OPEN ACCESS RULES AND THE BROADBAND RACE

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I. THE BROADBAND HORSE RACE

A "horse race" has emerged among providers of high-speed Internet access in the United States and elsewhere.[1] The two leaders in this race are the incumbent local exchange companies (ILECs) who deploy some variant of digital subscriber line (DSL) and cable television operators who are using cable modem (CM) technology. High-speed services delivered over existing wireless infrastructure is beginning to appear, though currently this technology is a distant third in residential penetration in the United States. Fixed terrestrial wireless services using Multichannel Multipoint Distribution Service (MMDS) and Local Multipoint Distribution Service (LMDS) spectrum and, to a lesser extent, two-way satellite are the more common deployments, but mobile broadband options will emerge as cellular systems are upgraded to the next-

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1. *See* SAM PALTRIDGE, ORG. FOR ECON. CO-OPERATION AND DEVELOPMENT, THE DEVELOPMENT OF BROADBAND ACCESS IN OECD COUNTRIES (Oct. 29, 2001), *available at* http://www.oecd.org/pdf/M00020000/M00020255.pdf, for a comparison of broadband penetration rates in thirty developed countries including the United States.

generation capability. "Powerline" transmission of broadband over the electric power grid is a final alternative that has not been deployed commercially as of yet.

These contenders will all provide broadband access by upgrading or modifying embedded networks that were initially designed to deliver other communications services.[2] Handicapping this race has been a chancy undertaking, certainly when viewed over an extended period of time. Going back a decade or more, the technology championed to lead the broadband race, Fiber to the Home (FTTH), is now widely viewed as too costly in its present design, and will not emerge as a serious contender until an affordable, all-optical Next Generation Network becomes feasible. On the horizon are several technologies that promise unprecedented data rates, but these remain technologically and commercially unproven.

Despite the demonstrated uncertainty surrounding the outcome of the broadband race, policy measures have been adopted that differentially impact broadband providers and their technologies.[3] Asymmetry in treatment of broadband deployment is no surprise given the regulatory and judicial patchwork governing this service.[4] Cable, telco, and wireless incumbent providers are subject to laws enacted by legislatures that respond to different constituencies, and the laws are implemented by regulations that differ due to myriad agencies responsible for implementing those laws. Principally, telcos are subject to federal regulation while cable operators are regulated by municipal franchise authorities and, to a lesser extent, by state Public Utilities Commission (PUCs). Even within the same agency, entirely separate bureaus may be assigned to different broadband providers, as in the case of the FCC's wireline competition, wireless communications, and media bureaus.[5] The courts have weighed in on broadband access issues taking a variety of positions, many of which are contradictory.

Nevertheless, the temptation for policy makers to take measures to promote the spread of high-speed Internet access is irresistible. Repeatedly, industry observers project significant contributions to the general welfare, and

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2. More speculative technologies will require that new networks be built from scratch. Many of these are wireless, including ultra-wideband wireless, free space laser, and unlicenced WiFi (IEEE 802.11) [wireless fidelity].

3. Still others were put in place for other purposes but impact broadband deployment though they have not been removed.

4. For more detail on the complex and contradictory state of broadband regulation see Roger G. Noll, Resolving Policy Chaos in High-Speed Internet Access, SIEPR Discussion Paper No. 01-13 (Jan. 2002) (unpublished manuscript, on file with Stanford University).

5. These are new names given to the former common carrier, wireless, and cable services bureaus, respectively.

to the nation's productivity growth, from widespread broadband access.[6] Despite scant empirical evidence confirming these benefits, one cannot ignore the continued growth in demand for Internet access and the potential for bandwidth-intensive multimedia applications and content–with prospects for new e-commerce applications being particularly intoxicating.

Against any benefits of broadband adoption, we must weigh the potential economic costs these decisions may imply. The recent string of bankruptcies by advanced service providers offers a painful reminder of the costs of overinvestment. A landrush that duplicates broadband access in metropolitan markets across the country could end in financial ruin as well, or at least in substantial waste of obsolete or underutilized infrastructure. Given the sunk nature of this investment, and its magnitudes, getting the timing and selection of technology correct will likely outweigh allocative inefficiencies of the sort that derive from errors in pricing broadband services.

As network industries undergo deregulation and restructuring to become more competitive, they continue to experiment with alternative specifications of "open access" rules. These rules seek to stimulate either facilities-based or service-based competition, or both. Entry of either type may occur in provision of upstream network services, or downstream broadband applications. I am particularly interested in the consequences of apparent asymmetries in the application of various open access rules to different technologies and different providers.

The focus of this paper is on policies that seek to promote broadband availability by opening up existing facilities to service-based providers. Under the broad rubric "open access," I include rules that unbundle incumbent networks and force the sharing of broadband facilities and services with competing providers. I am interested primarily in whether these policies achieve their goals of accelerating broadband deployment and creating broadband competition. I am also interested in how differential application of open access rules impact the pattern of broadband investment across providers and across technologies.

To generate predictions about the effects of open access rules, I investigate a "technology race" model having two incumbent providers who decide if and when to invest in broadband infrastructure in each geographic market. Given the setting of the cable-telco race, this investment amounts to upgrading and retrofitting their respective networks to allow for two-way, high-speed data access and transmission. On the other hand, when permitted,

6. *See* Robert W. Crandall & Charles L. Jackson, *The $500 Billion Opportunity: The Potential Economic Benefit of Widespread Diffusion of Broadband Internet Access*, CRITERION ECON., LLC (2001) (conducting rough calculations of the economic value of universal broadband services in the United States, with the highest estimates exceeding $500 billion per year).

service providers may choose to buy broadband network services from a facilities-based incumbent provider, rather than to build the infrastructure themselves. On occasion, I will introduce pure resellers who do not own any facilities at all, a strategy currently employed by certain data local exchange companies (DLECs) and Internet Service Providers (ISPs).

When choosing when to build its broadband network, a provider weighs the investment cost against expected profit flows. The model deployment in each geographic market occurs instantly for a one-time, lump-sum construction cost. This cost falls over time, reflecting continuous improvements in the technology and learning about its implementation.

Operating profit levels depend on industry structure and the extent of broadband deployment in the specific market. Apart from broadband services, both contestants derive revenue from services other than broadband data. This is certainly true for telephone companies and cable operators whose principal current revenue sources are switched voice telephony and broadcast video, respectively.[7] In terms of broadband services, the two incumbent providers compete on price and quality, and yet are likely not to dissipate all profits as their offerings will be somewhat differentiated.

In equilibrium of the race, the first mover will be the provider that is inclined to adopt earlier as a consequence of its low deployment costs and large incremental profits from broadband services. Because of the competitive pressure applied by the rival, the first mover will likely advance the date of its investment, deploying immediately before that time when its rival would find it profitable to lead rather than to follow. The competitive pressure inclines each firm to deploy sooner than if they were safe from any risk of being second to market. After the first deployment, the rival may deploy its broadband facility at some later date, though it may conclude a duplicate broadband network is unprofitable.

In the model, the impacts of different open access rules are assessed by first expressing how they alter providers' operating profits following deployment, and possibly their deployment costs as well. The rules then alter the equilibrium pattern of broadband deployment, which is compared against the benchmark of the technology race free of any regulation. First of all, I am interested in any departures from the unregulated time pattern of deployments, as well as which firm "wins" the broadband race and whether any contestants fail to finish. Given the one-to-one relationship between providers and broadband technologies, the deployment pattern determines which technologies

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7. Currently, cable and telco product markets may overlap to an extent, as when cable operators provide voice telephony over their networks in competition with local incumbent telephone companies.

are selected by the race, and hence the capabilities and limitations of broadband services made available. Of course, the provision of facilities-based and service-based broadband services will determine the price and variety available to users.

Open access rules applied to the broadband race uniformly distort the timing of deployment, and potentially the selection of the winning technology.[8] Typically, the second deployment is delayed as the incentive to buy network services become relatively more attractive under open access compared to the option of building infrastructure. This latter effect can be so strong that a second facilities-based provider never becomes viable. In certain instances, the order of deployment may be *reversed*, resulting in the inefficient technology being deployed first; in the most extreme case, the efficient technology is not deployed at all. More generally, we find that, for many open access regimes, a tradeoff arises between increased broadband service competition, with the benefits of expanded choice and lower prices, and delayed or inefficient deployment of broadband infrastructure. The social costs associated with this distortion encourage examination of the factors bearing upon the welfare tradeoff between these static benefits and dynamic inefficiencies, a task for subsequent research.

II. ASYMMETRIC REGULATION OF BROADBAND DEPLOYMENT

A. Some Basics of High-Speed Access Services

It is helpful to begin by defining the market that prospective broadband providers vie to serve. As a rough guide, broadband data services can be taken to be an always-on data connection operating at bit rates exceeding 256 kilobytes per second (Kbps) in both directions, or 386 Kbps in at least one direction.[9] At this speed, some form of full-motion video is possible. Of course, cable television service delivers dozens of high-quality video channels, but that transmission is only one way and is analog where digital upgrade has not occurred.

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8. In fact, many regulations, including those for narrowband services, bear upon providers' decisions to deploy broadband services, some more than others. Since we cannot hope to derive sharp results for a complete specification of all these regulations combined, the policy impacts of each type of regulation will be examined individually.

9. For a similar definition see *In re* Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, FCC Report, CC Docket 98-146 ¶ 20 (Feb. 2, 1999), *at* http://ftp.fcc.gov/Bureaus/Common_Carrier/Reports/fcc99005.txt.

The geographic extent of the market will vary depending on the technology. In the case of DSL service, the serving area extending from a single wire center is the basic unit of deployment. Cable modem service is deployed for each neighborhood served by a fiber node, which usually has about 500 homes. Fixed wireless services such as MMDS and LMDS would be deployed throughout a tower's footprint, which is considerably larger than the minimum area addressed by DSL and CM technologies.

The alternative technologies differ in their physical properties in ways that impact their ability to compete for broadband market.[10] For instance, DSL suffers from signal attenuation that shrinks its addressable market to households to an area within about 18,000 feet of a wire center. A cable network is a shared medium that is subject to congestion and increased security risk, even after many of the analog coaxial trunks have been replaced with optical fiber. Wireless services have reliability and environmental limitations due to propagation properties that depend on the portion of the radio spectrum they occupy.

Each technology experiences its unique scale and scope economies that determine the cost of deployment. While the incremental cost of adding broadband capabilities to existing infrastructure is likely to be relatively small for an incumbent provider, these embedded networks have been optimized to provide services that differ in several important respects from broadband Internet access. One advantage of a greenfield deployment would be greater freedom to choose the serving territory, network architecture, and transmission technology from scratch.

B. Public Policy Toward High-Speed Access

Policy toward broadband services varies across geographic regions, in large part due to the patchwork of legal and regulatory jurisdictions in this country. With regard to high-speed cable modem service, each municipal or country cable franchising authority could, in principle, adopt its own approach. State PUCs and the FCC have often found themselves in direct conflict over high-speed services, and even more time will be needed to sort out jurisdictional responsibilities and powers.

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10. The National Research Council offers an accessible description of broadband technologies being deployed in the United States. *See* COMPUTER SCI. AND TELECOMM. BOARD, NAT'L RESEARCH COUNCIL, BROADBAND: BRINGING HOME THE BITS (2002). *See also* MCKINSEY & CO. & JP MORGAN H&Q, BROADBAND 2001: A COMPREHENSIVE ANALYSIS OF DEMAND, SUPPLY, ECONOMICS, AND INDUSTRY DYNAMICS IN THE U.S. BROADBAND MARKET (Apr. 2, 2001).

Different types of providers of high-speed service are singled out for special treatment. Incumbents and entrants operate under vastly asymmetric rules, certainly for provisions of DSL service over the public switched network. In one of the most glaring asymmetries in this area, cable modem service providers are generally free of obligations to open up their networks whereas ILECs must furnish wholesale, network services, including network elements used in the provision of DSL services.

Related to differential regulation of carriers are differential treatments of broadband technologies. Since cable and telco carriers tend to deploy CM and DSL technology exclusively, asymmetric regulation of those carriers will necessarily impact the commercial success of those technologies. The same is true when high-speed service, delivered over a wireless network, faces a different set of rules than a landline network.

The Telecommunications Act of 1996 (Act)[11] changed the ground rules for providing all kinds of communications services, including broadband services. Prior to the Act, ILECs provided high-speed access and transport services to other incumbent providers and to business customers. Among the most prominent were switched and special access services that ran at T1 and T3 data rates. Presently these services are under price cap regulation. ILECs also offered residential and business customers Integrated Services Digital Network (ISDN) service in basic and primary rates, which would barely qualify as broadband services given today's standards.

The Act requires ILECs to share their networks with competitors in several ways. They must interconnect with other networks and exchange traffic with reciprocal compensation. They must permit competitors to collocate their facilities in various points of the network. They must also unbundle their network and lease it to competitors.[12] Unbundled local loops is a crucial network element in the provision of DSL by the DLECs. The FCC has also imposed "line sharing," which enables DLECs to purchase upper frequency bands on the loop to carry DSL.

While the FCC has the most responsibility for implementing the Act, its authority to regulate high-speed data services has been anything but clear. The FCC does derive some authority over the ILEC provision of these services from its responsibility to enforce the line of business restrictions on the Regional Bell Operating Companies (RBOCs) imposed as a condition of the AT&T divestiture. Under section 157 of the Act, however, the FCC is barred

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11. *See* Telecommunications Act of 1996, Pub. L. No. 104-104, 110 Stat. 56 (codified as amended in scattered sections of 15, 18, & 47 U.S.C.).

12. *See id.*

from imposing unbundling and leasing requirements on certain advanced services.[13]

With the passage of the Act, ILECs were required to unbundle their networks and lease the network elements to competitive local exchange carriers (CLECs) at cost-based rates. In particular, ILECs must create network service elements, including local loops that are used by competitive carriers to provide their DSL service. Furthermore, once DSL was classified as a "telecommunications service," ILECs were obliged to make available their DSL facilities (e.g., DSL Access Multiplexers (DLAMs)) to DLECs, though some exceptions have been allowed. Also, the FCC has required ILECs to unbundle the bitstream on the local loop and to lease use of the high frequency portion of the local loop to DLECs for residential DSL service, while they continue to deliver switched telephony over the voiceband.

On the cable side, the FCC asserted authority over CM service in its review of AT&T's acquisition of TCI, though it decided against imposing any open access conditions on that merger. Recently, the FCC moved to classify CM service as an "interstate information service" (thereby asserting jurisdiction), but also that it is neither a "cable service" nor a "telecommunications service" and so it is exempted from common carrier regulation.[14]

Cable provision of high-speed Internet access operates free of rate and service regulation. In fact, the Act eliminated (as of February 1999) all federal regulation of rates for cable television services that had been allowed under the 1992 Cable Act.[15] In contrast, municipalities wield considerable power over cable operators, derived from their authority to award cable franchises. Concerned that cable systems will favor affiliated ISPs, or one with which they have an exclusive relationship, cable franchise boards have placed new conditions on franchisees to open up their networks. In several highly visible decisions, boards have required nondiscriminatory access to multiple ISPs, only to be overturned by the courts.[16]

Reviews of other communications mergers have been the source of policy on treatment of high-speed access services, but has resulted in each case with *sui generis* policy. In the case of both the SBC-Ameritech and Bell Atlantic-

13. *See* 47 U.S.C. § 157 (2000).

14. *See In re* Inquiry Concerning High-Speed Access to the Internet Over Cable and Other Facilities, FCC Report, FCC 02-77 (Mar. 15, 2002), *at* http://www.fcc.gov/Daily_Releases/Daily_Business/2002/db0315/FCC-02-77A1.pdf.

15. *See* Cable Television Consumer Protection and Competition Act of 1992, Pub. L. No. 102-385, 106 Stat. 1460 (codified as amended in scattered sections of 47 U.S.C.).

16. *See* AT&T Corp. v. City of Portland, 43 F. Supp. 2d 1146 (D. Or. 1999), *rev'd*, 216 F.3d 871 (9th Cir. 2000).

GTE mergers, the FCC conditioned its approval on agreement by the merged entities that they would sell advanced services, including DSL, through separate affiliates.[17] By accepting this provision, designed to achieve parity in the provision of wholesale services to DLECs, the new carriers were exempted from the unbundling and resale requirements of the Act. However, SBC's exemption was later vacated by the courts.[18]

As a condition for its approval of the AOL-Time Warner merger, the Federal Trade Commission (FTC) ordered that the company strike access agreements with no fewer than three unaffiliated ISPs in those areas where it had cable systems that offered high-speed service.[19] AOL-Time Warner must also grant access to Earthlink wherever it chooses to bundle cable with high-speed service.[20] The FCC added ISP nondiscrimination and direct billing requirements. Once again, merger policy pried open incumbent networks, this time the cable networks, but the policy was adopted only for the one specific carrier, and not adopted as a general policy applied to other carriers.

At the federal level, the FTC signed a Consent Order with AOL-Time Warner as a condition of their merger that requires Time Warner Cable systems to offer users three or more unaffiliated ISPs in each market where AOL's broadband service is available.

In comparison, the courts have swept a wide range of possible positions on opening up cable systems to competing high-speed data access (HSDA) providers.[21] In the landmark case *AT&T Corp. v. City of Portland*,[22] the local cable franchising authority required AT&T to provide access to unaffiliated ISPs wanting to offer HSDA before allowing TCI to transfer its franchise.[23] When reviewing the Portland decision, the Ninth Circuit Court of Appeals concluded that bundled CM service is both a telecommunications and an information service and, hence, it falls in the FCC's jurisdiction, not that of local franchise authorities.[24]

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17. *See In re* Inquiry Concerning High-Speed Access to the Internet Over Cable and Other Facilities, 15:29 F.C.C.R. 19287 (Sept. 28, 2000); INDUS. ANALYSIS DIV., FCC, HIGH-SPEED SERVICES FOR INTERNET ACCESS: SUBSCRIBERSHIP AS OF JUNE 30, 2001 (2002), *at* http://ftp.fcc.gov/Bureaus/Common_Carrier/Reports/FCC-State_Link/IAD/hspd0202.pdf.

18. *See* Sprint Communications Co. v. FCC, 274 F.3d 549 (D.C. Cir. 2001).

19. *See* America Online, Inc. and Time Warner, Inc., [1997-2001 Transfer Binder] Trade Reg. Rep. (CCH) ¶ 24,835, at 24,854 (Apr. 17, 2001).

20. *See id.*

21. *See* Noll, *supra* note 4.

22. 216 F.3d 871 (9th Cir. 2000).

23. *See AT&T*, 43 F. Supp. 2d at 1155.

24. *See* AT&T Corp. v. City of Portland, 216 F.3d 871, 877 (9th Cir. 2000).

In contrast, reviewing the decision in *MediaOne Group, Inc. v. Court of Henrico*[25] of cable authority to force AT&T to open its cable network to unaffiliated HSDA providers, the courts declared CM service a "cable service," placing it under the jurisdiction of local franchise authorities.[26] The middle ground was explored in the case of *Gulf Power Co. v. FCC*.[27] In that case, involving the exercise of pole attachment rights, the Eleventh Circuit concluded that CM service did not fall within the definition of any of these traditional classifications, and consequently was not to be controlled by any agency.[28]

For completeness, I should mention regulatory treatment of broadband access using wireless technologies, both fixed and mobile. Until recently, the allocation of spectrum for these services has been quite generous; in some cases MMDS and LMDS licenses were given away for free. The providers do face caps on spectrum allocation and usage, which are becoming more binding as demand for their services grow. Facilities-based commercial mobile wireless services have been exempt from the unbundling and interconnection rules imposed on wireline ILECs by the Act.[29] Nevertheless, the FCC has imposed a resale rule on cellular and broadband Personal Communication Service (PCS) providers, among other wireless providers, forbidding restrictions on the resale of their services.[30]

At this time, provision of interactive broadband data services in the United States is largely free of *rate* regulation, whether wireline or wireless technology is used, whether provided over a switched voice or a cable network, and whether for residential or business customers. Yet, rates for other services provided over the very same infrastructure may be regulated, and this can impinge on the broadband deployment decision, as we will see below.

Given the newness of the technology, we should expect public policy toward high-speed data services to be in its formative stage. So far, however, it does not appear that the law and regulation of broadband service is evolving toward some well defined target. Nor is there indication that, as a group, policy makers have recognized the benefits of running multiple policy

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25. 97 F. Supp. 2d 712 (E.D. Va. 2000), *aff'd*, 257 F.3d 356 (2001).

26. *See* MediaOne Group, Inc. v. County of Henrico, 97 F. Supp. 2d 712 (E.D. Va. 2000), *aff'd*, 257 F.3d 356 (2001).

27. 208 F.3d 1263 (11th Cir. 2000).

28. *See* Gulf Power Co. v. FCC, 208 F.3d 1263, 1279 (11th Cir. 2000), *rev'd sub nom.*, Nat'l Cable & Telecomm. Ass'n v. Gulf Power Co., ___U.S.___, 122 S. Ct. 782 (2002).

29. *See In re* Interconnection and Resale Obligations Pertaining to Commercial Mobile Radio Services, 15:22 F.C.C.R. 13523 (July 24, 2000).

30. *See In re* Interconnection and Resale Obligations Pertaining to Commercial Mobile Radio Services, 16:13 F.C.C.R. 10009 (May 9, 2001).

experiments to ferret out the best, a sort of biodiversity strategy applied to open access policy. The variability in the approaches to intervening in these service markets is remarkable. Certainly at the federal level, we have seen the typical shifts in policy following changes in administration. Here the apparent lack of commitment to a consistent policy may be particularly harmful. Indeed, the deployment of broadband services requires significant sunk capital investments, investments that will not be undertaken when return is jeopardized after a short time period. The impact of asymmetric and variable policy on investment in this infrastructure is the main point of this paper, the task to which we now turn.

III. MODELING THE BROADBAND DEPLOYMENT RACE

The first step in assessing the various open access policies is to establish a baseline outcome that represents the deployment pattern we should expect to observe absent any intervention. This outcome would occur, in theory, were incumbent cable and telecom carriers free to choose where and when to upgrade their networks to deliver high-speed access services. Other communications services are likely related to broadband services, either through cost or demand, so that regulation of those services is part of the status quo.

A. Technology Race Model

We modify a well-known model to describe the competition for broadband deployment that arises between cable and telco providers. That model was designed to describe the race between two or more firms to discover and patent a new technology.[31] In my modification, two incumbent carriers must decide if and when to deploy a broadband network. When they do so, the carrier incurs a one-time, fixed deployment cost. This cost is assumed to fall over (calendar) time reflecting the relentless improvements in microelectronics, optics, radio technology, software, and other technologies that enable broadband networks. Notice that firms do not choose how much to invest in a market; rather, investment is completely lumpy. Nevertheless, firms can

31. See Michael L. Katz & Carl Shapiro, *R and D Rivalry with Licensing or Imitation*, 77 AM. ECON. REV. 402 (1987), for a general formulation of a technology race between two contestants. For an application to a context similar to this one, video competition between telephone companies and cable operators and its regulation see Michael H. Riordan, *Regulation and Preemptive Technology Adoption*, 23 RAND. J. ECON. 334 (1992). Many of the details of the model used here are placed in a Technical Appendix along with formal derivations of all the results. *See id.* at 348-49.

express a strong willingness to invest by deploying earlier, but not without incurring larger construction expense. Indeed, falling deployment costs argue for delay as we will see; counteracting this tendency is the desire to deploy ahead on one's rival.

Network construction in any given market may also benefit from learning spillovers from deployment experience gained in other markets. In general, we would expect the costs to vary across firms and across their chosen broadband technologies. The characteristics of their embedded network will have a large effect on the level of this cost and how it falls over time. This variation will be an important source of determining the equilibrium order of deployment.

As an example, cable systems have greater presence in residential neighborhoods than in the central business district, or other commercial areas of a city. Here, too, is where cable operators have upgraded their old analog systems to expand the number of digital video channels. In contrast, DSL more often runs into attenuation problems in residential neighborhoods, especially the low-density suburbs and rural areas where loop lengths are quite long, though DSL has a comparative advantage in serving business customers in high-density areas.

Broadband networks also entail substantial customer connection costs that vary with the market served. These one-time costs involving customer premise equipment (high-speed modems, network cards, local area hubs, and radio dishes) are proportional to the number of customers connected.[32] It is often the case that, as a marketing device, incumbent providers build these costs into monthly subscription fees. As the ease with which customers can install the equipment without the need of a technician rises, the total of these connection costs for all broadband technologies will fall. One other important consideration is the cost of acquiring a customer. We can expect this cost to be larger when an incumbent provider must poach existing broadband customers from rivals as opposed to attracting them to the service for the first time, and costs of both kinds will tend to exceed the cost of retaining a customer of the firm's non-broadband services.

Each contestant's operating profits (net of any one-time investment costs) at any moment will depend on the deployment history up through that time. We can assume that a carrier will earn the highest operating profit if it alone has deployed high-speed access services and least when it lags its rival. Each will make greater profits when there has been "dual deployment" as compared to when neither has done so, in which case all their earnings derive from their

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32. To a lesser extent the same is true of certain carrier equipment, such as DSL and cable modems and splitters and retrofits of digital loop carriers. It is likely that these expenses will be proportional to the number of neighborhood areas that are served.

traditional services. It is reasonable to assume that the baseline profits prior to deployment may grow even without broadband deployment, but likely at a rather slow pace given that the bulk of those revenues derive from non-broadband services. In contrast, post-deployment profits should track the growth in demand for broadband services, which should be quite rapid. In the event that a carrier is the second to deploy a broadband network, its incremental (operating) profits will depend on the ease with which customers can switch away from the first mover. One benefit of moving first, beyond the revenues derived from sales under monopoly provision of high-speed service, is that those customers may be foreclosed from turning to the rival once it deploys its broadband service.

A carrier's operating profits may fall when its rival deploys broadband technology ahead of it even when it is not supplying high-speed services as of yet. The reason is that a laggard may suffer falloff in its narrowband service demand as a result of its rival's broadband offering because users view them as substitutes. Also, by marketing and bundling narrowband and broadband services, a rival can carve into the laggard profits additionally.

It is worthwhile to pause here to question how accurately the model portrays the strategic situation currently observed in the industry. Unlike the simple race considered here, several other broadband technologies do offer broadband access to homes and businesses (and still others will do so in the future). In addition, even if DSL and CM technologies prevail, we can anticipate future advances will necessitate yet another retrofit of the phone and cable networks.

Unlike the technology race, the buildout of any network is a gradual process, and certainly a broadband data network is not built overnight.[33] In that case, firms would likely experience adjustment costs whereby faster deployment of the network is more costly than slower deployment with the same final coverage. Most likely, more rapid deployment of the broadband infrastructure will also result in degradation of service quality. This aspect could greatly complicate the strategic interaction if it was not known at any time at what stage the rival was in the construction program.

B. Outcome of the Technology Race

Each of the broadband contestants chooses its preferred date to build given its rival's timing strategy. Assume for the moment there were no

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33. *See* Gerald R. Faulhaber & Christiaan Hogendorn, *The Market Structure of Broadband Telecommunications*, 48 J. INDUS. ECON. 305 (2000). Faulhaber and Hogendorn develop a model of staged competition where broadband incumbent providers decide where to build as well as how much capacity to install in their serving territory.

competitive threat. In that case, a carrier would choose a date when the incremental operating profit from deploying equals a measure of the marginal cost of deployment. Here, since the margin on which these firms are operating is a deployment date, marginal cost is the amortized cost of building the network plus the reduction in deployment cost were it to instead delay a bit longer and enjoy somewhat lower deployment cost. This gives the best time "to lead." A similar rule defines the best time to "follow," wherein that case profits are measured given a broadband network already exists in the market. I assume that broadband deployments are profitable enough, and deployment costs are low enough, that it always pays to eventually deploy in each market. It may, nevertheless, not be profitable on net to build a second broadband network.

The leader and follower dates do not necessarily determine the equilibrium dates; while one firm might choose to deploy earlier whether it is a leader or follower, its rival prefers not to accept the remaining position in the order of deployment. To sort this out, define an incumbent provider's "preemption time" as the date when a carrier is indifferent between (i) leading at that date and (ii) allowing its rival to lead at that same date.

With this preemption time, we can state the main result regarding the outcome of the broadband deployment race. One carrier is, in effect, a born leader when the date that it would deploy its broadband network is earlier than the same date for his rival, and also, if his preemption date is earlier. In that case, the born leader will build the network at the *follower's* preemption date, and then later the rival will deploy at its best date to follow.

In other words, the carrier whose profit and cost conditions make it more eager to deploy will do so first, but the threat of being upstaged causes it to do so sooner than it otherwise would. Rather than deciding when to build the broadband network at its leisure, with the competitive threat of earning the profits of a follower and not a leader, the carrier deploys it just an instant before its rival would find it preferable for it to deploy its network. To wait beyond the rival's preemption date would ensure that it would have its lead stolen.

Cost and revenue conditions determine which of the two incumbent providers will take the lead and which one will follow in any given geographic market. As mentioned, it is likely that cable modem service will have the comparative advantage in low-density, residential neighborhoods, while DSL service will dominate in dense urban business districts.

Within a single market, the winner may "take all" in this race, so that once one incumbent provider has deployed a broadband network, a complete overbuild would not be profitable as a price war would ensue. But whereas households are unlikely to subscribe to more than one high-speed Internet access service, dual subscription may not be uncommon among business customers. Furthermore, depending on the technology, the costs may not be great to build a network that merely "passes" subscribers in the area, without incurring the additional investment necessary to hook up individual users.[34] Finally, some differentiation in the broadband services is inevitable given the differences in the technologies allowing for segmentation of customers.

C. Effect of Non-Broadband Regulation

We are particularly interested in how the broadband deployment pattern changes with parameters facing the two contestants. Some of these comparative statics exercises are straightforward. For example, lower construction cost (both in terms of level and the dynamic "marginal" cost) will accelerate all the deployment dates.

As an example of how intervention in the broadband race can alter the deployment pattern, consider the effects of regulation of non-broadband profits prior to broadband deployment. In the case of the cable-telco race for broadband, rate regulation would reduce cable's broadcast video profits and telephone companies' rates for basic voice services. There is no reason to believe there will be symmetry in the application of regulation to non-broadband services of the two providers.

Suppose, to begin with, that regulation has the effect of reducing operating profits by a fixed amount and this amount is the same amount over time and over industry structures for each incumbent provider. In that case, this regulation has no effect on the timing of deployment, whether or not the lead firm engages in preemption. First, what determines the timing of first deployment is the incremental profit from deployment. If profit under either scenario is reduced by the same fixed amount, then there is no change in the lead time. Second, in the case of preemption, a similar result occurs as the net effects of changes on the levels of the various operating profits cancel each other out, resulting in no change in any of the deployment times.[35]

Here we find that asymmetric treatment of the two carriers did not distort the outcome of the broadband race. Regulation was potentially asymmetric because the magnitude of the profit reduction was potentially greater for one carrier than the other. However, I did not allow for the profit reduction to vary

34. This is especially true for fixed wireless broadband technologies, which read great swaths of an urban population once a radio tower is erected, but then require the same expense to connect each additional subscriber.

35. Of course, profit regulation could be made conditional on the level of competition in the industry so as to either accelerate or delay deployment. At this point, I am interested in policies that appear to be neutral toward the broadband investment decision.

for a given carrier before and after deployment. In fact, regulation is not likely to be so consistent over time.

There is reason to believe that the profit constraint may be more binding after broadband deployment than before. In that case, the constraint on profits will likely *increase* after a firm has deployed broadband services. To see this, even when the two providers are treated symmetrically, so that their operating profits are reduced by the *same* absolute amounts, this regulatory rule results in *delay* of deployment. Neither carrier is quite as anxious to deploy since deployment triggers tighter regulation, and so this results in delay of a carrier's preemption date and also the follower's deployment date. Consequently, first and second broadband deployments occur later than they otherwise would.

To be a bit more specific, note that broadband services will use some portion of the network assets each incumbent provider uses to provide non-broadband services. This is certainly true of ILECs' local switched network and cable operators' hybrid fiber-coax video network. Any regulation that allocates some portion of the cost of these facilities to broadband services (in addition to directly attributable broadband investments) will make non-broadband services appear more profitable. By penalizing broadband deployment through the cost allocation rule applied to narrowband services, both firms are less eager to make the necessary investment, *even though broadband services are not directly regulated*.

This exercise suggests that, given existing regulatory institutions, "unregulation" of the broadband Internet access may be a policy maker's chimera.[36] Direct regulation of rates and features of these services is not the only means to affect their deployment. We examined regulation of a service that was related to broadband services through an artificial cost allocation rule. Alternatively, we could have applied regulation to a non-broadband service that is complementary in demand to broadband Internet access (or a close substitute such as ISDN) to arrive at the same conclusion through service substitution.

IV. IMPACTS OF OPEN ACCESS RULES ON THE OUTCOME OF THE BROADBAND RACE

The primary purpose of any open access policy is to create service-based competition by allowing a competing provider to share in the use of an incumbent's facilities. Depending on the context, these policies envision

36. *See* JASON OXMAN, THE FCC AND THE UNREGULATION OF THE INTERNET (Office of Plans and Policy, FCC, Working Paper No. 31, 1999), *at* http://www.fcc.gov/Bureaus/ OPP/working_papers/oppwp31.pdf.

different forms of competition. This competition may be directed toward either or both the provision of upstream infrastructure or downstream services and applications. Further, the goal may be to facilitate continued service-based competition in these markets, or to engender investment in facilities by these new competitors.

At its most ambitious, open access seeks to facilitate infrastructure competition. One way to accomplish this is to offer entrants a "stepping stone" whereby they are able to market some kind of service while they are building their own network. By getting to the market sooner, they are likely to be more viable competitors when infrastructure competition materializes.

Alternatively, open access rules may be designed to create competition in the downstream services market. This is the primary motivation for non-discriminatory treatment of ISPs seeking access to cable modem services. They wish to have the opportunity to compete for subscribers' traffic but may have no intention to compete with the cable operator in broadband access. Resale provides another means by which competing providers can exert discipline on incumbent providers, at least in limited terms, based on price and service characteristics. Resellers, like all service-based providers, trade off between the cost and risk associated with constructing a network against the lease rates they pay for using the incumbent's facilities, plus the loss in control of network capabilities.

The great fear associated with sharing any kind of private property, of course, is that return on the facilities owner's investment will be reduced, leading to diminished investment incentive, or in the extreme, to no investment at all.[37] A crucial determinant of investment incentives is the price the owner can charge for use of its facilities. These rates may be set unilaterally by the incumbent, they may be privately negotiated between providers, or they may be imposed by a regulator. As a result, conditions guiding price formation represent a crucial feature of any open access rule.

Open access rules vary across several dimensions. To begin with, which facilities-based broadband providers must grant access? Candidates include the first firm to build a broadband network, or all firms that eventually build such a network. Second, which interests are given rights to access existing broadband facilities, other facilities-based providers who have built (or potentially could build) a broadband network, or service-based providers who resell broadband services? Third, when must access be granted? Open access could be required immediately upon completion of the broadband

37. A related fear is that, compelled to open up its facilities, the owner will degrade the access services available to a competitor, or find some other way to disadvantage its rivals relative to its service. Open access rules seek to address these concerns with non-discrimination provisions.

facilities, or there could be a delay with the intention to give the owner some time to reap the benefits of its investment not unlike patent protection. Alternatively, once infrastructure competition is realized, requirements to open facilities could be eliminated, with the logic being that open access has served its purpose in stimulating competition. Finally, on what terms must facilities owners supply broadband services? I will be especially interested in Efficient Components Pricing Rule (ECPR) and Long Run Incremental Cost (LRIC) methodologies that are based on economic principles.

Versions of the open access rules will be examined by expressing them in the context of the broadband race. Comparing the outcome of the race with and without an open access rule will reveal its impact on deployment pattern relative to the unregulated outcome (i.e., equilibrium with no open access requirement and no offer extended). It is important to remember that the outcome of this benchmark case is not necessarily welfare optimal. Since firms find themselves in a winner-take-most contest, investment tends to take place too soon relative to the welfare optimum.[38]

In this section I evaluate the consequences of various open access rules on the pattern of broadband deployment. Open access rules differ along several dimensions. First, which facilities-based broadband providers must grant access? Open access obligations could apply only to the first to deploy, or they could apply to any incumbent provider who builds broadband facilities. Which providers are given rights to access existing broadband facilities? They could be available only to other facilities-based carriers who have built, or potentially could build, broadband facilities. Or, they could be reserved for providers who remain purely service-based.

Second, when must access be granted? A facility could be opened immediately upon completion or there could be a period of exclusivity before this occurs. Another possibility is that access to the facility is granted only until a second facilities-based broadband provider arrives, marking the beginning of broadband infrastructure competition.

Finally, and very importantly, on what terms must facility owners supply their broadband network services? Since access in not likely to be offered voluntarily, government intervention is required to establish price and nonprice terms–though they could be decided through private negotiations. Two leading

38. At bottom, the firms have no means to express the value they attach to deploying at specific times, except to actually make an investment. Suppose, for instance, the first firm derives its highest profit by deploying in year one, which is much lower than the highest profit the second firm can generate, and which is realized only when that firm deploys in year two. In absence of an auction of the right to deploy at the preferred time, the first firm may preempt the second firm if the first firm would earn much lower profit if it were to wait until year two. This would be inefficient if total welfare was roughly proportional to firm profits.

pricing rules that will receive our attention are the ECPR and pricing rules that use LRIC methodology.

Each open access rule is imposed prior to any broadband deployment but applied to established providers of non-broadband services. In principle, different rules can be applied to different geographic areas as has been the case in the United States. The effect of rules on the timing of broadband deployment turns on their impact on the levels of operating profits earned by the two contestants. None of the open access rules impact deployment costs.[39] Also, open access rules only kick in after broadband facilities are deployed so that pre-deployment profits are unaffected. I then ask how specification of each open access rule affects which firm(s) eventually build a broadband network, the timing of those deployments, and the order in which firms build.

I assume that the broadband race will have a leader who deploys its network at its preemption time, and that the other carrier eventually deploys as well. In that case, the effect of an open access rule is then expressed as a perturbation in the profit path of both firms during their "monopoly period" (when just one firm has built a network and offers broadband services) and the "dual deployment period" (when both firms have built networks).

The first open access rule allows the follower to use the leader's broadband facility until that time when it builds its own. No pure reseller is allowed to enter to use the available broadband facility; only an incumbent firm that already owns a facility and has the potential to upgrade to broadband has that right (even if it may choose never to do so).[40] The period during which access to the facility is required ends when infrastructure competition is realized with a second deployment.

This scenario, translated into the technology race framework, raises the profitability of the latecomer during the monopoly period. Notice that the profits of the follower during the monopoly period increase for both firms–even while a broadband leader is assumed never to follow. This out-of-equilibrium strategy will nevertheless alter deployment incentives. I first consider the case

39. Yet, open access policies could also alter broadband deployment costs such that telco and cable operators must incur additional expense to ensure their networks are open to all third parties.

40. Note that it may be less costly for one of the firms to lease the other's network, and this should be reflected by some differential cost of service-based broadband provision. An example would be the fact that the telephone network in most cases is designed around industry technical standards that do not vary from one region to another. Cable television systems, in contrast, adhere to a variety of technical specifications that make it more costly for a service-based competitor to make use of a cable operator's network. This situation is changing but it could make it easier for a cable operator to provide broadband service leasing unbundled elements from the ILECs than vice versa.

when profits of the leader are completely unaffected by open access. The interpretation of this additional assumption is that the facilities-based provider remains "whole" as if prices were set according to ECPR, either by a regulator or the self-interested firm. Besides these changes, profits after second deployment are assumed to be unchanged since the follower can no longer lease the leader's facilities (or vice versa).

In this case the impact of open access is quite simple to derive and intuitive to explain. The follower's preemption date (and hence, the timing of the first deployment in the outcome of the broadband race) is delayed as a result of the increase in profits derived from resale. Furthermore, the date at which the follower follows is also delayed. Thus, the option to lease the leader's network slows down both deployments.[41] The reason is quite apparent. The follower is now more profitable prior to deploying its broadband facilities and, since it gains less upon deployment, it puts off its deployment date. The leader also delays its deployment, which occurs at the follower's preemption date, because the follower is less threatening.[42]

Of course, the magnitude of the impact of open access rule depends on how profitable it will be for the follower to lease the leader's network. This profit increment would shrink, for example, if the follower was precluded from leasing the leader's broadband network for some fixed period of time, akin to the exclusivity period of a patent. If the period of exclusivity is short, then the results would continue to hold qualitatively. Since the profit increment from following does not change as a result of an exclusivity period, the follower will not alter the date at which it follows. However, forgone profit during the exclusivity period will reduce its overall profit from following (relative to open access without an exclusivity period), and so the preemption date will occur a bit earlier.[43]

Now suppose that we also increase the leader's profits to reflect the possibility that it, too, could earn higher profits should it instead follow the lead of its rival. In fact, assuming the order of deployment does not change, the leader would never be in a position to realize these profits. But the prospect

41. If, instead of preemption, the leader would deploy at its preferred time, then this policy would have no effect on the initial deployment. However, the second deployment would still be delayed.

42. The higher profits to the follower during the monopoly period raises the value of following independent of the first deployment because all other profit levels of the follower are unchanged, and the only way it takes advantage of the reselling of profits is by being a follower. The equality of the follower's profits of leading and following is restored when the first deployment is delayed because we start from a time earlier than the follower's monopoly deployment date.

43. Of course, if the exclusivity period grows indefinitely long (beyond the duration of the unregulated monopoly period), then the open access rule becomes irrelevant.

that the follower could lead instead, and that an open access rule would make the otherwise leader a slower follower, has the effect of advancing the follower's preemption date. If the actual leader engages in preemption, then this effect taken by itself will speed up the initial deployment, just the opposite direction from the previous case. The net effect of this more symmetric open access rule is ambiguous, depending on several factors. The earlier conclusion that both deployment dates are delayed is preserved if the follower derives relatively more profits from reselling than the leader.

Continuing along this line, suppose that during the period of unbundling the leader's profits are not unaffected but are reduced below their unregulated levels. The interpretation is that access prices shift some of the profits from the facilities-based leader to the service-based follower. This would occur, for example, if regulators imposed some form of LRIC pricing. The effect of this form of open access, as might be expected, delays deployment, as now the leader has reduced incentives to invest. To simplify analysis of this case, return to the asymmetric rule where the leader alone is required to open up its network. The rule then redistributes profits from the leader to the follower. In that case, delay occurs and all critical deployment dates are delayed. Consequently, once again the first and second deployments occur later than at the unregulated equilibrium as a result of the open access rule.

Another condition that may be imposed by an open access rule reserves use of an incumbent's network to a "pure reseller," denying access to another facilities-based incumbent. In practical terms, this would say the cable and telephone companies cannot gain access to each other's unbundled network services before or after they upgrade to broadband capabilities, but an independent service-based provider could lease either broadband network. This condition promotes open access as a means to stimulate downstream service competition, and not specifically to encourage potential infrastructure competitors. In terms of the broadband race, this rule uncouples the follower's decision to deploy broadband from its option to use the leader's network to provide service beforehand.

If the reseller simply earns a profit, and the leader remains whole (e.g., using ECPR), then the pattern of deployment will not depart from the unregulated outcome. This rule becomes more interesting when, possibly through LRIC access pricing, the leader's profits are reduced during the monopoly period. The effect of this condition is to slow deployment. In all cases the follower date is unchanged because incremental profits are independent of how much the leader earns. However, the leader's monopoly date and its preemption date are delayed; so, assuming the open access rule is applied to both firms, the initial deployment will be delayed. This is true whether the leader preempts the follower or is able to deploy at its monopoly time.[44]

Next, I want to examine the effects of allowing the follower to continue to rent the leader's broadband facilities after it builds its network. One efficiency justification for such a rule is to continue to give the follower more freedom in its buy-build decisions, thereby lowering its costs. Another justification (whose efficiency implications are less apparent) would be to offer continued access to the leader's facility as a further means to encourage the follower to deploy, and to exert competitive pressure on the leader.

Shortly, I will consider a more symmetric treatment of the firms whereby both have the option to rent the other's facilities. In the meantime, the open access rule has the effect of increasing the follower's profits during the dual-deployment period as well as during the monopoly period. The analysis is simplified if we assume no reduction in the leader's profit in either period, as if the ECPR was applied. It can then be shown that the effect of these profit changes will unambiguously delay the follower's preemption date. Assuming that the leader will preempt the follower, this open access rule works to delay initial deployment. Also, if the increase in profits is roughly the same in both cases, then there is no effect on when the follower deploys since the net effect on the incentive to follow is unchanged. Contrary to intent, the rule does *not* speed up the second deployment.

This last open access rule is discriminatory, and if its intent was to improve buy-build decisions, opening of the broadband facilities should be more symmetric, i.e., give the leader the same option. To examine this possibility, suppose that there is no open access during the monopoly period, but once the two broadband networks have been built, both firms can lease portions of the other's broadband network.[45] Here the focus of the rule is directly on improving the buy-build decisions.

We can characterize the effects of this rule by assuming both carriers now experience higher operating profits when both have built broadband networks. By increasing the profits from dual-deployment, the date at which either firm would follow the leader is advanced since the profit incentive to

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44. The characterization of this open access policy may be too limited. It could be the case that by signing up many customers for a particular technology a reseller could aid the facilities-based providers in defending against later competition from an alternative technology. Arguably, ILECs may reduce the loss of DSL customers once cable modem service becomes available in an area if broadband data CLECs have signed up many customers in the meantime. To capture this feature we would want to redistribute profits from the follower to the leader after the second deployment.

45. As before, we assume that leasing broadband network services does not reduce the facility owner's profit as if ECPR pricing was used.

follow has increased. The effect on the follower's preemption date (and hence the initial deployment of broadband) depends on the exact size of the profit changes. In fact, if the two incumbent providers are treated symmetrically (in that their profits rise the same absolute amount), then there is no change in the preemption date. However, these same changes will unambiguously delay the preemption date for the leader. This will not be critical unless it was large enough to *reverse* the order of the two firms. If the leader's preemption date is put off long enough, then in equilibrium it could become the follower, and the carrier who would otherwise follow now assumes the role of leader, deploying at its rival's preemption date. Here is one case where an open access rule could compel the *less efficient* technology to be deployed first, while the more efficient one would be deployed second, and possibly not at all.

CONCLUSIONS

I examined the impacts of various open access rules using an equilibrium dynamic model of broadband deployment. The rules altered deployment timing by two contestants, typically resulting in delay in either the first or second deployments, or both. Delays can be traced back to reduced incentives to invest in broadband facilities relative to service-based alternatives, or relative to no investment at all. I also found that asymmetric treatment of incumbent providers, and hence their corresponding technologies, can have significant effects on the pattern of deployment even while intervention can be quite subtle and indirect.

As formulated, the technology race model lacks sufficient detail to conduct a full welfare analysis of the different open access rules. It is reasonable to assume, however, that the more broadband providers that serve the same market, whether they own facilities or resell incumbent services, the lower prices will be for broadband services. Assuming narrowband rates are not affected, we can conclude that welfare rises with either form of competition. To the extent that we find open access tends to put off the deployment of broadband services, consumer welfare is foregone.

Certainly the welfare costs associated with deployment delays should factor importantly in the debate over the form of open access rules applied to broadband infrastructure. Indeed, the cost of delays in deploying other new telecommunications technologies have been found to be quite large.[46]

46. *See* Walter S. Baer, *Telecommunications Infrastructure Competition: The Costs of Delay*, 19 TELECOMM. POL'Y 351 (1995); Jeffrey Rohlfs et al., *Estimation of the Loss to the U.S. Caused by the FCC's Delay in Licensing Cellular Telecommunications*, National Economic Research Associates (Nov. 1991).

Nevertheless, this calculus may miss other welfare costs stemming from reduced pace of innovation in broadband technologies. First, it is likely that each generation of broadband technologies builds upon the previous generation, learning from earlier mistakes. Deployment delays will only retard the rate at which this knowledge accumulates. Furthermore, since new technologies often ride on at least some portion of existing infrastructure and customer equipment (as in the case of DSL and cable modem technologies), when investment is delayed and the current network is being amortized, so too may be the date when new technologies are deployed by upgrading or retrofitting existing infrastructure. Finally, the incentives for investing in Research and Development may be blunted depending on how open access rules alter rates of return on broadband investment. All of these considerations argue for an expanded analysis of the broadband race beyond modeling incentives to commercialize proven technologies.