PHOENIX CENTER POLICY BULLETIN NO. 23

PHOENIX CENTER FOR ADVANCED LEGAL & ECONOMIC PUBLIC POLICY STUDIES
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October 2009

EXPANDING THE DIGITAL DIVIDE:

NETWORK MANAGEMENT REGULATIONS AND THE SIZE OF PROVIDERS

Abstract: One goal of the American Recovery and Reinvestment Act of 2009 ("ARRA") is to provide all Americans with access to affordable broadband services, particularly to those Americans living in rural markets where demand and cost conditions do not favor network deployment. At the same time, there is growing support for regulations that may effectively force network operators to "invest their way out" of congestion rather than manage traffic to improve network efficiency and quality. In this BULLETIN, we demonstrate that such rules are likely to affect disproportionately networks located in rural areas or smaller networks in urban markets given the cost disadvantages faced by such firms. Since these markets are a central target of both the ARRA's stimulus funding and required National Broadband Plan, the imposition of strong "network management" provisions are likely to result in lower quality service and less availability in rural areas and potentially reduce competition in urban areas, as well as to reduce the effectiveness of stimulus grants and other subsidies. Further, we present some evidence indicating an elastic response of subsidy levels to increases in costs resulting from such regulations; specifically, a 1% increase in deployment costs arising from regulation increases the subsidy required for ubiquitous coverage by nearly 2%. Accordingly, policymakers seeking to expand quickly and efficiently broadband availability in rural markets should carefully and explicitly compare the benefits and costs from network management regulatory mandates, with a particular eye on disproportionate effects across market types.

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I. Introduction

The stated goal of the American Recovery and Reinvestment Act ("ARRA") of 2009 is to provide all Americans with access to affordable broadband services.[1] As such, a central focus of both the ARRA's stimulus funding and its mandatory National Broadband Plan is the expansion of availability in rural markets that today have little or no broadband service, thereby making service available to the last 5-10% of American households. Under the best of circumstances, however, this is no easy task: Building and operating broadband networks is an extremely expensive and difficult business, requiring the achievement of economies of scale and scope if prices are to be low enough for widespread consumption. These supply-side characteristics of communications networks are particularly potent deterrents of investment in rural markets, where populations are smaller (i.e., low demand) and population density is low (i.e., high cost). Backhaul costs are often higher in rural markets due to the scarce demand and high costs of deploying circuits over long distances.

Given the above, prudent broadband policy should reduce deployment and operational costs wherever possible, thereby inducing private investment and maximizing the payoff of government investments in broadband networks.[2] Many proposals do just that. At the same time, however, there are calls for tighter regulatory control over the network management practices of broadband providers.[3] These "network management," "open network", "network neutrality" or "application neutrality" proposals, regardless of the altruism behind them, are nonetheless very likely to reduce deployment, increase transaction costs, raise prices, reduce

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[1] American Recovery and Reinvestment Act of 2009 at Title VI—Broadband Technology Opportunities Program, (Public Law 111-5, 2009)(available at: http://www.gpo.gov/fdsys/pkg/PLAW-111publ5/pdf/PLAW-111publ5.pdf, 47 USC §1305(k) *et seq.*).

[2] *See, e.g.*, G.S. Ford, T.M. Koutsky and L.J. Spiwak, PHOENIX CENTER POLICY PAPER NO. 21, *Competition After Unbundling: Entry, Industry Structure and Convergence* (2005)(available at: http://www.phoenix-center.org/pcpp/PCPP21Final.pdf), *and reprinted in* 59 FED. COMM. L.J. 331 (2007); G.S. Ford, T.M. Koutsky and L.J. Spiwak, *The Consumer Welfare Cost of Cable "Build-out" Rules*, PHOENIX CENTER POLICY PAPER NO. 22 (Third Release, January 2007)(available at: http://www.phoenix-center.org/pcpp/PCPP22_Third_Release.pdf); G.S. Ford, T.M. Koutsky and L.J. Spiwak, PHOENIX CENTER POLICY PAPER NO. 34, *The Pricing of Pole Attachments: Implications and Recommendations* (December 2008)(available at: http://www.phoenix-center.org/pcpp/PCPP34Final.pdf); T. Randolph Beard and George S. Ford, PHOENIX CENTER POLICY BULLETIN NO. 22, *Do High Call Termination Rates Deter Broadband Deployment?*(October 2008)(http://www.phoenix-center.org/PolicyBulletin/PCPB22Final.pdf).

[3] The arguments for network neutrality, and its meaning, are constantly in flux. *See, e.g.*, *Preserving a Free and Open Internet: A Platform for Innovation, Opportunity, and Prosperity*, Prepared Remarks of Chairman Julius Genachowski, The Brookings Institution, Washington DC (September 21, 2009)(available at: http://www.openinternet.gov/read-speech.html); Letter from Ben Scott, Free Press, to Congresspersons Waxman, Barton, Boucher, and Stearns (April 22, 2009) (available at: http://www.freepress.net/files/FP_metering_letter.pdf); http://www.savetheinternet.com.

quality, and even potentially lead to increased industry concentration.[4] Accordingly, policymakers are going to have to make some hard policy trade-offs between the regulation of how broadband operators manage their networks and the efficient obtainment of ubiquitous broadband coverage. At a minimum, notions of "neutrality" must become more goal oriented, discarding unnecessary and costly appendages that frequently appear due to the lack of a formal definition of "neutrality" or even a clear statement of its intended purpose.

Building upon our prior research, we examine in this BULLETIN the view that network congestion should be managed mainly by expanding capacity rather than targeting congestion-causing applications or users. To illustrate the effects of a capacity-centric response to congestion, we present an economic model that highlights the effects of limiting network operators solely to capacity expansion in the face of congestion (which is a logical outgrowth of policies that both mandate the neutral treatment of all Internet traffic or the imposition of some sort of congestion or usage-based pricing). Unsurprisingly, limiting traffic management practices reduces an operator's degree of freedom in managing congestion, thereby increasing costs and, in turn, consumer prices.[5] More importantly, the regulation of network management may disproportionately affect networks located in rural areas or smaller networks in urban areas, and wireless networks that face relatively high capacity costs. Since these markets and technologies are a central target of both the ARRA's stimulus funding and National Broadband Plan, the imposition of strong "network management" provisions are likely to result in lower quality service and less availability in rural areas, as well as to reduce the effectiveness of ARRA stimulus grants. If anything, network management regulations, to the extent they increase

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[4] *See, e.g.*, T.R. Beard, G.S. Ford, T.M. Koutsky and L.J. Spiwak, *Network Neutrality and Foreclosing Market Exchange*, 1 INT. J. MANAGEMENT AND NETWORK ECONOMICS 160 (2009); G.S. Ford, T.M. Koutsky and L.J. Spiwak, *A Policy And Economic Exploration of Wireless Carterfone Regulation*, 25 SANTA CLARA COMPUTER & HIGH TECH. L.J. 647 (2009); G.S. Ford, T.M. Koutsky and L.J. Spiwak, *Consumers and Wireless Carterfone: An Economic Perspective*, PHOENIX CENTER POLICY BULLETIN NO. 21 (September 2008)(available at: http://www.phoenix-center.org/PolicyBulletin/PCPB21Final.pdf); G.S. Ford, T.M. Koutsky and L.J. Spiwak, *Using Auction Results to Forecast the Impact of Wireless Carterfone Regulation on Wireless Networks*, PHOENIX CENTER POLICY BULLETIN NO. 20 (Second Edition) (May 2008)(http://www.phoenix-center.org/PolicyBulletin/PCPB20Final2ndEdition.pdf); T.R. Beard, G.S. Ford, T.M. Koutsky and L.J. Spiwak, *Network Neutrality and Industry Structure*, 29 HASTINGS COMMUNICATIONS AND ENTERTAINMENT LAW JOURNAL 149 (2007).

[5] *C.f.*, Mike Shepard, *Computer Science Professor David Farber Explains His Opposition to Net Neutrality*, POST TECH (October 8, 2009) (available at: http://voices.washingtonpost.com/posttech/2009/10/computer_science_professor_dav.html) (According to David Farber, a professor of computer science and public policy at Carnegie Mellon and former Chief Technologist at the FCC during the Clinton Administration, "Should the FCC say that all applications that want to operate should be allowed? Practically unless we make magic with physics, that can't happen. *** We've always said the Internet has infinite bandwidth, but the economics of running a network don't allow you to do that. You share a cable of fairly small bandwidth with a lot of people.")

costs, will certainly require policymakers to increase significantly subsidies above current levels, which may not be socially optimal.[6] We present some evidence here indicating an elastic response of subsidy levels to increases in costs resulting from cost-increasing regulations; specifically, that a 1% increase in deployment costs increases the subsidy required for ubiquitous coverage by nearly 2%. As such, policymakers seeking to expand quickly and efficiently broadband availability in rural markets should compare carefully and explicitly the benefits and costs from such ex ante network management mandates.

II. Background

Dealing with the capacity constraints of broadband networks has long been, and is now, increasingly becoming an important issue for both broadband operators and policymakers as the capacity demands of modern applications rises sharply.[7] Since the capacity of even the most advanced broadband networks is limited, network operators (in particular wireless network operators) are forced to respond to the increasing capacity demands by managing traffic to maintain a high quality of service for all of their customers.[8] The range of traffic management techniques is wide and includes, but is not limited to, the prioritization of latency sensitive data, charging price premiums on congestion-causing applications and users, investing in capacity expansion, and even prohibiting the use of certain types of bandwidth greedy applications.

While many agree today that traffic control is an essential component of network management and typically a source of consumer benefit by reducing congestion and

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6 *See, e.g.*, Howard Berkes, *Stimulus Stirs Debate Over Rural Broadband Access*, NATIONAL PUBLIC RADIO (February 16, 2009)(available at: http://www.npr.org/templates/story/story.php?storyId=100739283) (quoting former FCC Chief Economist Dr. Michael Katz on how the $7.2 billion in broadband stimulus funds in the ARRA could be put to better societal use. According to Dr. Katz, "The notion that we should be helping people who live in rural areas avoid the costs that they impose on society … is misguided … from an efficiency point of view and an equity one.")

7 M. Welzl, NETWORK CONGESTION CONTROL: MANAGING INTERNET TRAFFIC (2005); G. Goth, *More Online Video Rekindles Network Capacity Debate*, IEEE INTERNET COMPUTING (May-June 2007); B. Briscoe, *A Fairer, Faster Internet Protocol*, IEEE SPECTRUM (Dec. 2008); B. Huberman and R. Lukose, *Social Dilemmas and Internet Congestion*. 277 SCIENCE 535-537 (July 25, 1997); J. Green, THE IRWIN HANDBOOK OF TELECOMMUNICATIONS MANAGEMENT (2001) at p. 232 (addressing the selection of an ISP: "One of the major factors you are trying to assess in choosing an ISP is the likelihood of congestion and single points-of-failure" so "…ask questions such as these: What is your strategy for congestion control on the access circuits?").

8 *See, e.g.*, *Guideline for Packet Shaping,* Japan Internet Providers Association (JAIPA), Telecommunications Carriers Association (TCA), Telecom Services Association (TELESA), Japan Cable and Telecommunications Association (JCTA) (May 2008)(available at: http://www.jaipa.or.jp/other/bandwidth/guidelines_e.pdf); see also J. Menn and C. Nuttall, *Warning on Surge in Wireless Traffic,* FINANCIAL TIMES (October 7 2009)(available at: http://www.ft.com/cms/s/0/c355e810-b378-11de-ae8d-00144feab49a.html?nclick_check=1).

prioritizing latency sensitive traffic, there are those who continue to advocate for regulatory constraints on the ability of network operators to manage freely Internet traffic to attenuate congestion. Some proposals call for application neutrality, where ISPs are prohibited from targeting particular applications for congestion control.[9] The more quixotic arguments call for a regulatory or legislative mandate requiring the neutral treatment of all Internet traffic (in addition to other regulations of ISP behavior).[10] In either world, the risk is that solutions to network congestion will be (largely) limited to capacity expansion, and many proponents of Internet regulation view this as a desirable outcome.[11]

The FCC made it quite clear in its 2005 Broadband Policy Statement that firms should be allowed to engage in some sort of "reasonable network management"[12] and, for the most part, even advocates of network neutrality rules generally state that they agree.[13] While many view this as a consensus, the definition of "reasonable network management" is unfortunately subjective and, therefore, the debate over how to define the term rages on. A significant group argues that this term should be defined very narrowly. More specifically, recent policy initiatives seem to indicate a distaste for granular network management and instead a preference that operators should be strongly encouraged (if not simply forced) to "invest their way out" of congestion problems by expanding capacity.[14] Even if not explicit, the effect of

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[9] L. Lessig and R. McChesney. *No Tolls on The Internet*, WASHINGTON POST (June 8, 2006) (available at: http://www.washingtonpost.com/wp-dyn/content/article/2006/06/07/AR2006060702108.html. ("Net neutrality means simply that all like Internet content must be treated alike and move at the same speed over the network. The owners of the Internet's wires cannot discriminate."). Yet, if an application is solely responsible for congestion, then it seems sensible for an ISP to "throttle" such use, even if in a targeted manner. Expanding congestion control to applications and users not causing congestion is plainly inefficient.

[10] *See, e.g.*, S. Meinrath and V. Pickard, *The New Network Neutrality: Criteria for Economic Freedom*, 12 INTERNATIONAL JOURNAL OF COMMUNICATIONS LAW & POLICY 225-243 (2008).

[11] *Id.*

[12] *FCC Broadband Policy Statement*, 20 FCC Rcd 14986, FCC 05-151(August 5, 2005)("The principles we adopt are subject to reasonable network management.")

[13] *See, e.g.*, Vint Cerf, Chief Internet Evangelist, *What's a Reasonable Approach for Managing Broadband Networks?* Google Public Policy Blog (August 4, 2008)(available at: http://googlepublicpolicy.blogspot.com/2008/08/whats-reasonable-approach-for-managing.html); Rick Whitt, Google Washington Telecom and Media Counsel, *Net Neutrality, Con't (Part 2): Type-Based Differentiation,* Google Public Policy Blog (June 27, 2007)("[W]e do not dispute that broadband providers should have the ability to manage their networks, as well as engage in a broad array of business practices.")(available at: http://googlepublicpolicy.blogspot.com/2007/06/net-neutrality-cont-part-2-type-based.html); Harold Feld, *The FCC Releases the Comcast Complaint Order Part I – Why This Is A Huge Win,* Wetmachine (August 20, 2008)(available at: http://www.wetmachine.com/totsf/item/1283).

[14] Congestion is but one factor requiring network management to maintain quality. Network quality also includes performance characteristics related to jitter, packet loss, and latency. Capacity expansion may do little or nothing to change these dimensions of quality.

certain rules may render traffic shaping or pricing options too costly for carriers to implement, leaving capacity expansion as the only feasible option.

For example, in last summer's hotly contested dispute over whether Comcast improperly blocked BitTorrent, a peer-to-peer ("P2P") application, the FCC held that a network provider could not discriminate against a particular application or protocol, even if that protocol causes significant congestion on the network.[15] Instead, the FCC concluded that carriers must treat *all* applications and protocols "equally."[16] Although the Commission stated that Comcast could have imposed a cap on average users' capacity and then charged the most aggressive users overage fees or throttled back the usage of *all* high capacity users (rather than just those who were using the congestion causing application),[17] the Commission reiterated that the alternative of "feasible facility improvements" remained very much on the table.[18] Today, there is significant resistance to cap- or price-based solutions to congestion management.[19]

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15 *But c.f., MGM v. Grokster*, 545 U.S. 913, 920 n. 1 (2005):

> Peer-to-peer networks have disadvantages as well. Searches on peer-to-peer networks may not reach and uncover all available files because search requests may not be transmitted to every computer on the network. There may be redundant copies of popular files. *The creator of the software has no incentive to minimize storage or bandwidth consumption, the costs of which are borne by every user of the network. Most relevant here, it is more difficult to control the content of files available for retrieval and the behavior of users.*

Emphasis supplied.

16 *In re Formal Complaint of Free Press and Public Knowledge Against Comcast Corporation for Secretly Degrading Peer-to-Peer Applications,* Memorandum and Order, FCC 08-183, 23 FCC Rcd 13,028 (rel Aug. 20, 2008) at ¶ 41.

17 *Id.* at ¶ 49.

18 *Id.* at ¶ 49, n. 227, citing *Service Rules for the 698–746, 747–762, and 777–792 MHz Bands; Revision of the Commission's Rules to Ensure Compatibility with Enhanced 911 Emergency Calling Systems; Section 68.4(a) of the Commission's Rules Governing Hearing Aid-Compatible Telephones; Biennial Regulatory Review — Amendment of Parts 1, 22, 24, 27, and 90 to Streamline and Harmonize Various Rules Affecting Wireless Radio Services; Former Nextel Communications, Inc. Upper 700 MHz Guard Band Licenses and Revisions to Part 27 of the Commission's Rules; Implementing a Nationwide, Broadband, Interoperable Public Safety Network in the 700 MHz Band; Development of Operational, Technical and Spectrum Requirements for Meeting Federal, State and Local Public Safety Communications Requirements Through the Year 2010; Declaratory Ruling on Reporting Requirement under Commission's Part 1 Anti-Collusion Rule*, WT Docket Nos. 07-166, 06-169, 06-150, 01-309, 03-264, 96-86, CC Docket No. 94-102, PS Docket No. 06-229, Second Report and Order, 22 FCC Rcd 15289, 15371, ¶ 222 (2007) (*700 MHz Second Report and Order*).

19 *See, e.g.,* April 16th 2009 Press Release of Senator Charles Schumer ("In the face of enormous community opposition and at [Senator] Schumer's urging, [Time Warner Cable] will shelve [their tiered pricing] plan for all of their test markets.")(available at: http://schumer.senate.gov/new_website/record.cfm?id=311573); *but c.f.* L. Spiwak, *Is YOUR Broadband Access About to Go Bye Bye?* FOX FORUM (June 2, 2009) (available at: http://www.foxnews.com/opinion/2009/06/02/broadband-access-bye-bye).

A more recent example comes in the form of the Notice of Funds Availability ("NOFA") recently issued by Rural Utilities Service (RUS)/National Telecommunications and Information Agency (NTIA) to allocate ARRA broadband stimulus funds.[20] There, the NTIA and RUS went beyond the FCC's "Four Principles" embodied in the Commission's 2005 Broadband Policy Statement[21] by imposing a "fifth" *ex ante* non-discrimination requirement to "ensure neutral traffic routing" and to prevent grant awardees from "favor[ing] any lawful Internet applications or content over others."[22] Although the NOFA would permit awardees to engage in "generally accepted technical measures" to facilitate reasonable traffic management "such as caching and application-neutral bandwidth allocation, as well as measures to address spam, denial of service attacks, illegal content, and other harmful activities", awardees are nonetheless prohibited from "charg[ing] some application and content providers for 'fast lanes' that would put others at a competitive disadvantage."[23] While perhaps carefully worded, the requirements have effectively discouraged any of the larger broadband providers, which presumably are some of the lowest cost providers in the country, from applying for such funds.[24]

Finally, and perhaps most extreme, is the recently introduced H.R. 3458, the "Internet Freedom Preservation Act" co-sponsored by Representatives Edward Markey and Anna Eshoo.[25] Under the plain terms of this bill, not only would an Internet access service provider be prohibited from "impos[ing] a charge on any Internet content, service, or application provider … beyond the end user charges associated with providing the service to such provider," but the service provider may "not provide or sell … any offering that prioritizes traffic over that of other such providers on an Internet access service" and may "not install or utilize network features, functions, or capabilities that impede or hinder compliance with this section."[26] Moreover, the concept of "reasonable network management" would be defined exclusively by FCC regulation (as opposed to the current and more flexible ex post adjudicative approach),[27]

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20 Department of Agriculture (RUS) and Department of Commerce (NTIA), Notice of Funds Availability, 74 Fed. Reg. 33104 (June 9, 2009)(hereinafter "*NOFA*").

21 *FCC Broadband Policy Statement, supra* n. 12.

22 *NOFA* at 33132-33.

23 *Id*. Notably, applications are not neutral with respect to their demands on the network, so treating all applications the same is, in fact, favoring certain applications over others.

24 *See, e.g.*, Cecilia Kang, *Major Carriers Shun Broadband Stimulus: Funds Would Come With Tighter Rules*, WASHINGTON POST (August 14, 2009)(available at: http://www.washingtonpost.com/wp-dyn/content/article/2009/08/13/AR2009081302433.html).

25 http://thomas.loc.gov/cgi-bin/query/z?c111:H.R.3458.

26 HR 3458 at §§ 12(b)(1)-(6).

27 *Id.* at § 12(k)(4).

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and congestion reducing activities would be considered "reasonable" only "if it furthers a critically important interest, is narrowly tailored to further that interest, and is the means of furthering that interest that is the least restrictive, least discriminatory, and least constricting of consumer choice available."[28] Efficient solutions play no role in the proposed legislation. Last, and perhaps most germane here, the Federal Communications Commission would be charged with promulgating rules to force network operators "to the extent feasible, make available sufficient network capacity to users to enable the provision, availability, and use of an Internet access service to support lawful content, applications, and services that require high bandwidth communications to and from an end user."[29]

A. *Managing Network Congestion via Capacity Expansion*

Combining various themes from our earlier work on the cost/benefits of various "open network" regulatory proposals, we present an economic model in the BULLETIN that highlights the effects of limiting network operators solely to capacity expansion in the face of congestion with an eye toward ISPs serving rural markets (or smaller carriers in larger markets). The model is similar to that we presented in POLICY PAPER NO. 32,[30] which dealt with the management of congestion, but here we ignore the use of price premiums to internalize the congestion externality, since that topic was covered in the earlier paper. In this model, attenuation of the congestion externality is accomplished by either demand management techniques or the expansion of capacity. To simulate network management regulation of the type some (but not all) propose, we impose the constraint that only capacity expansion is allowed, and model the costs of such expansion in two ways. First, we consider the case where capacity expansion is subject to economies of scale. Second, we ignore scale economies and consider the case where small or rural firms face higher absolute costs in capacity expansion. We then consider whether network management regulation of this type differentially affects firms of different sizes.

Scale and density economies are prevalent throughout communications networks. The price of a high capacity circuit is not linear in capacity, and there may be density economies in other components of the network that relate to capacity expansion. In addition, evidence indicates that the absolute cost differences for bandwidth in rural markets are, in many cases, enormous. For example, some parties claim that the wholesale backhaul capacity to the Internet backbone

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28 *Id.* at § 12(d).

29 *Id.* at § 12(c)(3).

30 G.S. Ford, T.M. Koutsky and L.J. Spiwak, *The Welfare Impacts of Broadband Network Management: Can Broadband Service Providers be Trusted?* PHOENIX CENTER POLICY PAPER NO. 32 (March 2008)(available at: http://www.phoenix-center.org/pcpp/PCPP32Final.pdf).

costing $4 per megabit per month in larger cities can cost $300 per megabit per month in rural markets.[31] Clearly, the capacity costs can be substantially different across urban and rural markets. Consequently, as we demonstrate here, Internet regulations that limit the ability to attenuate congestion by directly targeting bandwidth applications, users, or other sources should be expected to disproportionately harm rural providers and lead to lower quality service or less availability. Blanket prohibitions, whether direct or indirect, should be applied with great caution (or simply avoided). If the targeting is based on anti-competitive motivations, then there are processes for dealing with such actions.

As in POLICY PAPER NO. 25,[32] we show that the impact of network management regulations may not be uniform across all markets or all firms. Regardless of how the costs of capacity expansion are modeled, firms in small markets, rural markets, or smaller firms in larger markets, are differentially impacted by network management regulation limiting congestion solutions to capacity expansion (put simply, any firm with a cost disadvantage of some sort). This differential effect is expected to raise the cost of network deployment in rural markets and, consequently, reduce the deployment of broadband in rural markets. Smaller competitors in large markets that face a cost disadvantage are likewise disproportionately harmed by the rule. This result is important since many small, rural markets are relying on broadband Internet services for their economic viability and expansion. Further, since pro-regulation advocates consistently call for increased levels of competition, the differential effect on smaller competitors is of significant policy relevance. Limiting firms to capacity solutions may lead to an absence of service in some markets, and the elimination of competitors in others. Moreover, much of the ARRA's funding is largely targeted at rural, relatively high-cost markets. Internet regulations of this sort may reduce the effectiveness of such funds by raising the cost of network deployment and management.

III. Theoretical Model

We begin by positing the existence of two classes of consumers: (a) consumers who use congestion-causing applications (such as Peer-to-Peer) and (b) consumers who do not. For expositional convenience, we refer to these users as "large" or "small" users, and represent them by the subscripts L and S. We assume the large users impose a negative externality on all

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31 *See, e.g.*, B. Glass, *Ensuring Effective Broadband Stimulus: An Analysis of the Broadband-Related Provisions of the American Recovery and Investment Act of 2009* (Jan. 22, 2009) at p. 7 (available at: http://www.brettglass.com/bbstim.pdf).

32 G.S. Ford, T.M. Koutsky and L.J. Spiwak, *The Burden of Network Neutrality Mandates on Rural Broadband Deployment*, PHOENIX CENTER POLICY PAPER NO. 25 (July 2006)(available at: http://www.phoenix-center.org/pcpp/PCPP25Final.pdf).

users in the form of network congestion, and this congestion reduces the value of the network not only to small but to large users as well. That is, the online activity of large users creates network congestion for all users, thereby diminishing the value of broadband service to all users.

B. *Demand Side*

The demand for broadband service for small and large users is given by:

$$Q_S = \lambda(A - p - \tfrac{\theta}{K} Q_L) \quad (1)$$

$$Q_L = \lambda\eta(A - p - \tfrac{\theta}{K} Q_L - Q_X) \quad (2)$$

where Q_S is the number of small users subscribed to system; Q_L is the number of large users subscribed to system; λ is a market size scaling factor; η is a differential consumer type mix parameter; A is a constant, p is the price of service; Q_X is the number of large users disconnected or rationed out; θ is a congestion parameter ($\theta > 0$); and K is network capacity which reduces congestion caused by large users. We assume only large users cause congestion (but this is an unimportant simplification), which reduces the demand for service by both small and large users.

In POLICY PAPER NO. 32, we allowed the seller to levy a congestion premium on the large users in an effort to curb congestion.[33] If the cost of congestion was high enough, then this congestion premium was set high enough to exclude large users. We also showed that a welfare-maximizing regulator would respond more aggressively to increases in congestion than a profit-maximizing firm. Therefore, to some degree, we have already covered the economic implications of congestion premiums. In this BULLETIN, then, we preclude the use of a congestion premium from the analysis, leaving the network operator three ways to deal with congestion. First, the operator can increase the service price p to reduce both Q_L and Q_S (both user types pay the same price). Second, the network operator can reduce Q_L by choosing to disconnect Q_X of these large users (directly reducing Q_L). (Similarly, the operator may choke the greedy application.) Finally, the operator can reduce the costs of congestion by expanding capacity at a cost dependent on K.

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[33] *Supra* n. 30.

Solving Equation (1) and (2) for the reduced form demand expressions, we get:

$$Q_S = \lambda\left(\frac{A - p + \eta\lambda \frac{\theta}{K} Q_X}{1 + \eta\lambda \frac{\theta}{K}}\right) \tag{3}$$

$$Q_L = \lambda\eta\left(\frac{A - p - Q_X}{1 + \eta\lambda \frac{\theta}{K}}\right). \tag{4}$$

The demand side of the model has the following properties: (a) the network operator cannot differentially price to large and small users to reduce congestion; (b) congestion can be relieved by investing in increased capacity K; (c) congestion can be relieved by managing demand, either by raising price to all users or disconnecting congestion-causing large users; and (d) the market size (λ) is allowed to vary so that markets of different sizes can be evaluated.

C. *Supply Side*

Next, we consider the cost structure of the network provider. Our primary interest is on government regulation of responses to congestion and how such regulation can differentially impact small firms. Size is important because of the scale economies inherent to physical communications networks and the wide variation in market sizes across the United States. Smaller markets, such as those in rural America, are likely to use technologies that are relatively more costly per user. As such, we assume that the cost of capacity that reduces the congestion imposed by the large users is given by

$$c(K) = rK^{\sigma} \tag{5}$$

where r is an investment good price parameter, K is the extent of capacity, and σ ($0 < \sigma < 1$) is a parameter representing the extent of scale economies. The smaller is σ, the greater are scale economies in capacity expansion. We evaluate absolute cost differences later.

D. *Profit Maximization*

Given these demand- and supply-side assumptions, we now turn to the profit maximization. Assuming the firm is not prohibited by regulation from engaging in network management (i.e., $Q_X > 0$ is possible), the firm selects, K, and p to maximize:

$$\pi = \lambda p\left(\frac{A - p + \eta\lambda \frac{\theta}{K} Q_X}{1 + \eta\lambda \frac{\theta}{K}} + \frac{\eta(A - p - Q_X)}{1 + \eta\lambda \frac{\theta}{K}}\right) - c(K). \tag{6a}$$

subject to the constraint $0 \le Q_X \le A - p$. Collecting Q_X terms and rewriting Equation (6a) yields:

$$\pi \quad = \quad \lambda p\left(\frac{(1+\eta)(A-p)+\eta(\lambda\frac{\theta}{K}-1)Q_X}{1+\eta\lambda\frac{\theta}{K}}\right) - c(K). \tag{6b}$$

By inspection of Equation (6b), we see that profit is linear in Q_X (in that $\partial^2\pi/\partial Q_x^2 = 0$), so that the sign of the slope of the profit function with respect to Q_X ($\partial\pi/\partial Q_X$) depends solely on the sign of the expression $(\lambda\frac{\theta}{K}-1)$. This fact implies that the optimal Q_X value will reside at the endpoints of its feasible domain. In other words, the profit maximizing network operator will either select $Q_X = 0$ (not ration anybody) or select the upper limit, $Q_X = A - p$ where congestion is attenuated by disconnecting the technical limit of large users. In either of these cases, the optimal service price will be $p^* = A/2$.

The network operator's profits, if the large users are rationed ($Q_X = A - p$), will be

$$\pi^*_{A-p} = \lambda\frac{A^2}{4}. \tag{7}$$

In contrast, if no rationing occurs ($Q_X = 0$), then

$$\pi_0 = \lambda\frac{A^2}{4}\left(\frac{1+\eta}{1+\eta\lambda\frac{\theta}{K}}\right) - c(K). \tag{8}$$

Obviously, profits will generally differ when rationing is used versus when it is not. For our purposes, we are interested in whether this difference in profits is more substantial in smaller than in larger markets due to scale economies. If regulation prohibits demand management and limits firms to using only capacity expansion, and capacity expansion is more costly in small markets due to scale economies, then the regulation is more burdensome on small, rural operators or small competitors to larger, more established firms.

E. *The Effect of Network Management Regulation and Market Size*

In order to analyze the impact of market size on the rationing versus capacity expansion decision, we will examine the relative profit differential between the two choices. For notational simplicity, let $y = \lambda\frac{\theta}{K}$, and define the relative profit difference γ by

$$\gamma \; = \; \frac{\pi_0 - \pi^*_{A-P}}{\lambda} \; = \; \frac{A^2}{4}\left(\frac{\eta(1-y)}{1+\eta y}\right) - \frac{1}{\lambda}c\left(\frac{\lambda\theta}{y}\right), \tag{9}$$

where γ measures the difference between the profits of a network operator that does not ration congestion-causing users and one who does.[34] The variable y can be thought of as a measure of the size of the market relative to capacity. First notice that as long as y is kept less than one (by appropriately scaling capacity in relation to market size), γ will be greater than zero when λ is made sufficiently large.[35] Thus, it is more profitable for a firm with sufficiently large scale, to expand capacity (increase K) as a solution to congestion rather than ration the large users. This preference for capacity expansion occurs because scale economies make such a course relatively inexpensive in very large markets.

In contrast, consider what happens when the market is "small." The only way γ can be positive is if $y < 1$. In this case, γ would have an upper bound of $\eta(A^2/4)-(1/\lambda)c(\lambda\theta)$, and this expression is negative for a λ small enough.[36] This result implies that when the market is sufficiently small, the firm maximizes profits by selecting $Q_X = A - p$ (that is, the firm rations large users). Consequently, if a regulator forbids demand management by imposing $Q_X = 0$, then the small network operator would face reduced profits where a very large operator would not (as the firm gets larger, the cost essentially falls to zero as a construct of the theoretical model). This reduction in profits, in turn, may cause the system itself to be noneconomic and force exit. Notably, this effect is differentially felt by small firms, whether a small rural provider or a small competitor to a larger, more established firm.

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34 Note that if $y = \lambda(\theta/K)$, then $K = \lambda\theta/y$.

35 The relative cost term in (9) will be crushed when market size (λ) becomes large due to the scale economies assumed in Equation (5). Note that y can be held in check as market size is increased by appropriately scaling capacity, K.

36 The relative costs term can be made arbitrarily large due to the scale economies assumed in Equation (5).

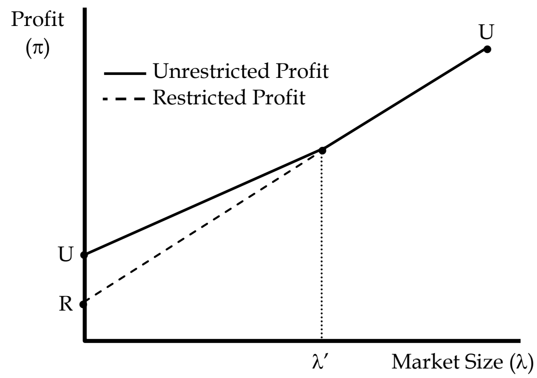

Figure 1. Regulation and Market Size

The effect of the regulation on profits is illustrated in Figure 1. For markets larger than λ′, regulation has no effect on profit because the operator is of sufficient scale to make capacity expansion relatively more profitable than rationing. Below market size λ′, however, a regulation prohibiting demand management reduces profits. The line segment labeled UU is profit without regulation so that $Q_X > 0$ is allowed, whereas the segment RU is profit with regulation that prohibits rationing so that $Q_X = 0$. Clearly, there is a positive profit difference when market size is "small." Of course, how large is "large" and how small is "small" is an empirical question, not a theoretical one, and a question that must be answered if public policy is to treat large and small markets differently. Our point is not to encourage differential treatment, but we aim simply to point out that identical treatment has different consequences for markets and firms of different sizes.

F. *Supply Side with Absolute Cost Differences*

In the previous analysis, we assumed capacity expansions were subject to scale economies. Here, we alter the assumption and simply allow capacity expansion costs to be constant but differ across markets. Thus, the cost of capacity *K* will simply be *cK*, where *c* is the constant marginal cost.

The demand side remains the same as does much of the other analysis. Equation (9) becomes

$$\gamma = \frac{\pi_0 - \pi^*_{A-P}}{\lambda} = \frac{A^2}{4}\left(\frac{\eta(1-y)}{1+\eta y}\right) - \frac{c\theta}{y}, \qquad (10)$$

where only the second term on the right-hand side has changed. If the marginal cost, *c*, is sufficiently small, then γ will be positive for some value of *y* less than one (sufficiently large capacity relative to market size). So, for a firm with sufficiently low marginal capacity expansion costs (e.g., an urban provider), the optimal value will be $Q_X = 0$ (no choking). Once again, notice that $\gamma \geq 0$ only if $y < 1$. Along the interval $0 < y < 1$, the expression for γ is bounded above by $\eta(A^2/4) - c\theta$. This is negative for sufficiently large marginal capacity costs c. For a sufficiently high marginal capacity costs, then, the optimal value must be $Q_X = A - p$. A restriction that $Q_X = 0$, would necessarily be sub-optimal for such a firm and would reduce profits.

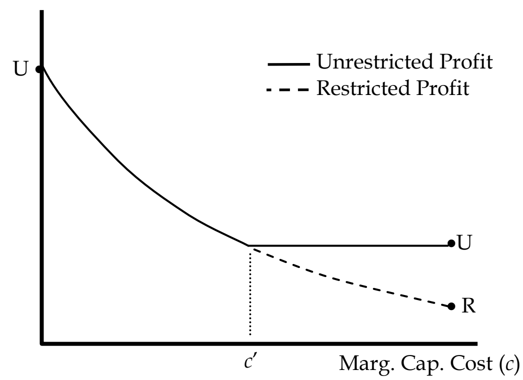

Figure 2. Regulation and Capacity Cost

In Figure 2, for carriers with marginal capacity costs smaller than c', regulation has no effect on profit because the operator is of sufficient scale to make capacity expansion relatively more profitable than rationing. (This "no effect" outcome does not suggest firms are not responsive to regulation. Given the theoretical setup, the cost of capacity expansion becomes trivial at large quantities. Whether this happens in reality is an empirical question). Above capacity cost c', however, a regulation prohibiting demand management reduces profits. The line segment labeled UU is profit without regulation so that $Q_X > 0$ is allowed, whereas the segment UR is profit with regulation that prohibits rationing so that $Q_X = 0$. If marginal capacity costs are sufficiently large (greater than c'), then regulation reduces the profits of firms and could lead to less service availability in high cost markets. Again, how large is "large" and how small is "small" is an empirical question, not a theoretical one, and a question that must be answered if public policy is to treat large and small markets differently.

IV. Cost-Augmenting Regulations and the Size of the Subsidy

In any geographic market that lacks broadband service today, the conclusion must be that the expected revenue of providing the service is below the expected costs. Service provision, then, requires a subsidy. The ARRA provides multiple mechanisms to subsidize broadband deployment in rural markets. The amount of subsidy, or the amount of network arising from a given level of subsidy, are dependent on the difference between revenues and costs. Above we have demonstrated that regulations that influence costs may harm deployment in rural markets (or small carriers) more than in urban markets (or large carriers). The same effect may be observed for wireless carriers who in many cases have a higher cost of capacity expansion than wireline networks. Cost-augmenting regulations also increase the subsidy required to expand availability to all households. If the subsidy is fixed, then the cost-augmenting regulation reduces the number of homes passed by the networks. Using the HAI Cost Model data, we generate a crude estimate of the response of the subsidy to changes in cost.

To begin, we collect block group loop cost estimates (*L*) for a large number of local exchange carriers from the HAI cost model.[37] The sample was constructed by choosing states randomly and including all carriers in the state with data available. The result of this procedure is significant diversity in geography and costs. In our sample, there are about 95 million access lines and about half of all Census Block Groups are represented.[38] This initial dataset is identical to that in POLICY PAPER NO. 25.[39] Loop cost levels are normalized by the sample mean so as to abstract from the level of costs rendering variable u.

An approximation of the change in the subsidy for an increase in costs is calculated as follows. First, assume a revenue amount resulting in a 90% coverage rate for the network.[40] The subsidy amount required to reach 100% coverage is then computed and labeled S_U. Next, u is increased by 1% and the subsidy level is again computed and labeled S_R.[41] The elasticity is computed using $[(S_R - S_U)/S_U]/0.01$. We calculate an elasticity of 1.8, implying that for a 1% increase in deployment cost the subsidy required to reach 100% of homes increases by 2%. The response of the subsidy to cost increases is elastic (that is, the percentage increase in the subsidy

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37 HAI Cost Model Version 5.0, which was the last version of this model to provide nationwide estimates of costs. We use the HAI model because it provides cost estimates down to the block group level, whereas the FCC's Synthesis Model results are provided at the Wire Center level only. The two models produce highly comparable estimates of relative loop costs, with the two series having a very high correlation coefficient. *See* PHOENIX CENTER POLICY BULLETIN NO. 9: *Federalism in Telecommunications Regulation: Effectiveness and Accuracy of State Commission Implementation of TELRIC in Local Telecoms Markets* (9 March 2004) (available at: http://www.phoenix-center.org/PCPB9Final.pdf. States included in the analysis are: AZ, CA, CO, FL, NY, GA, IA, LA, MD, MO, MS, MT, NC, NE, OH, SC, TX, VA, and WV.

38 In the 1990 Census, there were 229,466 Census Block Groups defined. Our sample includes 112,990 Census Block Groups.

39 *Supra* n. 32.

40 In levels, the revenue per line is about $44.

41 This 1% change is not a prediction but an assumption for illustrative purposes alone. Formal analysis of the cost of an unmanaged network indicate the cost could be very high. *See, e.g.,* R. Clarke, *Cost of Neutral/Unmanaged IP Networks* 8 REVIEW OF NETWORK ECONOMICS 61-89 (2009); G.S. Ford, T.M. Koutsky and L.J. Spiwak, *The Efficiency Risk of Network Neutrality Rules*, PHOENIX CENTER POLICY BULLETIN NO. 16 (May 2006)(available at: http://www.phoenix-center.org/PolicyBulletin/PCPB16Final.pdf).

is larger than the percentage increase in costs). The number of loops requiring a subsidy increases by 1.4%.

While the elasticity is crudely measured, its value is less the point than is the logic. The point here is that while regulations have purported (though sometimes questionable) benefits, all regulations have their costs. If the government is going to subsidize deployment in rural and other high-cost markets, then the conditions imposed on receiving such funding unfavorably alter the cost structure of the suppliers. An explicit cost-benefit analysis of any regulation, including network management requirements, should be conducted, particularly for new rules that are likely to impact deployment incentives.[42]

V. Conclusions

In this BULLETIN, we demonstrate one consequence of network management regulation that imposes a capacity-only solution to congestion. If capacity expansion costs are higher in rural markets (or for small firms), then there is a differential effect of a regulation prohibiting demand management across service providers. Whether costs differences are due to scale economies or absolute cost disadvantages, smaller providers are more substantially harmed by network management regulation than larger, more urban providers are. Since our model includes only the costs of this congestion-reducing capacity, the reduction in calculated profits will translate, in reality, directly into actual losses for some operators. Thus, when considering all the costs service providers face—including the sunk costs of entry, fixed costs of operation, other variable costs, and so on—the inability of a firm to manage its network efficiently and flexibly may be the "straw that breaks the camel's back" for the smaller, high-cost operators. Rather than encourage broadband deployment, network management regulation may make broadband too expensive to deploy in some markets. The more substantial effect in rural markets is of particular policy relevance, since so many hopes for development are pinned on the deployment of broadband in rural markets.

Of course, it is the consumers in small and rural markets, even those who would otherwise not wish to use high congestion applications, who are the ultimate victims of the prohibition on network congestion management. These users pay the price for regulation when they are unable to obtain broadband services because those firms that could otherwise profitably offer service are no longer interested in their needs due to regulation.

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[42] As noted *supra* n. 24, the costs of existing network neutrality conditions are high, as revealed by the fact that the most efficient providers of service (cable and telephone companies providing the vast majority of service today) decided that the conditions contained in the NOFA for ARRA funds are simply too onerous.

We stress that this analysis is by no means a complete treatment of network management or, more broadly, network neutrality regulation. It is not intended to be, nor could it be, since these are such a nebulous and elastic concepts. The takeaway is simple, however: If solving congestion problems is limited to capacity expansion, either directly or indirectly, then those firms with relatively high cost of capacity expansion are disproportionately harmed (as will be their consumers in most cases). Blanket prohibitions on particular types of network management, therefore, are dangerous, particularly for firms that have higher costs (small firms and rural firms). Since public funds are presently being directed at such markets, limitations on network management may reduce the returns on such investments. Network management regulation, then, should focus on anti-competitive acts, and which acts are anti-competitive is very difficult to determine ex ante. Case-by-case adjudication with few ex ante restrictions on management efforts is perhaps best.