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WIRELESS COMPETITION UNDER SPECTRUM EXHAUST

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Wireless Competition Under Spectrum Exhaust

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I. INTRODUCTION

Spectrum is an essential input for providers of mobile wireless voice and data service. Indeed, without spectrum there can be no service at all, and the more spectrum that a provider has, the better the services it can provide.[1] Unfortunately, as Americans continue to consume mammoth amounts of data with their smartphones and tablets, the United States is rapidly exhausting the capacity available from the existing supply of viable commercial spectrum. The *National Broadband Plan*, released in 2010, concluded that the present inventory of commercial spectrum represents "just a fraction of the amount that will be necessary to match growing demand."[2] Echoing that concern, Federal Communications Commission ("FCC") Chairman Julius Genachowski cautioned, "[w]ithout action, demand for spectrum will soon outstrip supply . . . . If we don't tackle the spectrum crunch now, network congestion will grow, and consumer frustration will grow with it."[3] The White House is also concerned, concluding that there is a "spectrum crunch that will hinder future innovation."[4]

As a result, both the FCC and the White House express the need "to free up [more] spectrum" and make it available for broadband use.[5] The *National Broadband Plan* called for the assignment of an additional 500 Megahertz ("MHz") of spectrum for broadband use, a portion of which is expected to come from spectrum currently used for broadcast television and a portion to be reallocated from government use.[6] Many praised the FCC's plan to increase the stock of spectrum for mobile broadband services, and a report by the National Telecommunications and Information

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1. T. Randolph Beard et al., *A Policy Framework for Spectrum Allocation in Mobile Communications*, 63 FED. COMM. L.J. 639, 642 (2011), *available at* http://www.law.indiana.edu/fclj/pubs/v63/no3/Vol.63-3_2011-May_Art.-03_Beard.pdf.

2. FCC, CONNECTING AMERICA: THE NATIONAL BROADBAND PLAN, at XII, 10 (2010) [hereinafter NATIONAL BROADBAND PLAN], *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-296935A1.pdf.

3. Julius Genachowski, Chairman, FCC, Prepared Remarks at the 2011 International Consumer Electronics Show 1 (Jan. 7 2011), *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-303984A1.pdf.

4. Press Release, President Obama Details Plan to Win the Future through Expanded Wireless Access (Feb. 10, 2011) [hereinafter White House Press Release], http://www.whitehouse.gov/the-press-office/2011/02/10/president-obama-details-plan-win-future-through-expanded-wireless-access.

5. Service Rules for Advanced Wireless Services in the 2000-2020 MHz and 2180-2200 MHz Bands, *Statement of Chairman Julius Genachowski*, FCC 12-32, at 81-82 (2012). *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-12-32A1.pdf; White House Press Release, *supra* note 4.

6. *See, e.g.*, NATIONAL BROADBAND PLAN, *supra* note 2, at 75-76; Grant Gross, *FCC Wants 120MHz of Spectrum From TV Stations*, PCWORLD (Mar. 15, 2010), http://www.pcworld.com/businesscenter/article/191561/fcc_wants_120mhz_of_spectrum_from_tv_stations.html.

Administration ("NTIA") outlined some ideas for this significant reallocation of spectrum.[7] To help facilitate the reallocation of spectrum, this past February, President Obama signed into law the Middle Class Tax Relief and Job Creation Act of 2012, which provides the FCC with the authority to hold voluntary incentive auctions to repurpose television spectrum for mobile broadband use.[8] However, by the FCC's own admission, the reallocation of spectrum has historically taken several years.[9] Therefore the reallocation of broadcast spectrum and government spectrum to higher-valued uses could take years to fully implement and, even then, provides only a portion of the needed spectrum.[10] Accordingly, a "spectrum crunch" may be the market reality for the foreseeable future. As such it is important to understand what effects a binding spectrum constraint has on the nature of market performance in mobile wireless communications and how policy must adapt to this reality.

In this article, we shed some light on this important policy issue by formally modeling wireless competition under a spectrum constraint. Our findings reveal that while some in Washington policy circles increasingly view rising industry concentration (i.e., rising values of the Hirschman Herfindahl Index or "HHI") in the mobile wireless industry as a bellwether of poor market performance, the addition of a spectrum crunch to standard models of competition turns this standard, textbook view of market structure and performance on its head. Indeed, our analysis finds that under a binding spectrum constraint, competition among few firms will produce *lower* prices than competition among many firms, and will possibly increase sector investment and employment. As a result, given spectrum exhaust, policies that aggressively seek to engineer entry into the mobile

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7. NAT'L TELECOMMS. & INFO. ADMIN., PLAN AND TIMETABLE TO MAKE AVAILABLE 500 MEGAHERTZ OF SPECTRUM FOR WIRELESS BROADBAND, at ii-iii (2010) [hereinafter NTIA REPORT], *available at* http://www.ntia.doc.gov/legacy/reports/2010/TenYearPlan_11152010.pdf; *see also* Andrew M. Seybold, *Seybold's Take: Finding 500 MHz of Spectrum*, FIERCE WIRELESS (Aug. 2, 2010), http://www.fiercewireless.com/story/seybolds-take-finding-500-mhz-spectrum/2010-08-02 ("Finding 300 MHz of spectrum that will support broadband technologies will not be easy and the FCC certainly will have its hands full trying, even with the Executive Order approving these spectrum allocations.").

8. Middle Class Tax Relief and Job Creation Act of 2012, Pub. L. No. 112-96 §§ 6402-03, 126 Stat. 156, 201-30; *but cf*. Julius Genachowski, Chairman, FCC, Remarks at the 2012 Consumer Electronics Show 8-9 (Jan. 11 2012), *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-311974A1.pdf (remarking on proposed statutory limits to flexibility of the FCC in optimizing auctioned spectrum allocation); Reed Hundt, *Message to Congress: With All Due Respect, If It Ain't Broke Don't Fix It,* CABLE360 (Dec. 15, 2011), http://www.cable360.net/ct/news/ctreports/commentary/Message-To-Congress-With-All-Due-Respect-If-It-Aint-Broke-Dont-Fix-It_49928.html.

9. NATIONAL BROADBAND PLAN, *supra* note 2, at 79 ex. 5-3 (summarizing years from first step until available for use: Cellular (11 years); PCS (6 years); Educational Broadband Service/Broadband Radio Service (10 years); 700 MHz (13 years); AWS-1 (6 years)).

10. *Id*. at 10, 88 (stating that the FCC seeks 120Mhz from broadcasters but concludes that the industry actually needs 500 Mhz).

market—such as efforts to impede incumbent carriers from acquiring more spectrum via either auction or acquisition—may do harm rather than good.

Our article is outlined as follows. First, we present some background material describing the looming spectrum exhaust, the government's expressed concerns about rising industry concentration, and the relevance of such details for antitrust and regulatory policy. Second, we present our theoretical model, which extends the Cournot framework to incorporate a special type of input which is *limitational* for the production of output (e.g., spectrum exhaust). Firms are taken to be capacity-constrained by their holdings of this input, and they use ordinary capital and labor inputs to produce output at or below their effective constraint. We assume that the maximal output rate of any firm is a convex, increasing function of its holding of the limiting factor (i.e., spectrum). That is, twice the spectrum holding permits more than twice the service to be delivered to consumers. We then analyze Cournot equilibria for key industry configurations, and demonstrate that under such plausible circumstances, industry output rates and consumer welfare may be increasing in the level of industry concentration. This result is counter to the standard view of competition in that under spectrum exhaust we find that few firms produce more output and sell that output at lower prices than do many firms. Concluding comments are provided in the final section.

II. BACKGROUND

In the coming decade, the federal government expects mobile wireless communications services to "be a key pillar of U.S. economic policy" and "a significant contributor to U.S. economic growth."[11] Certainly, consumer demand for mobile broadband services is rapidly growing, and mobile computing platforms are forecast to replace the desktop computer for many Americans.[12] As the demand for mobile data grows, however, so grows the capacity requirements of mobile broadband networks, and this capacity is closely linked to the amount of spectrum available to commercial wireless carriers.[13] By most measures, domestic mobile wireless carriers, today, fall short of their spectrum needs. According to the FCC, the estimated amount of additional spectrum needed

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11. *Id*. at 75.

12. *See* MORGAN STANLEY RESEARCH, THE MOBILE INTERNET REPORT 6 (Dec. 15, 2009) (on file with the Federal Communications Law Journal); CTIA - THE WIRELESS ASSOCIATION, CTIA'S SEMI-ANNUAL WIRELESS INDUSTRY SURVEY (2011), *available at* http://files.ctia.org/pdf/CTIA_Survey_Year_End_2010_Graphics.pdf.

13. NATIONAL BROADBAND PLAN, *supra* note 2, at 84 ("More bandwidth begets more data-intensive applications which begets a need for more bandwidth."); FCC, MOBILE BROADBAND: THE BENEFITS OF ADDITIONAL SPECTRUM 6-10 (Oct. 2010) [hereinafter FCC TECHNICAL PAPER], *available at* http://download.broadband.gov/plan/fcc-staff-technical-paper-mobile-broadband-benefits-of-additional-spectrum.pdf.

per operator ranges from 40 to 150 MHz.[14] CTIA, an association of wireless carriers, forecasts that the industry will need an additional 800 MHz to satisfy rising demand.[15] In 2009, the total amount of auctioned spectrum was only 361 MHz.[16] The FCC estimates that there are 547 MHz of spectrum "currently licensed under flexible use rules, which allows for mobile broadband and voice services."[17] Thus, the near-term spectrum needs of wireless carriers well exceed the current total stock of spectrum assigned to commercial services. In the FCC's latest *CMRS Report*, the agency states the problem plainly:

> . . . the current spectrum forecast demonstrates that the amount of mobile data demanded by American consumers is likely to exceed the capacity of wireless networks in the near-term, and that meeting this demand by making additional spectrum available is likely to create significant value for the mobile economy. Specifically, . . . mobile broadband growth is likely to outpace the ability of technology and network improvements to keep up by an estimated factor of three, leading to a spectrum deficit that is likely to approach 300 megahertz within the next five years.[18]

The shortage of spectrum is also acknowledged by the industry's financial analysts.[19] Notably, the spectrum crisis is not limited to the U.S., and several international organizations have also expressed concerns about a looming spectrum crunch, and have done so for many years.[20]

In light of rising demand for mobile data and a limited inventory of available commercial spectrum, many believe that the most significant recommendation of the *National Broadband Plan* is to "[m]ake 500 megahertz of spectrum newly available for broadband within 10 years, of

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14. NATIONAL BROADBAND PLAN, *supra* note 2, at 84.

15. Reply Comments of CTIA at 2, A National Broadband Plan for Our Future, FCC GN Docket No. 09-51 (rel. Nov. 13, 2009), *available at* http://fjallfoss.fcc.gov/ecfs/document/view?id=7020348306.

16. Beard et al., *supra* note 1, at 663.

17. FCC TECHNICAL PAPER, *supra* note 13, at 15 ("547 MHz, in total, is currently licensed under flexible use rules, which allows for mobile broadband and voice services.").

18. Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993 Annual Report and Analysis of Competitive Market Conditions With Respect to Mobile Wireless, Including Commercial Mobile Services, *Fifteenth Report*, FCC 11-103, para. 267 (2001) [hereinafter *15th Annual CMRS Report*], *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-11-103A1_Rcd.pdf.

19. *See*, *e.g.*, B. FELDMAN & D. MITCHELSON, DEUTSCHE BANK, COPING WITH THE SPECTRUM CRUNCH: PART 1 (Sept. 30, 2011) (on file with author) ("95% of wireless subscribers are supported by carriers that hold only 53% of licensed mobile spectrum" and "most carriers don't own enough spectrum to deliver competitive 4G services.").

20. Int'l Telecomm. Union [ITU], *Estimated Spectrum Bandwidth Requirements for the Future Development of IMT-2000 and IMT-Advanced*, Report ITU-R M.2078, 17, 26 (2006), *available at* http://www.itu.int/pub/R-REP-M.2078-2006.

which 300 megahertz should be made available for mobile use within five years."[21] Where this spectrum will come from remains unclear to this day, and finding large swaths of quality spectrum may prove more difficult than the authors of the *National Broadband Plan* predicted.[22] Many hope that some television broadcast spectrum, which is in the highly valued broadcast spectrum band, can be repurposed for mobile broadband use.[23] However, even though legislation was passed to give the FCC the authority to hold voluntary incentive auctions, history has shown that the bureaucratic implementation process is often slow and cumbersome.[24] Even optimistic estimates of the amount of spectrum that will be freed up by such plans falls short of industry requirements.[25] Thus, as the exact amount and delivery date of new broadcast spectrum in the auction pipeline is still very murky, acquiring spectrum resources by merger and acquisition through private transactions has become widely recognized as a sensible option for operators.[26]

However, the merger option as a solution to the spectrum shortage has been difficulty to pursue. Due to the high fixed and sunk costs of providing mobile wireless communications services, the industry has expectedly morphed into a relatively concentrated equilibrium industry structure (albeit with government approval every step of the way).[27] As a result, the question of who gets to acquire new spectrum, whether incumbent spectrum users or new entrants, is the subject of fierce political debate.[28]

According to FCC statistics, at the end of 2009, the HHI for the U.S. mobile wireless industry stood at about 2,800.[29] By the government's *Merger Guidelines* standards, the industry is classified as "Highly Concentrated," which is a label reserved for industries with an HHI

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21. NATIONAL BROADBAND PLAN, *supra* note 2, at XII.

22. NTIA REPORT, *supra* note 7, at 23-25.

23. Plans contemplate migrating about 120 MHz of broadcast spectrum. *See, e.g.*, *id.* at 8-10; NATIONAL BROADBAND PLAN, *supra* note 2, at 88-93, 102 n.82; Gross, *supra* note 6, at 1.

24. *See* NATIONAL BROADBAND PLAN, *supra* note 2, at 81-82, 100 nn.40-41.

25 *Id*. at 10, 88.

26. *See* Shara Tibken, *Verizon Defends AT&T Deal*, WALL ST. J. (Sept. 22, 2011), http://online.wsj.com/article/SB10001424053111903703604576584902573418910.html ("'I have taken the position that the AT&T merger with T-Mobile was kind of like gravity,' [Verizon CEO] Mr. McAdam said. 'It had to occur, because you had a company with a T-Mobile that had the spectrum but didn't have the capital to build it out. AT&T needed the spectrum, they didn't have it in order to take care of their customers, and so that match had to occur.'"); Sarah Frier, *Telecom Carriers Must Combine to Compete, Providence Equity Says*, BLOOMBERG (Sept. 27, 2011), http://www.bloomberg.com/news/2011-09-27/telecom-carriers-must-combine-to-compete-providence-equity-says.html.

27. *See* George S. Ford et al., *Competition After Unbundling: Entry, Industry Structure, and Convergence,* 59 FED. COMM. L.J. 331 (2007).

28. *See* Beard et al., *supra* note 1.

29. *15th Annual CMRS Report*, *supra* note 18, at para. 395.

exceeding 2,500.[30] That said, when talking about "concentration," it is also important to keep things in perspective. For example, an HHI of 2,500 equates to 4 equal-sized firms, and the FCC's most recent *CMRS Report* reveals that, by Census Block, 94.3% of all Americans have access to at least four or more mobile wireless providers, and 89.6% of all Americans have access to at least five or more wireless providers.[31] So, while the industry may be classified as "Highly Concentrated" by non-industry-specific standards like the *Merger Guidelines*, consumers in fact have numerous options when choosing a wireless carrier. Moreover, the *Fourteenth* and *Fifteenth CMRS Reports* presented compelling evidence of good market performance in the mobile wireless industry in terms of price and innovation,[32] forcing the agency to conclude:

> Shares of subscribers and measures of concentration are not synonymous with market power—the ability to charge prices above the competitive level for a sustained period of time. . . . [M]arket concentration, by itself, is an imperfect indicator of market power.[33]

Thus, while concentration statistics may have their uses, economic theory,[34] antitrust,[35] and even the FCC's own precedent[36] all make clear that such data is not the end of the analysis—it is merely the beginning.

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30. *Id*. at 9679; *see also* U.S. DEP'T OF JUSTICE & FED. TRADE COMM'N, HORIZONTAL MERGER GUIDELINES § 5.3 (2010), *available at* http://www.justice.gov/atr/public/guidelines/hmg-2010.html.

31. *15th Annual CMRS Report*, *supra* note 18, at 9881 chart 46..

32. *See generally* Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993 Annual Report and Analysis of Competitive Market Conditions With Respect to Mobile Wireless, Including Commercial Mobile Services, *Fourteenth Report*, FCC 10-81, *passim* (2010) [hereinafter *14th Annual CMRS Report*], *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-10-81A1.pdf; *15th Annual CMRS Report*, *supra* note 18, *passim.*

33. *14th Annual CMRS Report, supra* note 32, at para. 55.

34. *See generally* Duncan Cameron & Mark Glick, *Market Share and Market Power in Merger and Monopolization Cases*, 17 MANAGERIAL & DECISION ECON. 193 (1996) (legal precedent requiring courts to draw inferences about market power based primarily or exclusively on market shares and/or market concentration can often be misleading; the only alternative to such bright-line rules is to utilize modern economic tools to undertake more extensive competitive analyses); *see also* MICHAEL. L. KATZ & HARVEY S. ROSEN, MICROECONOMICS 508 (Gary Nelson ed., 2d ed. 1994); John E. Kwoka, Jr., *Regularity and Diversity of Firm Size Distribution in U.S. Industries*, 34 J. ECON. & BUS. 391 (1982); Ford et al., *supra* note 27; Beard et al., *supra* note 1; George S. Ford & Lawrence J. Spiwak, *The Need for Better Analysis of High Capacity Services*, 28 J. MARSHALL J. COMPUTER & INFO. L. 343 (2012).

35. *See, e.g.*, United States v. Baker Hughes Inc., 908 F.2d 981, 986 (D.C. Cir. 1990) (stating that market share statistics are "misleading" in a "volatile and shifting" market); S. Pac. Commc'ns Co. v. AT&T, 740 F.2d 980, 1000 (D.C. Cir. 1984) (stating that when a "predominant market share may merely be the result of regulation, and regulatory control may preclude the exercise of market power . . . in such cases market share should be at most

Nevertheless, of late, the naive notion that high concentration *a fortiori* equals market power in communications markets is back in vogue. For example, in the Department of Justice's ("DOJ") comments to the FCC during the development of the *National Broadband Plan*, the DOJ unequivocally equated market performance to market concentration. The DOJ specifically recommended that the FCC "evaluat[e] the degree of competition" by doing little more than "measuring market concentration in various local markets using the HHI."[37] Similarly, in evaluating the proposed merger between AT&T and T-Mobile, the DOJ's *Complaint* consists of little more than a review of the HHI data and boilerplate commentary on the ills of high concentration.[38] Interestingly, in stark contrast to these views, many industry financial analysts believe there is an *excessive* level of competition in the mobile wireless industry.[39]

The current FCC appears to concur with the DOJ's view. For example, the FCC staff's condemnation of AT&T's proposed acquisition of T-Mobile made absolutely no inquiry into the effect of spectrum exhaust on industry structure and performance. Instead, the staff report summarily dismissed the merger because "the effect on spectrum concentration as a result of the [proposed merger] would be so substantial—well beyond what the Commission has seen to date—that significant competitive concerns are

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a point of departure in determining whether market power exists"); Metro Mobile CTS, Inc. v. New Vector Commc's Inc., 892 F.2d 62, 63 (9th Cir. 1989) ("Reliance on statistical market share in cases involving regulated industries is at best a tricky enterprise and is downright folly where . . . the predominant market share is the result of regulation.").

36. *See, e.g.*, AT&T Corp. to Be Reclassified as a Non-Dominant Carrier, *Order*, FCC 95-427 (1995), *available at* http://transition.fcc.gov/Bureaus/Common_Carrier/Orders/1995/fcc95427.txt; NYNEX Corp. and Bell Atl. Corp. for Consent to Transfer Control, *Memorandum Opinion and Order*, FCC 97-286, para. 143 (1997) (citing another source), *available at* http://transition.fcc.gov/Bureaus/Common_Carrier/Orders/1997/fcc97286.txt (stating that "market share and concentration data provide only the starting point for analy[sis]"); NATIONAL BROADBAND PLAN, *supra* note 2 at 37 ("The lack of a large number of . . . facilities-based providers does not necessarily mean competition among broadband providers is inadequate . . . Moreover, modern analyses find that markets with a small number of participants can perform competitively . . . ."); Special Access Rates for Price Cap Local Exchange Carriers, *Order and Notice of Proposed Rulemaking*, FCC 05-18, para. 101 (2005), ("A high market share does not necessarily confer market power, but it is generally a condition precedent to a finding of market power.").

37. Ex Parte of the U.S. Dep't of Justice at 13, A National Broadband Plan for Our Future, GN Docket No. 09-51 (rel. Jan. 4, 2010), *available at* http://fjallfoss.fcc.gov/ecfs/document/view?id=7020355122.

38. *See* Compl., United States v. AT&T, Inc. et al., No. 1:11-cv-01560 (D.D.C. Aug. 31, 2011), *available at* http://www.justice.gov/opa/documents/Justice-ATT-TMobile-Complaint.pdf.

39. *See, e.g.*, Bengt Nordstrom, *Mobile Operators: Too Many to Make Money*, BUS. WK. (Mar. 31, 2010), http://www.businessweek.com/globalbiz/content/mar2010/gb20100331_755059.htm; James K. Glassman, *Uncle Sam Should Leave Wireless Companies Alone*, FORBES (July 16, 2009), http://www.forbes.com/2009/07/16/wireless-telecom-government-opinions-contributors-james-glassman.html (citing a recent report that stated that "there are too many competitors").

raised."[40] As a result of such "high concentration and a substantial increase in subscriber and spectrum concentration in most individual CMA markets and nationally," the agency's staff concluded that "under traditional structural analysis used to apply the antitrust laws, AT&T's proposed acquisition of T-Mobile is presumed to create or enhance market power or facilitate its exercise, creating significant potential for competitive harm in most retail mobile wireless services markets, to the detriment of consumers."[41]

Furthermore, as we detailed in our paper *A Policy Framework for Spectrum Allocation in Mobile Communications*,[42] the current FCC has a demonstrated proclivity for imposing incumbent-exclusion rules. An example of this is the way the FCC approved the merger of the firm that is now known as LightSquared.[43] The agency's approval came with a curious "voluntary" commitment, generally considered to be mandatory, wherein LightSquared agreed that it would not resell any spectrum to the two largest commercial carriers without prior FCC approval.[44] Given that LightSquared's stated business plan is to provide wholesale capacity to retail carriers,[45] this *de facto* spectrum cap seems odd indeed. Moreover, this voluntary commitment had no apparent connection to any specific anticompetitive harm revealed in the order's competitive analysis. Most troubling is the fact that this "voluntary" commitment was negotiated and adopted behind closed doors on the day the order was released, so that the public had no ability for notice and comment.[46]

The total absence of any integration of a spectrum constraint into any implicit or explicit models of concentration and market performance (particularly from the expert agency directly charged with understanding and managing the complexities of spectrum allocation) in the current policy debate is highly troubling. For some, high industry concentration implies poor market performance and thus lower economic welfare.[47] This strict

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40. Application of AT&T Inc. and Deutsche Telecom AG for Consent to Assign or Transfer Control of Licenses and Authorizations, *Staff Analysis and Findings*, DA 11-1955, para. 45 (2011), *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-11-1955A2_Rcd.pdf.

41. *Id*. at para. 47.

42. Beard et al., *supra* note 1.

43. SkyTerra Comm'ns, Inc., Transferor, and Harbinger Capital Partners Funds, Transferee, Applications for Consent to Transfer of Control of SkyTerra Subsidiary, LLC, *Memorandum Opinion and Order and Declaratory Ruling*, DA 10-535 (2010) [hereinafter *Harbinger Order*], *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-10-535A1_Rcd.pdf.

44. *See id*. at para. 72.

45. LIGHTSQUARED, http://www.lightsquared.com/about-us/ (last visited Oct. 6, 2012) ("LightSquared will offer network capacity on a wholesale-only basis to a variety of business partners.").

46. *See Harbinger Order, supra* note 43, at para. 72.

47. JAMES W. FRIEDMAN, OLIGOPOLY THEORY 35 (Phyllis Deane & Mark Perlman eds., 1983).

structure-to-performance link is based, in part, on the predictions of the Cournot model of competition, which says that prices and profits will decline as the number of firms increase.[48] The Cournot model does not, however, provide unambiguous predictions on other outcomes such as industry quality or innovativeness.[49] Outside the Cournot framework, it is not always the case that high concentration leads to relatively poorer market performance; but in the policy debate, particularly in traditionally regulated and highly concentrated industries, the predictions of the simple, generic Cournot model are king.[50] Since the Supreme Court has stated that economic "analysis must always be attuned to the particular structure and circumstances of the industry at issue," we believe a formal analysis of the effect of a capacity constraint on the relationship between market concentration and market performance is of significant policy relevance to both the FCC and the DOJ in the future.[51] We provide such an analysis in the next section.

III. COURNOT COMPETITION UNDER A CAPACITY CONSTRAINT

The Cournot model has been the primary theoretical framework for the analysis of industrial competition, and serves as the benchmark model of competition at both antitrust and regulatory agencies.[52] The reason is that, even in its simplest guise, the Cournot model produces a set of plausible relationships between industry structure and welfare relevant market statistics such as output, price and profit rates. In general, market equilibrium price falls and output rises as n, the number of firms, increases. Likewise, firm profits and aggregate industry profits fall as the market becomes less concentrated.[53] The relationships between n and prices,

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48. *Id*. at 44.

49. This outcome may also arise with product differentiated price competition (*i.e*., Bertrand Competition). *See generally id*.

50. *See generally id*.

51. Verizon Commc'ns Inc. v. Law Offices of Curtis V. Trinko, L.L.P., 540 U.S. 398, 399 (2004); *see also id*. at 411 (The Court specifically noted that "[p]art of that attention to economic context is an awareness of the significance of regulation. As we have noted, 'careful account must be taken of the pervasive federal and state regulation characteristic of the industry.'" Thus, as spectrum allocation is 100% controlled by government, there will always be an inherent tension between what policymakers want the equilibrium number of firms to be and what the economics dictate the efficient equilibrium number of firms should be.).

52. Beard et al., *supra* note 1, at 642 n.14.

53. The appeal of the model is increased by several important extensions of the analysis. For example, Kreps and Scheinkman (1983) demonstrate that the Cournot model can be consistent with a more realistic, two-stage game in which firms first make binding capacity investments and, under complete information, then engage in a Bertrand style pricing game. David M. Kreps & José A. Scheinkman, *Quantity Precommitment and Bertrand Competition Yield Cournot Outcomes*, 14 BELL J. ECON. 326, 326-37 (1983). Despite the extreme substitutability between firms' outputs in this scenario, the Cournot quantities and price can be obtained as an industry equilibrium at least so long as output

output and profits is subject to diminishing marginal returns, so that as *n* rises, the additional effect on market outcomes becomes smaller and smaller (see Figure 1, Panel B, below).

We consider the generic case of an *n*-firm Cournot industry in which firms hold shares (denoted later by "*s*") in some finite pipeline or platform used to deliver services to buyers. In particular, no individual firm can sell more than some quantity of output determined directly and solely by their allocation of the limiting factor. However, unlike the typical case of a capacity constraint, we allow that the quantity of goods potentially sold can be an increasing, convex function of the share, so that there is, in effect, a kind of "scale economy" in the share.[54] Nevertheless, we will maintain the conventional assumption that, if adequate capacity is available, output may be produced at constant marginal and average costs.[55]

We determine and then consider symmetric Cournot equilibria for the resulting market, and make the distinction between equilibria that are output constrained, and those that are not. We consider how the nature of the implied equilibria can change as the size of the market for firm services gets larger, but the availability of the limiting input does not. In particular, for large enough levels of product demand, the output constraints are binding in the Nash equilibrium so that total market output will decline (and price will rise) when there are more firms inefficiently sharing the available input.[56] This result suggests that, in such markets, decreases in market concentration may, as in other cases of scale economies in the conventional sense, raise prices, reduce sales, reduce employment (labor usage) and reduce consumer welfare.

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rationing is efficient. Carl Davidson & Raymond Deneckere, *Long-Term Competition in Capacity, Short-Run Competition in Price, and the Cournot Model*, 17 RAND J. ECON 404, 404-15 (1986). Additionally, the Cournot model is solvable by iterated elimination of dominated actions, and the Cournot quantities are obtained uniquely. Thus, although the Cournot model does not really explain how equilibrium prices are implemented, the properties of the solution are appealing and more general than might first be apparent.

54. *See* Joint Declaration of Jeffrey H. Reed and Nishith D. Tripathi at 6, Applications of AT&T Inc. and Deutsche Telekom AG for Consent to Assign or Transfer Control of Licenses and Authorizations, WT Docket No. 11-65 (rel. June 10, 2011), *available at* http://fjallfoss.fcc.gov/ecfs/document/view?id=7021686851; Kevin Fitchard, *Does blocking AT&T's merger hurt the future of mobile broadband?*, CONNECTED PLANET (Sept. 6, 2011), http://connectedplanetonline.com/3g4g/news/Does-blocking-AT-Ts-merger-hurt-the-future-of-mobile-broadband-0906 ("Regardless of how AT&T would exercise those economies of scale, there's no question they would exist. AT&T could build much more high-capacity networks by combining it and T-Mobile's advanced wireless services (AWS) spectrum. It could build that high-capacity network on a single infrastructure, rather than divide it among two separate network builds. That network could not only support greater connection speeds to the device, but it could support many more of those connections simultaneously—all at a lower cost per bit.").

55. *See*, *e.g.*, Martin K. Perry & Robert H. Porter, *Oligopoly and the Incentive for Horizontal Merger*, 75 AM. ECON. REV. 219, 220-21 (1985).

56. *Id*. at 222.

A. *Supply Side*

We begin by considering a representative firm that is able to produce some service, q, using the classic Cobb-Douglas production technology:[57]

$$q = \sqrt{kl}\ , \tag{1}$$

where k and l are capital and labor inputs. The inputs can be purchased in any desired quantity for uniform prices r and w, respectively. The profit maximizing firm will attempt to minimize production costs for any desired output level (q):

$$c(q) = \min_{l,k}\{wl + rk\} \quad \text{such that} \quad \sqrt{kl} = q. \tag{2}$$

The solution to the firm's minimization problem yields input demands and a cost function that are all linear in the desired level of output (q):

$$l_d = q\sqrt{\frac{r}{w}}\ , \tag{3}$$

$$k_d = q\sqrt{\frac{w}{r}}\ , \tag{4}$$

$$c(q) = \beta q, \quad \text{where} \quad \beta = 2\sqrt{wr}\ . \tag{5}$$

Let S be the total industry supply of the finite shared input, and let s be the amount available to our representative firm. Our primary interest is in allowing the level of s to determine the firm's maximum salable output. Furthermore, we want to allow for the existence of scale effects in this relationship. Since diseconomies seem uninteresting and quite unlikely, we focus instead on the case of positive scale effects. For simplicity, we define the firm's maximum salable output level, $q_{\max}$, as:

$$q_{\max} = s^{1+\sigma}, \tag{6}$$

where σ is a positive constant. Thus, the maximum amount a firm can sell to consumers rises more than proportionally with its share of the finite resource, S.

57. Gerald Beer, *The Cobb-Douglas Production Function,* 53 MATHEMATICS MAG. 44, 44 (1980).

B. Demand Side

We turn next to the nature of product demand. We will restrict attention to the case of identical goods, so there is but a single market price, P, for output.[58] (Allowing for mild, symmetric differentiation is a relatively straightforward extension.) We wish to have the simplest representation of demand that is, however, "scalable," so that we can examine the effects of a large market size on the nature of the resulting equilibrium and the effects of market structure on price, quantities, input use, and welfare. The proposed candidate market demand curve is characterized by:

$$P = A - Q/M \ , \tag{7}$$

where Q is total market quantity sold and A and M are positive parameters. In particular, increases in M allow us to examine the implications of market scale for equilibrium.

C. Equilibrium

We may now specify equilibrium for the Cournot game in which n of these representative firms select their quantities given the distribution of S among firms. We will deal with the symmetric case, but our analytical framework can also be extended to asymmetric circumstances. Hence, assume that each firm has an identical holding of s, so $s_i = S/n$ for all i. Broadly speaking, there are two possibilities: either the capacity constraints are binding at the "conventional" Cournot equilibrium point, or they are not (under symmetry, either all bind or none do). In the case in which the constraints are binding, no firm has any incentive to unilaterally reduce its output rate, since firm marginal revenue exceeds marginal cost at this point. It is, in fact, irrelevant how severe the constraint is: given the assumptions on cost and market demand, if all the other firms are producing levels of output that collectively are less than the Cournot point, then each firm wishes to expand, not contract, output, and the constraint is binding on him. Thus, the symmetric supply of the individual firm will be:

$$q^* = \min\left\{ M\frac{(A-\beta)}{(n+1)}, \left(\frac{S}{n}\right)^{1+\sigma} \right\}. \tag{8}$$

The first expression in Equation (8) is the standard Cournot equilibrium output and the second expression is the capacity constraint.

Clearly, if the market is made to be relatively large (by sufficiently increasing M), then the first expression will be larger than the second and

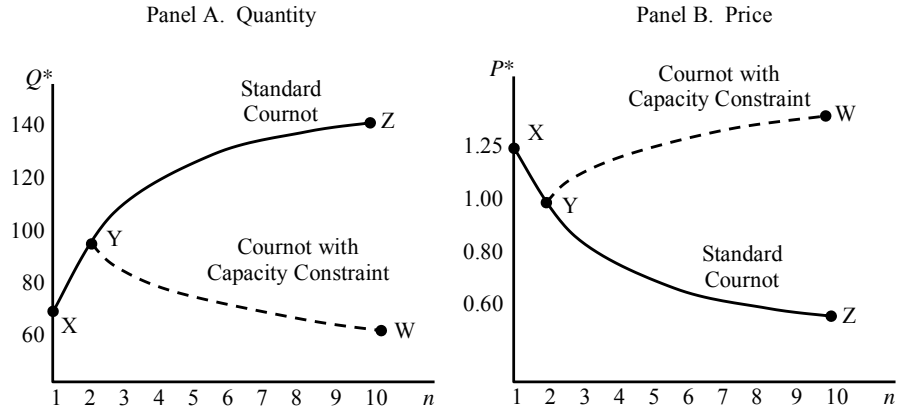
58. Owen A. Lamont & Richard H. Thaler, *Anomalies: The Law of One Price in Financial Markets*, 17 J. ECON. PERSP. 191, 191 (2003).

the firm's salable output constraint will be binding. Thus, in the case of a binding constraint, the total market output of services, Q^*, will be:

$$Q^* = nq^* = n\left(\frac{S}{n}\right)^{1+\sigma} = S\left(\frac{S}{n}\right)^{\sigma} \tag{9}$$

The result given by Equation (9) is illustrative of the combined effects of a binding S (with respect to the unconstrained Cournot quantity) and the posited existence of scale effects of any positive degree in the utilization of this resource. In particular, the market quantity of services is declining with the number of firms. Stated another way, when the constraints are binding, increases in concentration (declines in the number of firms) actually *increase* the market output of services—an outcome opposite that of the Cournot model absent such a constraint. As output rises, prices fall (by Equation 7).

Figure 1. Equilibrium Quantity and Price with Spectrum Constraint



In Figure 1, we illustrate the relationship between the equilibrium outcomes and the number of firms for some specific parameter values.[59] Both the standard Cournot and capacity-constrained Cournot outcomes are illustrated. In Panel A, we have equilibrium industry quantity (Q^*) measured on the vertical axis and the number of firms, or the inverse of the HHI given symmetry, along the horizontal axis. The standard Cournot equilibrium quantity (without a capacity constraint) is illustrated by the line segment labeled XYZ in Panel A. As n rises, quantity rises—the standard result. The line segment labeled XYW illustrates the equilibrium quantity when the capacity constraint is binding. At the chosen parameter values, the capacity constraint is binding at $n = 2$ (point Y). Thus, output rises as

59. Assumed parameter values for Equation (9) are: ($M = 100$); ($A = 2$); ($\beta = 0.5$); ($S = 45.73$); ($\sigma = 0.25$).

the number of firms increases from monopoly to duopoly, but then output falls (along segment YW) when the number of firms exceeds duopoly. So, while the standard Cournot-type framework holds that output is higher and prices lower with six firms than with two firms, under a spectrum constraint this need not be true. Indeed, for the chosen parameters, the six-firm outcome is essentially the same as the monopoly outcome. Price is lowest, and output highest, at duopoly (under the assumed parameter values).

In Panel B, we observe what happens to equilibrium price as the number of firms increase. In the standard Cournot case, price falls as the number of firms increases (line segment XYZ). Once the spectrum constraint is binding ($n = 2$), however, price rises as the number of firms increases, following line segment XYW. With a binding constraint, the more firms there are in the industry, the higher are prices.[60] *The spectrum constraint turns the standard thinking on the relationship between prices and concentration on its head—i.e., in the case of spectrum exhaust, fewer firms lead to lower prices*.

These figures illustrate clearly the primary results from adding a spectrum constraint to the standard Cournot model. If the constraint is binding, then equilibrium quantity is lower and the price is higher as the number of competitors increases. Obviously, the presence of a spectrum crunch requires substantial modification to the standard competitive model used in most cases by antitrust and regulatory agencies.

D. Jobs and Investment

The increase in market quantity generates a reduction in market prices and an increase in consumer welfare.[61] Furthermore, we see from Equation (3) that the labor demand curve is increasing in the quantity of services. Hence, when the market supply of services increases, the market demand for labor rises. The benefits are also likely to spill over into other markets as the output of services may be a key input into the production of other products. Likewise, the increases in labor demand and employment generate additional household income that increases demand in other

60. Indeed, there is already mounting anecdotal evidence that firms are responding to spectrum constraints with price to ration available capacity. *See, e.g.*, FELDMAN & MITCHELSON, *supra* note 19, at 2 (on file with author) ("The 'spectrum crunch' is real . . . [and] carriers are coping the best they can . . . [via] price increases/tiering, throttling, higher capex budgets, greater use of Wi-Fi and infrastructure sharing."); Mark Hamblen, *Sprint Adds $10 Monthly Data Charge to New Smartphone Users*, PCWORLD (Jan. 18, 2011), http://www.pcworld.com/article/216915/sprint_adds_10_monthly_data_charge_to_new_smartphone_users.html; Kevin C. Tofel, *Verizon Unplugging Unlimited Plans July 7*, GIGAOM (July 5, 2011), http://gigaom.com/mobile/verizon-unplugging-unlimited-plans-july-7; David Twiddy, *Virgin Mobile Raises Price of Unlimited Data plan, Curbs Big Users*, KANSAS CITY BUS. J. (Feb. 15, 2011), http://www.bizjournals.com/kansascity/blog/2011/02/virgin-mobile-raises-price-of.html.

61. *See* Perry & Porter, *supra* note 55, at 219.

markets. All of these impacts reflect an initially excessively atomized distribution of the resource *S* among too many firms.[62] In other words, industry structure is inefficient and a more concentrated structure is preferred from the standpoint of social welfare.

The results described above are *not* just a reformulation of the observation that, with scale economies present, market structure has an ambiguous effect on welfare due to the tradeoff between production costs/scale economies and the degree of price competition. This is apparent because the use of labor and capital inputs in production will *rise* if the industry becomes more concentrated. Usually, cost savings arising from a merger will tend to suppress input use due to direct gains in the efficiency of factors.[63] In the case at hand, use of both labor and capital inputs is proportional to quantity, i.e., there are constant returns to scale in production. The bottleneck arises because of the limitation imposed by the scarce factor *S*, the means by which the firms are able to distribute services to consumers. There is a difference between the technology of production, and the technology by which the service is delivered to consumers, a distinction that recalls Scherer's discussion of cost savings from mergers and the roles of plant-level and firm-level synergies.[64]

E. Spectrum Technology

As noted above, firms are taken to be capacity-constrained by their spectrum holdings, and we assumed that the maximal output rate of any firm is a convex, increasing function of its spectrum holdings, as characterized in Expression (6). It is not this particular assumption, however, that breaks the link between price and the number of competitors. Figure 1 can be used to illustrate this fact. If we assume there are constant returns to spectrum holdings ($\sigma = 0$ from Exp. 6), then the line segments YW in Panel B will be horizontal rather than upward sloping. In other words, once the constraint is binding, price is unrelated to the number of competitors since it does not matter how the spectrum is divided among industry participants.

F. The Asymmetric Case

We have thus far restricted attention to symmetric equilibria, and the question naturally arises as to the consequences of changes in market structure when that structure is asymmetric, as is sometimes the case in

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62. *See supra* Equation (3).

63. Such effects are firm-specific and need not apply to the industry. *See* George S. Ford & Lawrence J. Spiwak, *Wireless Mergers and Employment: A Look at the Evidence*, PHOENIX CENTER POL'Y PERSP. 11-02, at 2 (2011), *available at* http://www.phoenix-center.org/perspectives/Perspective11-02Final.pdf.

64. FREDERIC M. SCHERER & DAVID ROSS, INDUSTRIAL MARKET STRUCTURE AND ECONOMIC PERFORMANCE 162-67 (Houghton Mifflin Co. ed., 3d ed. 1990).

practical application. This is a relatively difficult problem to solve in a general context because of the possibility that some firms may face binding constraints at equilibrium, while others may not. Very specific applications are straightforward in a numerical context. The important ideas from the symmetric case are still at work even in an asymmetric context. When output is capacity constrained and there are economies of scale in the use of the scarce factor, a reduction in firms and a more efficient distribution of the scarce factor can generate an increase in market quantity.[65]

G. Caveats

Our analysis is based on a Cournot model of competition; a choice based on the practical reality that the Cournot model is the foundation for most regulatory and antitrust policy. We note, however, that the Cournot set-up, at least in its more tractable formulations, has several practical defects as a policy tool. Perhaps the most obvious failing in this regard is its application in the analysis of mergers, which is the primary mechanism in the U.S. by which to consolidate spectrum holdings among fewer firms.[66] Indeed, it is difficult to rationalize mergers in the Cournot model.[67] While the merger of two firms creates a firm with higher profits than those firms existing prior to the merger and industry profits rise, the profit of the merged firm is less than two times the profit of the firms existing before the combination except in the case where a merger results in a monopoly.[68] Thus the real beneficiaries of such mergers are the non-merging firms, because they reap much of the profit arising from a reduction in the equilibrium number of firms. As such, there are many mergers that raise industry profits, but insufficient incentives exist for them to occur.

A fundamental problem with mergers in simple Cournot models is that the merged firm may not look any different than those that did not merge: only the number of firms has changed. Perry and Porter (1985) note that the difficulty arises from a lack of any effective distinction between the merger partners and the other sellers.[69] They correct for this defect by proposing that industry firms own an input (termed "capital") that they bring to any merger in which they participate. Starting then from a

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65. Such outcomes may be relevant to the analysis of spectrum swaps and divestitures.

66. *See, e.g.*, JASON B. BAZINET & MICHAEL ROLLINS, CITI EQUITIES, WIRELESS SUPPLY AND DEMAND (Sept. 22, 2011) (on file with the Federal Communications Law Journal) ("[L]arger carriers may need to acquire smaller competitors with underutilized spectrum holdings.").

67. *See* Stephen W. Salant et al., *Losses from Horizontal Merger: The Effects of an Exogenous Change in Industry Structure on Cournot-Nash Equilibrium*, 98 Q. J. ECON. 185, 187, 189, 196 (1983) (stating that in some cases, the joint profits of merged firms may be smaller than the sum of their profits prior to merger in the Cournot equilibrium).

68. George J. Stigler, *Monopoly and Oligopoly by Merger*, 40 AM. ECON. R. 23 (1950).

69. Perry & Porter, *supra* note 55, at 225.

symmetric configuration, the merged firms are *not* identical to those who do not merge: rather, they are "larger" in the sense that they possess more capital used in production. This capital lowers their costs and changes the nature of the resulting equilibrium. However, it is still true that the merged entity generally produces less than the sum of the partners' pre-merger outputs, but the increase in the combination's capital stock can be sufficient to overcome this disincentive. They further examine the role of the intensity of competition in merger incentives by introducing a conjectural variations parameter relevant to their comparative static results.

Finally, a central thesis of this paper is that there exists no tradeoff between market concentration and social welfare in a mobile wireless industry in which spectrum constraint is binding—even if we treat the firms as Cournot competitors. With spectrum exhaust, even when production itself is characterized by constant returns to scale, inefficient allocations of the spectrum to too many sellers reduces consumer welfare: prices are higher and quantities are lower than those arising from a more concentrated structure. This is not necessarily the case, however, when these constraints are *not* binding. In that circumstance, we get the usual Cournot-type results; but with that said, we also get the usual Cournot-type anomalies just mentioned. Without binding constraints on output delivery, mergers reduce social welfare and raise prices although, as usual, no incentive for merger exists.[70]

An important avenue for further study concerns the more general problem of asymmetric distributions of the scarce capacity variable, the precise consequences of this for the equilibrium, and the effects of mergers or other reductions in the number of firms. This issue is likely to require numerical methods for specialized cases or applications, but many of the key features brought to light by the symmetric case are likely to arise in many contexts.

IV. CONCLUSION

Whether we like it or not, as demand for wireless broadband continues to grow exponentially and the problem of spectrum exhaust is here to stay. As noted above, while policymakers are making laudable efforts to hold voluntary incentive auctions for broadcast spectrum and to free-up new government spectrum for commercial use, these measures are unlikely to provide either a quick or even an ultimately conclusive fix to the problem. Accordingly, the pressure for further industry consolidation remains strong.

In an effort to establish the relevance of spectrum exhaust on competition and regulatory policy, this article extends the standard Cournot framework by allowing firms to be capacity-constrained by their holdings

70. *See* Salant et al., *supra* note 67.

of the spectrum resource. We demonstrate that, under a binding spectrum constraint, industry output rates and consumer welfare may be *increasing* with the level of industry concentration. Put simply, *spectrum exhaust turns the standard thinking about the relationship between prices and concentration on its head—i.e., in the case of spectrum exhaust, fewer firms lead to lower prices*. As such, there exists no tradeoff between market concentration and social welfare for Cournot-type markets in which a constraint, like spectrum exhaust, limits market output to levels below the Cournot quantity. In the case of spectrum exhaust, too many sellers will reduce consumer welfare resulting in higher prices and lower quantities than those arising from a more concentrated structure. As a result, policies that impede incumbent carriers from acquiring more spectrum, either by auction or acquisition, may do harm rather than good.

We also demonstrate that, in this framework, increased market concentration does not necessarily result in declines in labor or capital usage, although whether one regards that as a good or a bad situation ultimately depends on the policy environment. For example, usually if mergers create savings, they do so by allowing the firm to produce more output with fewer inputs. Here, the technical conditions imposed on the firms by spectrum exhaust create a scale effect which can lead to increased usage of inputs (e.g. labor) due to total output expansion.

Our analysis has significant implications for spectrum policy going forward. First, in the face of continuing spectrum exhaust, policymakers should not view either spectrum acquisitions or intra-carrier mergers with automatic hostility. Indeed, given the complex economics of the wireless industry, responsible policymaking requires more than simple "headcounts" as an indicator of market performance. Equally as important, when those rare and unique occasions occur where the government does make new spectrum available for commercial use (e.g., voluntary incentive auctions), our analysis cautions against imposing incumbent-exclusion rules or set-asides in the hopes of creating "more" firms and de-concentrating the market. As we demonstrated, adding more firms to an already spectrum constrained market does not help matters, but puts upward pressure on prices and reduces quality.

In sum, our analysis again demonstrates that the laws of economics, and not the desires of policymakers or interest groups, will best dictate the most efficient market structure going forward. In the case of wireless broadband, this means, by definition, small numbers competition. Rather than trying to fight this trend, policymakers need to adapt their thinking to accommodate economic realities if they are serious about maximizing social welfare.