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1. Summary of Conclusions

In this declaration, I explain why it is important to protect the opportunity for smaller operators, like Avantel, to acquire lower frequency spectrum when designing spectrum auction rules. More specifically, I explain that:

- (1) Ensuring the sustainability and viability of structural, or equivalently, facilities-based competition in mobile voice and broadband services offers significant benefits for the Colombian economy. Wireless mobile services are essential infrastructure, and effective competition offers the best way to ensure that demand for wireless services is met efficiently. Markets for mobile telecommunication services in Colombia are highly concentrated, but policymakers have made important strides toward promoting structural competition through forward-looking policies. This progress and the benefits of a healthy and competitive wireless sector are at risk if spectrum auctions are not appropriately designed.
- (2) Access to radio frequency spectrum is an essential input for all wireless services. For economic viability, a Mobile Network Operator (MNO) must secure access to adequate spectrum resources. Although modern 4G LTE networks may utilize spectrum in multiple frequency bands, spectrum in different bands have different technical and economic characteristics that make them imperfect substitutes. Lower frequency spectrum (below 1GHz) propagates further which offers special benefits for expanding coverage and scalable network deployment; whereas higher frequency spectrum (above 1GHz) affords expanded bandwidths to support higher data rate services, and is often a lower-cost option for expanding capacity once coverage needs

are met. Access to lower frequency spectrum is especially important for smaller MNOs that are simultaneously trying to expand their network coverage and subscriber bases in the face of entrenched competition from well-established incumbents that already have national networks.

- (3) The planned auctions for lower frequency (below 1GHz) and higher frequency (above 1GHz) spectrum represent significant positive steps toward addressing the pressing need to expand commercial access to essential spectrum resources. Expanding commercial access to spectrum is necessary to meet growing demand for wireless services and to promote sustainable and robust facilities-based competition. Failure by smaller MNOs to secure access to appropriate spectrum resources in these auctions, especially for spectrum below 1GHz, will adversely impact the ability of those MNOs to compete effectively, threatening the viability of facilities-based competition. Consequently, market structure considerations are important and relevant to the design of the spectrum auctions, and hence, the appropriate competition authorities in Colombia should be included in the design process.
- (4) Spectrum caps that limit the amount of spectrum that may be acquired by dominant incumbents are a tried and true policy mechanism for promoting and protecting structural competition. Such rules have been employed widely, including in Colombia. Their use, potentially in conjunction with other preferences for smaller operators, are recommended as key features for the below 1GHz auctions. Today, Claro and Movistar control 100% of the IMT spectrum below 1GHz. An appropriate way to redress this imbalance and ensure multiple smaller MNOs acquire the lower frequency spectrum needed to be viable would be to hold the 700MHz auction in two

stages. In the first stage, 30MHz of spectrum would be auctioned with only smaller MNOs that have no 700MHz spectrum allowed to bid.[1] Winning bidders would be limited to acquiring at most a single 10MHz spectrum block (2x5MHz paired). In the second stage, the remaining 50MHz would be offered and all MNOs would be allowed to bid with the spectrum caps relaxed.[2]

- (5) Adopting such policies as part of the auction design is consistent with the goal of promoting sustainable structural competition and with maximizing the value to be realized by Colombia from its scarce spectrum resources. Adopting such policies is consistent with the public interest in maximizing the value realized from utilizing Colombia's national spectrum resources. Moreover, theory and experience from auctions elsewhere indicates that spectrum caps are consistent with promoting participation in the auctions and need not adversely impact aggregate auction proceeds. Finally, adopting such policies is consistent with the recommendations of the OECD Review of Telecommunications Policy and Regulation in Colombia.[3]

2. Benefits of Structural Competition in Telecommunication Services

Mobile telephony, text messaging, and increasingly, mobile broadband Internet access services are recognized to be essential infrastructure for society and the economy. Much of the promise of future economic growth in increasingly information-centric,

[1] Under existing spectrum caps, Claro and Movistar would be precluded from participating in the first bidding round.

[2] Relaxing the spectrum caps in the second round would allow both Claro and Movistar to participate.

[3] See OECD (2014), *OECD Review of Telecommunication Policy and Regulation in Colombia*, OECD Publishing, http://dx.doi.org/10.1787/9789264208131-en.

connected economies depends on the availability of ubiquitous anywhere/anytime mobile communication services. Policymakers around the globe have been adopting ICT strategies committing to the universal deployment of broadband Internet access services, and increasingly, it is recognized that much if not most of such access will be provided over wireless mobile broadband networks (see Figure 1).[4] In the United States, Europe and other mature mobile markets, penetration exceeds 100%, with a growing number of consumers having multiple and more capable devices (Figure 2).[5] In Colombia, the Ministry of Information Technologies and Communication's (MINTIC's) *Plan Vive Digital 1.0* and the 2010-2014 *Prosperidad para Todos* national plan for economic development set forth a bold agenda to promote competition and availability to advanced telecommunication services, including mobile broadband, for all Colombian citizens. Progress toward implementing these goals continues in the 2014-2018 *Plan Vive Digital 2.0*,[6] and 2014-2018 *Todos por un Nuevo País: Paz, Equidad y Educación* national plan for economic development with a special emphasis on expanding access coverage and choice for all consumers, including those at the bottom of the income pyramid.

[4] Both the United States and Europe have Digital Broadband Agendas (see FCC (2010), "Connecting America: The National Broadband Plan," Federal Communications Commission, Washington, DC, March 2010, available at: http://www.broadband.gov/; and EC (2010), "Digital Agenda for Europe," European Commission, COM(2010) 245 final/2, available at http://ec.europa.eu/digital-agenda/digital-agenda-europe). For a comparison of digital agendas from a number of countries, see OECD (2011), "National Broadband Plans", OECD Digital Economy Papers, No. 181, available at http://dx.doi.org/10.1787/5kg9sr5fmqwd-en. Most of those articulate a national commitment and goals to provide universal access

[5] A growing number of subscribers have eReaders, tablets, cameras and other mobile connected devices in addition to cell phones; and increasingly, the cell phones are more capable smartphones.

[6] See http://micrositios.mintic.gov.co/vivedigital/2014-2018/index.php.

Policymakers in Colombia and around the globe have generally recognized that empowering competition offers the best way to promote efficient economic development of the essential telecommunications infrastructure, including mobile telecommunication services that are needed by Colombians. Competition directs resources to their highest value uses (allocative efficiency) and induces firms to operate at minimum cost (productive efficiency). The battle for profits and market shares drives firms to innovate and invest to better serve their customers (dynamic efficiency). Consumers' benefit from expanded choice, improved quality, and lower prices.

For competition in mobile services to thrive, there have to be multiple (more than just two) facilities-based Mobile Network Operators (MNOs). Enabling sustainable MNO competition confronts a number of challenges. Building and operating a mobile network is capital intensive. The pace of technical and market innovation and growth is rapid, and MNOs must continuously invest to upgrade their networks and expand capacity to keep pace with expanding penetration and growing traffic per-user, driven increasingly by bandwidth-hungry multimedia data applications.

Deploying and operating a mobile telecommunications network requires billions of dollars of investment in network infrastructure that is largely fixed or sunk. A key component to the value proposition for mobile communication services is the promise of everywhere access. To offer nationwide service, a provider needs a network with national coverage. Moreover, because the same network can support multiple services (e.g., legacy mobile telephony and messaging services, as well as newer services such as mobile broadband), most of an MNO's costs are shared across multiple services and market segments. Because the value of communication network services increase with the number of total users of the network, demand growth benefits from positive network externalities.

These economics mean that there are substantial scale and scope economies, or increasing returns to scale, which favor larger incumbent MNOs. Those operators that have already constructed a national network and acquired a large subscriber base benefit from having lower average costs than smaller operators. In addition to these fundamental economic advantages, incumbents have benefited from a legacy of regulatory preferences that protected them from competition and provided them with preferential access to essential inputs such as spectrum for many years. Consequently, incumbent operators have a potentially overwhelming competitive advantage in terms of lower costs and, absent regulatory protections, the means and opportunity to effectively foreclose competitive challenges.

Policymakers in Colombia had addressed several of these key issues with sensible, forward-looking policies. These included passage of major communications regulatory reform with passage of the ICT Act in 2009 that significantly overhauled the regulatory framework for telecommunications, adopting provisions that liberalized licensing and franchise rules and opened markets to competition.[7] To facilitate competitive entry,

[7] Law 1341, the Information and Communications Technology Act of 2009 ("ICT Act of 2009") established the CRC with broad regulatory authority over telecommunications.

policymakers allocated spectrum for new MNOs.[8] Moreover, in recognition of the fact that entrants would be at a severe cost and market disadvantage relative to incumbents until they could complete their networks and establish their brands in the marketplace, policymakers adopted regulations that established national roaming as an essential facility for mobile operators.[9]

Policymakers also adopted rules to facilitate the emergence of additional retail-level competition by Mobile Virtual Network Operators (MVNOs). These MVNOs do not have networks or spectrum rights, but rely on their ability to purchase wholesale network services from the MNOs that are used to provision the retail services that the MVNOs sell to their customers. The MVNOs and MNOs compete with each other in the retail markets, thereby further expanding consumer choices, improving quality, and driving down prices. For example, today MVNOs like UFF, Virgin Mobile and others provide services to 6% of the retail market.[10] The effectiveness of the competitive discipline offered by MVNOs, however, depends on the extent of structural competition among facilities-based MNOs. While MVNOs are an important addition to the competitive landscape, their ability to innovate and flexibility to price is limited by the technology and business decisions of the MNO's whose services the MVNO's rely on. MVNOs are most effective when there is a robust market for MNO wholesale services, which depends

[8] MinTIC 449 (Mar 2013).

[9] CRC 4112 (Feb 2013).

[10] See page 45 in "Documento de Consulta Pública, Proceso de selección objetiva para asignación de espectro radioeléctrico en las bandas 700 MHz (Dividendo Digital), 900 MHz, 1.900 MHz y 2.500 MHz para servicios móviles terrestres," May 2015, available at http://mintic.gov.co/portal/604/articles-9301_recurso_1.pdf

on there being multiple (more than two) MNOs. Although MNOs might prefer not to confront retail competition from MVNOs, a robustly competitive wholesale market precludes MNOs foreclosing MVNO competition. Competition in the wholesale market provides additional incentives to MNOs to invest in expanding capacity and strive for efficiency.

Structural facilities-based competition among MNOs also contributes to ensuring the robustness of national communications infrastructure. Having multiple networks with different operators and technologies avoids the problem of putting all of Colombia's infrastructure eggs in a single basket. Mobile network technologies and markets are complex and confront significant technical and business uncertainty. Markets are better at managing this complexity and uncertainty than are regulators.

If effective competition among multiple MNOs cannot be sustained, policymakers will be forced to undertake more direct and heavy-handed regulation. Because regulators lack the expertise and resources of industry, and because regulatory processes are inherently cumbersome and costly, less competitive telecommunications service markets perform less well. Consumer choices are more limited, prices are higher, and innovation is slower.[11] Ensuring the viability of sustainable structural competition helps protect against the efficiency losses and excess costs of inefficient regulatory oversight.

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[11] See Grzybowski L. (2005) "Regulation of mobile Telephony across the European Union: An Empirical Analysis" Journal of Regulatory Economics; 28:1 (2005) 47-67; Beard, T. Randolph, Richard P. Saba, George S. Ford and R. Carter Hill (2005) "Fragmented Duopoly: A Conceptual and Empirical Investigation." *The Journal of Business*, 78(6), 2377-96; Emmons, William M. and Robin A. Prager (1997) "The Effects of Market Structure and Ownership on Prices and Service

3. Mobile Market Competition and Spectrum Allocation in Colombia

Around the world and in Colombia, mobile service subscriptions, traffic, and revenues have grown rapidly since 2000 (Figure 2 and Table 1). After initially lagging significantly, Colombia has managed to catch up with other developed countries, with mobile penetration exceeding 116% by 2013 (Figure 3). This growth has been enabled by and helped propel investment in expanding network coverage and capacity, and upgrading the technology of Colombia's mobile networks. These are transitioning from 2G to 3G networking, and more recently, to 4G LTE mobile networks (Figure 4). While legacy and voice telephony remain essential components in the bundle of services purchased by consumers, a growing share of users are now using mobile Internet services and mobile data traffic continues to grow rapidly (Table 1).

Access to expanding spectrum resources is the fuel that makes this growth possible. Over the next decade, forecasts call for over a 150% increase in the spectrum allocated to commercial mobile services (Figure 5). To date, policymakers have allocated a total of 405MHz of International Mobile Telecommunications (IMT) spectrum to MNOs in Colombia (Table 2). The planned auctions are expected to result in the allocation of an additional 135MHz of spectrum for MNOs, which will increase the total allocation by a

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Offerings in the U. S. Cable Television Industry." *The RAND Journal of Economics*, 28(4), 732-50 third to 540MHz (Table 3). Of this, 100MHz will be in the bands below 1GHz that are especially valuable for entrants and small operators seeking to build out their networks.[12]

Although the growth of mobile services and infrastructure in Colombia has been impressive and policymakers have taken significant steps to enable robust structural competition among MNOs, mobile markets remain highly concentrated. The top 2 MNOs (Claro and Movistar) account for 77% of the subscribers (Figure 6) and the HHI is 3723 (Figure 7). Although mobile markets tend to be quite concentrated (for the reasons discussed earlier), this is high even by international standards (Figure 8 and 9). The high market concentration in Colombia is mirrored in the allocation of below 1GHz spectrum, where 100% of the lower frequency spectrum is controlled by the two largest MNOs (Table 2). This is much more concentrated than in the U.S., which is also too concentrated (Figure 10 and 11).

To avoid undoing the progress already achieved in Colombia by policymakers' efforts to promote sustainable competition, it is important that the imbalance in spectrum allocations be addressed. The upcoming auctions should be designed to ensure that smaller operators be able to acquire the lower frequency spectrum needed to cost-effectively allow them to compete nationwide with incumbents. The lower frequency spectrum is needed to allow the smaller MNOs to offer service bundles that include voice

[12] As shown in Table 3, 90MHz will be auctioned in the 700MHz band and 20MHz in the 900MHz band, for a total of 110MHz; however, the 10MHz of the 700MHz spectrum that is designated for Public Protection and Disaster Relief (PPDR) network services is excluded from the total to be auctioned for commercial mobile services.

(e.g. VoLTE), text, and data services that are competitive with those that incumbents can offer. Incumbents with their current spectrum portfolios have an unfair advantage with regards to smaller MNOs without similar spectrum resource portfolios. Ensuring smaller MNOs access to the spectrum resources they need will enable them to continue to innovate and remain viable as efficient competitors.

4. Value of Lower Frequency Spectrum to Smaller Operators

Spectrum is a scarce resource, but lower frequency spectrum is especially scarce. First, there is simply less of it: there is 4 times as much spectrum between 1 and 5GHz as is below 1GHz. More importantly, lower frequency spectrum has unique propagation characteristics that enable signals to propagate better and have better non-line-of-sight (NLOS) performance. Lower frequency signals are better at penetrating buildings, passing through leaves, raindrops, and other things that may interfere with higher frequency transmissions.

On the other hand, it is often easier to get larger bandwidth (MHz) channels[13] at higher frequencies, and when the distance from the base station to the mobile user is small, NLOS and longer-range propagation are less important. Unlike mobile telephony and text messaging, which do not require high data rates and can be supported in narrowband channels, mobile Internet applications like streaming media or gaming may benefit from the higher capacity channels more easily available with higher frequency

[13] Larger frequency channels (measured in MHz) can support higher data rate services (measured in Megabits per second, or Mbps), but the bits/Hz depends on a many additional elements of the radio network design, including the coding and modulation schema, channel quality, receiver sensitivities, etc.

spectrum. Also, since the wavelength is inversely related to the frequency, the frequency used has implications for antenna design.

From the above, it should be clear that the best frequency to use in any particular situation depends on the context. MNOs design their networks as a series of over-lapping cells to provide coverage over their serving area. The larger each cell or area served by each base station, the fewer cell sites are required to serve a given geographic region and the lower the total physical infrastructure costs (for cell sites, antennas, base station radios, and backhaul facilities). If an MNO can cover a given geographic area with fewer cell sites, then the MNO can deploy the network faster and at lower total expense. This substantially reduces the costs of constructing a network.

Lower frequency spectrum makes it feasible to operate with much larger cell sites, and hence realize significant cost savings. For example, Cave & Webb (2013) estimated that the propagation range goes from 3.1km at 1800MHz to 6.2km at 800MHz. An operator using the higher frequency spectrum would require 4.8 times as many cells as would be needed at the lower frequency.[14] Moral, Vergara *et al*. (2010) estimated that construction of a 3G network using UMTS technology at 900MHz instead of 2100MHz would realize capital and operating cost savings of 50 to 70 percent.[15] A more recent

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[14] See Martin Cave & William Webb, "Spectrum Limits and Auction Revenue: the European Experience," attached to Ex Parte Presentation of Sprint Corporation, GN Docket No. 12-268 & WT Docket No. 12-269, July 29, 2013, available at http://apps.fcc.gov/ecfs/document/view?id=7520934210.

[15] See Moral, Antolín, Arturo Vergara, Jorge Pérez and Catalina Ovando (2010) "Assessment of the Benefits of Introducing a HSDPA Carrier at 900mhz," *GLOBECOM Workshops (GC Wkshps), 2010 IEEE*. IEEE, 834-38.

analysis of deployment costs in the U.S. for a 4G LTE network confirmed these results.[16]

For these sorts of reasons, the World Bank concluded that:

> "Operators need spectrum in the bands that are most effective for deploying mobile broadband technologies. For instance, a fourth-generation broadband mobile technology such as Long-Term Evolution (LTE) can operate in multiple frequency bands, *but the lower bands* (such as 700 and 800 megahertz, or MHz) can be *more cost-effective*, allowing for both wider coverage from fewer radio base stations (an important consideration for rural area deployments) and higher powers to support building penetration (an important consideration in urban areas)."[17]

The relative scarcity and inherent benefits of lower frequency spectrum explain why it is typically valued more highly in auctions and analyses of spectrum values. For example, Bazelon & McHenry (2015) valued paired 700MHz spectrum at $3.25/MHz-POP, paired 1700MHz spectrum at $2.50/MHz-POP, and 2.5GHz spectrum at $1.50/MHz-POP in the U.S., where demand for new spectrum resources is especially strong (Figure 12).[18] Another study estimated significant value premium for 850MHz

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[16] An analysis by CostQuest, an economic modeling firm, estimated the costs of constructing a 4G network in 1900MHz and 700MHz spectrum and found the costs would be substantially higher in at the higher frequency – estimating that those costs would be as much as 2,108% higher in Kentucky, a rural, mountainous state) using a forward-looking cost model that accounted for differences in geography, population, and network coverage requirements. (See Ex parte submission by T-Mobile to FCC, re: Policies Regarding Mobile Spectrum Holdings, WT Docket No. 12-269 Expanding the Economic and Innovation Opportunities of Spectrum through Incentive Auctions, Docket No. 12-268, January 29, 2014.)

[17] Italics added. See page 105 in World Bank (2012), "Information and Communications for Development 2012: Maximizing Mobile" (2012), available at http://siteresources.worldbank.org/EXTINFORMATIONANDCOMMUNICATIONANDTECHNOLOGIES/Resources/IC4D-2012-Report.pdf.

[18] Spectrum values are often reported in terms of the price per MHz-POP, which is computed by taking dividing the total license value (measured in $ or some other currency) by the number of MHz and the population in the geographic area covered by the licenses. The estimates of spectrum values in the text and Figure 12 are from Bazelon, C., & McHenry, G. (2015), "Mobile Broadband Spectrum: A Vital Resource for the U.S. Economy," a Brattle Group White Paper, prepared for the CTIA, March 2015, available at http://www.ctia.org/docs/default-source/default-document-library/brattle_spectrum_051115.pdf.

over 1800MHz spectrum for Australia (Figure 13). Finally, it is worth noting that the value of spectrum varies significantly over time and across national markets, although the relative premium for lower frequency spectrum persists (Figure 14).

In addition to differences in local market conditions, the value of different bands depends on the availability of radio equipment. The markets for lower frequency radio equipment are typically more mature and equipment and silicon costs are often lower. This is due in part to the way radio technologies have evolved over time. For example, to digitize higher frequency signals requires sampling at a higher data rate. As Moore's Law-driven innovations have reduced the costs of Digital Signal Processors (DSPs), it has become increasingly feasible to inexpensively sample at higher signaling rates. This has expanded the ranges of frequencies that may be used for mobile telephony over time. As new bands have been commercialized, global markets for appropriate radio equipment have developed, and scale and learning economies have driven costs down over time.

The benefits of operating in lower frequency spectrum are most relevant when the MNO is seeking to expand coverage, especially of legacy telephony and text messaging services which have moderate data rate requirements. The lower frequency spectrum may offer adequate capacity even at high subscription rates in rural areas (where population density is low). Indeed, with a single 10MHz allocation of paired (2x5MHz channels), a new MNO can deploy a national 4G LTE network.

Although mobile telephony and text messaging services are much less resource intensive and aggregate traffic growth is increasingly driven by mobile Internet data traffic, the ability to support legacy voice and messaging services remain critical elements of any MNO's wholesale and retail offerings. Recognition of this fact helped motivate the decision to designate national roaming as an essential facility. Additionally, while 2G services are increasingly being replaced by 3G or 4G, there is still a significant population of subscribers which are not yet using mobile Internet data services.

Over time, as a MNO adds subscribers and traffic, the network is more likely to become capacity (rather than coverage) constrained. To address the capacity constraints, the MNO has a number of options. This includes using more spectrally efficient radio technologies. Indeed, a key motivation for upgrading from 2G to 3G to 4G was to take advantage of more spectrally efficient radio technology that allows more traffic to be packed into a given amount of frequency. However, another key advantage of improving mobile technologies is the ability to support a wider-array of more bandwidth hungry services. Thus, the capacity recovered through increased spectral efficiency is quickly offset by the growth in traffic from new services. Of course, an MNO might manage capacity costs by seeking to dampen demand by raising prices or refusing to offer more advanced services such as mobile broadband. Ensuring robust MNO competition prevents operators from following such a strategy.

A second strategy for expanding capacity is to add spectrum resources. To planned auctions are expressly designed to make this possible. As will be explained further below, to ensure that the auctions enhance rather than harm prospects for sustainable competition, it is important the auctions be designed appropriately. To ensure balanced access to required spectrum resources, it is especially important to expand the access to lower frequency for smaller MNOs.

A third common strategy is to lower the power of individual base stations and add more smaller cell sites. Shrinking the size of cells enables spatial reuse of the scarce spectrum resources, but comes at a cost. It requires higher investment in infrastructure, but may be employed selectively and scaled to address capacity or special coverage issues where they arise. Also, smaller cells may make it easier to add additional higher-frequency spectrum or undertake other capacity and performance enhancing initiatives.

Emerging or new MNOs are much more likely to be coverage constrained than national incumbents who have had national networks in place for over a decade already. Thus, lower frequency spectrum is especially valuable to smaller MNOs with smaller market shares. Lundborg *et al* (2012) modeled the difference in deploying and operating a mobile network at 800 or 1800MHz and found that the benefits of operating at the lower frequency decline as market share increases.[19] At low market shares, the higher frequency spectrum may be four times as expensive, but at high market shares (when the operator is more likely to be capacity constrained and obligated to shrink cell sizes) the

[19] See Lundborg, M., Reichl, W., Ruhle E., (2012) Spectrum allocation and its relevance for competition. Telecommunications Policy 36 (2012) 664–675.

costs of the 900MHz network increase rapidly, approaching the costs of the 1800MHz (Figure 15).

Over time, it is reasonable to expect that MNOs will move toward smaller cell architectures, which offer additional benefits beyond helping alleviate spectrum scarcity, but this will take time and is most likely to occur in locations where demand is high (urban and other high-traffic areas) and the operator is more likely to be capacity constrained.[20] Where operators have smaller cells and are operating with 4G LTE networks, higher frequency spectrum will be increasingly valuable and more fungible with lower frequency spectrum.[21] This is good news since as noted earlier, meeting future demand growth for wireless services is impossible with below 1GHz spectrum alone and increasingly will require accessing the more abundant higher frequency spectrum.

Furthermore, it is important to note that having balanced portfolios of spectrum, including lower frequency spectrum in the globally-important 700MHz band for 4G LTE makes it easier for MNOs, their wholesale customers (e.g., MVNOs and other value-added resellers of complementary services), and their retail customers to benefit from the

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[20] Chapin & Lehr (2011) explain why transitioning to smaller cell architectures is likely for reasons that go beyond spectrum scarcity, and why this may tend to reduce the value discrepancies between spectrum in different frequency bands in locations where small cells are deployed (see Chapin, John and Lehr, William (2011), “Mobile Broadband Growth, Spectrum Scarcity, and Sustainable Competition,” TPRC2011, September 2011, available at at SSRN: http://ssrn.com/abstract=1992423).

[21] Lehr & Oliver (2014) explain why the transition to small cells will be challenging (see Lehr, W. and M. Oliver (2014), "Small cells and the mobile broadband ecosystem," Euro ITS2014, Brussels, June 2014, available at http://econpapers.repec.org/paper/zbwitse14/101406.htm).

global scale economies associated with maturing markets for 700MHz radio equipment and devices. For example, GSMA reported that many more LTE-capable devices are available in the 700MHz band than in any other LTE band globally. And, while most of the currently deployed LTE systems have been in bands above 1GHz, the 700MHz band provides a significant opportunity for global harmonization and the realization of the significant cost-savings in equipment that will give rise to.[22]

In conclusion, therefore, the lower frequency spectrum is especially important to smaller MNOs, and the current distribution of allocations in the lower frequency bands places small operators at a significant cost disadvantage, threatening their sustainability as viable and effective competitors (Table 2).

5. Spectrum Caps should be part of the Auction Design

In the preceding, I have explained why access to lower frequency spectrum is especially important for ensuring that robust MNO competition remains viable. Here I will explain why Spectrum Caps should be included as part of the auction design.

Spectrum caps are a common and well-tried method for managing structural competition in mobile networks. Historically, decisions of how much spectrum to allocate to services were made by figuring out how much spectrum each network would need and how many networks policymakers wanted to license to compete with each

[22] See GSMA (2013), "Overview of LTE Device Landscape: Building the Mobile Broadband Ecosystem for 700MHz Band," Global Mobile Suppliers Association, presentation slides, February 28, 2013, available at http://www.gsma.com/spectrum/wp-content/uploads/2013/03/Overview_of_LTE_devices_landscape_GSA_280213-.pdf.

other. These licensing and band planning practices effectively dictated the spectrum holdings that each operator could have. In this older regime, the regulators often went so far as to specify what technology operators had to use and many other aspects of how the MNOs operated. In a world with strictly limited MNO competition and confronting the constraints imposed by earlier generation radio technologies, this form of Command & Control ("C&C") regulation of spectrum and MNO operations was appropriate.[23]

Over time, as technologies have matured and spectrum allocation has moved from beauty contests to auctions, the trend has been to shift toward increased reliance on market forces, with increasingly liberalized licensing that allows operators more scope to manage their choice of technologies and service offerings. At the same time, spectrum allocations for commercial mobile services have expanded to include spectrum in a growing array of bands both above and below 1GHz.

In the shift from C&C regulation toward markets and auctions, policymakers made frequent recourse to setting Spectrum Caps to manage the allocation of spectrum resources among MNOs and thereby influence the extent of structural competition in wireless services. A key attraction of spectrum caps is there simplicity to understand, monitor, and implement. It is easy for regulators to keep track of the MHz licensed to each operator. Because MNOs cannot operate without adequate spectrum resources,

[23] For a discussion of legacy spectrum management practices, see FCC (2002), "Report of the Spectrum Efficiency Working Group," Federal Communications Commission, Washington, DC, Rep. ET Docket 02-135, November 2002, available at https://transition.fcc.gov/sptf/files/SEWGFinalReport_1.pdf or ITU (2015), "Module 5: Radio Spectrum Management," International Telecommunications Union (ITU) and InfoDev, downloaded June 13, 2015, available at http://www.ictregulationtoolkit.org/sectionexport/pdf/5.

ensuring that access rights are distributed among multiple MNOs helps ensure the viability of structural competition. Without restrictions on the allocation of spectrum rights, it might be feasible for an MNO to secure a sufficiently large lock on spectrum to foreclose competition from other MNO directly (by denying them access to adequate spectrum) or indirectly by using the cost-advantages accruing from having excess spectrum to otherwise compete unfairly (e.g., by subsidizing efforts to raise rivals' costs).

With the transition to auctions, the design of auctions includes a range of additional techniques beyond spectrum caps to impact the allocation of spectrum to auction participants, and hence, the post-auction allocation of spectrum.[24] These include restrictions on bidding participation (e.g., excluding certain MNOs from participation is equivalent to setting an MNO-specific spectrum cap of zero for the auction), bidding preferences such as credits or set-asides (e.g., subsidies or designated spectrum allowances for certain MNOs or classes of MNOs designed to enable them to acquire spectrum in the auction), and other features of the auction design. The band plan, license territory size, and bidding rules may all play a part in helping to determine which MNOs are most likely to obtain spectrum from the auction. For example, auctioning spectrum via national licenses as opposed to multiple licenses that each correspond to smaller territories may make it more expensive (and hence less likely) that smaller operators may participate. Alternatively, the choice of license block size may make it easier or harder

[24] For a discussion of the range of instruments available to regulators to impact competition in downstream markets, see Cramton, Peter, Evan Kwerel, Gregory Rosston and Andrzej Skrzypacz (2011) "Using Spectrum Auctions to Enhance Competition in Wireless Services," *Journal of Law and Economics*, 54(4), S167-S88, available at http://www-siepr.stanford.edu/repec/sip/10-015.pdf.

for different MNOs to participate. For example, in the planned auction for 700MHz spectrum, if current spectrum caps are kept in place and spectrum is auctioned in 10MHz blocks of paired (2x5MHz) channels, incumbent operators will be precluded from participating. This would be one way to ensure that smaller MNOs are able to acquire lower frequency spectrum and would help rectify the asymmetric current situation in which Claro and Movistar control 100% of the lower frequency spectrum. The lack of lower frequency spectrum accentuates the cost-advantage that MNOs that already have large subscriber-based and national networks have relative to smaller MNOs. Smaller MNOs without lower frequency spectrum are at a sever cost-disadvantage when it comes to expanding coverage and cost-effectively balancing investments in coverage and capacity. To be consistent with the goal of promoting sustainable structural competition, the 700MHz auction needs to ensure that smaller MNOs are able to acquire the lower frequency spectrum they need to be able compete cost-effectively and efficiently.

Because of the direct linkage between virtually every aspect of the auction design and the potential for it to have important implications on structural competition -- not just on the allocation of spectrum, but also the choice of technologies, services, and pricing that will prevail in the markets – it is important that the Competition Authorities be consulted and participate in the auction design. While many of these details are important, the balance of this paper will focus on the role of spectrum caps in the design of the upcoming auctions, which may be used to complement other aspects of the design as noted earlier.

Not surprisingly, incumbents often argue against spectrum caps. They claim that any restrictions on their ability to bid for and acquire spectrum will lower expected auction proceeds, will limit their ability to expand capacity and offer innovating services, and will result in slower growth, higher prices, and lower quality for wireless services. While it is certainly true that overly restrictive spectrum caps may have significant adverse effects, economic theory and the empirical evidence from past auctions and wireless market performance do not support the arguments of incumbents against reasonable spectrum caps.

The presence of spectrum caps or other preferences that ensure smaller MNOs may participate may make it more likely that auction participation will be broader. Cramton (2013a) explains why spectrum limits can enhance auction participation and mobile competition.[25] Roetter M. and A. Pearce (2013) looked at auctions of 1.7/2.1GHz spectrum in the U.S. (2006), Canada (2008), and Mexico (2010) that differed with respect to whether the auctions had bidding restrictions. They concluded that the presence of restrictions did not adversely impact participation or auction proceeds. If demand for the spectrum is sufficiently high, then even foreclosure of certain providers need not adversely impact auction proceeds. Cave and Webb (2013) looked at 800MHz spectrum auctions in Europe did not find evidence that spectrum caps adversely impacted auction proceeds. Cramton (2013b) noted that without spectrum limits the U.S., the 700MHz

[25] See Peter Cramton (2013), "The Rationale for Spectrum Limits and Their Impact on Auction Outcomes," prepared for T-Mobile and attached as Ex Part to FCC, GN Docket No. 12-268 & WT Docket No. 12-269, Sept. 9, 2013, available at http://www.cramton.umd.edu/papers2010-2014/cramton-spectrum-limits-ex-parte.pdf.

auction resulted in the largest two operators (Verizon and AT&T) further cementing their dominant market position in below 1GHz spectrum by acquiring 85% of the spectrum available.[26] In light of this evidence, it is hardly surprising that spectrum caps are widely used to manage the allocation of spectrum resources. Figure 15 summarizes European spectrum caps, finding that the average aggregation limit is 39%.[27]

Finally, it is worth noting that the goal of spectrum policy should not be to maximize auction proceeds from any particular auction, but to maximize the value for Colombia from use of its scarce spectrum resources. This is best promoted by ensuring a healthy and competitive market for mobile services.

Over time, aggregate spectrum caps need to be relaxed to be ensure each MNOs have access to the spectrum needed to expand capacity and continue to innovate in the services they offer. Although there is not a direct connection between the quantity of spectrum (in MHz) and the capacity of a mobile network, capacity and spectrum are positively related. However, as already noted, higher frequency spectrum is increasingly valuable for addressing capacity needs and to support the offering newer mobile broadband Internet services.

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[26] See Peter Cramton (2013), "The Revenue Impact of Competition Policy in the FCC Incentive Auction," attached to Ex Parte Presentation of T-Mobile, GN Docket No. 12-268 & WT Docket No. 12-269, December 6, 2013, available at http://apps.fcc.gov/ecfs/document/view?id=7520961134.

[27] The aggregation limit refers to the spectrum holdings that any single MNO may have in a market. In addition to aggregation limits, regulators may have spectrum caps that are applicable to a particular auction.

Current allocations of spectrum in Colombia suggest that the operators most in need of additional spectrum resources are the smaller MNOs. Incumbent operators have 85MHz of spectrum, even Tigo-UNE has more than that, compared to Avantel's 30MHz (Table 2). Today, Colombian operators already face spectrum caps that limit the frequency holdings that MNOs may have to 30MHz for spectrum below 1GHz and 85MHz in the higher frequency spectrum above 1GHz.[28] Under the assumption that the below 1GHz licenses will be offered in 10MHz blocks of paired spectrum (2x5MHz), retention of the present caps would preclude participation of incumbent operators and would guarantee a post-auction allocation of spectrum that would be consistent with sustainable MNO competition. The Top 2 MNOs' share of lower frequency spectrum would go from 100% to 1/3rd, comparable to their share of above 1GHz spectrum.[29] With a more symmetric and efficient allocation of both lower and higher frequency spectrum, smaller MNOs would be better able to offer attractive service bundles that cost-effectively offered both the coverage and capacity performance that today incumbent operators are able to offer.

As an alternative, it may be deemed appropriate to conduct the 700MHz auction in two stages. In the first stage, the spectrum caps would be maintained and 30MHz of spectrum would be offered, with only smaller MNOs allowed to bid in the first round. Each bidder would be limited to bidding for at most one block of 10MHz of paired

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[28] Current spectrum caps limit each operator to a maximum of 30MHz in 698-960MHz, and 85MHz in 1710-2690MHz.

[29] As a consequence of the auction, 100MHz of spectrum would be allocated to other MNOs (assuming the spectrum is fully allocated), resulting in a post-auction allocation of 50MHz controlled by the Top 2 operators out of 150MHz total spectrum, or 33.3%.

spectrum (2x5MHz). This would allow three smaller MNOs to acquire the 700MHz spectrum they need.

In the second round, the remaining 50Mhz of 700MHz spectrum could be auctioned. In this round, the spectrum caps could be relaxed to, say, 40MHz. Once again, each MNO would be limited to bidding for a single 10MHz block. The proposed approach would allow all of the providers to participate. This would result in the Top 2 operators controlling 47% of the below-1 GHz spectrum.[30]

Adopting spectrum caps along the lines suggested above would not unreasonably constrain the ability of all MNOs to acquire spectrum to expand coverage and capacity. Moreover, this is fully consistent with the recommendation of the OECD which commented that:

> "Smaller players and new entrants should be given priority in new spectrum assignments in order to promote market competition. In particular, the upcoming 700 MHz auction should ensure that smaller players achieve the right balance between higher and lower frequencies"[31]

6. Concluding Remarks

In this affidavit, I explain why it is important to design the upcoming spectrum auctions in Colombia with due consideration being paid to the implications of auction design for the viability of structural competition in mobile services. Mobile services and

[30] Claro and Movistar each have 25MHz already, so each could acquire an additional 10MHz for a post-auction total of 35MHz.

[31] See page 12 in OECD (2014), *OECD Review of Telecommunication Policy and Regulation in Colombia*, OECD Publishing, http://dx.doi.org/10.1787/9789264208131-en.

infrastructure are essential infrastructure for society and the economy, and if promoted, will contribute to the growth of the Colombian economy. Ensuring viable competition among multiple (more than two) MNOs offers the best way to ensure this essential infrastructure is provided efficiently.

For this to outcome to occur, MNOs have to have access to the spectrum resources they need. Providers need a mix of spectrum resources to adjust to changing market conditions and to be able to respond effectively with bundles of services that are competitive in the marketplace. Smaller MNOs who lack adequate spectrum resources below 1GHz have a special need for lower frequency spectrum to enable them to build out their networks to efficiently expand coverage and enable scalable capacity expansion as they add subscribers to their networks. Larger MNOs already have significant lower frequency spectrum. They have already established their national networks and acquired significant market shares in today's highly concentrated telecommunications markets in Colombia. The Top 3 providers – Claro, Movistar, and Tigo -- are better able to take advantage of higher frequency spectrum. Current spectrum allocations below 1GHz are even more concentrated than the downstream markets, which are still excessively concentrated. Adopting moderate spectrum caps or other small operator preferences as part of the upcoming auctions offers an appropriate solution to redress the imbalance in existing spectrum allocations, and helps ensure that the progress made in enabling viable structural competition among MNOs is not lost.

7. About the Author

Dr. William Lehr is a telecommunications/Internet industry economist and policy analyst with over twenty years of experience in academic research and industry consulting.[32] He is currently a research scientist in the Computer Science and Artificial Intelligence Laboratory (CSAIL) at the Massachusetts Institute of Technology (MIT). Dr. Lehr's research focuses on the economic and policy implications of broadband Internet access, next generation Internet architecture, and the evolution of wireless technology.

In addition to his academic research, Dr. Lehr regularly advises industry and regulatory authorities in the United States and abroad on matters associated with the evolution of broadband, spectrum policy, and regulatory reform.

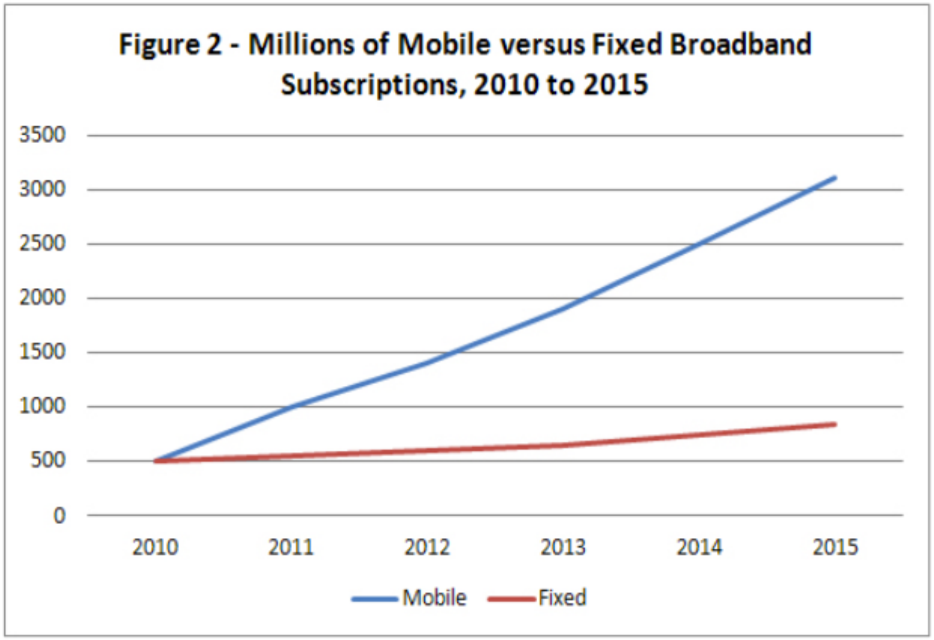
Dr. Lehr holds a PhD in Economics from Stanford, an MBA in Finance from the Wharton School, and MSE, BA, and BS degrees from the University of Pennsylvania

[32] For more information, please visit http://people.csail.mit.edu/wlehr.

8. Figures and Exhibits

8.1. Figure 1: Mobile Subscribers Outstrip Fixed

Figure 1: Mobile Subscribers Outstrip Fixed



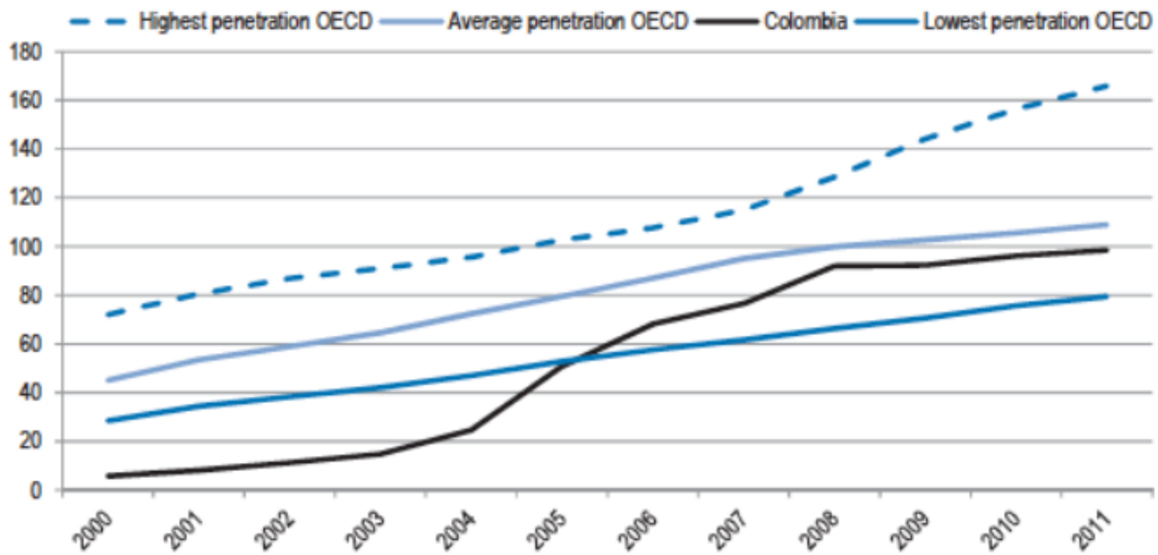
Sources: Wireless Intelligence, July 2011; Informa Telecoms & Media (WBIS), July 2011

Source: West, D. (2011), "Ten Facts about Mobile Broadband," Brookings Research Papers, December 2011, available at http://www.brookings.edu/research/papers/2011/12/08-mobile-broadband-west.

8.2. Figure 2: Mobile Penetration – Colombia v. OECD Countries, 2000-2011

Figure 2: Mobile Penetration – Colombia v. OECD Countries, 2000-2011

Figure 1.4. Mobile subscriptions per 100 inhabitants, Colombia compared to other OECD countries, end 2011



Sources: OECD (2013d), *OECD Communications Outlook 2013*, OECD Publishing, http://dx.doi.org/10.1787/comms_outlook-2013-en; CRC.

Source: OECD (2014), ***OECD Review of Telecommunication Policy and Regulation in Colombia***, OECD Publishing, http://dx.doi.org/10.1787/9789264208131-en

8.3. Table 1: Growth of Mobile Services in Colombia

Table 1: Growth of Mobile Services in Colombia

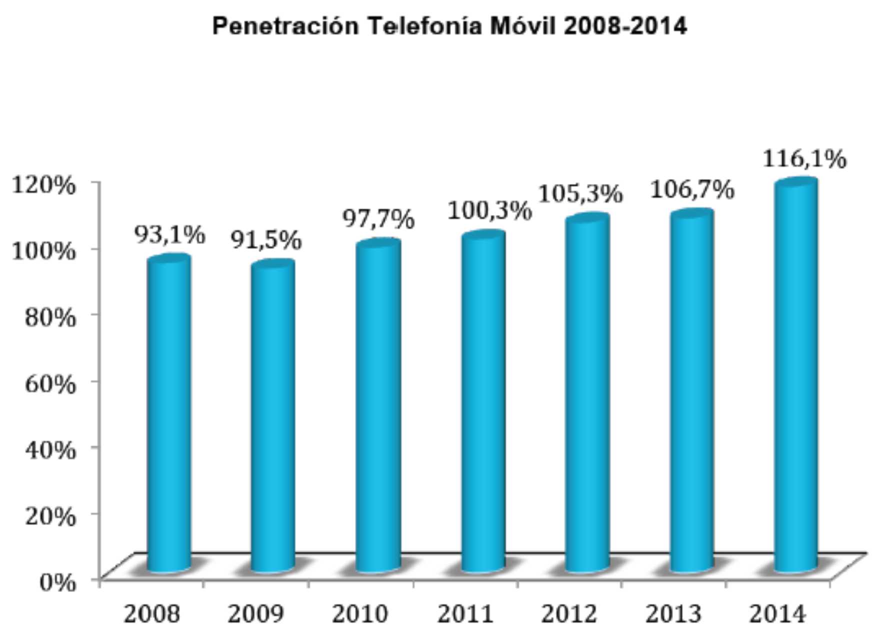
	2008	2014	CAGR
Mobile Telephone			
Subscribers (millions)	41.4	55.3	5%
Traffic (billions minutes calling)	52.1	103.0	12%
Revenue (billions COP)	6.70	7.45	2%

	2010	2014	CAGR
Mobile Internet			
Subscribers (millions)	5.1	28.9	54%
Traffic (Terabytes, 1Q & 4Q)	3.1	30.6	77%
Penetration	11%	57%	

Source: "Documento de Consulta Pública, Proceso se selección objetiva para asignación de espectro radioeléctrico en las bandas 700 MHz (Dividendo Digital), 900 MHz, 1.900 MHz y 2.500 MHz para servicios móviles terrestres," May 2015, available at http://mintic.gov.co/portal/604/articles-9301_recurso_1.pdf

8.4. Figure 3: Mobile Telephone Penetration in Colombia

Figure 3: Mobile Telephone Penetration in Colombia



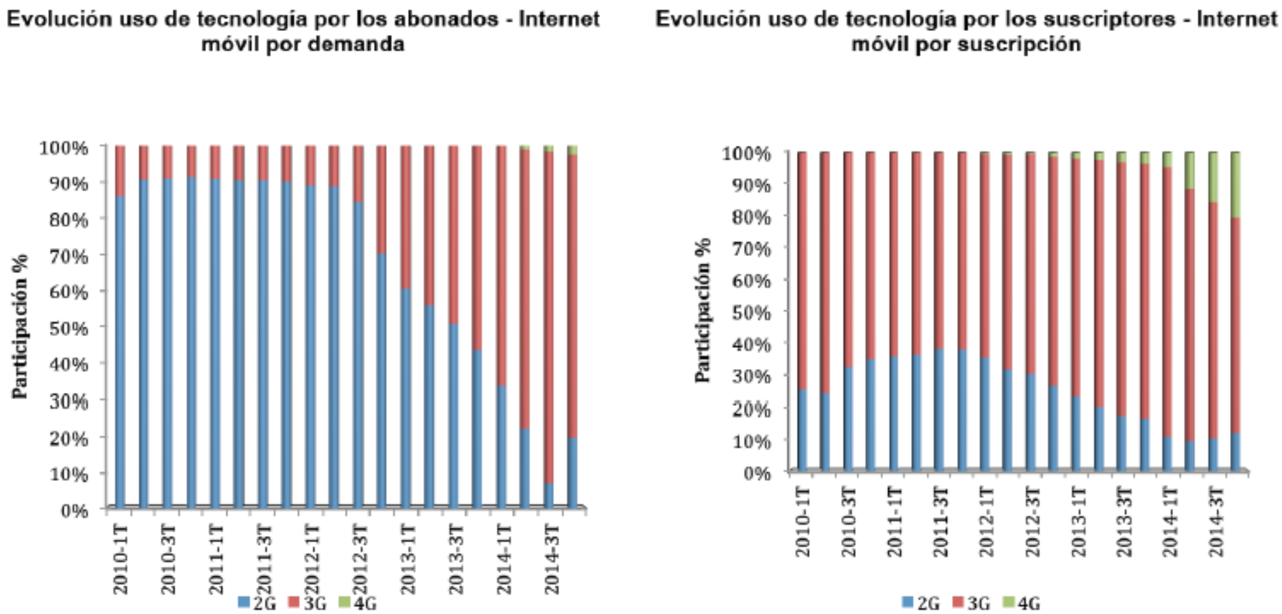
(Note: OECD developed country penetration 121% in 2014.)

Fuente: Cálculos CRC con información de ColombiaTIC y DANE

Source: "Documento de Consulta Pública, Proceso se selección objetiva para asignación de espectro radioeléctrico en las bandas 700 MHz (Dividendo Digital), 900 MHz, 1.900 MHz y 2.500 MHz para servicios móviles terrestres," May 2015, available at http://mintic.gov.co/portal/604/articles-9301_recurso_1.pdf

8.5. Figure 4: Evolution of Mobile Technology in Colombia from 2G to 3G to 4G

Figure 4: Evolution of Mobile Technology in Colombia
from 2G to 3G to 4G

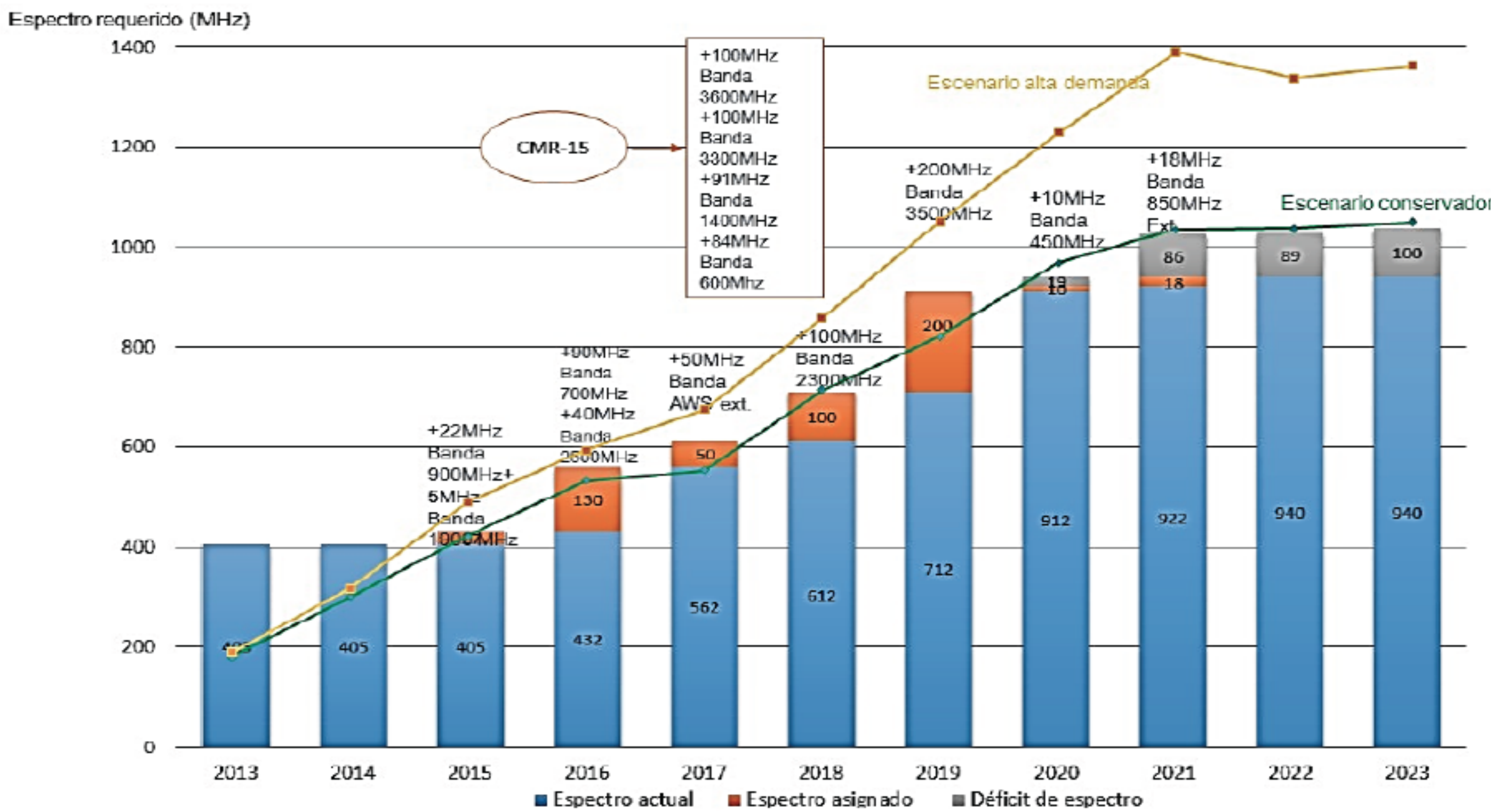


Fuente: CRC a partir de la información de Colombia TIC 2014

Source: "Documento de Consulta Pública, Proceso se selección objetiva para asignación de espectro radioeléctrico en las bandas 700 MHz (Dividendo Digital), 900 MHz, 1.900 MHz y 2.500 MHz para servicios móviles terrestres," May 2015, available at http://mintic.gov.co/portal/604/articles-9301_recurso_1.pdf

8.6. Figure 5: Forecast of Spectrum Demand for Mobile Services in Colombia

Figure 5: Forecast of Spectrum Demand for Mobile Services in Colombia



Source: Documento de Consulta Pública, Proceso se selección objetiva para asignación de espectro radioeléctrico , May 2015, available at http://mintic.gov.co/portal/604/articles-9301_recurso_1.pdf

8.7. Table 2: IMT Spectrum Holdings of Colombian MNOs (MHz)

Table 2: IMT Spectrum Holdings of Colombian MNOs (MHz)

	Below 1GHz	Above 1GHz	Total
Claro	25	60	85
Movistar	25	60	85
Tigo		85	85
Avantel		30	30
DirectTV		70	70
UNE (currently part of Tigo, to be divested)		50	50
	50	355	405
Claro+Movistar	100%	34%	
Current Spectrum Cap (MHz)	30	85	

Notes:

(1) Claro has 25 @850MHz, 30 @1900MHz, and 30 @2500MHz. This excludes 5MHz that Claro has under a temporary license.
(2) Movistar has 25 @850MHz, 30 @1700MHz, and 30 @1900MHz
(3) Tigo has 30 @1700, 55 @1900MHz.
(4) Avantel has 30 @ 2500MHz. This excludes 9.5MHz @800MHz since this is not IMT spectrum.
(5) DirectTV has 70 @ 2500MHz
(6) UNE (acquired by Tigo, but to be divested) has 50MHz at 2500MHz
(7) Current spectrum caps limit each operator to a maximum of 30MHz in 698-960MHz, and 85MHz in 1710-2690MHz

8.8. Table 3: Colombian Commercial MNO Spectrum Auction Plans

Table 3: Colombian Commercial MNO Spectrum Auction Plans

	MHz
700MHz band	80
900MHz band	20
Below 1GHz	100
1900MHz band	5
2500MHz band	30
Above 1GHz	35
Total	135

Notes:

(1) Above excludes 10MHz of 700MHz band spectrum that will be designated for Public Protection and Disaster Relief (PPDR).

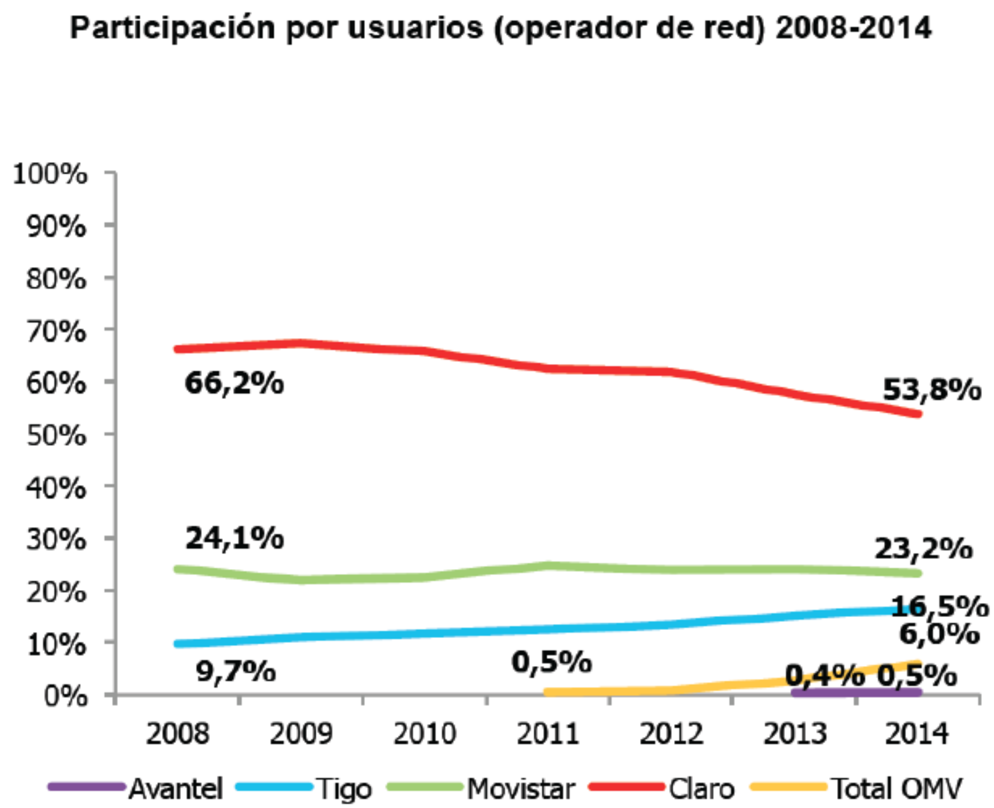
(2) Below 1GHz spectrum will be sold in 10MHz blocks of paired (2x5MHz channels): 8 @700,Mhz, 2 @900MHz

(3) 1900MHz will be sold as single 5MHz block of paired (2x2.5MHz channels).

(4) 2500MHz may be paired (FDD) or unpaired (TDD). Band plan is not yet known. Channels may be 5, 10, 15, or 20MHz.

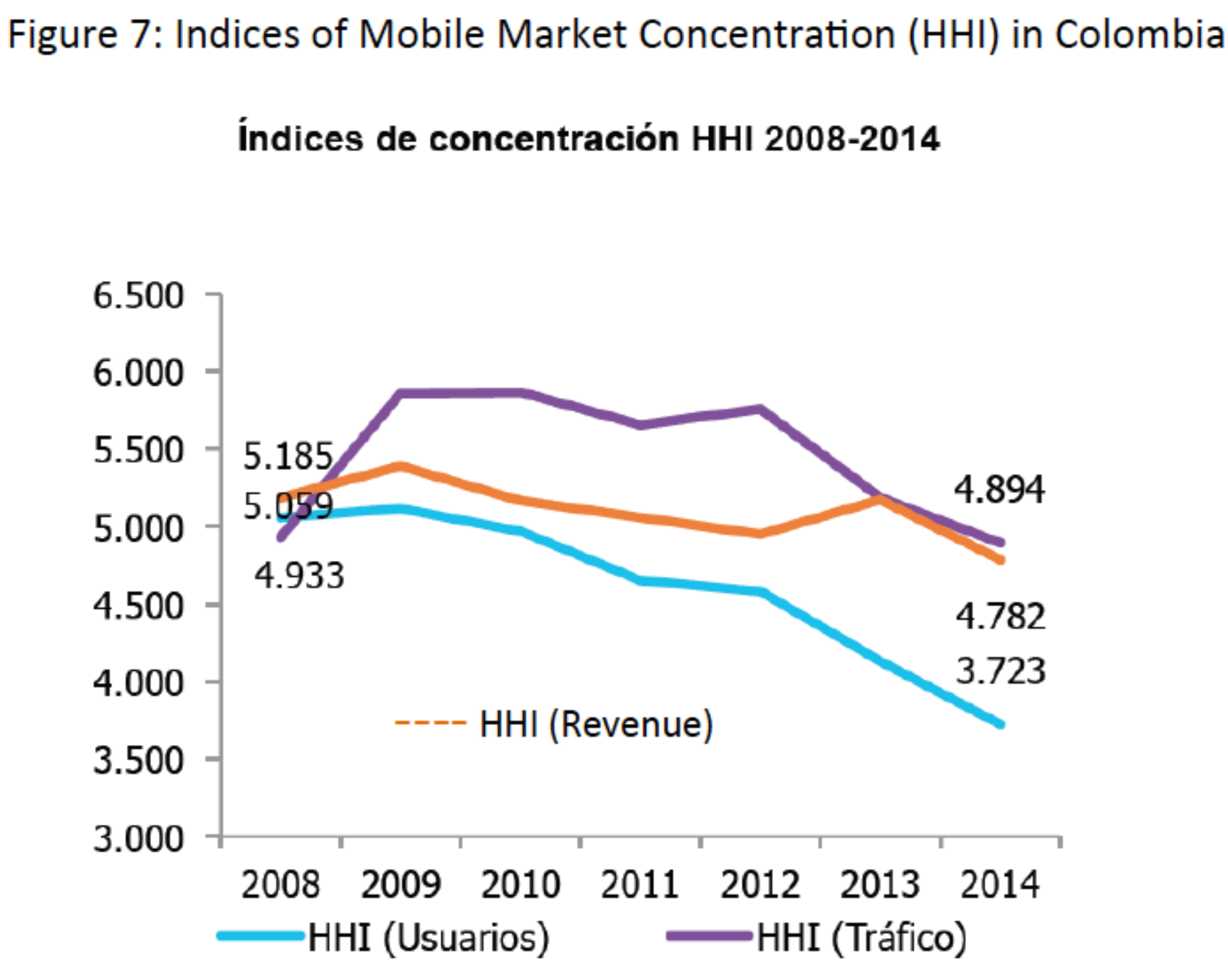
8.9. Figure 6: Mobile Market Shares in Colombia (Share Top 2 is 77%)

Figure 6: Mobile Market Shares in Colombia
(Share Top 2 is 77%)



Source: Documento de Consulta Pública, Proceso se selección objetiva para asignación de espectro radioeléctrico , May 2015, available at http://mintic.gov.co/portal/604/articles-9301_recurso_1.pdf

8.10. Figure 7: Indices of Mobile Market Concentration (HHI) in Colombia



Source: Documento de Consulta Pública, Proceso se selección objetiva para asignación de espectro radioeléctrico , May 2015, available at http://mintic.gov.co/portal/604/articles-9301_recurso_1.pdf

8.11. Figure 8: Mobile Market Shares in European Union (2009)

Figure 8: Mobile Market Shares in European Union (2009)

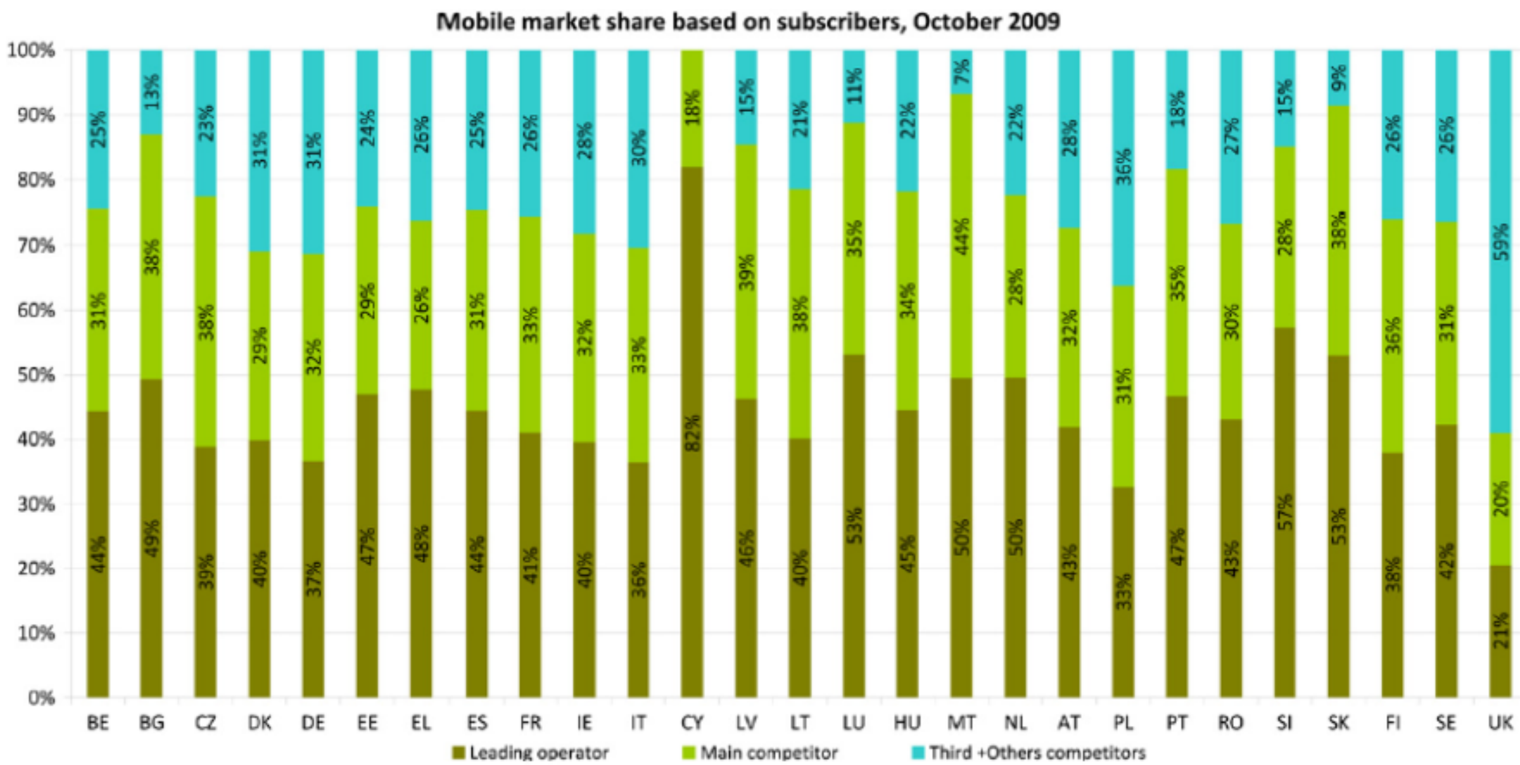
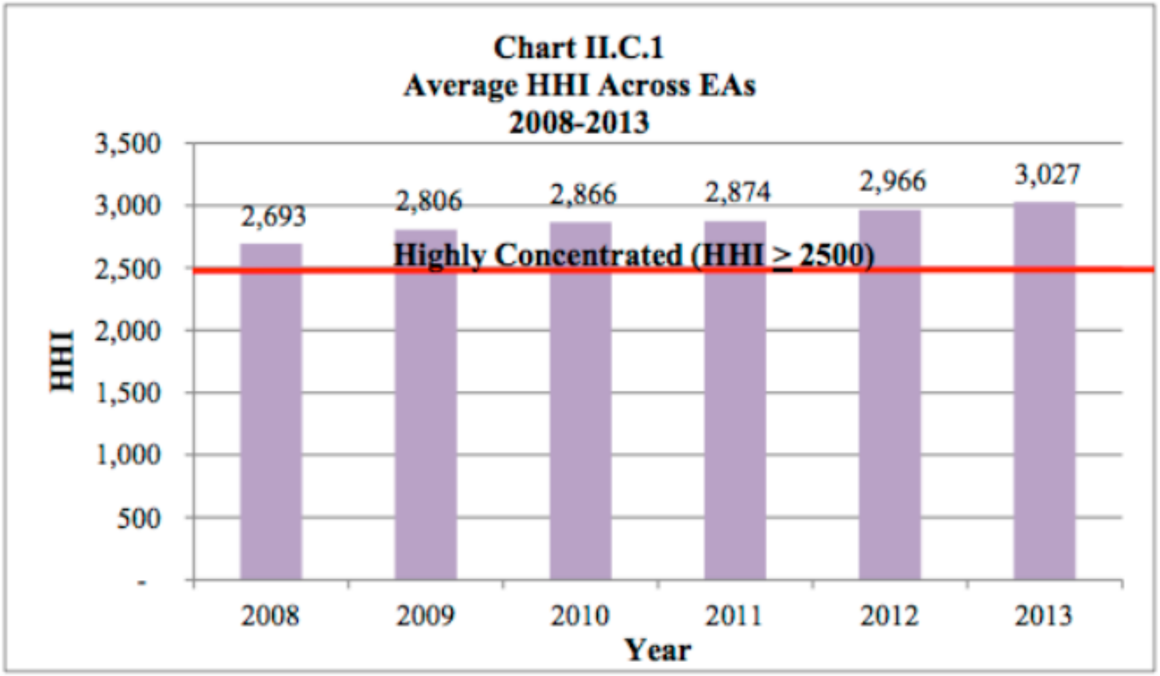


Fig. 1. Market shares of the mobile operators. (EU Commission (2009), Annex 2, p. 18.).

Source: Lundborg, M., Reichl, W., Ruhle E., (2012) Spectrum allocation and its relevance for competition. Telecommunications Policy 36 (2012) 664–675

8.12. Figure 9: U.S. Mobile Service Market Concentration

Figure 9: U.S. Mobile Service Market Concentration



Source: NRUF and 2010 census data, EAs defined as in 1995. The latest NRUF data available is 2013.

Source: FCC (2014), ***Seventeenth Report, In the Matter of Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993 and Annual Report and Analysis of Competitive Market Conditions With Respect to Commercial Mobile Services***, WT Docket No. 13-135, Released December 18, 2014, ("FCC 17th CMRS Report").

8.13. Figure 10: MNOs Spectrum Holdings in United States: MHz by band

Figure 10: MNOs Spectrum Holdings in United States: MHz by band

Table IV.A.3
Population-Weighted Average Megahertz Holdings
by Licensee, by Frequency Band*

	700 MHz	Cell.	SMR	PCS	H Block	AWS-1	AWS-4	WCS	BRS	EBS
Spectrum Counted	70 MHz	50 MHz	14 MHz	130 MHz	10 MHz	90 MHz	40 MHz	20 MHz	67.5 MHz	112.5 MHz***
Verizon Wireless	21.7	24.6	0.0	21.1	0.0	34.7	0.0	0.0	0.0	0.0
AT&T	28.4	22.8	0.0	38.0	0.0	14.2	0.0	18.3	0.0	0.0
Sprint	0.0	0.0	13.9	36.6	0.0	0.0	0.0	1.7	58.6	78.5
T-Mobile	6.0	0.0	0.0	28.3	0.0	36.8	0.0	0.0	0.0	0.0
US Cellular	2.5	2.2	0.0	2.1	0.0	0.5	0.0	0.0	0.0	0.0
DISH**	4.6	0.0	0.0	0.0	10.0	0.0	40.0	0.0	0.0	0.0
Other***	6.8	1.6	0.5	4.5	0.0	3.8	0.0	0.1	8.9	34.0

* Estimates in Table IV.A.3 include all transactions consummated as of the beginning of June, 2014.
** Dish Network Corporation currently does not provide mobile service.
*** In the application of the spectrum screen in secondary market transactions, 89 megahertz of EBS spectrum is included.

Source: FCC (2014), ***Seventeenth Report, In the Matter of Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993 and Annual Report and Analysis of Competitive Market Conditions With Respect to Commercial Mobile Services***, WT Docket No. 13-135, Released December 18, 2014, ("FCC 17th CMRS Report").

8.14. Figure 11: MNOs Spectrum Holdings in United States

Figure 11: MNOs Spectrum Holdings in United States: % Share by band

Table IV.A.2
Percentage Spectrum Holdings, Measured on a MHz-POPs Basis by Licensee, by Frequency Band*

	700 MHz	Cell.	SMR	PCS	H Block	AWS-1	AWS-4	WCS	BRS	EBS
Spectrum	70 MHz	50 MHz	14 MHz	130 MHz	10 MHz	90 MHz	40 MHz	20 MHz	67.5 MHz	112.5 MHz***
Verizon Wireless	31.0%	48.0%	0.0%	16.2%	0.0%	38.6%	0.0%	0.0%	0.0%	0.0%
AT&T	40.6%	44.6%	0.0%	29.1%	0.0%	15.8%	0.0%	91.1%	0.0%	0.0%
Sprint	0.0%	0.0%	96.5%	28.0%	0.0%	0.0%	0.0%	8.6%	86.8%	69.8%
T-Mobile	8.6%	0.1%	0.0%	21.7%	0.0%	40.9%	0.0%	0.0%	0.0%	0.0%
US Cellular	3.6%	4.2%	0.0%	1.6%	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%
DISH**	6.6%	0.0%	0.0%	0.0%	100%	0.0%	100%	0.0%	0.0%	0.0%
Other***	9.7%	3.1%	3.5%	3.5%	0.0%	4.2%	0.0%	0.3%	13.2%	30.2%

Source: FCC (2014), ***Seventeenth Report, In the Matter of Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993 and Annual Report and Analysis of Competitive Market Conditions With Respect to Commercial Mobile Services***, WT Docket No. 13-135, Released December 18, 2014, ("FCC 17th CMRS Report").

8.15. Figure 12: Spectrum Values in Different Frequency Bands

Figure 12: Spectrum Values in Different Frequency Bands

Table 2: Licensed Wireless Broadband Spectrum Value (March 2015)

	Band Name	Location	Potential Spectrum Supply *MHz*	MHz-Pop Price of Band *$ / MHz-Pop*	Value of Band *$ Billions*
	[a]	[b]	[c]	[d]	[e]
	700 MHz				
[1]	Paired	700 MHz	58	$3.25	$60
[2]	Unpaired	700 MHz	12	$1.95	$7
[3]	Cellular	800 MHz	50	$3.25	$52
[4]	SMR	800 MHz / 900 MHz	14	$3.25	$15
[5]	AWS-1	1.7 GHz / 2.1 GHz	90	$2.50	$72
[6]	PCS	1.9 GHz	120	$2.50	$96
[7]	G-Block	1.9 GHz	10	$2.50	$8
[8]	H-Block	1.9 GHz /2.0 GHz	10	$1.50	$5
	AWS-3				
[9]	Paired	1.7 GHz / 2.1 GHz	50	$2.50	$40
[10]	Unpaired	1.7 GHz	15	$0.40	$2
[11]	AWS-4	2.0 GHz / 2.2 GHz	40	$1.50	$19
[12]	WCS	2.3 GHz	20	$0.75	$5
[13]	BRS/EBS	2.5 GHz	156.5	$1.50	$75
[14]		**Total:**	**645.5**		**$455**

Source: Bazelon, C., & McHenry, G. (2015), "Mobile Broadband Spectrum: A Vital Resource for the U.S. Economy," a Brattle Group White Paper, prepared for the CTIA, March 2015, available at http://www.ctia.org/docs/default-source/default-document-library/brattle_spectrum_051115.pdf

8.16. Figure 13: Comparison of 850 to 1800MHz Spectrum Values

Figure 13: Comparison of 850 to 1800MHz Spectrum Values

Table 4: Valuations of 800 MHz and 1800 MHz Licenses in Australia

Frequency Band	International Benchmarking Valuation, $ per MHz-POP	Modeling: Cost Reduction Valuation, $ per MHz-POP	Modeling: Full Enterprise Valuation, $ per MHz-POP
850 MHz	0.53-1.26	1.02	3.36
1800 MHz	0.24	0.16	0.49

Source: Plum Consulting

Source: Roetter M. and A. Pearce (2013), "Impact of Bidding Eligibility Conditions on Spectrum Auction Revenues," Information Age Economics, Washington, DC, February 2013, available at http://www.ccianet.org/wp-content/uploads/library/IAE%20Report%20-%20Final.pdf

8.17. Figure 14: Selected Pricing for Higher Frequency Spectrum

Figure 14: Selected Pricing for Higher Frequency Spectrum

Table 3: Examples of Prices Recently Paid for Spectrum Awards

Country	Frequency band	Date of award	Price per MHz/pop, $
Brazil	2.1 GHz	12/2007	0.159
Chile	1.7/2.1 GHz	09/2009	0.0113
Colombia	2.5 GHz	06/2010	0.0188
Peru	2.5 GHz	08/2009	0.0058 (unpaired)
Mexico	1.7/2.1 GHz	07/2010	0.176
U.S.	1.7/2.1 GHz	09/2008	0.54
Netherlands	2.5 GHz	04/2010	0.00177
Denmark	2.5 GHz	05/2010	0.153**
Finland	2.5 GHz	11/2009	0.00465
Germany	2.5 GHz	05/2010	0.0292
Sweden	2.5 GHz	05/2008	0.247
India	2.1 GHz	05/2010	0.300

*Source: Regulators' websites and MFRConsulting calculations, based on exchange rates at times of awards; all prices are national averages for paired spectrum except where noted. Notes: ** mix of paired and unpaired*

Source: Roetter, M. (2011), "Spectrum for Mobile Broadband in the Americas: Policy Issues for Growth and Competition," paper prepared for GSMA, January 2011, available at http://www.gsma.com/latinamerica/wp-content/uploads/2011/01/gsmaamericasmbbspectrumpaperjan2011-1.pdf

8.18. Figure 15: Lower v. Higher Frequency as Market Share Increases

Figure 15: Cost Benefits of Lower v. Higher Frequency Spectrum as Market Share Increases

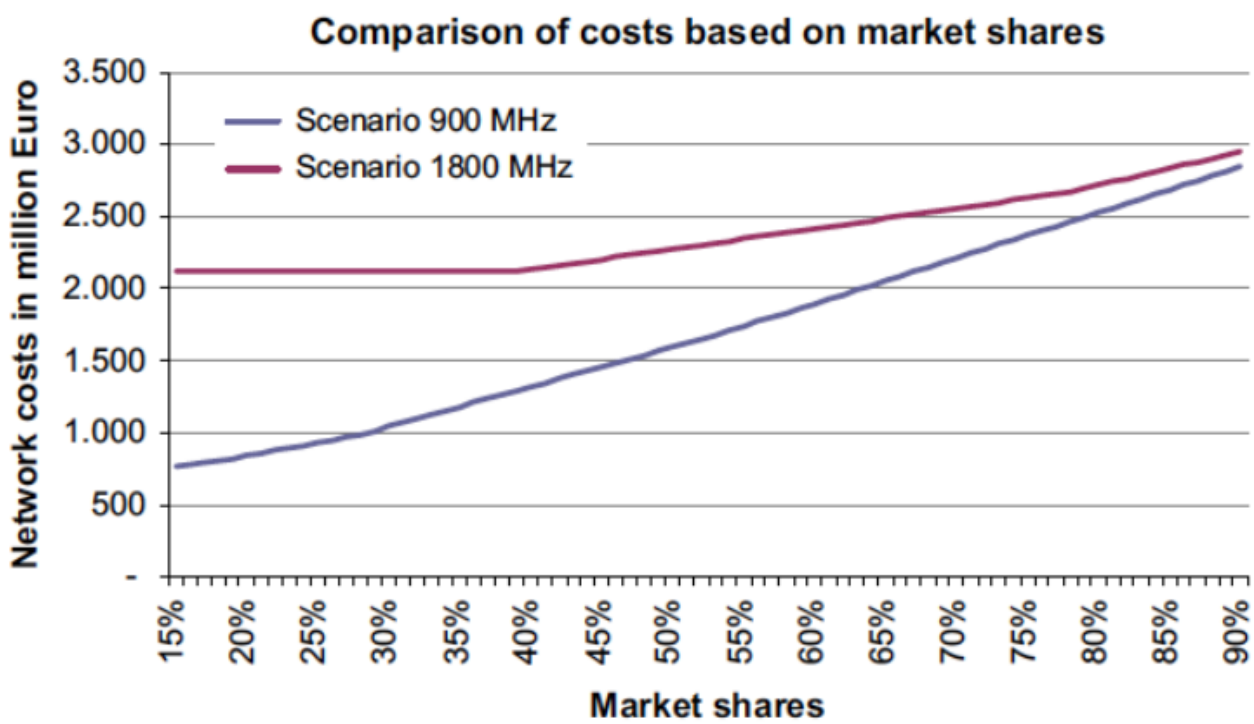


Fig. 5. Market shares and network costs.

Source: Lundborg, M., Reichl, W., Ruhle E., (2012) Spectrum allocation and its relevance for competition. Telecommunications Policy 36 (2012) 664–675

8.19. Figure 16: European Spectrum Caps (avg = 39%)

Figure 16: European Spectrum Caps (avg = 39%)

(excludes Netherlands because they had point system)

Country	Aggregation limit for spectrum below 1 GHz
Sweden	31%
Ireland	31%
Poland	33%
Portugal	34%
Germany	35%
Czech Republic	35%
France	39%
Italy	39%
Spain	39%
Finland	41%
United Kingdom	42%
Denmark	49%
Austria	54%
Netherlands[7]	84%

Table 2: Spectrum aggregation limits in European Union for spectrum below 1 GHz[8]

Source: Gretschko, V. and S. Knapek (2013), Spectrum Aggregation Limits in Auctions with Spectrum below 1 GHz: the European Experience," paper prepared for T-Mobile USA, December 2013, available at http://apps.fcc.gov/ecfs/document/view?id=7520961800