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Comments of Wayne A. Leighton

In the above-captioned proceedings, the Commission seeks comment on, among other issues, the need to ensure that adequate spectrum is made available for wireless communications services, including broadband services. I am pleased to provide comments in these proceedings in the form of the attached study, "Measuring the Effects of Spectrum Aggregation Limits: Three Case Studies from Latin America." While the countries considered in this study have spectrum aggregation policies that are different from those in the U.S., the analysis is nonetheless relevant to these proceedings, as it demonstrates the potential costs of certain limits when imposed on service providers that already are spectrum constrained.

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Measuring the Effects of Spectrum Aggregation Limits: Three Case Studies from Latin America

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Executive Summary

Spectrum is a critical input and a required key ingredient for mobile communications services, one of the most important technologies of the past century in terms of economic impact. As mobile communications evolves from a voice-only service to a broadband connection—a high-speed connection for voice, video, data and more—the amount of spectrum needed to provide this service increases exponentially. Spectrum is truly the lifeblood of the wireless industry. Yet mobile service providers in some countries are constrained, both by a lack of spectrum in the market and by limits on the amount of spectrum that may be held by any one provider. This study examines the potential economic effects of spectrum aggregation limits in three countries: Argentina, Chile, and Colombia. The core costs of building a mobile broadband wireless network in each country are estimated for providers with existing mobile wireless networks. Evaluating spectrum blocks ranging from 2x5 MHz to 2x20 MHz, it is shown that policies such as spectrum aggregation limits that prevent or constrain expansion with larger blocks could double or even quadruple the cost of providing, and thus the price charged for, mobile broadband service. Such a significant increase in prices would likely produce a correspondingly detrimental economic impact on consumers, enterprises and the overall economy. Finally, alternatives to spectrum aggregation limits are reviewed, with the goal of providing policymakers other means to restrict potentially anticompetitive behavior while not thwarting pro-competitive investments in spectrum that make advanced services possible.

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I. INTRODUCTION

A. The Importance of Mobile Communications, and Spectrum to Provide It

The distribution of new technology is recognized by economists as a factor that significantly affects economic growth and one of the key drivers of rapidly rising living standards over the last century.[1] The past three decades have seen numerous examples, such as the personal computer and the Internet, that change the way we live. One of the most important technologies introduced during this period is modern cellular communications. No other technology has had as much reach or impact in as little time.[2] Whereas wireline voice communications was first adopted at the end of the 19th Century and expanded over many decades, modern cellular communications has, in about 20 years, grown to surpass wireline service as the dominant form of voice communications worldwide. The International Telecommunication Union (ITU) estimates that at the end of 2008 there were over 4 billion mobile subscriptions across the globe, more than three times the number of fixed telephone subscriptions.[3]

This expanded communications capability is life-changing. One well-known example—based on research by Brown University professor Robert Jensen—demonstrates how fishermen off the coast of India increase their incomes by using mobile phones to call ports as they return with a catch, thus finding the market with the greatest demand.[4] This is more than an anecdote; it shows that improved communications can lead to improved productivity and thus a higher quality of life for individuals of all income, education, and skill levels.

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[1] *See, e.g.*, Joseph A. Schumpeter, *Capitalism, Socialism and Democracy*, Harper Books (1975, 1942) at 82; Robert Solow, "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics*, 70:1 (1956); Paul M. Romer, "Endogenous Technological Change," *Journal of Political Economy* (1990).

[2] For a discussion of the adoption rates of mobile phones v. other technologies, *see* Adam Thierer and Grant Eskelsen, "Media Metrics: The True State of the Modern Media Marketplace," Progress and Freedom Foundation (Summer 2008). On the prevalence and importance of mobile phones in developing countries, *see* Allen L. Hammond, William J. Kramer, Robert S. Katz, Julia T. Tran, and Courtland Walker, "The Next Four Billion: Market Size and Business Strategy at the Base of the Pyramid," World Resources Group, International Finance Corporation, The World Bank Group (March 2007). For an estimate of the economic impact of mobile communications, *see* Leonard Waverman, Meloria Meschi and Melvyn Fuss, "The Impact of Telecommunications on Economic Growth in Developing Countries," Vodafone Policy Paper 2 (March 2005); and "The Economic Impact of Mobile Services in Latin America," a report for the GSMA, GSM Latin America and AHCIET, by Indepen and Ovum (December 2005).

[3] International Telecommunication Union, "Measuring the Information Society – The ICT Development Index, 2009 Edition," (March 16, 2009).

[4] Robert T. Jensen, "The Digital Provide: Information (Technology), Market Performance and Welfare in the South Indian Fisheries Sector," *Quarterly Journal of Economics*, 122(3), (2007), pp. 879 - 924.

In addition, while expanded communications capability makes workers more productive and thus raises incomes, the overall effects are more far-reaching for societies as a whole. For example, cellular phones have enabled mobile banking, which has helped many low-income individuals establish a bank account for the first time. Similarly, the extended reach and constant access made possible by cellular communications helps doctors and other medical professionals monitor patients who lack easy access to medical facilities.

Moreover, unlike other great technologies, mobile communications may remain iconic for some time. The reason is that the mobile phone is evolving into a mobile device that is capable of delivering basic functionality similar to that of a personal computer. The device that has made voice communications more affordable and more accessible, is now delivering mobile data service, mobile high-speed Internet access, mobile video and image viewing—in short, mobile broadband. The new devices are not simply smart phones; they include netbook computers, which are smaller, lighter and generally much less expensive than traditional notebook computers and designed specifically for Internet use. The combination of low price and good functionality has helped make the penetration of netbooks higher than that of notebook computers in Latin America, while worldwide in the second quarter of 2009 netbook computers accounted for 22% of the portable computer market.[5] As with smart phones, the use of netbooks will continue to grow, thus increasing the demand for mobile broadband services.

The capabilities of these new devices are as potentially life-changing as the expansion of voice calling for Indian fishermen. Whereas citizens in many of the wealthiest economies were introduced to broadband via wireline services from their phone or cable company, for the majority of the world's population, the benefits of broadband will be delivered over airwaves, not wires. A recent survey by the Pew Internet and American Life Project predicted that in 2020 the mobile device would be the primary means to access the Internet, and for the majority of people on the planet, the *only* means of Internet access.[6]

The benefits of mobile broadband communications, while hard to quantify, are both economic and noneconomic. The benefits may be especially significant because they leverage two influences: 1) mobile networks, which have the reach and cost effectiveness needed to promote real benefits, even when limited to voice services, and 2) broadband services, which have the potential to offer even

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[5] "Mini-Note PC (Netbook) Shipments Grow at Twice the Rate of Notebook PCs in Q2'09," Display Search (August 31, 2009), available at http://www.displaysearch.com/cps/rde/xchg/displaysearch/hs.xsl/090831_mini_note_pc_netbook_shipments_grow_at_twice_rate_notebook_pcs_q2_09.asp

[6] Janna Quitney Anderson and Lee Rainie, "The Future of the Internet III," Pew Internet and American Life Project (December 14, 2008), available at http://www.pewinternet.org/~/media/Files/Reports/2008?PIP_FutureInternet3.pdf.pdf.wor.html.

greater capabilities. For example, while mobile voice communications allow medical professionals to monitor their patients, mobile broadband may enable telemedicine, ranging from diagnosis to treatment. Similarly, broadband may facilitate education, both for students who are unable to be physically present at schools and colleges, and for anyone interested in the myriad sources of learning available on the Internet. Further, broadband may improve the effectiveness of public entities, from police and firefighters to the everyday affairs of federal, state and local governments.

With regard to the economic perspective, a February 2009 study by McKinsey & Company argues that mobile networks may be a particularly effective way to bring broadband to the masses in developing countries. The study estimates that raising broadband penetration in developing countries to levels currently seen in Western Europe could increase the combined GDPs for all regions by US$300 to $400 billion and add between 10 and 14 million jobs. For Latin America, GDP could increase by US$50 to $70 billion, with an additional 1.1 to 1.7 million jobs.[7] Looking beyond the economic returns, the benefits to education, health care, public safety, and more are harder to estimate but likely to be broader in scope.

Furthermore, just as the mobile phone was rapidly adopted and enjoyed by individuals of all levels of income and education—with profound economic and social benefits—one can expect the same of smart mobile devices. Building mobile networks to meet these communications needs, however, requires a massive investment in resources. Like its wireline cousin, a mobile network requires significant investments in network equipment and skilled labor. The mobile network, however, requires an additional and critically important input: radio spectrum.

Because spectrum is a necessary input for mobile communications, access to it is a critical issue for mobile communications providers. Policymakers regulate both the amount of spectrum that is available for mobile communications, and the amount of spectrum that may be assigned to any one mobile service provider. As noted and highlighted below, policies that significantly hinder a mobile service provider's access to spectrum therefore frustrate and impede the timely and economic deployment of advanced mobile services. The end result is that the diffusion of new technology—and the many economic and social benefits that accompany it—may be stifled.

[7] "Mobile Broadband for the Masses: Regulatory Levers to Make it Happen," McKinsey & Company (February 2009), available at http://www.mckinsey.com/clientservice/telecommunications/Mobile_broadband_for_the_masses.pdf.

B. Global Trends: More Spectrum, Larger Bandwidths, More Intensive Use

The mobile communications market is witnessing—or soon will witness—a surge in data traffic due to a perfect storm of availability, adoption, and use of the latest technology. Specifically, more mobile broadband connections are being made available; more individuals are adopting these advanced services; and once subscribed, individuals tend to use the mobile network with greater frequency and intensity.[8] As many countries approach 100 percent mobile phone penetration—and the countries in this analysis either approach or exceed this range—the challenge for network operators will not be dealing with more users; it will be dealing with more communications traffic per user.

The increase in mobile traffic is explained by the introduction of new mobile services to the consumer. Until several years ago, mobile communications was synonymous with mobile voice service. Soon thereafter, text messaging was offered and has become extremely popular while mobile voice use has continued to rise. Today, mobile networks offer an ever-greater variety of services to meet the expectations of an increasingly demanding and competitive market. In addition to voice calling and emails, advanced networks offer Internet access at broadband speeds, which gives users the ability to share large data files, play games, and send and receive high-quality video.

Although the services associated with mobile broadband are enormously popular and hold the promise of many social and economic benefits, they also create congestion in the network. A December 2008 report by Rysavy Research illustrates the extent to which the use of certain services translates into significant loads upon the network.[9] The Rysavy report estimates that, even with modest assumptions about usage, an average subscriber could consume 55 megabytes per month with email, 200 megabytes for web browsing, 2.7 gigabytes per month for Internet radio, 9 gigabytes per month for video, and 27 gigabytes per month for HD movie downloads.[10]

Given that providers already express concerns about capacity constraints under current consumption patterns—which in many countries includes relatively few subscribers watching videos or downloading HD movies—the fact that these data-intensive applications are expected to grow implies that future capacity constraints are likely to be even more severe. As these advanced services become more popular, their load will not increase in a linear fashion. More likely, the rate

[8] Chetan Sharma, "Managing Growth and Profits in the Yottabyte Era," Chetan Sharma Consulting (2009), at 7 [hereinafter *Chetan Sharma Study*], available at http://www.chetansharma.com/yottabyteera.htm.

[9] Rysavy Research, "Mobile Broadband Spectrum Demand," (December 2008) [hereinafter *Rysavy Paper on Spectrum Demand*], available at http://www.rysavy.com/Articles/2008_12_Rysavy_Spectrum_Demand_.pdf.

[10] *Rysavy Paper on Spectrum Demand* at 16-17.

of increase will be exponential. For example, 15 minutes spent watching YouTube requires about 100 megabytes (MB) of capacity on a digital network, approximately the same as 1,000 minutes of voice communication.[11] Stated differently, a user operating a device at 1 Mbps—a standard speed for the latest generation mobile technologies such as HSDPA[12]—will need 100 times more bandwidth than a voice caller.[13] A study by Cisco Systems, Inc. calculates that a single iPhone, Blackberry or other advanced mobile device generates the same amount of traffic as 30 phones with basic features, while a laptop integrated into the mobile network may generate as much traffic as 450 basic-feature phones.[14] With a methodology that is largely consistent with the Rysavy research, but showing somewhat lower estimate of usage, the Cisco study further predicts that if laptops and other devices are included, monthly mobile traffic per user could escalate from 1 gigabyte (GB) in 2009 to 14 GB by 2015.[15] This would be a tremendous strain on existing networks.[16]

For networks as a whole, Cisco estimates that mobile data traffic growth will double every year for the next four years, with the result that data usage in 2013 will be 66 times greater than it was in 2008.[17] Moreover, this growth in usage is not expected to be limited to Western Europe and Japan. The highest expected growth in data usage for the period 2008-2013 is for Latin America, which is projected to see a 166 percent increase.[18]

Such heavy data traffic simply cannot be handled on the amount of spectrum currently available. This is not idle speculation; it is the essence of an ITU report issued in 2006, in which the U.N.-sponsored telecommunications body estimated spectrum needs for mobile communications.[19] The ITU considered the spectrum needs for two groups of technologies: first, the IMT- 2000 standard, as well as its precursors and some enhancements; and second, the IMT-Advanced standard. Spectrum requirements were estimated for the years 2010, 2015 and 2020.

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[11] Rysavy Research, "Wireless E-Mail Efficiency Assessment: RIM BlackBerry and Microsoft Direct Push (Including iPhone)," (January 27, 2009), at 2-3 [hereinafter *Rysavy White Paper on Wireless Efficiency*], available at http://www.rysavy.com/Articles/2009_01_27_Rysavy_EMail_Efficiency.pdf.

[12] Rysavy Research, "HSPA to LTE-Advanced: 3GPP Broadband Evolution to IMT-Advanced (4G)," (August 2009), at Figure 1 [hereinafter *Rysavy White Paper on LTE*], available at

[13] *Rysavy White Paper on Wireless Efficiency* at 2-3.

[14] "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update," Cisco Systems, Inc., White Paper (January 29, 2009) [hereinafter *Cisco White Paper*].

[15] *Cisco White Paper* at Figure 5.

[16] For a discussion network capacity relative to subscriber usage, *see Rysavy Paper on Spectrum Demand* at 16-20.

[17] *Cisco White Paper* at 1.

[18] *Cisco White Paper* at Appendix A.

[19] International Telecommunication Union, "Estimated Spectrum Bandwidth Requirements for the Future Development of IMT-2000 and IMT-Advanced," Rep. ITU-R M.2078 (2006).

The ITU concluded that by the year 2010, the total spectrum needed would range from a low of 760 MHz to a high of 840 MHz, and that by the year 2020 this requirement would range from 1,280 MHz to 1,720 MHz. Further, the ITU study clarified that these estimates assumed a single network for a country; when multiple networks were assumed, the total spectrum needs were expected to be higher. With three networks, the low estimate for 2020 rose by 280 MHz, to 1,560 MHz.[20]

The ITU's estimated requirements, even if taken at the lowest estimate for 2010, represent a greater quantity of spectrum—760 MHz—than is available in any country in the Americas. Indeed, this is more than three times the spectrum currently available in most countries in Latin America, which generally have less than 200 MHz allocated and available for mobile communications. Alarmingly, this estimate is for a date that is fast approaching. Perhaps just as worrying is the fact that the low estimate of spectrum needed roughly one decade from now—1,280 MHz, or 1,560 MHz with three networks—is four times the amount of spectrum currently available in many countries in the region.

Using these ITU estimates, in 2007 the NGMN Alliance reviewed existing allocations across the globe and calculated the amount of additional spectrum that would need to be allocated to meet the ITU requirements.[21] The review concluded that between 500 MHz and 1000 MHz of additional spectrum would be needed. The NGMN Alliance also argued that the amount of new spectrum allocated by policymakers should be closer to the higher end of this estimate, to enhance flexibility in providing advanced services and to increase the likelihood that some portions of the bands may be harmonized across countries.[22]

C. The Challenge to Mobile Network Operators

How should network operators manage their networks to account for a 30- or 60-fold increase in the amount of data transmitted per subscriber? There is no single solution; rather, carriers will need to employ a variety of engineering and economic solutions, ranging, for example, from investments in new technologies to business models that provide incentives for subscribers to conserve network resources.

On the demand side, network operators may encourage customers to avoid non-critical but data-intensive applications during peak hours. An example is discounted service bundles that allow unlimited transmissions during off-peak

[20] *Id.* at 26, Note 1.

[21] "Spectrum Requirements for the Next Generation of Mobile Networks," NGMN Alliance (June 20, 2007) [hereinafter *NGMN Study*].

[22] *NGMN Study* at 22-23.

hours and apply limits to, or charge higher prices for, peak-hour transmissions.[23] Another option is to encourage customers to use femtocells in their homes or offices, which grab the user's signal and transmit it via a wireline link to the Internet, thus taking the signal off the local cellular tower and decreasing the spectrum load.[24] The net benefits of femtocells, however, are unknown at present. They may lower congestion on a local tower and improve the user's experience, especially in the home, thus increasing the popularity of mobile devices. At the same time, femtocells also may create millions of small cell sites that pose new spectrum management challenges, including, for example, avoiding interference between adjacent users.[25]

On the supply side, network operators have a number of options to increase their data transmission capacity. Much of the recent attention has been focused on advanced networks, especially HSPA+ and LTE. HSPA+ will provide higher data speeds and capabilities by a simple upgrade to today's HSPA networks. LTE will provide a new radio access technology and a flatter "all IP" core network. In the U.S., AT&T and Verizon have announced LTE deployments starting in 2010 and increasing notably in 2011 and beyond. Some providers in many countries in Latin America expect to deploy LTE technology only a few years after that. Providers in Chile have requested to the Chilean regulator experimental licenses to trial LTE in 2010. Providers in Argentina and Chile could deploy LTE in 2012, while providers in Colombia could deploy LTE in 2013.[26] In addition to deploying new technology, other means to raise capacity include increasing the number of towers used to serve a given geographic area (cell splitting), and increasing the number of antennae deployed per cell.

Finally, an obvious solution for increasing capacity is to increase the amount of spectrum available for this service. For advanced mobile broadband technologies, large amounts of spectrum produce tangible benefits. For example, increasing the size of a service provider's spectrum block from 10 MHz (a pair of 5-MHz blocks) to 20 MHz (two 10-MHz blocks) doubles the transmission

[23] While some wireline providers of broadband service, including cable companies, have considered such pricing models, there also has been opposition. For example, Free Press has opposed market experiments in congestion pricing by Time Warner Cable. *See* "Free Press Organizes Nationwide Opposition to Time Warner Cable Metering," press release, Free Press (April 10, 2009), available at http://freepress.net/node/56030. Nonetheless, a service package that allows unlimited transmissions at all times, including peak hours, costs more than a service package that limits peak-hour transmissions but allows unlimited transmissions during non-peak hours. To the extent carriers are prohibited from offering this latter package of services, a lower-cost service option is kept out of the market.

[24] For an engineering perspective on traffic management options, *see Chetan Sharma Study* at 15-20.

[25] *See, e.g., Rysavy Paper on Spectrum Demand* at 22-23.

[26] *See* "A Compendium of Data and Regulatory Issues Related to the Mobile Industry in Latin America," Signals Telecom Consulting (June 2009).

capability. Increasing the spectrum block from 20 MHz to 40 MHz (two 20-MHz blocks) may double the transmission capability again.[27]

Given that there are multiple means to increasing transmission capability utilizing existing spectrum resources—better phones, better networks, more cell sites, etc.—is more spectrum necessary? The answer is clearly yes. Failure to make more spectrum available for mobile networks, and failure to allow network operators sufficient spectrum to operate efficiently, makes it difficult if not impossible for service providers to find an optimal mix of inputs, a task that involves considering tradeoffs in the use of resources. For the provision of mobile communications, as with any other service, these tradeoffs are both a theoretical and empirical reality.

To understand the theoretical problem, imagine two towns separated by a large mountain. The residents of these towns wish to be connected by a road. There are multiple ways to connect them, but they all involve some combination of concrete and engineering. Connecting the towns by building a road around the mountain would involve a large amount of concrete but little engineering. In contrast, connecting the towns by building a road over the mountain would involve much less concrete but much more engineering. Which option is best? The answer depends on the relative scarcity of concrete and engineers, and in a market economy the scarcity of these resources will be determined by prices.

With mobile networks, the tradeoff is the same. That is, network operators optimally balance the expense (*i.e.*, scarcity) of additional spectrum against the expense of additional cell sites, more-advanced networks, and other inputs. A minimum amount of spectrum, however, is needed to operate no matter which solution is adopted.

The reason why a minimum amount of additional spectrum is necessary is that, while investments to improve transmission capability for a given amount of spectrum are important, these steps also face diminishing returns; the laws of physics limit the incremental benefits of adding cell sites or antennae. In other words, while it is true that network operators can substitute cell sites or antennae for additional spectrum, this strategy only works up to a point. To return to the above example, the problem is analogous to a two-lane road built to connect two towns that have now become major cities, with significantly more traffic between them. More traffic could be handled if congestion pricing were implemented to encourage off-peak use. Similarly, more traffic could be handled if automakers built cars with sensors that automatically kept each car at a safe distance from the one in front of it while travelling at high speed. Nonetheless, sooner or later the

[27] *See, e.g.*, Erik Dahlman, Stefan Parkvall, Johan Skold and Per Beming, *3G Evolution: HSPA and LTE for Mobile Broadband*, Academic Press (2008) at 553-560. *See also*, http://business.motorola.com/experiencelte/lte-depth.html.

returns to these innovative solutions will be swamped by the straightforward and necessary solution—either expand this road into a highway, or build a new one. With networks that depend on spectrum, the problem is the same. Exponential increases in mobile data traffic call for bigger highways to handle that traffic, and spectrum is the building block for that construction. Policymakers increasingly recognize this fundamental insight. For example, the importance of additional spectrum is one of the key findings in the *Digital Britain Report*, a major review of digital communications policy in the United Kingdom.[28] In contrast, as explained below, the failure to allow for additional spectrum blocks may impose significant costs.

D. Why Limited Spectrum Allocation, and Spectrum Aggregation Limits, May Cause Harm

In a market where providers optimally balance their mix of inputs to produce value for consumers, spectrum aggregation limits may cause serious distortions. First, such limits may result in an inefficient number of providers. For example, in theory, policymakers could meet the exponential growth in mobile data traffic by allocating more spectrum while not allowing any one provider to hold more than a minimal amount (*e.g.*, 40 or 60 MHz). In practice, most countries with such a rule would need a significant increase in the number of carriers, several times the current average of three or four. Assuming a spectrum aggregation limit of 60 MHz and a demand for services requiring 720 MHz—the low end of the ITU's estimates—this would imply 12 nationwide carriers, an implausible number not seen in any developed market.[29] At the other end of the continuum of policy options, a single carrier could hold the entire bandwidth for mobile communications. While a single provider with the entire spectrum allocation might be technically efficient, it also would be a monopoly and thus—given market conditions that can support multiple operators in a country—almost certainly not economically efficient.

Moreover, while policymakers may be tempted to seek a "middle solution" when allocating additional spectrum—for example, by encouraging an additional entrant or two—such an approach is risky. The economically efficient number of providers will vary by market, but in few countries are there more than three or four major national operators. As the analysis below demonstrates, spectrum aggregation limits to facilitate entry by new operators may significantly hinder the ability of existing network operators to expand into advanced services and

[28] "Digital Britain Final Report," Presentation to Parliament by the Department of Culture, Media and Sport, and the Minister for Communications, Technology and Broadcasting (June 2009) [hereinafter *Digital Britain Report*], available at http://www.culture.gov.uk/images/publications/digitalbritain-finalreport-jun09.pdf.

[29] Martyn F. Roeter, "Mobile Broadband, Competition and Spectrum Caps," Arthur D. Little, prepared for the GSM Association (January 2009).

thus raise the price or reduce the viability of mobile broadband. This is precisely the opposite outcome desired by policymakers.

The reason for this unexpected outcome is grounded in engineering and economics. Specifically, in the absence of sufficient spectrum, additional cell sites are required to provide mobile broadband service. Because cell site acquisition, build out, and maintenance is costly, an overly burdensome network build out can reduce the viability of mobile broadband service and also may create inefficiencies for the existing providers' current operations in the market. These inefficiencies may include degradation of existing services and an increase in their cost, problems already faced by some providers in today's market. Service providers may substitute other inputs up to a point, but these inputs necessarily are more expensive, otherwise the provider would have chosen to employ them first. Ultimately, either the cost of providing service increases or the quality of service decreases, if not both.

A common example of this service degradation problem is the challenge providers face in allocating a limited amount of spectrum to their existing 2G voice networks as well as their expanding 3G data networks. As network congestion increases despite additional investment in cell sites and equipment, the network operator must choose between allowing more voice calls to be dropped or providing slower data service. This is a lose-lose proposition. Without a minimum reliability for voice calls, subscribers will lose one of the key features of a mobile service. Without a minimum data speed, subscribers will be unable to make use of the increasingly popular services discussed above, and will be unwilling to pay for an "enhanced" service that does not live up to its name. Such a result would not simply mean less demand for a provider's mobile broadband and other services and thus less deployment; it could mean that the significant economic and social benefits of broadband penetration may fail to materialize.

Similarly, delays in the deployment of advanced service may occur for the simple reason that providers may be hesitant to build if they expect they will lack the capacity to handle the traffic their advanced services will generate. In other words, even with the availability of the latest technologies to provide advanced services such as LTE networks, providers may be unwilling to build out their advanced networks without sufficient access to spectrum.

Finally, a decrease in future innovation is likely whenever the inputs needed to promote those innovations are lacking. Providers that already struggle for an optimal mix of spectrum for 2G and 3G services hardly have sufficient spectrum to take risks with innovative but untested next-generation services. Yet it is the trial-and-error process of launching new services, scrapping the failures and improving on the promising ones, that leads to future benefits for consumers. Significantly, the advanced mobile broadband services of the future cannot be predicted, and thus this particular type of harm is difficult to measure. The lost opportunities, however, are no less real and may cut across large and important sectors of society, including not only economic development, but also future advances in access to education, health care, financial service, public safety services, and more.

E. Review of the Literature

As discussed in Sec. IV, policymakers have generally limited the amount of spectrum that may be held by any one provider, with the goal of preventing consumer harm in the market for services supplied with this spectrum. It is, therefore, important to understand what the economics literature does and does not say regarding control of the market for an essential input, which spectrum clearly is for the production of mobile communications. This section provides a brief review of this literature on essential inputs, as well as a review of existing studies of spectrum aggregation limits in particular.

Economists have long recognized the potential for consumer welfare losses as the result of anticompetitive behavior by firms; indeed, protection against such behavior is the core of antitrust law.[30] A classic example of such anticompetitive behavior is raising rivals' costs by foreclosing supply, as when one firm acquires most or all of an essential input. It is not, however, always easy to identify when a competitor is engaging in foreclosure and when it is simply acquiring an input. The extreme cases are easy: at one end, a firm may acquire exclusionary rights to an essential input with no intention of using it, an anticompetitive practice that also is relatively rare. At the other end, when one firm acquires some portion of the key input, however small, by definition it excludes others from use of that input, even if there is no anticompetitive effect and consumers benefit from the service provided. The challenging question for policymakers, then, is whether it is anticompetitive for an existing provider to acquire additional units of the input.

A simple test helps answer this question, based on an understanding in the antitrust literature that consumer harm is most likely when two conditions hold: First, acquisition of the input by one firm raises the costs of operation for other competitors. Second, by raising the costs of its competitors, the firm gains an increased ability to raise the price paid by consumers.[31] Applied to the mobile communications market, in theory it is conceivable that both conditions could be

[30] *See, e.g.*, Phillip Areeda, *Antitrust Analysis*, 3rd edition, Little Brown (1981); Robert H. Bork, *The Antitrust Paradox*, Basic Books, Inc. (1978); Milton Handler, Harlan M. Blake, Robert Pitofsky and Harvey J. Goldschmid, *Cases and Materials on Trade Regulation*, 3rd edition, Foundation Press (1983); Richard Posner, *Antitrust Law: An Economic Perspective*, University of Chicago Press (1976).

[31] Thomas G. Krattenmaker and Steven C. Salop, "Anticompetitive Exclusion: Raising Rivals' Costs to Achieve Power over Price," *Yale Law Journal* 96:2 (December 1986); *see also* Patrick Rey and Jean Tirole, "A Primer on Foreclosure," in *Handbook of Industrial Organization III*, Mark Armstrong and Rob Porter, eds. (2006).

met under certain circumstances, especially if one firm's acquisition of spectrum results in another firm facing higher marginal costs due, for example, to the need to invest more in towers or other equipment to handle its traffic. Another way a firm may raise the costs to competitors is by preventing these competitors from acquiring sufficient amounts of the input to achieve minimum efficient scale.[32] If a competitor is unable to reach the lowest point on its average total cost curve because of insufficient spectrum, for example, such a result may be obtained.

In the market for spectrum, however, these anticompetitive practices may be difficult to execute. First, the firm wishing to raise the costs of its rivals must ensure that all viable spectrum blocks are unavailable. In addition, as Professor Dennis Carlton has argued, when denial of economies of scale are the issue, this strategy is not likely to be successful unless the firm can drive its competitors out of business, rather than simply raise their costs.[33] Further, such anticompetitive behavior is relatively easy to counter with less-stringent rules than spectrum aggregation limits, as explained in Sec. IV.

More fundamentally, however, this type of anticompetitive behavior is most effectively prevented by simply making sufficient spectrum available. Ironically, the first condition in establishing harm—raising the costs of other firms—may inadvertently be applied to all firms as a result of the limited availability of this key input. That is, there may be insufficient spectrum available for the industry as a whole, or a number of individual firms may face limits on the amount of spectrum they may hold.

Several papers have examined spectrum aggregation limits and suggested that these limits may ultimately harm consumers. In 2001, when the U.S. Federal Communications Commission (FCC) was reconsidering its strict spectrum cap for CMRS licensees, John Haring, Harry Shooshan and Kirsten Pehrsson laid out several principles that still apply in the modern debate.[34] First, the authors note that any type of aggregation limit likely will become increasingly restrictive and thus need regular readjustment. More fundamentally, consistent with the antitrust literature, they observe that the relevant question for policymakers is whether a given transaction (acquisition of spectrum) will raise or lower consumer welfare. Finding the answer involves weighing the potential for anticompetitive action (a harm to consumers) against the potential for expanded services and improved economies of scale and scope (a benefit to consumers).[35] A strict cap, the authors conclude, is too rigid to achieve this balance in a dynamic market, for the same

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[32] *See* Einer R. Elhague, "Better Monopolization Standards," *Stanford Law Review*, 56:2 (November 2003).

[33] *See* Dennis W. Carlton, Patrick Greenlee, and Michael Waldman, "Assessing the Anticompetitive Effects of Multiproduct Pricing," *Antitrust Bulletin* (Fall, 2008).

[34] John Haring, Harry M. Shooshan III and Kirsten M. Pehrsson, "White Paper on elimination of the Spectrum Cap," Strategic Policy Research (April 12, 2001).

[35] *Id*. at 2-8.

reason that "[a] hat that fits an infant is unlikely to continue to fit the child as the child grows."[36]

More recently, Professor Michael Katz has argued in U.S. policy debates that spectrum caps are an imperfect and inefficient tool for policing competition in the market for mobile communications.[37] In particular, Professor Katz focuses on the inefficiencies associated with proposals to limit the ability of existing mobile service providers to bid on additional allocations of spectrum.[38] These inefficiencies arise because they limit the ability of existing providers to offer new services that require more spectrum, precisely the challenge facing providers in many countries today.[39] Katz takes the argument further, however, arguing that auction-specific restrictions, not only industry-wide restrictions, have negative effects. He concludes that limitations on spectrum aggregation "would thus harm consumers through the resulting combination of higher prices, lower service quality, and diminished innovation in service and handset offerings."[40]

For a more global perspective, Dr. Martyn Roetter recently reviewed spectrum cap policies in Canada, the United States, the United Kingdom, India, and a number of countries in Latin America.[41] Consistent with the discussion above, Dr. Roetter finds significant increases in the demand for additional spectrum to provide advanced services. On a positive note, he finds "the trend in Europe has been to rely on measures such as permitting spectrum trading and relying on 'loose' and generous spectrum caps in the new bands being auctioned for broadband services to achieve a reasonable balance between maintaining competition in the mobile market while enabling operators to acquire enough bandwidth to offer broadband services efficiently and economically."[42] More

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[36] *Id*. at 8.

[37] *See* Michael L. Katz, "An Economic Analysis of the Rural Telecommunications Group's Proposed Spectrum Cap," Opposition of Verizon Wireless, Appendix A, In the Matter of Rural Telecommunications Group Petition for Rulemaking to Impose a Spectrum Aggregation Limit on All Commercial Terrestrial Wireless Spectrum Below 2.3 GHz, RM- 11498 (December 2, 2008); Michael L. Katz, "Measuring Effective CMRS Competition," Reply Comments of AT&T, Inc., Appendix A, In the Matter of Wireless Telecommunications Bureau Seeks Comment on Commercial Mobile Radio Services Market Competition, WT Docket 09-66 (July 13, 2009).

[38] *See, e.g.,* Rural Telecommunications Group, Inc. Petition for Rulemaking To Impose a Spectrum Aggregation Limit on all Commercial Terrestrial Wireless Spectrum Below 2.3 GHz (filed July 16, 2008); "Wireless Telecommunications Bureau Seeks Comment On Petition For Rulemaking Of Rural Telecommunications Group, Inc. to Impose a Spectrum Aggregation Limit On All Commercial Terrestrial Wireless Spectrum Below 2.3 GHz," *Public Notice*, DA 08-2279 (October 10, 2008).

[39] Katz, "Measuring Effective CMRS Competition," at ¶¶ 68-69.

[40] Katz, "Measuring Effective CMRS Competition," at ¶ 69.

[41] Martyn F. Roetter, "Mobile Broadband, Competition and Spectrum Caps," An independent paper prepared for the GSM Association, Arthur D. Little, Inc. (January 2009).

[42] *Id*. at 5.

worryingly, however, a number of countries in Latin America continue to maintain rigid caps.[43]

While these studies make a clear case that spectrum aggregation limits may be harmful, they do not attempt to quantify the extent of the harm. The following section offers an approach for making such an estimate.

II. Measuring the Costs of Spectrum Aggregations Limits

We estimate the costs of spectrum aggregation limits for three countries: Argentina, Chile, and Colombia. In each country, we examine how spectrum aggregation limits affect the provision of service in the three largest metropolitan areas in each country; that is, in the markets that are most likely to suffer from congestion.

A. Summary of the Cost Model

The model developed here estimates the costs of strict spectrum aggregation limits by comparing the costs of building a new mobile broadband (LTE) network with increasingly large quantities of spectrum. The model does not consider other costs that are not directly related to building and maintaining such a network but that carriers nonetheless incur, such as employee training and development, benefits, and marketing expenses.

At a high level, the model is constructed as follows:

- The number of wireless data users in the highest cost markets is estimated.
- Investment in wireless equipment necessary to serve these customers is estimated for 2x5 MHz, 2x10 MHz, 2x15 MHz, and 2x20 MHz of spectrum.
- The monthly average revenue per user (ARPU) necessary for the carrier to break even after eight years is determined for each spectrum allotment.
- The differences between break-even user charges gives an estimate of the benefits to consumers in a competitive wireless market of assigning larger swaths of bandwidth to carriers.

The model assumes that existing mobile providers are at or near the current spectrum aggregation limit and that they operate in competitive markets, such that price increases unrelated to costs cannot be sustained. We further assume that these carriers wish to obtain additional spectrum, which they will use to provide mobile broadband (LTE) service as they integrate it with their current spectrum holdings, which will be used to provide 2G and 3G service.

[43] *Id*. at 14-19.

In greater detail, the model is first parameterized with the following inputs:

1. Interest rate charged to the firm
2. Area (in square kilometers) of a metropolitan area
3. Data subscribers, estimated as the product of population, carrier market share, wireless penetration, and expected data penetration
4. Cell site cost, which is the average cost of leasing tower space, building the tower, and installing and servicing network equipment
5. Users per cell site for 2x5 MHz, 2x10 MHz, 2x15 MHz, and 2x20 MHz of spectrum.

We allow the carrier to build out and increase data subscribers in two phases. That is, an initial level of data penetration is assumed from years 1 through 4, and a second level of data penetration occurs between years 5 and 6. Fifty percent of initial build-out costs are incurred in year zero—that is, before the carrier is able to add subscribers to the new LTE network. In the first year of operations, the remainder of the initial build-out costs are incurred and the carrier is able to fully serve its phase I LTE customers.

The cost of debt carried forward is based on the real rate of interest charged to the firm. The carrier reduces its debt in years two and three by monthly revenues from its customers. In years 4 and 5, the carrier then incurs additional costs of expanding its network and increases subscribers, its phase II customers, in years 5 and 6. In year 5, the carrier increases subscribers by fifty percent of the total increase in subscribership that occurs in years 5 and 6 combined. The final subscribership increase occurs in year 6, which brings the carrier to full network capacity.

The model is completed by finding the monthly revenue per subscriber necessary for the carrier to break even after the eighth year of operations and under different spectrum allotments. The model assumes sufficient competition that carriers charge only enough to break even on their investment in the new service. Prices will not exceed cost under such conditions, but if prices are below cost, firms will not invest in deploying the new service. Because larger amounts of spectrum allow the carrier to serve more customers on a given cell site, network equipment investments are diminished with greater quantities of bandwidth, and prices paid by consumers are correspondingly lower.[44]

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[44] *See* Alcatel-Lucent, "Long-Term Evolution (LTE) Overview," at 2 (stating that cell capacity is approximately 200 active users for 5 MHz and 400 users for larger amounts of bandwidth); UMTS Forum, "Towards Global Mobile Broadband," Feb. 2008, at 3 (finding that LTE can, in theory, accommodate 200 users per cell with a 5 MHz carrier). Significantly few users are accommodated with pre-LTE, especially for high data speeds. *See, e.g.*, Sadia Murawwat and Kazi Ahmed, "Performance Analysis of 3G and WiMax as Cellular Mobile Technologies," Second International Conference on Engineering and

We report the cost estimates for each spectrum allocation—2x5 MHz, 2x10 MHz, 2x15 MHz, and 2x20 MHz—as it compares to other allocations. That is, while actual costs are calculated for the three largest cities in each country, we report here a ratio that expresses the change in the cost of building a mobile broadband network as the amount of spectrum available changes. We note that the ratios expressed tend not to be sensitive to certain assumptions about the cost of building a broadband network, *e.g.*, site cost and maintenance. As a result, the ratios reported likely would remain consistent even if alternative assumptions of site cost, maintenance and other expenses were employed.

B. Elements of LTE Business not Considered in the Model

The model outlined above—and implemented below—estimates the cost-savings to consumers of assigning additional amounts of bandwidth to mobile operators facing binding spectrum aggregation limits. Put simply, it is a cost-side model based on a network build-out process for a new product. Not considered in this model are other factors that could amplify the effect of spectrum aggregation limits that are overly burdensome. Among these concerns are the transition of 2G/3G customers to LTE service in existing spectrum allotments, and the inability of firms to deliver some particularly bandwidth-intensive services in smaller bandwidths.

As was stated above, the model assumes that existing spectrum allocations would be used to provide 2G and potentially 3G service. Because LTE can be offered through existing radio spectrum allocations, those existing allotments could, in theory, be used to provide LTE. Such a transition, however, would involve degrading if not cannibalizing existing 2G/3G service for the newer LTE service. As a result, the transition would be a more costly and time-intensive process than building out an LTE network on new spectrum. Therefore, in countries with binding spectrum aggregation limits and congested 2G/3G networks, the cost model outlined above is appropriate.

Accordingly, this model does not attempt to estimate the effects of a provider investing to offer advanced services in spectrum bands currently used for 2G/3G service. This does not mean that some providers will not follow such an expansion strategy as a second-best solution. Nonetheless, such an approach is likely to be problematic for both providers and consumers. Although the provider likely would save capital costs associated with the purchase of spectrum licenses, it may need to degrade or cannibalize existing 2G/3G operations as it converts customers from its old service to its new service. The end result is that the quality

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Technology, (March 25-26, 2008) University of Engineering and Technology, Lahore (Pakistan); José Antonio Portilla-Figuerasa, Sancho Salcedo-Sanza, Alicia Oropesa-Garcíab, Carlos Bousoño-Calzónb, "Cell Size Determination in WCDMA Systems Using an Evolutionary Programming Approach," Computers & Operations Research 35 (2008) 3758 – 3768.

of existing voice service and the new mobile broadband service will be reduced and the roll out could be delayed relative to a scenario in which the network operator has at its disposal sufficiently large blocks of new spectrum with which to provide the new service.

Finally, it is also worth noting that from a product-offering perspective more bandwidth will be needed to reliably deliver, not only advanced mobile broadband to the mass market, but certain bandwidth-intensive services, such as high-definition mobile television, as well. Specifically, LTE service is delivered via "carriers" that typically meet or exceed 2x5 MHz in size. A bandwidth allotment of, say, 2x20 MHz can, in theory, be broken into four 2x5 MHz carriers, two 2x10 MHz carriers, or one 2x15 MHz and one 2x5 MHz carrier. The advantage of larger carriers is that with greater throughput one can deliver a product that is more data-intensive. Therefore, some applications may not be commercially feasible in the near-term with 2x5 MHz carriers. Although this aspect of the LTE business is not built into the model presented here, policymakers should be aware of it in determining spectrum aggregation limits.

III. THREE CASE STUDIES

A. Argentina

Argentina has 170 MHz of spectrum available for mobile communications services, including licenses in the 800 MHz, 850 MHz and 1900 MHz bands. The country maintains a spectrum aggregation limit of 50 MHz per carrier, which has been in place since 1998. From December 1998 to 2008 the wireless subscribership grew from 2.9 million to 43.6 million customers.

The market in Argentina is primarily served by three large providers: Claro, Movistar Argentina, and Telecom Personal. In addition, Nextel has a relatively small market share that is focused on business users.

Argentina's telecommunications regulatory authority, the Secretariat of Communications (Secom), currently is considering rules to license spectrum in the 1700 MHz and 2100 MHz bands. This upcoming auction is expected to make available an additional 90 MHz of spectrum. At this time, however, the service and auction rules remain undefined. The general expectation is that Secom will allow incumbent licensees to bid on this spectrum while also taking steps to encourage participation by a new entrant.[45]

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[45] For more information, *see* "A Compendium of Data and Regulatory Issues Related to the Mobile Industry in Latin America," Wireless Reference Document, Prepared by

The model described above is applied to the largest provider in the three largest metro areas in Argentina: Buenos Aires, Córdoba, and Rosario, which have a combined population that represents 29 percent of the population for the country as a whole. Evaluating these areas, the model considers build out of advanced services (*i.e.*, LTE) under various spectrum constraints, estimating the monthly ARPU that would be needed to break even (*i.e.*, no monopoly profit). This estimate shows the relationship between the minimum price counsumers would have to pay for the service and the different spectrum allocations that were considered. Table 1 lists the results for Argentina.

TABLE 1: ARGENTINA

Minimum Monthly Cost of LTE Service under various spectrum allocations

	2 × 20 MHz	2 × 15 MHz	2 × 10 MHz	2 × 5 MHz
Buenos Aires	X	1.3X	2X	4X
Córdoba	Y	1.3Y	2Y	4Y
Rosario	Z	1.3Z	2Z	4Z

The results indicate that decreasing the amount of spectrum available for LTE from 2x20 MHz to 2x10 MHz would double the price consumers pay for this service, while a decrease from 2x10 MHz to 2x5 MHz would double again the price paid by consumers. Thus, increasing the amount of spectrum from 2x5 MHz to 2x20 MHz would reduce the amount the consumer would pay for service by four fold.

This cost-side model estimates only the higher prices consumers would pay for advanced services as a result of limited availability of spectrum to existing service providers. It is important to note, however, that higher prices inevitably lead to lower quantity demanded in the market. As fewer consumers adopt mobile broadband services, both the economic effects—such as increased GDP and employment—and the social benefits—such as improved education, health care, etc.—will be reduced accordingly.

Signals Telecom Consulting (June 2009). *See also* Martyn F. Roetter, "Mobile Broadband, Competition, and Spectrum Caps," *supra*.

B. Chile

Chile has 260 MHz of spectrum available for mobile communications, including licenses in the 800 MHz, 850 MHz, 1900 MHz, and 1700/2100 MHz bands. The country maintains a spectrum aggregation limit of 60 MHz, which has been in place since January 2009. From December 1998 to 2008 the wireless subscribership grew from 900,00 to almost 16 million customers.

The market in Chile is, like the market in Argentina, served primarily by three providers. These include Claro, Movistar Chile, and Entel Móvil. Nextel also has a very small market share in the country. In 2010 Nextel will expand its presence in the mobile market with 60 MHz of spectrum acquired in the recent auction of 1700/2100 MHz, and a new provider, VTR, will enter with 30 MHZ of spectrum acquired in the same auction. Chile's telecommunications regulatory authority, the Subsecretariat de Telecomunicaciones (Subtel), originally allocated 200 MHz of spectrum in the 1700/2100 MHz band for 3G services. However, a January 2009 court decision established a hard limit of 60 MHz for any participant in this auction, effectively shutting the established providers out of the market.[46]

The model is applied to the largest provider in the three largest metro areas in Chile: Santiago, Concepción, and Valparaíso. These areas have a combined population that represents 34 percent of the population for the country as a whole. Considering the build out of advanced services under various spectrum constraints, we estimate the monthly ARPU needed to break even, which represents the prices consumers will have to pay for the service. Table 2 lists the results for Chile, showing the relative change in price as the spectrum allocation changes.

TABLE 2: CHILE

Minimum Monthly Cost of LTE Service under various spectrum allocations

	2 × 20 MHz	2 × 15 MHz	2 × 10 MHz	2 × 5 MHz
Santiago	X	1.3X	2X	4.1X
Concepción	Y	1.3Y	2Y	4.1Y
Valparaíso	Z	1.3Z	2Z	4.1Z

[46] For more information on this market, *see Id.*

Similar to the case of Argentina, the results indicate that decreasing the amount of spectrum available for LTE from 40 MHz to 20 MHz would double the cost of providing this service, while a decrease from 2x10 MHz to 2x5 MHz would double again the price paid by consumers. Thus, increasing the amount of spectrum from 2x5 MHz to 2x20 MHz would reduce the amount the consumer would pay for service by four fold.

As with the case of Argentina, the model estimates only the higher prices consumers will pay for advanced services. Nonetheless, higher prices inevitably lead to lower quantity demanded in the market, less adoption of broadband and fewer economic and social benefits that accompany such adoption.

C. Colombia

Colombia has 120 MHz of spectrum available for mobile communications services, including licenses in the 850 MHz and 1900 MHz bands. The country maintains a spectrum aggregation limit of 40 MHz per carrier, which has been in place since 2004. From December 1998 to 2008 the wireless subscribership grew from 1.9 million to almost 40 million customers.

The market in Colombia is served by three providers: Comcel, Movistar Colombia, and Tigo. Each of these firms holds licenses for 40 MHz of spectrum. Colombia's telecommunications regulatory authority, the Ministerio de las Tecnologías de la Información y las Comunicaciones, is considering rules to allocate spectrum in the 1.7 and 2.1 GHz band, as well as the 2500-2690 MHz band. At present, no rules have been adopted for either of these bands.[47]

The model is applied to the largest provider in the three largest metro areas in Colombia: Bogotá, Cali, and Medellin. These areas have a combined population that represents 25 percent of the population for the country as a whole. Considering build out of advanced services under various spectrum constraints, the model estimates the monthly ARPU needed to break even, which is equivalent to the price consumers will pay for the service. The estimate shows the relationship between the minimum price paid by consumers and the different spectrum allocations that were considered. Table 3 lists the results for Colombia.

[47] For more information on this market, *see Id*.

TABLE 3: COLOMBIA

Minimum Monthly Cost of LTE Service under various spectrum allocations

	2 × 20 MHz	2 × 15 MHz	2 × 10 MHz	2 × 5 MHz
Bogotá	X	1.3X	2X	4.1X
Cali	Y	1.3Y	2Y	4.1Y
Medellin	Z	1.3Z	2Z	4.1Z

Again the results indicate that decreasing the amount of spectrum available for advanced services from 40 MHz to 20 MHz would double the price paid by consumers, while a decrease from 2x10 MHz to 2x5 MHz would double prices yet again. Thus, increasing the amount of spectrum from 2x5 MHz to 2x20 MHz would reduce the amount the consumer would pay for service by four fold.

As with the analyses for Argentina and Chile, this model estimates only the higher prices consumers would pay for advanced services as a result of strict spectrum aggregation limits. These higher prices nonetheless would lower adoption and diminish the other economic and social benefits that accompany increased broadband use.

IV. ALTERNATIVES TO STRICT SPECTRUM AGGREGATION LIMITS

A. Set-Asides (Examples in the Americas)

On a number of occasions and in a variety of countries, policymakers have set aside portions of a band to be auctioned, normally with the goal of ensuring that a new entrant may acquire this spectrum. The logic is that existing licensees have an incentive to bid up the price of the spectrum for the new entrant so as to ensure that they do not face additional competition in the market for their services. In practice, however, spectrum set-asides have often been accompanied by negative unintended consequences. First, set-asides have been associated with price distortions, whereby winners pay significantly less than a market price in which all industry players are included.[48] Second, set-asides have been shown to allow collusion.[49]

[48] *See* Robert W. Crandall and Allan T. Ingraham, "The Adverse Economic Effects of Spectrum Set-Asides," *Canadian Journal of Law & Technology*, 6:131 (November 2007); and Peter C. Cramton, Allan T. Ingraham and Hal J. Singer, "The Effects of Incumbent Bidding in Set-Aside Auctions: An Analysis of Prices in the Closed and Open Segments of FCC Auction 35," *Telecommunications Policy* 32 (2008).

[49] Lance Brannman and Luke Froeb, "Mergers, Cartels, Set-Asides, and Bidding Preferences in Asymmetric Oral Auctions," *Review of Economics and Statistics* 82:283 (2000).

In the U.S., the most well-known spectrum set-aside earned its reputation based on some disastrous consequences. In 1995, the FCC auctioned the PCS C block in a special set-aside auction, with final bids totaling over US$10 billion.[50] The dominant bidder in this auction, NextWave, later filed for bankruptcy with a 30-MHz block of PCS spectrum included in its assets. In a battle that involved a decade of litigation, the FCC tried but failed to keep NextWave's licenses out of the bankruptcy courts. Ultimately, NextWave sold its assets to the incumbent providers Verizon and Cingular (now AT&T).

More recently, Canada experienced various undesirable outcomes in a 2008 auction for AWS spectrum. In that auction, the Canadian telecommunications regulator, the CRTC, set aside a 40-MHz block (2x20 MHz) for a new entrant while leaving a 50 MHz block (2x25 MHz) for all bidders. Despite the set-aside, no new nationwide entrant resulted. Although a new entrant gained licenses in a number of provinces, it was shut out of others. Further, the auction witnessed significant price distortions, with set-aside prices well below those for blocks that were open to all bidders.[51] In Latin America, the Peruvian government set aside 25 MHz in the 1900 MHz band for a nationwide license for a new provider and banned the incumbent providers from bidding on this spectrum; since September 2008 there have been two unsuccessful attempts in attracting new investors.

Ultimately, the strongest argument against spectrum set-asides is that the benefits this approach is designed to achieve (*i.e.*, limiting the ability of existing providers to acquire all of this input) can be achieved with other approaches that are less likely to have the negative effects of price distortions or collusion. In particular, auction-specific caps may be a less-distorting remedy.

B. Auction-Specific Spectrum Caps

As described above, the challenge for policymakers is to allow all service providers in the market the opportunity to acquire the spectrum they need while disallowing spectrum aggregation that will have anticompetitive effects. Properly implemented, auction-specific caps may be an effective means to this end.

When properly implemented, an auction-specific cap necessarily recognizes the needs of likely bidders in an auction. For example, if the provision of next-

[50] For information about the winning bidders in the C-block auction, including NextWave, *see* http://wireless.fcc.gov/auctions/05/releases/da960716.pdf. In 1994, the FCC provided a list of answers to commonly asked questions about the auctions for all PCS licenses, referring to the C-block as the "Entrepreneurs' Block." *See* http://www.fcc.gov/Bureaus/Wireless/Public_Notices/1994/pnwl4021.txt

[51] For information on the Canadian AWS auction, *see* http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf08891.html.

generation services requires large blocks of contiguous spectrum, all providers should be able to achieve such spectrum pairings. At the same time, the auction-specific cap may be tailored to prevent any one provider from thwarting all other providers in their attempt to acquire similar spectrum. One way to achieve this outcome is to make the number of licenses available greater than the number of incumbent providers, then prohibit aggregation during the auction. In simple terms, for an auction of 120 MHz of spectrum in a market with three nationwide providers, this approach would suggest an auction of four 30-MHz licenses.

While auction-specific spectrum caps have not been broadly applied, they have been adopted in certain auctions by two respected regulatory authorities. The German government auctioned UMTS spectrum in 2000 using rules that limited the amount of spectrum any one bidder could hold. Specifically, 120 MHz was auctioned in 10-MHz blocks (2x5 MHz), making a dozen blocks available. No bidder could win more than three of these blocks, or 30 MHz. While there were four incumbent providers in the country, a new entrant only would have been precluded if all four providers individually bid and won the maximum amount. In fact, two new entrants won spectrum licenses. Subsequent defaults by these entrants, coincident with the end of the telecom bubble, kept the number of competitors at its pre-auction level. Nonetheless, the goal of ensuring competition while not thwarting efficient behavior by incumbents was effectively met by these auction rules.[52]

More recently, the United Kingdom has adopted a similar approach for its upcoming auction of the 2500-2690 MHz band. According to the *Digital Britain Report*, the U.K. telecommunications regulator, Ofcom, will promptly auction licenses for the unpaired spectrum in this band. Further, in an attempt to make a large amount of spectrum available at the "earliest possible date," which is represented as mid-2010, there will be a combined auction of paired licenses in the 2500-2690 MHz band and licenses for spectrum in the 800 MHz band (the "Big Auction"). Ofcom will apply an auction-specific cap of 2x65 MHz, which is sufficiently large to allow advanced services such as LTE.[53]

Significantly, none of the discussion here refers to spectrum already held by existing licensees. This is because the goal is not to limit the amount of spectrum any one provider may hold, which can have significant negative consequences. Rather, the goal is to limit the ability of any single provider to thwart entry by other potential competitors. In that, the auction-specific spectrum cap achieves its goal.

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[52] For further discussion of this auction, *see* Robert W. Crandall and Allan T. Ingraham, "The Adverse Economic Effects of Spectrum Set-Asides," *supra.*

[53] *Digital Britain Report* at 74.

C. Antitrust Review

As opposed to the prescriptive policies described above, the need for sound antitrust review of transactions involving spectrum generally is less controversial. Economists and legal scholars debate whether antitrust sufficiently protects consumer interests in the absence of additional measures,[54] but most nonetheless recognize the central role played by antitrust rules in affording at least some protection to consumers. Sound competition policy with regard to the acquisition of spectrum licenses is important.

In the U.S., the FCC reviews transactions involving the transfer of control of spectrum licenses.[55] Additionally, the Antitrust Division of the Department of Justice reviews major transactions of spectrum licenses.[56] While the agencies have potential overlap in their efforts, both apply traditional antitrust principles in assessing spectrum transactions. The FCC explains that, similar to DOJ, in performing this antitrust analysis it "considers how a transaction will affect competition by defining a relevant market, looking at the market power of incumbent competitors, and analyzing barriers to entry, potential competition and the efficiencies, if any, that may result from the transaction."[57]

As this quote from the FCC indicates, the challenge for regulators is to properly balance the risk that a given transaction will create market power (and thus harm consumers) with the potential that a given transaction will allow for efficiencies (and thus benefit consumers). With regard to the risk of harm to consumers, for spectrum transactions the FCC applies a spectrum screen similar to that described earlier. Transactions that would result in one party holding more than a third of the available spectrum in a given geographic area are subject to strict review, in effect limiting the maximum amount of spectrum that may be held, but with a less-rigid standard.[58] Thus, antitrust review works much like the rolling spectrum screen currently used by the FCC. This approach offers

[54] For an argument in favor of reliance on antitrust courts over regulatory agencies, *see*, Peter Huber, *Law and Disorder in Cyberspace: Abolish the FCC and let Common Law Rule the Telecosm*, Oxford University Press (1997). For an argument stressing the role of regulatory agencies, *see* Jonathan Nuechterlein and Philip Weiser, *Digital Crossroads: American Telecommunications Policy in the Internet Age*, MIT Press (2005).

[55] The FCC's authority in these matters is established by sections 214(a) and 310(d) of the Communications Act. *See* 47 U.S.C. § 214(a), 310(d).

[56] DOJ reviews transactions that exceed $50 million. Section 7 of the Clayton Act, as amended by the Hart-Scot-Radino Act, establishes DOJ's authority in these matters. *See* 15 U.S.C. § 18.

[57] *See, e.g.*, Applications of Cellco Partnership d/b/a Verizon Wireless and Atlantis Holdings LLC For Consent to Transfer Control of Licenses, Authorizations, and Spectrum Manager and De Facto Transfer Leasing Arrangements, Petition for Declaratory Ruling that the Transaction is Consistent with Section 310(b)(4) of the Communications Act, *Memorandum Opinion and Order and Declaratory Ruling*, WT Docket No. 08-95 (November 10, 2008) at ¶ 28.

[58] *Id*. at ¶ 64 and ¶ 68.

flexibility, especially as compared to rigid rules that prohibit all spectrum acquisitions above a certain limit. However, the effectiveness of this approach hinges on the continued availability of more spectrum for advanced services.

With regard to the benefits of spectrum acquisitions, it is here where current policy debates may be most likely to fall into error. Specifically, as described above, public demand for advanced communications—especially video and other bandwidth-intensive applications—places inordinate and untenable demands on the existing networks of current providers. Without significant additions to current spectrum allocations, these providers will fail to provide the services consumers demand. Further, existing providers have established networks, having already made investments in management structure, field staff, towers, backhaul, and (limited) spectrum to provide their existing services.

Thus, while appropriate antitrust oversight is necessary to continue to protect consumers, just as important is a set of rules that allows spectrum to be assigned according to market needs, not regulatory fiat. Substantial variation from market processes will distort the allocation of this critical resource.

V. Review of Results

The model described above provides new and specific estimates of the costs to consumers of spectrum aggregation limits. To review, these findings are the following:

- Mobile broadband services combine economic and social benefits of mobile networks and broadband communications, and may have a greater impact than the deployment of mobile voice service.
- Spectrum is a critical input for these services, and the ITU and other experts estimate that mobile broadband communications requires significantly more spectrum than is currently available.
- Network operators optimally balance spectrum and other inputs to provide mobile broadband. A lack of spectrum will result in lower-quality voice and broadband services, if broadband is deployed at all.
- Strict spectrum aggregation limits may significantly raise the cost to existing providers of building out these advanced services.
- As the costs of building an advanced network increase, these costs are passed on to consumers in the form of higher prices.
- As prices rise, broadband adoption slows. The economic and social benefits that accompany it are decreased.
- In constrained markets, spectrum aggregation limits that restrict a network operator to 2x5 MHz for a new service may double the price for the same service if provided on 2x10 MHz, and quadruple the price for the same service if provided on 2x20 MHz.

VI. CONCLUSION

While technological innovation has been and likely will continue to be a key driver of economic growth and the social benefits that follow, it is impossible to know with certainty what the next great innovation will be. Despite these limitations, it is a safe bet that mobile communications will be an important technology of the future, for a variety of reasons, not least of which is the relatively high price of wireline infrastructure and the cost-effective, broad reach of mobile networks. Equally likely is the increase in consumers' demand for information and communications—to stay in touch with family and friends, to be more productive on the job, and to have better health care, educational, financial and other opportunities. Mobile broadband communications is the technology most likely to make this fundamental change in the lives of millions, if not billions, of people.

The transition from mobile voice communications to mobile broadband, however, requires much more than an incremental adjustment in the amount of spectrum available. Indeed, over the next three to five years the average monthly data usage of each subscriber is likely to increase by a factor of 30 to 60, or more. Simply stated, policymakers must make more spectrum available to meet this demand, in many cases doubling or tripling the current allocations.

At the same time, policymakers have legitimate concerns about the harm to competition in the market—and the resulting harm to consumers—if only one or two firms acquire all of this essential input. It is from these legitimate concerns about protecting competition that spectrum caps emerged as a policy in many countries, especially in the Americas. But legitimate concerns about competition can be addressed with superior regulatory tools. In fact, not only may other policies better protect competition in the market, spectrum aggregation limits may produce the opposite effect from what their advocates intend.

By restricting the availability of spectrum to existing network operators, spectrum aggregation limits raise the costs of expanding into new, advanced services such as LTE. The result is higher prices paid by consumers. Further, these price increases are not trivial. Strict limits on the amount of spectrum available to existing providers may double or even quadruple the price consumers otherwise would pay for advanced services. These non-trivial price increases threaten broadband deployment and the many economic and social benefits that accompany such deployment.