# TECHNOLOGY STANDARDS AND COMPETITION IN THE MOBILE WIRELESS INDUSTRY

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## INTRODUCTION

The last few decades have witnessed enormous changes in the mobile wireless industry. In a blink of an eye, mobile technologies have transformed the way we live, work, and stay connected, and recent decades have been called out as the largest explosion in technological innovation since the industrial revolution.[1] High speed mobile wireless communications enable today's consumers to use their mobile devices not just for voice calls, but for internet, email, and a variety of other applications.[2] It is hard to overstate the scale of these developments.[3]

At the heart of this revolution lies a series of technological innovations in wireless technology standards. For mobile wireless, this started with the second generation ("2G") digital cellular systems in the early 1990s. Significant advances were made with the introduction of third generation ("3G") mobile broadband in the early 2000s, and innovation continues today with much faster and efficient wireless fourth ("4G") and future fifth generation ("5G") systems.[4]

Each system builds upon a long series of technology standards.[5] The core wireless cellular technologies incorporated into these technology standards form the backbone of a growing and vibrant industry value chain.[6] Higher data transmission speeds and efficient communications enabled by these technologies have unleashed a range of new mobile data ser-

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1 DAN STEINBOCK, THE MOBILE REVOLUTION: THE MAKING OF MOBILE SERVICES WORLDWIDE 1-4 (2005).

2 *See* News Release, World Economic Forum Head of Media Fon Mathuros, The Mobile Revolution Is Just Beginning (Sept. 13, 2013), http://www.weforum.org/news/mobile-revolution-just-beginning.

3 *ICT Facts and Figures: The World in 2013*, INT'L TELECOMM. UNION (Feb. 2013), http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2013-e.pdf.

4 For example, 3G and 4G wireless cellular technologies have reached over three billion users globally in less than fifteen years and are likely among the most rapidly adopted consumer technologies in history. *See Ericsson Mobility Report on the Pulse of the Networked Society*, ERICSSON (Nov. 2014), http://www.ericsson.com/res/docs/2014/ericsson-mobility-report-november-2014.pdf.

5 *See* STEINBOCK, *supra* note 1, at 36-40.

6 *See id.*

vices (e.g., applications and streaming videos) and complex products (e.g., smartphones and tablets).[7] A broad variety of firms collaborate to develop common technology standards to address new technology problems and to ensure interoperability, which offers enormous benefits to all participating firms.[8]

While recognizing the benefits of standardization, a growing number of scholars and regulators have expressed concerns about the role of intellectual property rights ("IPRs") in facilitating the commercialization of standardized technologies, stimulating innovation, and benefiting consumers.[9] In particular, some commentators have argued that Standard Essential Patents ("SEPs") confer market power on their owners and allow for potential "patent hold-up."[10] Critics worry that after a technology standard is set, the users relying on the standard must license SEPs from the major patent owners.[11] With no alternative to the standard, patent owners can potentially "hold-up" the standard's implementers, deriving supracompetitive rents and harming competition and consumers.[12]

Such a model of "patent hold-up" assumes that the patent holder has disproportionate bargaining power compared to the implementer.[13] However, this does not recognize the ability of the implementer (who may be infringing a patent right) to litigate the validity of the patent if and when licensing negotiations fail.[14] Regardless, after over a decade of debate, little empirical evidence exists for or against the suggested model.[15] Indeed, ac-

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7 *See id.* at 178, 181-87.

8 *See id.* at 138.

9 Kai-Uwe Kühn et al., *Standard Setting Organizations Can Help Solve the Standard Essential Patents Licensing Problem*, COMPETITION POL'Y INT'L ANTITRUST CHRON., Mar. 2013, at 1, 2-5, *available at* https://www.competitionpolicyinternational.com/assets/Free/ScottMortonetalMar-13Special.pdf.

10 Mark A. Lemley & Carl Shapiro, *Patent Holdup and Royalty Stacking*, 85 TEX. L. REV. 1991, 1992-93 (2007) [hereinafter Lemley & Shapiro, *Patent Holdup*].

11 *Id.*

12 Some commentators analogized a patent owner demanding royalties from an implementer to a bank robber pointing a gun at a bank clerk. *See* Eingestellt von Florian Mueller, *Motorola Likens Its Enforcement of FRAND Patents to Bank Robbery: "It Only Takes One Bullet to Kill"*, FOSS PATENTS (Feb. 7, 2012, 4:58 PM), http://www.fosspatents.com/2012/02/motorola-likens-its-enforcement-of.html. This anarchical situation contrasts with reality in which both patent owners and implementers can resort to the legal system to protect their interests in the event that licensing negotiation fails.

13 J. Gregory Sidak, *Holdup, Royalty Stacking, and the Presumption of Injunctive Relief for Patent Infringement: A Reply to Lemley and Shapiro*, 92 MINN. L. REV. 714, 714-18 (2008).

14 *Id.* at 732-33.

15 For example, during cross-examination in the 2012 *Microsoft vs. Motorola* trial before Judge James Robart in the Western District of Washington, Microsoft's economic experts failed to identify any SEP license or other empirical evidence that supported their "patent hold-up" theory. Transcript of Record Day 1, at 180, 201-02, Microsoft Corp. v. Motorola Inc., No. C10-1823-JLR, 2012 WL 11896339, (W.D. Wash. Nov. 13, 2012) (Testimony of Kevin Murphy) (stating that the existence of hold-up is an "open question" and admitting that "hold-up has not necessarily been a problem"). *See also* Transcript of Record Day 4, at 67, *Microsoft Corp.*, 2012 WL 11896339 (Testimony of Timothy

cording to a recent empirical study, consumer prices in SEP-intensive industries decline much more rapidly than those in non-SEP-intensive industries, conveying a conclusion contrary to the prediction of the hold-up theory.[16]

Likewise, others have expressed concern over an increasing number of patents, both in standards and otherwise, in the information and communications technology ("ICT") industry.[17] It has been argued that products in complex technologies typically read upon many patents owned by different parties.[18] A downstream manufacturer without its own patent portfolio therefore will pay royalties to many separate patent owners.[19] This additive risk of "royalty stacking," if it were to occur, would be prohibitively costly for the implementer as a percentage of the manufactured product's value, diminishing their profit margins and commercialization incentives.[20] Estimates of hypothesized aggregate royalties on mobile devices for 2G and 3G SEPs vary widely, with some projected to be between 15 and 30 percent of the total price of the device.[21] However, these projections have not been observed in connection with 2G or 3G devices. In any event, what aggregate royalty rate is *too much* remains an open question without guidance from economic theory or empirical evidence.[22]

These concerns highlight the important responsibility of standard-setting organizations ("SSOs"), the institutions that develop technology standards. SSOs must balance the incentives of multiple stakeholders whose voluntary participation is crucial to the process of standard setting.

While securing firm participation in the standard-setting process, SSOs must also look to the ex post effects of the standards they create. Because all implementers of a standard need a license for standard-essential intellec-

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Simcoe) (responding in the affirmative to the question that he "can't nail down any particular license from any company as an example of hold-up"); *id.* at 135-36 (Testimony of Matthew Lynde) (acknowledging that "I have no basis from economic evidence to conclude whether or not patent hold-up is a real problem").

16 *See* Alexander Galetovic et al., *Patent Holdup: Do Patent Holders Holdup Innovation?* 15-16 (Hoover Inst. Working Group on Intell. Prop., Innovation, & Prosperity, Stanford Univ., Working Paper No. 14011, 2014), *available at* http://www.hoover.org/sites/default/files/ip2-wp14011-paper.pdf.

17 *See* Lemley & Shapiro, *Patent Holdup*, *supra* note 10, at 2012-13.

18 *See id.* at 1992.

19 *See id.* at 1992-93.

20 Mark A. Lemley & Carl Shapiro, *Probabilistic Patents*, 19 J. ECON. PERSPECT. 75, 82-83 (2005) [hereinafter Lemley & Shapiro, *Probabilistic Patents*].

21 *See* Eric Stasik, *Royalty Rates and Licensing Strategies for Essential Patents on LTE (4G) Telecommunication Standards*, LES NOUVELLES, Sept. 2010, at 114, 114-15, *available at* http://beta.investorvillage.com/uploads/82827/files/LESI-Royalty-Rates.pdf.

22 Indeed, in the recent *Ericsson v. D-Link* case, Judge Leonard Davis ruled that the defendants failed to identify or quantify the royalty burdens from SEPs associated with the 802.11 standard in question, rendering their "royalty stacking" argument as merely a theoretical issue. *See* Ericsson, Inc. v. D-Link Sys., Inc., No. 6:10-CV-473, 2013 WL 4046225, at *18 (E.D. Tex. Aug. 6, 2013), *aff'd in part, vacated in part, rev'd in part*, 773 F.3d 1201 (Fed. Cir. 2014).

tual property ("IP"), SSOs generally seek to have their members publicly declare any potential SEPs and to license SEPs to any interested parties on fair, reasonable and nondiscriminatory ("FRAND") terms.[23] Most SSOs clearly state that the purpose of the FRAND commitment is to both ensure *access* to the standardized technology and *fairly compensate the contributors* to the standardized technology.[24] However, there is much debate over whether FRAND commitments can effectively prevent patent owners from imposing excessive royalty obligations on licensees.

Notwithstanding FRAND commitments, alleged competitive concerns raised by patent hold-up and royalty stacking have prompted calls for antitrust treatment of SSOs and the determination of royalty rates for SEPs.[25] All the while, the empirical success story of the mobile wireless industry—the most patent- and standard-heavy of all industries—is entirely at odds with the bleak picture painted by some commentators.[26]

What explains the disconnect between these policy concerns about competitive harm and the reality of a healthy, thriving industry? While one can always argue that the "but for" world would be better in some way, antitrust remedies demand consideration of some objective criteria.[27]

This Article documents the lack of any empirical evidence of feared competitive harms from SSOs and SEPs in the context of the mobile wireless industry. In the absence of adequate, existing measures for gauging the

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23 Although the IP policies of SSOs vary widely, FRAND terms are a common in ICT standards for wireless technologies. *See* RUDI BEKKERS & ANDREW UPDEGROVE, A STUDY OF IPR POLICIES AND PRACTICES OF A REPRESENTATIVE GROUP OF STANDARDS SETTING ORGANIZATIONS WORLDWIDE (2012), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2333445 (providing a recent survey of IPR policies across SSOs).

24 For example, European Telecommunications Standards Institute ("ETSI") states that the purpose of its policy is to "reduce the risk . . . that investment in the preparation . . . of standards could be wasted as a result of an essential IPR . . . being unavailable" and also that "IPR holders . . . should be adequately and fairly rewarded for the use of their IPRs." *ETSI Directives: Rules of Procedure: Annex 6: ETSI Intellectual Property Rights Policy*, EUR. TELECOMM. STANDARDS INST. § 3.1, at 36 (Dec. 2014), http://www.etsi.org/images/files/IPR/etsi-ipr-policy.pdf.

25 *See* Joseph Farrell et al., *Standard Setting, Patents, and Hold-Up*, 74 ANTITRUST L.J. 603, 607-09 (2007); Lemley & Shapiro, *Patent Holdup*, *supra* note 10, at 2042-44. *See also* FED. TRADE COMM'N, THE EVOLVING IP MARKETPLACE: ALIGNING PATENT NOTICE AND REMEDIES WITH COMPETITION 18-19 (2011), *available at* http://www.ftc.gov/sites/default/files/documents/reports/evolving-ip-marketplace-aligning-patent-notice-and-remedies-competition-report-federal-trade/110307patentreport.pdf; Lemley & Shapiro, *Probabilistic Patents*, *supra* note 20, at 91-95.

26 Roger G. Brooks, *SSO Rules, Standardization, and SEP Licensing: Economic Questions from the Trenches*, 9 J. COMPETITION L. & ECON. 859, 861-64 (2013).

27 FTC Commissioner Joshua Wright highlighted the importance of "evidence-based antitrust enforcement, [and] the importance of its application to the technology sector" in a recent speech. *See* Joshua D. Wright, Commissioner, Fed. Trade Comm'n, Evidence-Based Antitrust Enforcement in the Technology Sector, Remarks at the Competition Law Center, Beijing, China 1-6 (Feb. 23, 2013) (internal quotation marks omitted), *available at* http://www.ftc.gov/sites/default/files/documents/public_statements/evidence-based-antitrust-enforcement-technology-sector/130223chinaevidence.pdf.

competitiveness of a patent- and standards-heavy industry, this Article explores a series of potential measures for the mobile wireless industry.[28] Rather than proposing a comprehensive toolkit, this Article's initial measures hope to start the dialogue for building a robust empirical foundation at the intersection of antitrust and IP that informs evidence-based policymaking on the issue of standards and SEPs.

Part I of this Article provides a background of the mobile wireless industry and its use of technology standards. Part II highlights how SSOs work with an example from the third generation partnership project ("3GPP"). Part III proposes basic measures that provide a first-order empirical analysis of the competitive effects from economic theories regarding patent hold-up and royalty stacking. Part IV explores these empirical measures and gauges the competitiveness of the mobile wireless industry. The final Part offers a brief summary and a conclusion.

## I. STANDARDS AND THE MOBILE WIRELESS INDUSTRY

Today's diverse mobile wireless industry is simultaneously deeply collaborative and fiercely competitive. A wide range of IP innovators make enormous investments in developing and manufacturing core wireless communications technologies, wireless devices, mobile network infrastructure, mobile applications, and mobile service providers.[29]

Technology standards reside at the heart of this industry. Without common standards, users would not experience the worldwide interoperability and interconnectivity across mobile devices at the core of wireless's business and consumer appeal. This Part first describes the stages of technology development, then recounts key advances in mobile wireless standards, and finally details the complex value chain in the mobile wireless industry.

### A. *Stages of Development*

Technology development begins years before products hit the marketplace for most complex technologies that rely on interoperability stand-

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28 These measures are primarily based on data for over three hundred firms that participated in the research, development, and implementation of wireless cellular technology standards, particularly the 3GPP working groups that developed the 3G and 4G wireless cellular standards.

29 The core wireless communications technologies refer to the 1G, 2G, 3G, and 4G wireless cellular technology generations that enable wireless connectivity and communications. *See The Evolution of Mobile Technologies: 1G → 2G → 3G → 4G LTE*, QUALCOMM (June 2014), https://www.qualcomm.com/media/documents/files/the-evolution-of-mobile-technologies-1g-to-2g-to-3g-to-4g-lte.pdf. Mobile devices such as phones and tablets built by manufacturing firms incorporate this technology that enables wireless connectivity.

ards.[30] This Section describes the stages of technological development in standards-heavy industries like the mobile wireless industry. Because industry players make investments at different stages in the industry value chain, it is important to understand the risk profile of each of these stages to realize the role of standards in this industry.

The industry evolves primarily in three stages. First, technology standards begin development several years before products or features are commercialized.[31] Second, as a common standardized solution emerges, product manufacturers (such as device and infrastructure makers) can start building products compliant with the standardized technology.[32] Finally, if product manufacturing and roll-out appears viable, network operators can deploy their infrastructure to enable connectivity, and manufacturers can offer devices to subscribers through retail shops.[33] Figure 1 depicts this evolution.

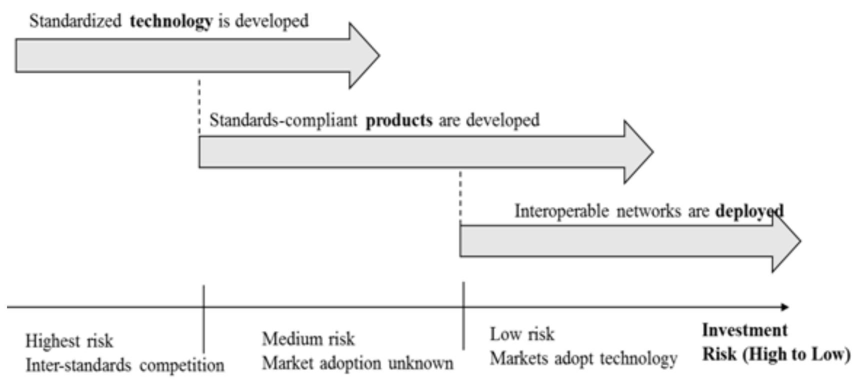


*Figure 1: Stages of development for the mobile wireless industry*

Each of the stages entails a different type of risk and investment for firms. Notably, the first stage requires the development of technology standards several years before any product development or commercialization occurs.[34] Development of the core communications technologies that allow for wireless connectivity and enable the entire mobile wireless value

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30 Julio Bezerra et al., *The Mobile Revolution: How Mobile Technologies Drive a Trillion-Dollar Impact*, BOS. CONSULTING GROUP 28-35 (Jan. 15, 2015), https://www.bcgperspectives.com/content/articles/telecommunications_technology_business_transformation_mobile_revolution/.

31 *See id.* For example, the GSM standards body was formed for building 2G standards in 1982, but the first commercial system in the United States using 2G standards was launched in 1995. *See also History and Timeline of GSM*, EMORY UNIV., http://www.emory.edu/BUSINESS/et/P98/gsm/history.html (last visited Mar. 1, 2015).

32 *See id.* For example, after the GSM standards were finalized and published in 1990 and a first pilot trial of the system occurred in 1991, it took nearly a year before the handheld terminals were tested and fit for market entry in 1992.

33 *See id.* For example, after GSM-based devices were available in 1992, the first commercial GSM service was launched in the United States only in 1995.

34 *See* Bezerra et al., *supra* note 30, at 35-36.

chain requires decades of upfront research and development ("R&D") investments.[35] Competition between potential standards at this initial phase makes such investments extremely risky.[36] As the timeline progresses, establishment of common standards significantly reduces the risk of investments from firms that specialize in manufacturing or deploying standards-compliant products.[37] The Sections that follow describe each of these three stages in greater detail.

1. Stage One: Development of Technology Standards

Development of technology standards often begins with SSOs, especially for traditional voluntary standards-development activities. SSOs provide a platform for industry scientists and engineers to come together and propose new features for consideration.[38] Any participant can propose a new feature.[39] If a proposal receives consensus approval by all the participating firms, the SSO begins an effort to generate common technical solutions to enable those features.[40] This effort leads to the development of the technology standards and solves complex technology problems.[41] For example, developing standards for fast and efficient data transmission, seamless connection transitions as users move at fast speeds, and video streaming all required years of innovation.[42]

Several firms participate in the development of technology standards, but few actively invest in R&D and contribute their technology to these standards.[43] Data from 3GPP shows that only approximately 30 percent of the firms attending SSO meetings ever made a single technology contribution to the 3G and 4G standards.[44] Even among contributors, very few firms consistently committed technology or research over the long period of time

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35 Kirti Gupta, *The Patent Policy Debate in the High-Tech World*, 9 J. COMPETITION L. & ECON. 827, 847-48 (2013).

36 *See* Brooks, *supra* note 26, at 867-68. *See also* Kirti Gupta, The Process and Data Behind Standard Setting in Wireless Communications, Remarks at the Fourth Annual Research Roundtable on the Law & Economics of Digital Markets at Northwestern University School of Law 28 (June 2013), *available at* http://www.law.northwestern.edu/research-faculty/searlecenter/events/entrepreneur/documents/Gupta_standard-setting-process-3gpp.pdf.

37 *See* Brooks, *supra* note 26, at 867-68. *See also* Gupta, *supra* note 36, at 23-24.

38 *See* Aija Elina Leiponen *Competing Through Cooperation: The Organization of Standard Setting in Wireless Telecommunications*, 54 J. MGMT. SCI. 1904, 1908 (2008). Firms vote on whether the SSO should work on new features based on the usefulness of these features to the overall industry.

39 *Id*.

40 *See* Bezerra et al., *supra* note 30, at 28.

41 *See id.*

42 *See id.*

43 *Id.* at 30.

44 *See id.*

it took to develop these standards.[45] This makes sense; at its very nature, R&D investment is a risky proposition.

During standards development, contributing firms face two major risk factors: (1) strong interstandard competition; and (2) weak market adoption.[46]

For known technology problems, the wireless industry experiences a race to innovation, and standards are no exception. Competition between several standards that address the same technological problem through very different solutions is common throughout history.[47] For example, VHS defeated its rival BetaMax in the video standard wars, the wireless standards GSM and IS-95 were developed for 2G wireless communications based on different underlying technologies, and wireless cellular standard LTE prevailed over WiMax (IEEE 802.16e) in 4G wireless communications.[48]

Additionally, the prospect of lower-than-anticipated consumer demand creates adoption risks in the standard-setting process.[49] Despite successful standard development, Global Videophone, Digital Video Broadcasting for handheld devices, and MediaFlo, which all enabled watching streaming live television on mobile devices, each fell victim to tepid consumer demand, disappointing the industry contributors to these standards.[50]

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45 *Id.*

46 The example of WiMax illustrates both of these concepts: the former in competition between Sprint and Clearwire and the latter in widespread and eventual universal adoption of LTE. *Se*e Brooks, *supra* note 26, at 870 ("In a standardized industry, in which I as an innovator cannot feasibly take my solution to market unless it becomes part of the standard, we must add to that the risk that even if I 'succeed' in my R&D, a competitor's solution will be selected for the next standard, resulting in *zero* market adoption of my invention. . . . [Post-standardization investors] face a reduced risk of 'betting on the wrong horse,' of making technology-specific investments in expertise, manufacturing capabilities, complementary technologies, infrastructure, or marketing that lose out when a different solution wins in the competition to be included in the standard.") *See also* Justus Baron & Tim Pohlmann, *Who Cooperates in Standards Consortia—Rivals or Complementors?*, 9 J. COMPETITION L. & ECON. 905, 928 (2013). ("[I]n SDO working groups, evaluate the strength of rivaling technological proposals, and dissuade potential competitors from entering into patent races.").

47 Baron & Pohlmann, *supra* note 46, at 913 ("[M]any companies have developed and patented competing technologies with the goal of inclusion in a standard.").

48 *See* Christina Bonnington, *So Long, WiMax: Sprint Confirms LTE Rollout by 2013*, WIRED (Oct. 7, 2011), www.wired.com/gadgetlab/2011/10/Sprint-lte-rollout-2013/.

49 *Se*e Brooks, *supra* note 26, at 870 n.30.

50 *See* George Winslow, *Mobilizing for Mobile DTV: Broadcasters, Wireless Carriers Eye New Technologies That Will Break Limits*, BROADCASTING & CABLE (Apr. 23, 2012), http://www.broadcastingcable.com/news/technology/mobilizing-mobile-dtv/49205; *DVB-H Mobile TV Downfall Continues*, IHS TECH. (Apr. 11, 2011), https://technology.ihs.com/394264/.

### 2. Stage Two: Development of Products

Firms can only develop standards-compliant products once a standard is complete or near completion.[51] Commercialization often continues long after a standard is defined.[52] As an example, 3GPP published the first release of the 3G standard in 2000 and issued significant releases through 2007.[53] On the product side, Apple Inc. only started supplying iPhones incorporating the 3G standardized solution in 2008.[54]

At the product development stage, the risk of interstandard competition is significantly mitigated.[55] After a clear winner among the competing standards has emerged, product manufacturing firms largely avoid the risk of sunk costs invested into failed standards.[56] Yet, market adoption risks still remain until products are rolled out in the marketplace.[57]

### 3. Stage Three: Deployment of Networks

Network operators play an important role in the third stage of the mobile wireless value chain. Network operators make large capital investments in blocks of spectrum auctioned by government.[58] This spectrum is the primary physical asset required for wireless communication, and operators deploy and maintain the infrastructure (i.e., the base stations and the servers) to provide the mobile wireless services.[59]

During network deployment, both interstandard competition and market adoption risks present at stage one and stage two of the technology evolution process are significantly mitigated.[60] Operators have the benefit of

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51 *See* Bezerra et al., *supra* note 30, at 30.

52 *Id.*

53 *3GPP Specification Detail*, 3GPP, http://www.3gpp.org/DynaReport/21101.htm (last visited Jan. 31, 2015).

54 *See Timeline*, THE IPHONE WIKI, https://theiphonewiki.com/wiki/Timeline (last visited Feb. 13, 2015); *Apple Introduces the New iPhone 3G,* APPLE (June 9, 2008), https://www.apple.com/pr/library/2008/06/09Apple-Introduces-the-New-iPhone-3G.html.

55 *See* Brooks, *supra* note 26, at 870.

56 *Id.*

57 *Id.* at 870-71.

58 *See Spectrum Licensing*, GSMA, http://www.gsma.com/spectrum/spectrum-licensing/ (last visited Feb. 12, 2015); *With U.S. Spectrum Auction Nearing, Comsearch Announces Suite of Offerings for Network Operators*, COMMSCOPE (Sept. 8, 2014), http://www.commscope.com/NewsCenter/PressReleases/With-U-S--Spectrum-Auction-Nearing--Comsearch-Announces-Suite-of-Offerings-for-Network-Operators/.

59 GORDON A. GOW & RICHARD K. SMITH, MOBILE AND WIRELESS COMMUNICATIONS: AN INTRODUCTION 5 (2006).

60 *See* Brooks, *supra* note 26, at 870.

rolling out and scaling up their networks based on gauging the consumer demand for a given technology.

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In conclusion, firms farther down the innovation value chain need a rock-solid foundation upon which to implement new or upgraded products and solutions. This holds regardless of whether firms are designing compatible components, rolling out expensive infrastructure, or developing new content, applications, or services to engage users. With stable core technologies developed by early IP innovators, players farther down the value chain can make low-risk capital investments, which in turn boost consumer adoption and usage.

### B. *Key Advances in Wireless Cellular Standards*

Utilization of the mobile wireless networks for internet browsing, emailing, gaming, and mobile applications would not be possible without the high data rates enabled by core communications technology incorporated in the cellular standards.[61] Significant advances have been made in this domain in the last fifteen years.[62] The 3G and 4G standards have ushered the mobile wireless industry into an era of *data-driven* services, commonly referred to as mobile broadband.[63]

To gain insight into the essentiality of these technology standards, it is important to appreciate the fundamental challenge faced by any wireless communications system. Mobile wireless devices communicate with networks by transmitting and receiving radio signals over the limited radio frequency spectrum allocated by regulatory bodies.[64] The fundamental underlying constraint of a wireless network is the radio frequency spectrum.[65] The efficiency of spectrum use determines the number of bits per second that can be transmitted through the network, which, in turn, defines what types of services the network can support.[66] The maximum mobile data download rate is an important indicator of improved speed and efficiency

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61 *See Ericsson Mobility Report on the Pulse of the Networked Society*, ERICSSON 16 (June 2014), http://www.ericsson.com/res/docs/2014/ericsson-mobility-report-june-2014.pdf ("The modernization was primarily driven by the introduction of more efficient base stations that were capable of handling multi-standard technologies such as GSM/EDGE and WCDMA/HSPA. By contrast, modernization in other regions was primarily driven by the introduction of LTE.").

62 *Id.* at 10. The total data monthly traffic chart demonstrates the rise of the data-driven services.

63 Prior to data-driven service capability, mobile users could primarily use their devices for voice calls and text messaging.

64 GOW & SMITH, *supra* note 59, at 11, 23.

65 *Id.* at 9-10.

66 *Id.* at 17.

and measures success in overcoming the fundamental challenge of wireless networks.[67]

Figure 2 illustrates the maximum download data rates with each significant release of the 3G standards and 4G standards defined by 3GPP. Each release incorporates important additional features that increased the maximum data download rates displayed in this chart.

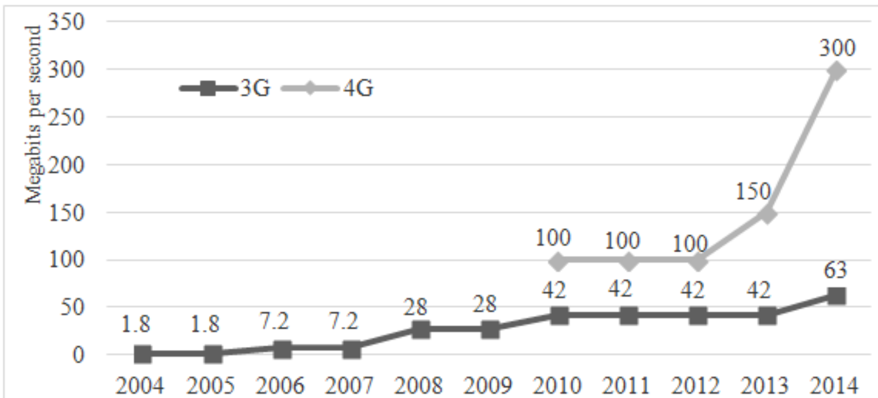


*Figure 2: Maximum (peak) data rates enabled by 3G and 4G wireless cellular standards*[68]

While 3G initiated the era of mobile broadband, 4G has reset user expectations of what is possible with mobile communications. Now, peak data speeds are comparable to fixed line broadband.[69] This has opened up a host of possibilities for new business models over mobile wireless networks.[70] Investments in 3G and 4G standards continue to improve the performance of existing networks.[71]

## C. *Mobile Wireless Industry Value Chain*

The fundamental technological advances in wireless cellular standards have seeded a complex, specialized, and evolving industry. As data rates

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67 Data download rates are not the only measure of improved speed and efficiency. Other metrics include mobile data traffic and the types of mobile applications used by consumers. *See Ericsson Mobility Report*, *supra* note 4, at 14.

68 See 3GPP, www.3GPP.com (last visited Mar. 6, 2015).

69 *See The Mobile Economy 2014*, GSMA 16 (2014), http://www.gsmamobileeconomy.com/GSMA_ME_Report_2014_R_NewCover.pdf.

70 New business models such as application developers, operating systems, and content providers have arisen in the mobile wireless ecosystem due to high data speeds. *See* Bezerra et al., *supra* note 30, at 26.

71 *See Ericsson Mobility Report*, *supra* note 4, at 18; *see also Ericsson Mobility Report*, *supra* note 61, at 25.

increased, new players including high-level operating systems, applications developers, and service providers have entered the value chain and allowed the industry to grow.

Figure 3 illustrates the main features of the growing mobile industry value chain. As described in Section II.A., the development of technology standards occurs first, seeding the start of product development, and eventually resulting in the deployment of networks.

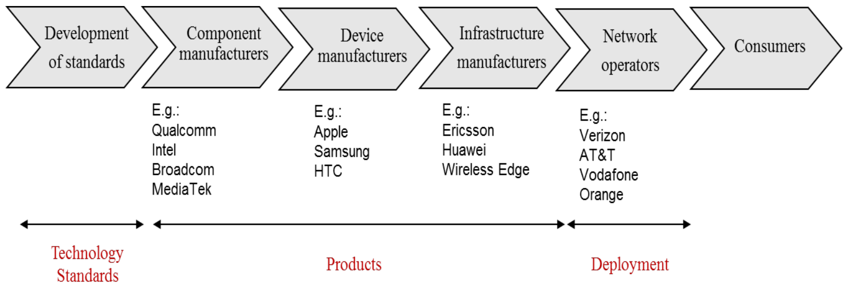


*Figure 3: The mobile wireless industry value chain*

The products in the mobile wireless industry span a variety of functional groups or industry segments. Firms within each group leverage their comparative advantage to manufacture the specific products that together make the industry whole. For example, firms such as Qualcomm, MediaTek, and Broadcom manufacture baseband chips that incorporate wireless cellular communications technologies.[72] Some component manufacturers also build specific components incorporated into mobile devices like cameras and sensors.[73]

Another set of firms integrate these components into full-fledged devices (e.g., phones and tablets) and design features for these devices that consumers ultimately use. Device manufacturers include firms such as Apple, Samsung, and HTC.[74]

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72 *See, e.g.*, *Snapdragon*, QUALCOMM, https://www.qualcomm.com/products/snapdragon (last visited Feb. 12, 2015); *Smartphone Products*, MEDIATEK, http://www.mediatek.com/en/products/mobile-communications/smartphone1/ (last visited Feb. 12, 2015); *About Us*, BROADCOM, http://www.broadcom.com/company/ (last visited Feb. 12, 2015).

73 *See* Simon Hill, *From J-Phone to Lumia 1020: A Complete History of the Camera Phone* (Aug. 11, 2013), http://www.digitaltrends.com/mobile/camera-phone-history/; David Nield, *Making Sense of Sensors: What You Don't Know Your Phone Knows About You* (Apr. 30, 2014), http://www.techradar.com/news/phone-and-communications/mobile-phones/sensory-overload-how-your-smartphone-is-becoming-part-of-you-1210244. Examples of companies that build these types of technologies include: Optilux, OmniVision, Freescale Semiconductor, and Innovative Sensor Technology.

74 "In 2011, smartphone shipments totaled 491.1 million units worldwide." *Global Smartphone Shipments from 4th Quarter 2009 to 3rd Quarter 2014, by Vendor (in Million Units)*, STATISTA, http://www.statista.com/statistics/271490/quarterly-global-smartphone-shipments-by-vendor/ (last visited Jan. 31, 2015).

Mobile devices communicate with base-stations and servers in the network in order to interact with each other.[75] This network infrastructure must incorporate the same communications components that are present in the devices (i.e., baseband chips that enable wireless cellular communications).[76] Each network server also performs a variety of other functions such as providing interoperability between systems or ensuring quality of service.[77] Infrastructure manufacturers often focus on these specific functions.[78] Finally, once all products are manufactured, the network operators deploy and maintain networks and manage user subscriptions and interactions.

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As shown in this Part, the mobile wireless value chain is a diverse, interdependent, and constantly evolving system. Despite this complexity, the recent decade has featured great advances in mobile wireless services. At the base of these advances are technology and interoperability standards. The next Part describes how standard setting works, focusing on the 3G and 4G standards responsible for today's wireless value chain.

## II. HOW STANDARD SETTING WORKS

Standards-setting bodies are tasked to solve the industry's complex technology challenges on behalf of a wide base of affected adopters.[79] Participation in most SSOs is voluntary, and their standards may be adopted (or rejected) by anyone in the industry.[80] SSOs strive to facilitate the best possible technological solutions through a collaborative and meritocratic process.[81] "While the standards-setting process has laid the groundwork for mobile's historic rise, it is not always well understood."[82] This Part explains how SSOs work through the example of 3GPP.

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75 *See* GOW & SMITH, *supra* note 59, at 30.

76 *Id.*

77 *Id.* at 31-32.

78 *See id.*

79 *See* Bezerra et al., *supra* note 30, at 29.

80 *Id.* at 29-30.

81 *Id.* at 29.

82 *Id.* 3GPP—the standards-setting body behind the most successful and widely deployed 3G and 4G standards—is a collaboration between seven global telecommunications SSOs. Membership is open and voluntary, and currently over three hundred unique firms from over forty-three countries are listed as members on the 3GPP website. Often, a single firm or organization and its subsidiaries are listed multiple times. After rolling up all the subsidiaries into parent firms, a list of over three hundred members emerges. *See Membership*, 3GPP, http://www.3gpp.org/about-3gpp/membership (last visited Feb.

Standards begin with clear requirements for the desired technical and performance goals and features.[83] To achieve these technical requirements, a set of companies proposes work items.[84] Once approved by all SSO members, specific working groups begin work on the items following a systematic process to achieve the requirements' stated goals.[85]

Any participant can propose a technical solution for the stated problem by submitting the solution prior to the regularly scheduled standards meetings.[86] The proposer must usually indicate whether any IPR may be associated with the proposed solution.[87] Advance notice allows participants to come prepared to discuss the various proposed solutions in the standards meetings.[88]

At the standards meeting, each proposed solution is presented by the proposer and discussed in front of an open forum moderated by an elected and neutral chairperson.[89] Selection of a technology solution from among the various proposals is based on consensus among participants.[90] If consensus fails, a supermajority of greater than 71 percent is required to incorporate the proposal into the standard.[91] In short, voluntary, transparent, and consensus- or supermajority-based participation and decision making is fundamental to the nature of the standard-setting process.

Despite widespread participation, very few participants present at these meetings make any contribution to the standards.[92] Data from 3GPP shows that only 30 percent of the firms attending meetings ever made a

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12, 2015); *About 3GPP*, 3GPP, http://www.3gpp.org/about-3gpp/about-3gpp (last visited Feb. 12, 2015).

83 For example, in 1988, a year after the GSM standard was established in Europe, the Cellular Telecommunications Industry Association ("CTIA") in the United States issued a set of requirements that called for an immediate tenfold increase in wireless network capacity compared to 1G analog systems. *See* Robert Roche, *Wireless Industry Innovation: The Digital Revolution*, CTIA BLOG (June 10, 2011), http://blog.ctia.org/2011/06/10/wireless-industry-innovation-the-digital-revolution/. Any technological solutions that enabled such an increase efficiently were viable solutions. Indeed, multiple technologies competed to be a part of 2G systems. *Id.*

84 *See* Talia Bar & Aija Leiponen *Committee Composition and Networking in Standard Setting: The Case of Wireless Telecommunications*, 23 J. ECON. & MGMT. STRATEGY 1, 5 (2014) ("The development of technical specifications proceeded formally through work items. Work items are new technical features that are proposed by individual members. The firm that proposed the work item was referred to as the 'source' of the work item. Each work item was proposed in a meeting where other firms chose whether to 'support' the work item.").

85 *Id*.

86 *Id*.

87 *Id*. at 6 ("3GPP members are expected to declare a patent as 'essential' when the underlying technology is necessary for the implementation of a new specification under development in standard-setting committees.").

88 Gupta, *supra* note 36, at 10-11.

89 *Id.*

90 *See id.*

91 *Id*. at 11.

92 *See* Bar & Leiponen, *supra* note 84, at 5.

single contribution to 3G or 4G standards, and even among those that contributed, only a handful of firms made the bulk of the total contributions.[93]

Why, then, do the other firms participate, and what is their role? Because standards are complex technologies, most firms closely follow SSO discussions to aid their own implementation of standard technologies.[94] Firms also participate to influence which technology solution is adopted by the standard.[95] That is, although majority of the firms do not contribute their technology to standards, noncontributing firms have power to influence what is or isn't adopted as a standardized solution.[96] IPR disclosure, coupled with strong motivations for attentiveness and influence by noncontributing firms, makes any idea of patent hold-up based on deception of noncontributors by the patent owner unlikely.

Over the course of months of research, simulations, and debate, the contributing firms combine and revise several technical proposals in order to form each feature of a standard.[97] A set of features combined together lead to a major release of the standard; the 3G and 4G standards have issued over ten releases (or roughly one every eighteen months) since 2000.[98]

This leads to another important observation: standard setting is a dynamic and an iterative process. For example, if a firm charges exorbitant royalty rates for one release of the standard, it may face punishment by the same industry participants in the next release for its unreasonable behavior in the previous round.[99] Reputation effects, therefore, play an important role in reaching an equilibrium across and within standard rounds.[100] Therefore, static efficiency models used by antitrust economists may not be a good fit for evaluating the dynamic and iterative standard-setting process.

Meetings between industry participants consumed over one million engineering man-hours during the formation of 3G and 4G standards.[101]

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93 *See* Gupta, *supra* note 36, at 22.

94 *See* Bar & Leiponen, *supra* note 84, at 5 ("[M]any members in standards development organizations participate to learn about upcoming technologies and to align their innovation activities with the industry rather than to actively promote a standardization agenda involving the adoption of their preferred technical solutions.").

95 *Id.* at 6 ("[T]he opportunities to influence standards negotiations may indeed motivate and direct technology development and patenting activities." (citation omitted)).

96 *Id.*

97 *Id.* at 5 ("Work-item committees lasted around 13 months on average, and they involved substantial R&D work to figure out the details and draft the specification.").

98 For example, 492 technical specifications form Release 12 of the 4G standard. One major feature may map to multiple such specifications. *See* Bezerra et al., *supra* note 30, at 30.

99 *See generally* Brian DeLacey et al., *Strategic Behavior in Standard-Setting Organizations* (Harvard NOM Working Paper No. 903214, 2006), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=903214.

100 *Id.*

101 *See* Gupta, *supra* note 36, at 16.

This represents only the tip of the iceberg since most R&D work occurs outside of the standards meetings.[102]

These considerable investments have yielded impressive returns. 4G wireless network capacity has increased by a factor of twelve thousand over 2G networks with maximum download speeds rising from twenty kilobytes per second to 250 megabytes per second.[103]

Large R&D investments motivate SSOs and SEP owners to facilitate widespread adoption of the standard's technologies. Yet, some scholars have argued that ambiguities in SSO FRAND commitments create a risk of patent hold-up.[104] Engaging in patent hold-up seems to contradict SEP owners' strong incentives toward widespread adoption of the standard.

Empirical evidence also disputes scholarly concerns. The widespread adoption of standards across the mobile wireless industry and incredible performance improvements from 2G to 3G to 4G indicates that the standard-setting process is likely working. The next Part provides evidence of past success and proposes empirical metrics for evaluating the future performance of the standards-setting process in the mobile wireless industry.

## III. PROPOSED EVIDENCE-BASED MEASURES

In a recent speech on SEPs and licensing, Federal Trade Commission ("FTC") Chairwoman Edith Ramirez explained the reason for antitrust scrutiny of SEPs and FRAND-based licensing: "Where a licensing agreement *harms competition* by, for example, eliminating close competition between product or technology market rivals, or harming the incentives of licensees to develop complementary technologies without legitimate justification, the FTC will act."[105]

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102 *Id.* at 20.

103 *See* Bezerra et al., *supra* note 30, at 9.

104 Some competition law scholars who have closely studied SSO and FRAND contractual provisions dispute this theoretical argument. According to these scholars, FRAND contract incompleteness persisted across SSOs and over time. This leads some to conclude that, notwithstanding antitrust considerations, incompleteness is a rationally intended and efficient feature of a competitive contracting process, which allows efficient bilateral negotiations between firms. *See* Joanna Tsai & Joshua D. Wright, *Standard Setting, Intellectual Property Rights, and the Role of Antitrust in Regulating Incomplete Contracts*, 80 ANTITRUST L.J. (forthcoming 2015) (manuscript at 4), *available at* http://ssrn.com/abstract=2467939.

105 *See* Edith Ramirez, Chairwoman, Fed. Trade Comm'n, Standard-Essential Patents and Licensing: An Antitrust Enforcement Perspective, Address at the 8th Annual Georgetown University Law Center Global Antitrust Enforcement Symposium 4 (Sept. 10, 2014) (emphasis added) (citing IP Guidelines, §§ 5.1, 5.6), *available at* http://www.ftc.gov/system/files/documents/public_statements/582451/140915georgetownlaw.pdf.

The same speech argues that consumers are best served when sound economic analysis of competitive effects solely informs antitrust enforcement.[106]

This Article agrees that sound economic analysis of competitive effects is a prerequisite for antitrust enforcement. Unfortunately, with respect to SEPs and the standard-setting process, such empirical analysis of competitive effects remains absent. Notwithstanding this gap, the FTC has begun applying antitrust enforcement to alleged SEP abuse.[107]

The FTC has repeatedly justified enforcement against SEP licensing based upon the risk of patent hold-up, which allegedly harms competition by discouraging investments to implement the standard, ultimately reducing competition in downstream markets for standards-compliant products.[108] The FTC also accepts the theoretical premise of royalty stacking when asserting that the reasonable royalties should be determined based upon "the aggregate royalty demands facing firms implementing a complex standard with many essential patented technologies."[109] As of now, neither the Commission nor scholars have presented any empirical evidence of purported harms to competition from patent hold-up or royalty stacking, yet antitrust enforcement continues.

This Article suggests several first-order metrics to measure whether SEP licensing is actually causing competitive harm. Competitive harms may include discouraging investments to implement the standard or reducing competition in downstream markets for standards-compliant products. Fortunately, patent hold-up and royalty stacking theories supply some simple testable hypotheses for such first-order analysis. This Part discusses these two theories and how to proceed from theoretical reasoning to empirical analysis.

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106 *Id*. at 9.

107 FTC Commissioner Joshua Wright, a lawyer and an empirical economist, notes this gap and has stated that the Commission needs to apply real-world economic data to its policymaking on patents the way it does in antitrust cases. In particular, Commissioner Wright believes that the agency has wrongly used its authority under Section 5 of the FTC Act to reach settlements over the alleged abuses of SEPs. *See* Mike Swift, *FTC Commissioner Expresses Concern About Use of Section 5 in SEP Cases*, HOOVER IP$^2$ (May 20, 2014), http://hooverip2.org/wp-content/uploads/Swift-Press-Release.pdf.

108 *See* Ramirez, *supra* note 105 at 5 ("[F]irms that own essential patents may gain the leverage to demand licensing terms that reflect the investments made to implement the standard rather than the competitive value of the technology at the time the standard was adopted. The risk of patent hold-up harms competition by discouraging investments to implement the standard, ultimately reducing competition in downstream markets for standard-compliant products.").

109 *See id.* at 11. *See also* FED. TRADE COMM'N, *supra* note 25, at 35. This FTC report does not present any empirical analysis yet cites several companies such as Intel, Cisco, and others who offer one-sided patent hold-up theories.

## A. *Patent Hold-Up*

Hold-up[110] is a well-defined economic theory introduced by Nobel laureate economist Oliver Williamson concerning traditional physical products and contracting.[111] "Hold-up arises when part of the return on an agent's relationship-specific investment is *ex post* expropriable by his trading partner."[112]

The relationship between a planter and a shipper in the banana industry presents a textbook example of hold-up.[113] Once a planter picks the fruit, it rapidly begins to decay. Recognizing this, the shipper can take advantage of the planter by changing the terms of their contract on the dock after the fruit has been picked. However, once the shipper's boat is half full with perishable fruit, the planter can now take advantage of the shipper by changing terms of the contract. Since each side can hold-up the other, in a negative equilibrium, neither side has an incentive to plant trees or ship bananas, and both industries shrink.[114] Efficient contracts between the parties can overcome the hold-up problem.[115]

In the context of standard setting, hold-up can occur between an inventor of standardized technology (patent owner), and a product manufacturer (implementer). Often ignored in discussions of patent hold-up, the economic concept of hold-up is symmetric.[116] As frequently cited, the patent owner can opportunistically increase the price of the licensed technology after the standard is set and other potential solutions have been ruled out.[117] However, as is often underappreciated, the implementer can refuse to pay the licensing fee after the standard is set and the patent owner has sunk significant costs into standard-specific R&D.[118] In equilibrium, inventors will not

110 Notably, the original idea of hold-up is distinct and different from the newly formed definition of patent hold-up.

111 *See* Oliver E. Williamson, *Credible Commitments: Using Hostages to Support Exchange*, 73 AM. ECON. REV. 519, 519-540 (1983).

112 Yeon-Koo Che & József Sákovics, *Hold-up Problem*, *in* THE NEW PALGRAVE DICTIONARY OF ECONOMICS (Steven N. Durlauf & Lawrence E. Blume eds., 2d ed. 2008), *available at* http://www.columbia.edu/~yc2271/files/papers/holdup.pdf.

113 *See* Galetovic, *supra* note 16, at 9.

114 *Id.*

115 *See* Che & Sákovics, *supra* note 112, at 4. For example, the banana industry has been able to solve the problem of inefficient contracts by vertical integration, where planters and shippers often belong to a common conglomerate of firms.

116 *See* Einer Elhauge, *Do Patent Holdup and Royalty Stacking Lead to Systematically Excessive Royalties?*, 4 J. COMPETITION L. & ECON. 535, 543 (2008).

117 *See* Farrell et al., *supra* note 25, at 613.

118 Scholarly literature refers to the potential hold-up of the implementer by the patent owner as "patent hold-up" and the potential hold-up of the patent owner by the implementer as "hold-out" or "reverse hold-up." Regardless of terminology, the idea is the same: hold-up is a symmetric problem in which each party to the transaction can behave opportunistically ex post.

invest up front in risky R&D towards creating technology standards without confidence in ex post payments from implementers. Likewise, implementers won't manufacture standards-compliant products under the ex post risk of having to pay excessive royalty rates to patent owners.

Thus, the theory of hold-up presents a few first-order testable implications for further analysis:

(1) Have investments in R&D increased or decreased over time for 3G and 4G standards? Hold-up would imply firms reducing their investment in R&D; and

(2) Have 3G- and 4G-compliant products become more or less available over time? Hold-up would imply less availability over time.

Part IV evaluates these testable hypotheses in the mobile wireless industry.

## B. *Patent Royalty Stacking*

Royalty stacking concerns arise when the cumulative royalty demands of multiple patent owners in a standard are prohibitively high for the implementer.[119] In the context of standard setting, royalty stacking arguments have so far relied on evidence counting the number of SEPs[120] and extrapolating initial maximum royalty rates from a handful of SEP holders to the entire standard SEP portfolio.[121]

As noted in Part III, standards are large cross-firm efforts with hundreds of specifications and thousands of technical contributions.[122] Simply listing the number of patents related to a standard and citing these lists as potential evidence of royalty stacking is not a valid argument. Likewise

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119 *See* Damien Geradin, *The Meaning of "Fair And Reasonable" in the Context of Third-Party Determination of FRAND Terms*, 21 GEO. MASON L. REV. 919, 944 (2014) ("It is far from clear, however, that the cumulative royalty rates such firms would have to pay, even if it rose to sizable amounts (e.g., 20 percent), would be unreasonable. The patent portfolios held by the vertically integrated or pure upstream firms are generally the result of costly and risky R&D efforts, which need to be adequately rewarded. It should therefore be expected that pure downstream firms would pay higher royalties to be able to implement technology they did not invent in order to participate in a market they did little to help create.").

120 *See* Microsoft Corp. v. Motorola, Inc., No. C10–1823JLR, 2013 WL 2111217, at *80 (W.D. Wash. Apr. 25, 2013) ("Another problem with using patent pools as the *de facto* RAND royalty rate is that the patent-counting royalty allocation structure of pools does not consider the importance of a particular SEP to the standard or to the implementer's products as the court's hypothetical negotiation requires." (citing Testimony of Matthew Lynde, *supra* note 15, at 143)).

121 Ann Armstrong et al., The Smartphone Royalty Stack: Surveying Royalty Demands for the Components Within Modern Smartphones 51 (2014) (unpublished manuscript), *available at* http://www.wilmerhale.com/pages/publicationsandnewsdetail.aspx?NewsPubId=17179872441.

122 *Supra* Part III.

determining aggregate royalties by extrapolating a handful of rates initiating negotiations, while ignoring rates that are ultimately reduced through bargaining and cross-licensing, also distorts the debate. Furthermore, neither patent counts nor extrapolated rates answer whether royalty prices are appropriate or cause competitive harm.

As with patent hold-up, the underlying economic theory of royalty stacking yields testable implications. Per economic theory, potential royalty stacking combines two inefficiencies on products sold by implementing firms at a positive margin: double marginalization and Cournot complements.[123] Double marginalization arises when input suppliers with market power sell to a downstream firm that can set product prices.[124] Cournot complements occur when multiple suppliers with market power sell complementary products.[125] Under both double marginalization and Cournot complements, the end price can be higher than a price set by an integrated monopolist.[126]

Applied to SEPs, these theories suggest that the aggregate royalties recouped by patentees, when prohibitively high, will drive up input prices for manufacturers of a product. Thus, the theory directly implies one or more of the following outcomes: (1) rising prices for end consumers if manufacturers can pass through inflated royalty rates; (2) reduced profit margins if manufacturers cannot pass through stacked royalties to consumers; (3) both higher consumer prices and lower manufacturer profits if pass-through is incomplete; and (4) manufacturer exit if profit margins are squeezed beyond the point of profitability.

Thus, economic theory suggests a few more first-order testable implications to evaluate royalty stacking concerns for the mobile wireless industry:

(3) Have consumer prices generally risen or fallen for 3G- and 4G-compliant products?;

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123 *See* Lemley & Shapiro, *Patent Holdup*, *supra* note 10, at 2013-14.

124 *Id.*

125 Economist Antoine Augustin Cournot (1801-1877) used the famous example of two firms independently selling and pricing zinc and copper, both of which are necessary to manufacture brass. *See Antoine Augustin Cournot Game Theory*, ECON. THEORIES, http://www.economictheories.org/2008/08/antoine-augustin-cournot-game-theory.html (last visited Feb. 13, 2015). If the firm selling zinc increases its prices, the firm selling copper can also increase its prices as it knows that the brass manufacturer will need both the inputs. This raises input prices for the brass manufacturer. If a single firm sold both the inputs, that firm would internalize the adverse effect on brass output caused by increasing input prices. But where the inputs are sold by separate firms, neither firm internalizes effects on brass output from the other's price increases, resulting in higher prices of both inputs and lower overall output. Therefore, Cournot argued that an integrated monopolist is more efficient than multiple complementary monopolistic input providers.

126 *See* Lemley & Shapiro, *Patent Holdup*, *supra* note 10, at 2014.

(4) Have profit margins generally risen or fallen for manufacturers of 3G- and 4G-compliant products?; and

(5) Is market entry or exit more common among manufacturers of 3G- and 4G-compliant products?

Data from the mobile wireless industry, particularly among firms participating in 3GPP's development of 3G and 4G standards (i.e., from 2000 until present) can be utilized to analyze these questions.

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This Article does not claim that the metrics listed above are a definitive list. Rather than presenting a full toolkit for antitrust analysis of IP, this Article hopes to offer first-order empirical metrics and an analysis of the mobile wireless industry at the heart of the SSO debate. As such, this Article welcomes further tools and analysis that will inform the debate over standard setting with much-needed but heretofore-absent empirical data.

## IV. EVIDENCE FROM THE WIRELESS INDUSTRY

Empirical evidence of competitive effects is essential for evaluating competitive concerns and justifying antitrust enforcement regarding patent hold-up and royalty stacking.

To measure the competitive effects of standards and SEPs in the mobile wireless industry, this Article applies the metrics discussed in Part III to the mobile wireless industry.

This Part first explains the methodology for constructing the dataset, and then analyzes this dataset for the metrics discussed in Part III. The analysis is based on information about firms that participated in the formation of the 3G and 4G standards through the 3GPP standards meetings between 2004 and 2013 (both years inclusive).[127] Although the large majority of the firms that attended these meetings did not actively contribute to the development of 3G and 4G technology standards, they influenced and followed the development of these standards to build standards-compliant products.[128] Therefore, firms participating in 3GPP form a representative sample of firms in the industry involved in developing, implementing, and operating 3G and 4G wireless technology.

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127 The first formal release of the 3G standard occurred in 2000, which would be the ideal starting point for the data. However, due to the unavailability of financial data for firms prior to 2004 from any of the available comprehensive financial data sources, this particular analysis begins in 2004. Later analyses begin in 2000, where possible.

128 *See* Gupta, *supra* note 36, at 23.

## A. *Methodology for Constructing Wireless Industry Dataset*

The analysis begins by defining a list of participating firms. Two sources of information define this preliminary list: 3GPP membership rolls[129] and meeting attendance records from relevant standards meetings and working groups.[130] After merging these lists, removing duplicate firms, cleaning firm names, and rolling up subsidiaries and acquisitions into parent companies, 518 unique organizations were identified as affiliated with these standards between 2004 and 2013.

Then, financial information for these 518 firms was obtained over the period from 2014 to 2013.[131] Of the 518 organizations, 158 were either educational institutions, research institutions, other SSOs, or government agencies that do not report financial information such as profit margins and R&D spending. Therefore, these entities were removed from the analysis of such information. Of the remaining 360 for-profit firms, financial information was available for 322 firms. The missing organizations tended to be smaller firms, and none were major contributors to standard development or meeting attendees.[132]

The remaining firms were then categorized into different industry segments in the mobile wireless industry value chain according to their single main activity.[133] A firm's single main activity was determined by a combination of factors: the firm's categorization in a financial database,[134] the firm's statements of purpose,[135] and an independent review by a group of industry engineers who participated in 3G and 4G standard setting.[136] Although several firms fall into multiple industry segments, this dataset categorizes each based on its main activity, which is typically the firm's

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129 Membership data is available from 3GPP. *Membership*, 3GPP, www.3gpp.org/membership (last visited Feb. 11, 2015).

130 Attendance records for meetings held by all thirteen known 3GPP working groups that work on 3G and 4G standards were collected. These include all the Radio Access Network ("RAN"), System Architecture ("SA"), and Core Networks ("CN") working groups. *ETSI Calendar of Meetings*, EURO. TELECOMM. STANDARDS INST. http://webapp.etsi.org/meetingcalendar/ViewMeetings.asp (last visited Feb. 25, 2015).

131 Data were obtained from Avention, a financial data source that aggregates financial information, industry categories, location, and other information for firms from fifty-five different content providers. AVENTION, www.avention.com (last visited Mar. 1, 2015).

132 None of these firms were in the top 50 percent of all firms in terms of total contributions or total meetings hours attended.

133 *See supra* Section I.C (describing the different industry segments of the mobile wireless value chain).

134 *See supra* note 127 and accompanying text.

135 Firms' statements of purpose are often available from their public websites. *See, e.g.*, ALCATEL-LUCENT, http://www.alcatel-lucent.com/about (last visited Jan. 28, 2015).

136 Discussions with Qualcomm's standard-setting engineers helped to distinguish into which part of the value chain each company fits. This was based on the firm's primary business.

largest revenue generator, in order avoid double counting of the same firm in multiple categories. For example, Samsung is a manufacturer of components, devices, and infrastructure but is characterized in this dataset as a device manufacturer.[137] Table 1 presents the breakdown of 3GPP participants by industry category in the dataset.

| Relevant industry segments | No. of firms | Examples of firms |
|---|---|---|
| Component Manufacturers | 45 | Qualcomm, MediaTek, Broadcom, Texas Instruments |
| Device Manufacturers | 38 | Samsung, Apple, HTC, Microsoft, Nokia |
| Infrastructure Manufacturers | 60 | Ericsson, Alcatel-Lucent, Airvana, Hewlett-Packard Oracle |
| Network Operators | 48 | AT&T, Verizon, Vodafone, Orange, China Mobile |
| Other | 16 | |

*Table 1: Participants in 3GPP by industry category*[138]

For the purpose of categorization, it is difficult to remove the non-mobile revenue portion of many firms. Conversely, although the firms in this dataset are representative of the firms in the mobile wireless industry, a much larger group of firms benefit from mobile technology. Some of these firms, such as mobile service and content providers and new entrants to the mobile industry, are represented in the "other" category of the sample since they represent new business models recently added to the mobile industry value chain. The Sections below apply the competitive effects metrics proposed in Part III to this representative sample of the mobile wireless industry.

## B. *Investment in Standards and R&D*

As discussed in Part III, investments in standards and R&D can measure the effects of patent hold-up in the mobile wireless industry.[139] Low or declining levels of investment may indicate harms to competition from hold-up problems. Two metrics can evaluate investment in standards and

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[137] Devices represent the majority of Samsung's revenues compared to its other manufacturing sectors in the wireless industry. *See* Andrew Martonik, *Samsung Posts $51.8 Billion in Revenues, $7.3 Billion Net Profit in Q1 2014*, ANDROIDCENTRAL (Apr. 28, 2014), http://www.androidcentral.com/samsung-posts-518-billion-revenues-73-billion-net-profit-q1-2014 (noting "strong sales of the Galaxy S4 and Note 3 as being big sales drivers").

[138] *See supra* note 127 and accompanying text.

[139] *See supra* Part III.

R&D: (1) whether firms continue to participate in subsequent releases of 3G and 4G standards following a potential threat of patent hold-up; and (2) whether firms in the mobile wireless industry increase or decrease financial investments in R&D.

### 1. Participation in Standards

Continued high levels of participation in standards-setting processes lessen concerns for patent hold-up. Based on the meeting records gathered from the specific working groups,[140] it is possible to identify the number and types of unique firms that participated in the development of 3G and 4G standards over time. Since each firm can send multiple delegates to each meeting, the total amount of time spent in meetings across all firms also indicates the aggregate interest and intensity of involvement of firms in standard setting. Therefore, this Section analyzes both of these metrics from the meeting attendance records of 3G and 4G specific working groups.

Figure 4 presents the total number of unique firms that participated in more than one 3G or 4G meeting from 2004 to 2012. The number of participating firms increased from 117 in 2004 to 213 in 2012. If patent hold-up exists, it is not stopping firms from participating in standards development.

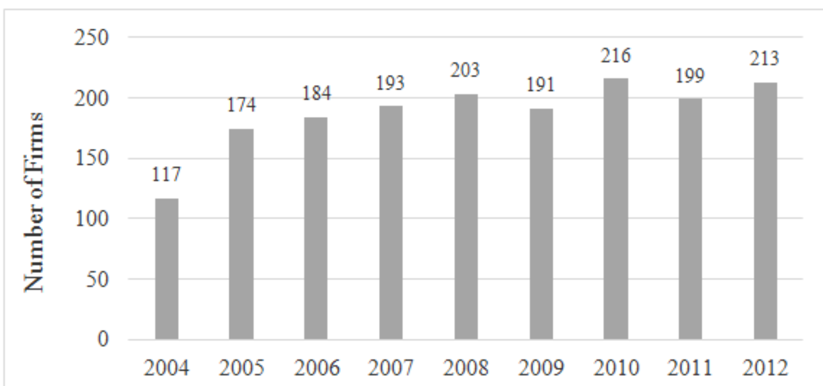


*Figure 4: Number of firms attending 3GPP meetings for 3G and 4G standard setting*[141]

Figure 5 presents the total number of person-hours spent by delegates of firms participating in 3G or 4G meetings from 2004 to 2012.[142] Contrary to what would occur if patent hold-up were widespread, Figure 5 shows a

140 *See ETSI Calendar of Meetings*, *supra* note 130.

141 *See id.*

142 Person-hours are calculated by multiplying the number of delegates attending each meeting times the reported length of each meeting in days, assuming eight hours per day.

steady rise in hours invested from 2004 to 2011. As noted earlier, time spent at meetings is the tip of the iceberg of the effort spent on the development of standards since most of the R&D is performed outside of the meetings.[143]

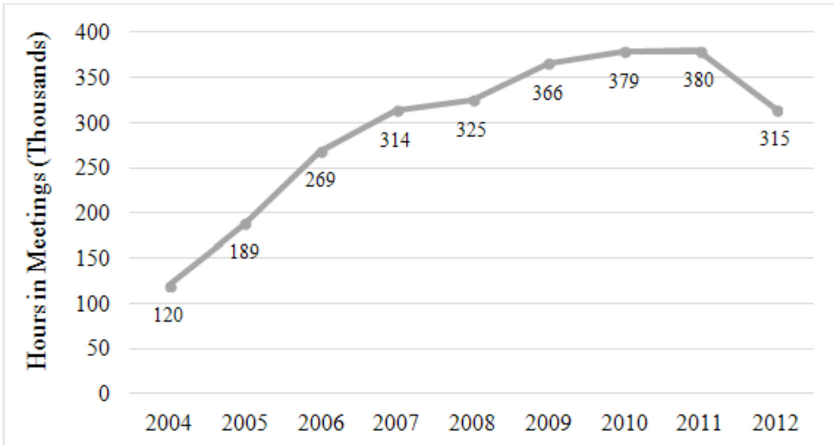


*Figure 5: Total person-hours spent in 3G and 4G standard-setting meetings in 3GPP*[144]

To conclude, the alleged threat of patent hold-up is not stopping firms from participating in standards development. Firms consistently return for subsequent releases of the standards, and the number and intensity of firm participation has increased over time.

2. R&D Intensity

High levels of R&D investment—both absolute and relative to revenues—also mitigate patent hold-up concerns. R&D intensity (measured by R&D spending as a percentage of sales revenue) in the mobile wireless industry is extremely high (14.4 percent of revenues), compared to the average R&D intensity across all industries in the United States (2.3 percent).[145] Figure 6 shows the levels and trends of R&D investment across segments of the mobile wireless industry from 2004 to 2013.

143 The year 2012, where the number of person-hours spent in standards meetings dropped, seems to be an exception to this trend. This anomaly has two potential explanations, each resulting in a different conclusion. First, lags in the updating of meeting records may explain apparent person-hour declines; second, the data may actually reflect a drop in participation, which may be explained by either perceived patent hold-up problems or extraneous factors.

144 *See ETSI Calendar of Meetings*, supra note 130.

145 *See generally* OECD, OECD SCIENCE, TECHNOLOGY AND INDUSTRY SCOREBOARD 2011 (2011), *available at* http://www.oecd-

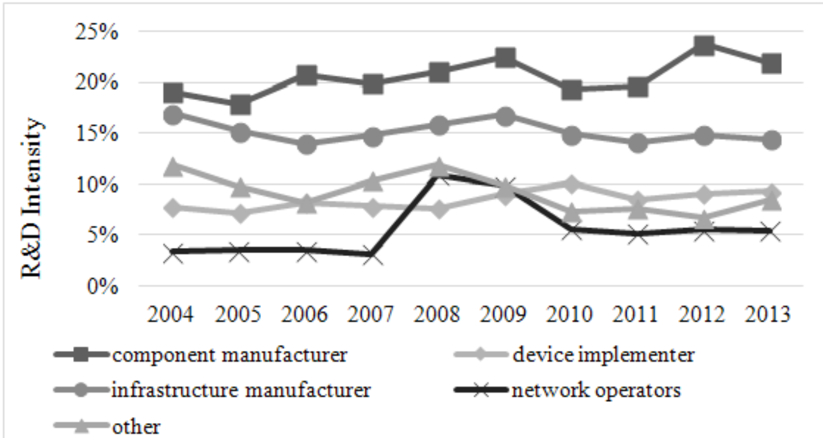


*Figure 6: Percentage of revenues invested in R&D for different industry segments of the mobile wireless value chain*[146]

Some of the individual segments of the mobile wireless industry that are most dependent upon technology standards are even more R&D intensive than industry averages. Figure 7 shows that component manufacturers, whose profitability depends on incorporating standards into products, have invested around 20.6 percent of revenues into R&D between 2004 and 2012.[147] Contradicting concerns of "patent hold-up" component manufacturers have increased R&D to 21.9 percent in 2013.[148]

R&D spending has also grown steadily over the period, almost doubling from a total of about $79 billion in 2004 to $136 billion in 2013.[149] Figure 7 shows that R&D growth was highest among standard-dependent component manufacturers and device implementers, at about 8.2 and 7.6 percent,[150] respectively, compared to the average 5.5 percent for all industry segments.

Such data paints the picture of a growing industry that continues to be R&D intensive. Of course, one might argue that R&D investments might be even higher without patent hold-up or following antitrust intervention. Therefore, other metrics, such as manufacturer profit margins must be measured to identify potential evidence of competitive harm that might be missing from investment and participation data.

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brary.org/docserver/download/9211041e.pdf?expires=1432657066&id=id&accname=guest&checksum=D33A6629F67C40472ED282E0914D0C95.

146 See AVENTION, supra note 131.

147 This is significantly higher than the average for the device (8.5 percent) infrastructure implementers (14.2 percent) and network operators (4.5 percent).

148 *See* Figure 7.

149 *See* Figure 7.

150 These groups accounted for over half of total R&D in 2013.

## C. *Profit Margins*

Profit margins of manufacturers of standards-compliant products provide another metric to evaluate competitive harms from royalty stacking in the mobile wireless industry. If royalties are prohibitively high, manufacturer profit margins should decrease due to the higher input costs.[151] A competitive industry in equilibrium features relatively flat profit margins with costs not growing any faster than revenues.[152]

Figure 7 displays the profit margins for all industry segments in the mobile wireless value chain from 2004 to 2013. For each manufacturing industry segment, profit margins have remained flat, consistent with a competitive industry.[153] Network operators, the industry segment that observed a sharpest change in their profit margins over this time period, solely provide services to consumers and do not pay royalties for technology standards.

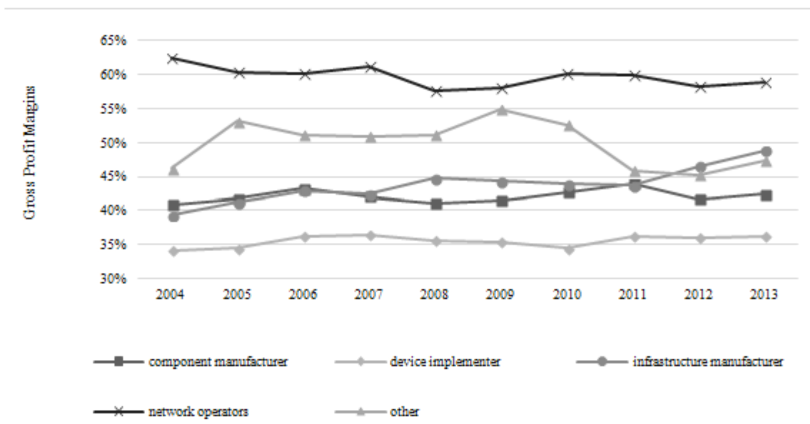


*Figure 7: Profit margins for different industry segments of the mobile wireless value chain*[154]

These results are compelling. During a time of rapid revenue growth, R&D expenditures in the mobile wireless industry remain high, and profit margins are consistently flat. Thus, firms in the mobile wireless industry do not display any first-order indication of competitive harm from patent hold-up or royalty stacking. One possibility, however, remains. The next Section

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151 This is true unless the manufacturer can completely pass through royalty costs to consumers.

152 *See Profit Maximization in Perfectly Competitive Markets*, WILEY 245, http://www.wiley.com/college/browning/0471389161/pdf/ch09.pdf (last visited May 26, 2015).

153 The compound average growth rate for each category is: network operators (-0.5 percent), infrastructure manufacturers (2.2 percent), device manufacturers (0.6 percent), and component manufacturers (0.4 percent).

154 *See* AVENTION, supra note 131.

evaluates whether standards-setting processes negatively impacts products offered to consumers.

### C. *Number of Products*

As discussed in Part III, an industry characterized by patent hold-up would likely see reductions in the number of consumer products being offered. In equilibrium, ex post payment risks would deter IP innovators from investing in upfront R&D towards creating technology standards, and excessive royalties would constrain implementers from manufacturing standards-compliant products.[155] Therefore, the number of 3G- and 4G-compliant consumer products offers additional first-order evidence to evaluate patent hold-up theories.

Various industry analyst reports track the number of cell phones and tablets that device manufacturers offer to consumers each year.[156] These reports list brand and price information for each device. One such report (GSMArena) also contains comprehensive and up-to-date information on mobile device features, including whether the device uses 3G and/or 4G standards.[157] To test for competitive effects, the data from this report was manually parsed into a list of products based on 3G and 4G technologies starting from 2000, the year of the first 3G release.

Figure 8 shows the number of unique consumer devices offered under 3G and 4G standards from 2000 to 2013.

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155 *See supra* Part III.

156 *See All Mobile Phone Brands*, GSMARENA, http://www.gsmarena.com/makers.php3 (last visited Mar. 1, 2015).

157 This Article uses GSMArena as its data source because it provides one of the most comprehensive and up-to-date mobile phone information resources. The GSMArena data listed ninety-eight mobile device brands when this Article was written.

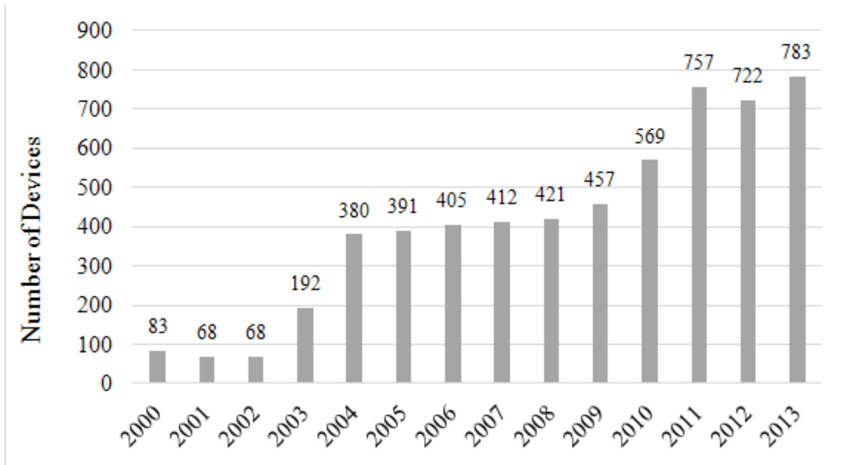


*Figure 8: Number of unique 3G and 4G device models produced per year*[158]

The number of unique consumer device models increased by nearly an order of magnitude from 83 in 2000 to 783 in 2013. Such explosive growth in consumer products is indicative of a thriving mobile wireless industry, likely unencumbered by major royalty stacking concerns.

## D. *Entry and Exit of Standards-Compliant Product Manufacturers*

In addition to evaluating consumer products and prices, any antitrust analysis must look at market shares and entry in the relevant consumer market.[159] If a few large manufacturers dominate the marketplace and extract royalty discounts from SEP owners, higher royalties for smaller manufacturers may stifle entry and harm competition.[160]

The GSMArena data also enables a deeper look into entry into the market for 3G- and 4G-compatible devices. Trends in the number of unique firms offering devices approximate entry and exit in the mobile wireless industry.[161] Figure 9 lists the number of unique firms that offered 3G and 4G compatible phones and tablets by year.

158 *See All Mobile Phone Brands*, *supra* note 156.

159 *See* U.S. DEP'T OF JUSTICE, COMPETITION AND MONOPOLY: SINGLE-FIRM CONDUCT UNDER SECTION 2 OF THE SHERMAN ACT 21 (2008), *available at* http://www.justice.gov/atr/public/reports/236681.htm.

160 *See* Lemley & Shapiro, *Probabilistic Patents*, *supra* note 20, at 2012.

161 The number of unique manufacturers releasing a product by year can be manually created in a manner similar to that used for the number of 3G- and 4G-compliant products per year.

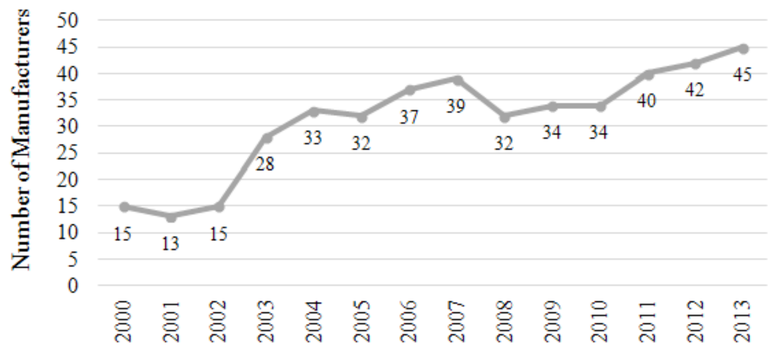


*Figure 9: Number of unique firms offering 3G and 4G mobile devices per year*[162]

The number of unique firms offering mobile wireless devices has grown steadily from fifteen brands in 2000 to forty-five in 2013. Consistent with a healthy industry, the total of eighty-seven unique manufacturers listed over all years in the dataset demonstrates constant entry and exit from the mobile device market.

The market for mobile devices also appears extremely competitive. The International Data Corporation ("IDC") tracks quarterly demand for mobile phones by manufacturer.[163] IDC data on market shares suggests low market concentration and widely fluctuating market shares among the major incumbent firms.[164] Since 2007, Samsung's market share has grown (currently at 23.7 percent) while Apple's has shrunk (currently at 11.7 percent). Furthermore almost half (49.3 percent) of the market goes to manufacturers outside of the major five device manufacturers, Samsung, Apple, Xiaomi, Lenovo, and LG.[165]

Finally, the identity of the major device manufacturers also keeps changing rapidly. Data reported by the International Telecommunications Union ("ITU") shows market turnover from well-known incumbents like Nokia and Blackberry (formerly Research in Motion) to ascendant latecomers such as Apple and HTC.[166] Constant entry and exit, fluctuating market shares, and large numbers of smaller firms provide first-order evidence of a thriving mobile wireless device market, contrary to fears of royalty stacking.

162 *See All Mobile Phone Brands*, *supra* note 156.

163 Industry firms use the IDC data to build competitive strategies based upon estimated future demand. *See Smartphone Vendor Market Share, Q3 2014*, INT'L DATA CORP., http://www.idc.com/prodserv/smartphone-market-share.jsp (last visited May 26, 2015).

164 *Id.*

165 *Id.*

166 The ITU market shares of mobile wireless firms are available online. *See Statistics*, ITU, http://www.itu.int/ict/statistics (last visited Mar. 3, 2015). *See also* Brooks, *supra* note 26, at 863-64.

### E. *Prices of Products*

Apart from consumer product offerings, price trends can measure competitive harm in the mobile wireless industry if manufacturers pass through high royalty costs to consumers.

Here too the mobile wireless industry shows little evidence of competitive harm. From 1992 to 2013, the quality-adjusted relative prices for mobile wireless devices fell 6.7 percent per annum, to about one-fifth of 1992 levels.[167] By contrast, relative prices in many non-SEP-intensive industries, such as automobiles, which fell by 2.3 percent per annum, declined more slowly.[168] Confirming the general theory, industries traditionally associated with hold-up problems, such as bananas, sugarcane, and electricity, saw fairly stagnant consumer prices falling only about 0.6 percent per annum.[169]

Industry data on mobile devices enables observing the prices of the 3G and 4G standards-compliant products. The IDC reports that average smartphone prices in the United States fell 22 percent from $430 in 2008 to $335 in 2013 despite significant advances in features and functionality.[170] Falling consumer prices—both in the telephone industry generally and the wireless device industry specifically—provide first-order evidence against competitive concerns of patent hold-up or royalty stacking in the mobile wireless industry.

## CONCLUSION

The mobile wireless industry has undergone enormous change within the past two decades. Growing from a tiny industry providing voice services to wealthy users, today's mobile phones are ubiquitous worldwide, and modern smartphones now access a huge range of mobile data services.

Advances in the wireless cellular standards have enabled a rich and complex industry value chain with several distinct functional groups. Despite this remarkable progress, scholars and policymakers continue to debate antitrust treatment of SEPs and the standards-setting process in the wireless cellular industry. Unfortunately, proposed antitrust remedies for theoretical patent hold-up and royalty stacking concerns neither capture the dynamic nature of the standards-setting process nor reflect the empirical

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167 *See* Galetovic, *supra* note 16, at 16.

168 *Id.* The soft drink industry, in which the prices are 20 percent higher today than in 1951, provides another contrasting example.

169 *Id.*

170 Historical retail prices of smartphones, unadjusted for quality improvements, can be found at www.idc.com. IDC reports price data for smartphones only starting from 2008. *See generally* IDC, www.idc.com (last visited Mar. 3, 2015).

experience in the highly competitive, SEP-intensive mobile wireless industry.

This Article has derived first-order empirical metrics of competitive harm to examine patent hold-up and royalty stacking concerns from a principled antitrust perspective. Quite simply, if patent hold-up and royalty stacking concerns were true, one would predict some combination of decreasing participation by manufacturing firms in standards-setting processes or R&D, lower profit margins or higher consumer prices from standard implementers, and/or fewer consumer products or decreased market entry in the mobile wireless industry.

None of these indicators of competitive harm are present in the mobile wireless industry. By all accounts, this standards-intensive industry features high levels of SSO participation and R&D, stable profit margins, falling consumer prices, constant entry and exit, equal and fluctuating market shares, and sustained growth and innovation in products and features.

These developments in the mobile wireless industry have many implications for competition policy. To date, the mobile wireless industry has thrived in the absence of antitrust enforcement against SEPs in the standard-setting process. Since many types of firms contribute to the success of standards-based technologies, products, and services, all should have equivalent opportunities to participate in total returns. In particular, to provide appropriate ongoing incentives for enabling inventions, returns to technology innovators should reflect an appropriate share of the value they contribute to the whole ecosystem.

This review demonstrates that the technology standards in the mobile wireless industry have created enormous value to both producers and consumers. For the most part, a small number of technology innovators have led this development. This Article finds no evidence that the technology innovators impair competition through patent hold-up or by extracting excessive returns.

In the face of the great value and minimal first-order harms of standards to the mobile wireless industry, the antitrust agencies need to present sound economic analysis and empirical evidence before converting any proposed theories of competitive harm into remedies that risk disrupting the dynamic ecosystem of technological innovation.