>Competition and merger policy aim at safeguarding the conditions for effective competition ex post and ex ante.</td>
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<tr>
<td>Access to networks, infrastructure, and content</td>
<td>Access to rights of way</td>
<td>Unbundling of access to towers, ducts</td>
<td>Unbundling reduces the costs of entrants by allowing them to lease access to towers etc. It may reduce the incentives of incumbents to upgrade infrastructure.</td>
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<tr>
<td>Interconnection</td>
<td>Requirement to offer interconnection; possibly regulation of terms</td>
<td>Interconnection obligations reduce the advantages of large players from network effects and economies of scale; reduces transaction costs for players and assures a seamless Internet.</td>
<td></td>
</tr>
<tr>
<td>Roaming</td>
<td>Voice and data roaming</td>
<td>Mandatory roaming expands to footprint of smaller network operators and lowers their costs but it may reduce the incentives of the operators subject to it.</td>
<td></td>
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<tr>
<td>Open access to network services</td>
<td>Provisions to allow MVNOs</td>
<td>Open access to content and application providers reduces their cost of using subscribers and intensifies competition.</td>
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<tr>
<td>Wireless network neutrality</td>
<td></td>
<td>Wireless network neutrality seeks to safeguard open and nondiscriminatory access by players in the upper layers of the Internet to networks and network transportation services.</td>
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<tr>
<td>Access to content</td>
<td>Limitation on exclusive content</td>
<td>An obligation to content providers to make content available to competitors mitigates concerns about discrimination by vertically integrated operators with a strong presence in networks and content.</td>
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<tr>
<td>Price regulation</td>
<td>Retail prices</td>
<td>Rate-of-return, price cap regulation</td>
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<td></td>
<td></td>
<td>Because mobile broadband is considered a competitive market in most countries, retail price regulation is rare but it would directly affect a performance metric</td>
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<tr>
<td></td>
<td>Wholesale prices</td>
<td>Rate-of-return, LRIC, price cap regulation</td>
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<td></td>
<td></td>
<td>Wholesale prices are complements to other types of access regulation and seek to assure that smaller players can interconnect and get access to networks at fair and efficient prices</td>
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<tr>
<td>Facilitation of coordination</td>
<td>Standards</td>
<td>Mandatory standards; voluntary standards; de facto standards driven by market forces</td>
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<td></td>
<td></td>
<td>Standards reduce the coordination costs among the players in the mobile broadband ecosystem and hence reduce the cost of service provision; however, developing them is afflicted with direct and indirect costs.</td>
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<tr>
<td></td>
<td>Numbering</td>
<td>Mandated numbering plans, voluntary approaches</td>
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<td></td>
<td></td>
<td>Unified numbering conventions are critical in the mobile Internet and will be even more urgent in the Internet of Things (IoT). They reduce the cost of service provision.</td>
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<tr>
<td>Harnessing societal benefits</td>
<td>Universal service</td>
<td>Subsidies to providers, reverse auctions, subsidies to users</td>
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<tr>
<td></td>
<td></td>
<td>Universal service policies can help bring mobile broadband to high-cost areas, to low income users, and to disadvantaged user groups.</td>
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<td></td>
<td>Education</td>
<td>Programs to enhance digital literacy</td>
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<td></td>
<td></td>
<td>One reason for non-adoption in many countries are lacking user skills and lack of awareness of the benefits of (mobile) broadband</td>
<td></td>
</tr>
<tr>
<td>Industrial policy</td>
<td>R&amp;D policy</td>
<td>Programs to facilitate mobile innovation</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Several countries, including the US, have R&amp;D programs focusing on the development of advanced wireless technology</td>
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</tbody>
</table>
Public sector projects | Public procurement of advanced technology | The public sector can lead adoption of mobile broadband with innovative projects, including e-government, e-health, public safety infrastructure, smart grids, and advanced transportation systems.

Open data | Initiatives to allow developers access to public data | Making public data available to developers reduces their cost of innovation and hence should stimulate it. A key concern is how to retain public access to data given for free to private players.

Often, this net effect can only be determined empirically or possibly using computational and simulation approaches. Alas, as many policies are forward-looking, past empirical observations may provide only poor guidance for the future. Even if sufficient empirical data is available, an empirical assessment is complicated by two challenges. First, because it is difficult to find a counterfactual in one specific country, studies often use a comparative design to assess the effects of policy interventions. While the increasing availability of internationally comparative data has facilitated much high-quality research, it has also illustrated the theoretical and methodological problems of such approaches (Bauer, 2010). One challenge is that the size of the positive and negative effects may vary depending on the specific context, such as the income level of a country, socio-demographic conditions, and the quality of public policy. Even if these factors can be controlled for, there may not just be one process that explains how policy interacts with system performance (Belloc, Nicita, & Parcu, 2013; Belloc, Nicita, & Rossi, 2012). Most importantly, policy often does not work as one isolated instrument (although accountability and transparency obligations on government agencies often result in piecemeal approaches that modify one instrument at a time) but in a constellation of multiple related policies (see Table 1 above). This has been recognized in fields such as comparative political science and sociology for some time and led to the development of new empirical methods that allow a detailed analysis of the necessary and sufficient conditions for policies to achieve intended outcomes (Ragin, 1987, 2000). Only recently have such methods—including Qualitative Comparative Analysis (QCA), positioned between case study research and large-
scale econometric methods—been employed to mobile broadband, with the most detailed study thus far Tsai (2015).

Not surprisingly, in dynamic systems, policy decisions often will be based on a mix of solid evidence and experimentation so that mistakes will happen with some regularity. Recent communications policy is full of such experiences, such as the failure of early unbundling policy in the U.S., the poor performance of broadband unbundling in many European countries, or the early problems with 3G spectrum auctions in Europe. It would be too simplistic to attribute these observations to incapable policy makers or agencies captured by partisan interests. Rather, this is the outcome of the unique dynamic environment of advanced communications systems and the gap between our theoretical and practical models used to inform their governance. One of the lessons for policy, which will be discussed in more detail in section five below, is to generate continuous feedback and adaptation if performance does not respond to a measure in the anticipated way.

IV. GOVERNING THE DYNAMIC MOBILE BROADBAND SYSTEM

Rational governance of the mobile broadband system would ideally proceed in several systematic steps. First, it is necessary to develop a clear understanding of whether there is a problem or a performance deficit that can be addressed by public policy. Is there a problem of mitigating market power, a resource management issue, the need to facilitate coordination and reduce transaction costs, or the need to stimulate business and private demand for mobile broadband? Once the overarching diagnosis and objectives are established, a second step is to explore the most effective way of addressing them. Not all problems can be solved by policy and sometimes a hands-off, market-driven approach might be the best feasible way of achieving the stated goals. However, most of the time markets will need an appropriate legal and regulatory framework that is congruent with sector conditions to function well. Third, the choice and design of instruments will have to be based on an appropriate analytical framework. If sector conditions are fairly static and well known, traditional regulatory economics can serve as a guidelines. If the technology is dynamically evolving and interdependencies and indirect effects are important, as is most likely the case in mobile broadband, then a more dynamic and
systemic approach will need to be adopted, taking direct and indirect effects of an intervention into account. As all players in a dynamic system adapt to policies in anticipated but sometimes also in unanticipated ways, it is important to monitor outcomes and, if the expected results are not forthcoming, to initiate remedial action. This section first illustrates such an approach using the example of open access provisions for wireless services and then derives insights for a more general set of principles.

Open access provisions have been imposed upon (or been negotiated voluntarily by) wireless network operators in several forms. No unified terminology is used but in a broad sense provisions such as mandates to grant access to competitors to towers, poles, and ducts; obligations to interconnect; roaming; mandated sale of network services to mobile virtual network operators (MVNOs); and most recently wireless network neutrality rules all are related to keeping networks more open than would result from private decisions of the network operators. All these provisions affect stakeholders differently compared to a situation without such rules. If these effects go in the same direction (e.g., increase performance) this is less of an issue than if they affect players in opposite directions (e.g., performance improvements for some, performance decline for others). In the latter case, it will be important to develop a good understanding of the overall net effect on performance that results from these conflicting positive and negative direct and indirect effects.

For example, other things being equal a first round effect of mandated roaming will be to reduce the incentives of incumbent operators to invest in network upgrades (as they might need to share network innovations with competitors). At the same time it will reduce the cost of smaller network operators to enlarge their footprint, hence increase diversity for consumers and possibly even intensify competition (a lot will depend on the level and design of roaming charges). These initial responses will lead to further adjustments: incumbent operators may respond to intensified competition with service quality improvements or they may seek to cut costs and inadvertently reduce quality of service. Smaller competitors may attract a sufficient number of subscribers to warrant own network investment or they may lobby the regulatory agency to lower roaming costs rather than roll out additional facilities. Whether such desirable positive or undesirable negative responses occur can often not be anticipated with sufficient reliability. Nonetheless, it behooves the policy maker to assess in advance, as far as possible, direct and indirect effects and explore the risk that unintended consequences may result and
undermine the policy objectives. In contrast, policy makers often focus on the immediate direct first round effects and therefore may inadvertently adopt an erroneous approach.

Another example is the net neutrality debate. In the U.S. this discussion started as a response to the deregulation of broadband access networks and their reclassification of information service providers. In conjunction with the increasing commercialization and the emergence of private IP-based networks, this reclassification raised concerns that network operators might abuse their newly gained freedom to undermine the end-to-end, open architecture of the Internet, which is widely seen as one of the main factors nourishing its innovative prowess (Bauer & Obar, 2014; Lee & Wu, 2009). After an extended policy struggle, the latest step was the promulgation of an Order by the Federal Communications Commission (FCC) that reversed these earlier deregulatory moves by reclassifying broadband access as common carrier service subject to broad non-discrimination obligations (FCC, 2015). Key provisions include three bright lines (no blocking, no throttling, and no prioritization) that are potentially rebuttable and hence subject to case-by-case modification; safeguards to prevent discrimination against users and edge players (e.g., app providers, service providers); and provisions to potentially regulate interconnection and other historically unregulated aspects of the Internet. Furthermore, the provisions were expanded beyond fixed networks to also include wireless services. The Order is based on a loosely articulated view that it will safeguard the virtuous cycle of innovation that involves physical network infrastructure (lower layers of the Internet) as well as applications and services (upper layers).

However, a closer look at the innovation dynamics reveals once more a complicated web of direct and indirect, positive and negative relations with the overall outcomes much less certain than pragmatically assumed in the Order. Figure 2 illustrates, in a simplified fashion the direct and indirect effects of wireless net neutrality regulations. The signs next to the arrows illustrate whether two variables move in the same direction (“+”) or in opposite direction (“−”). The principles codified in the FCC Order require that mobile network operators make their platforms available at non-discriminatory conditions to content, application, and service providers in higher layers of the mobile broadband ecosystem. This has two first-round effects: Other things being equal, stricter net neutrality rules (i.e., rules that prescribe a more limited set of allowable network pricing and quality
differentiation) reduce the incentives of network operators to invest in network upgrades as they reduce their ability to price differentiate and to improve their return on their investment. At the same time, stricter neutrality improves innovation conditions for players at upper layers as it reduces transaction costs and adaptation costs of innovation. Consequently, more innovation projects will be potentially profitable and the number of innovation experiments should increase (Bauer, 2007).

<Figure 2> Governance as a dynamic system

This acceleration of innovation in the upper layers of the mobile broadband system in turn will generate higher user demand and more mobile data traffic. In response to this increased demand for connectivity and bandwidth, network operators may accelerate investment and innovate by deploying new network capabilities. Other things being equal, the negative first round effect on network operators is therefore counteracted by a positive stimulus from the increased activity of upper layer players. The tacit assumption of the Order and most advocates supporting its adoption is that these positive indirect effects outweigh the negative effects, although there is at best anecdotal evidence available to substantiate this presumption. If the negative effect on network operators is stronger,
it too will percolate through the system and, in turn, further dampen innovation in upper layers (indicated by the “+” sign, so that less network innovation is translated to less application/services innovation. The overall net effect on innovation activity is the outcome of these conflicting effects and may be positive or negative, depending on the relative magnitude of direct and indirect effects. However, it is nearly impossible to establish that direction a priori. Of course, there are more interactions in this system. Most likely there will also be some additional feedbacks from overall performance to policy (indicated by the dotted lines in Figure 2) which ideally could be used to adapt the policy choices to “tune” the system in ways to generate positive overall effects.

<table>
<thead>
<tr>
<th>Governance instrument</th>
<th>Network operators</th>
<th>Content, application providers</th>
<th>Overall sectoral effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incumbent</td>
<td>New entrant</td>
<td>Modular</td>
<td>Coupled</td>
</tr>
<tr>
<td>R&amp;D support</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Demand-side measures</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Mobile data roaming</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Mobile net neutrality</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

There is a more generic lesson in this simplified but highly relevant example of the effects of policy interventions in a dynamically related ecosystem. Table 2 expands the perspective to a few selected policy instruments from Table 1 and captures the effects of policy interventions on the investment and innovation incentives of four types of players in the mobile ecosystem. Like in Figure 2, a positive sign implies that more intense intervention results in a better investment and innovation incentives whereas a negative sign indicates that more intense intervention weakens them. The signs are based on research that has studied these relations or on a conceptual examination of the likely direction. Traditional policy typically focuses on one single direct effect (e.g., the effect of net neutrality on providers of complementary content). This is only defensible if the effects of that policy on other players are negligible or zero. Thus a first step in policy design in a
dynamic environment will have to be to assess whether this is the case. Is so, traditional types of policy models and optimization are a workable representation of the problem.

If this is not the case, the main message is visible from the pattern of signs. It is, first, immediately evident that some governance mechanisms (e.g., support for R&D) have only positive effects whereas others (e.g., wireless net neutrality) have both positive and negative effects across the four identified stakeholders. In some cases, it may even be difficult to clearly assess ex ante the effects on one specific stakeholder (indicated by “+/-”). Second, if policies have positive and negative impacts the overall effect across all stakeholders can only be predicted if the relative strength of the countervailing forces is known with reasonable accuracy, which may often not be the case at the time a policy is adopted. Third, reading the table along rows, individual stakeholders are affected by policy instruments in likewise differing ways. Unless the set of policies is carefully designed it may well be that some of the measures weaken or even neutralize others. This is but another way to establish that policies need to be as consistent as possible across stakeholders and for individual stakeholders. The diversity of these partial effects and the interrelatedness of advanced communication systems make this a complicated and challenging task.

<Figure 3> Non-linear effects of regulatory intensity on investment and innovation incentives (example net neutrality)
A final complication is the non-linearity of many of the relations in dynamic adaptive communications systems. Non-linearities such as critical mass effects, first-mover advantages, and tipping points are familiar phenomena in the economics of networks (Easley & Kleinberg, 2010). They are also known from innovation theory, which has observed that in many markets there is an inverted U-shaped relation between the intensity of competition and the rate of innovation (Aghion, Bloom, Blundell, Griffith, & Howitt, 2005). Similar relations have been identified between the intensity of regulated competition in fixed broadband (Briglauer, 2014; Grajek & Röller, 2012) and (on a more preliminary basis) in mobile voice markets (Katz, 2010). In other words, these studies suggest that performance suffers if there is too little regulation but it also suffers if regulation is too intrusive. Unfortunately, the exact shape of such non-linear relations is typically now known in advance. Therefore, it will be nearly impossible for regulation to determine the point of optimal performance (e.g., the regulatory intensity $R^*$ associated with the highest investment incentives in Figure 3). However, it should be possible to identify a zone of acceptable performance and to design regulation so that the system does not perform below that level. This implies that regulation will have to remain within a “workable” zone between lower ($R_L$) and upper ($R_U$) bounds of regulatory intensity that correspond to the acceptable minimal performance bound.

Although mobile broadband is receiving increasing attention from researchers, considerable empirical deficits continue to exist. A very detailed study is the cross-sectional analysis by Tsai (2015) of the factors driving mobile broadband adoption across the OECD. One overarching finding of that study is that the drivers of mobile broadband performance are multifaceted and complicated. Very few factors are of equally strong importance across all countries. Among the factors that can be influenced by policy makers are the intensity of competition in the market and the adoption of neutral spectrum licensing, both of which have positive effects on adoption. Other policies, such as mobile broadband universal service only have positive effects if other contextual factors prevail. The study also showed the importance of contextual factors, such as per capita income and education, both factors that are not easily influenced by mobile broadband or general government policies. Lastly, the study showed a strong complementarity between fixed and mobile broadband for the OECD member states. These results provide first strong hints and form a good basis for additional empirical work as more complete data becomes available.
V. CONCLUSION

This article has reviewed the challenges of designing effective governance for the mobile broadband sector. It started with an analysis of the new technological and economic conditions that characterize mobile broadband services (much like other advanced communications services). Two waves of convergence have contributed to a transition from specialized network infrastructures engineered for relatively specific purposes to an all-IP general purpose infrastructure. In this network of networks, logical protocol layers (mainly TCP/IP but also others) integrate the heterogeneous technologies that make up the physical network into a seamless web. This web includes the public Internet but it is also encompasses an increasing number of insular private Internets (e.g., networks to offer VoIP) that are also IP-based and use the architecture and design principles of the public Internet (Claffy & Clark, 2013; Noam, forthcoming). Mobile broadband is embedded in this broader all-IP infrastructure and the associated applications and services. It also exhibits similar economic attributes, including direct and indirect network effects, network externalities and spill-overs, economies of scope and scale, exponential performance improvements, pervasive multi-sided market relations, and systemic interdependence among the many players in the mobile broadband system.

These sector conditions deviate significantly from the basic modeling assumptions of the prevailing theoretical foundations of regulation and public policy and the practices derived from them. Rational governance will therefore have to examine, whether these models can be applied or whether a new framework is necessary. This will depend on the rapidity of technological change, the extent to which indirect effects that go beyond the regulated entity are present, and the importance of systemic, possibly non-linear, relations among the players. The article has outlined a framework for governance that can help design a consistent and workable overall set of policies. It emphasized the need to develop a better understanding of the direct and indirect effects of policy interventions and their potentially positive and negative effects across the interrelated set of stakeholders and players in the mobile broadband system. Likewise, it encouraged the development of a deeper understanding of how different policy instruments affect a single player, as these effects also may work in opposite directions if carelessly designed. Most importantly, the paper pointed to the need for more adaptive approaches to
governance that combine regular monitoring of performance metrics with a reassessment of the prevailing policies and, if justified, their modification or abandonment. Additional work that needs to be done includes developing a better evidentiary basis of the effect size and directions of different policy instruments. Simulation and computational approaches can possibly help to better understand the direct and indirect effects of governance in situations when historical evidence is not available or only of limited value. Such work can also benefit from international comparisons as long as the different national conditions are sufficiently captured. Many countries have intuitively adopted some of the principles discussed in this article. With assistance from the research community, these first steps can be put on more solid footing.

REFERENCES


Governing the Mobile Broadband Ecosystem

_FOOTNOTES_:


