

SEP ROYALTIES: WHAT THEORY OF VALUE AND DISTRIBUTION SHOULD COURTS APPLY?

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We argue that in adjudicating SEP royalty rates, courts should do what they do in pricing other assets or the flows of income they produce: rely on information from the market about the value of comparable assets or their rental rates. The comparables method is based on price theory, which explains where value comes from and how it is distributed among factors of production, including intellectual property. Courts should not employ the “bottom-up” or “top-down” techniques of royalty apportionment. Both are based on the theory of patent holdup and royalty stacking, which assumes that any observed royalty is the result of “excessive royalties” wrought by the additional monopoly power conferred by standardization. This theory has been shown to be logically inconsistent and logically

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incomplete, and its predictions have been rejected by systematic empirical tests. As a practical matter, the bottom-up technique cannot actually be operationalized. Top-down techniques can be operationalized, but employing them requires a court to reject the implications of price theory.

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Our conclusion is . . . that the accumulation of knowledge is governed by the same economic laws as any other process of capital accumulation. Costs must be incurred if benefits are to be achieved.

- Griliches & Jorgenson²

I. Introduction

Courts are often required to answer an important question: What is the royalty to which the owner of a FRAND-encumbered³ Standard Essential Patent (“SEP”) is entitled?⁴ Courts have been advised by the FTC, the DOJ, the European Commission, and any number of academics and industry consultants that they should rely on either of

² Z. Griliches & D.W. Jorgenson, *The Explanation of Productivity Change*, 34 REV. ECON. STUDS. 249, 274 (1967).

³ FRAND is an acronym for “fair, reasonable, and non-discriminatory.” John Cassels, *What is FRAND?*, FIELDFISHER (Aug. 23, 2013), <https://www.fieldfisher.com/en/insights/what-is-frand#:~:text=FRAND%20is%20the%20acronym%20for,a%20licence%20on%20FRAND%20terms> [https://perma.cc/VB87-PJGJ].

⁴ See Tim Pohlmann, *Industry Report - FRAND Royalty and Mobile Telecoms SEPs – an Analysis of Recent Court Cases*, IAM, <https://www.iam-media.com/frand-royalty-and-mobile-telecoms-seps-analysis-recent-court-cases> [https://perma.cc/3S7P-B4VF].

two methods to determine SEP royalty rates: the “bottom-up” technique, or the “top-down” technique.⁵ These approaches reject the idea that courts should use observed market prices as a guide to valuation, because any observed market price is the result of “excessive royalties” wrought by the additional monopoly power conferred by standardization.⁶ Instead, the court should conduct an accounting exercise designed to estimate the “incremental value” of the SEP prior to its incorporation in a standardized technology.⁷

The central point of this Article is that courts should not heed this advice. Both bottom-up and top-down techniques of apportionment are based on the theory of “patent holdup and royalty stacking.” A sizable literature shows that this theory fails tests for logical consistency, logical completeness, and fit between its predictions and empirical evidence. As Epstein et al. and Sidak have shown, the game theory that underpins patent holdup and royalty stacking implicitly assumes that firms make investments not knowing that they will have to pay patent royalties.⁸ Numerous researchers have also pointed out that no evidence has been offered in support of the theory’s core predictions.⁹

⁵ See U.S. FED. TRADE COMM’N, *THE EVOLVING IP MARKETPLACE: ALIGNING PATENT NOTICE AND REMEDIES WITH COMPETITION* 185-89 (2011); see generally Jorge L. Contreras et al., *The Effect of FRAND Commitments on Patent Remedies*, in *PATENT REMEDIES AND COMPLEX PRODUCTS: TOWARD A GLOBAL CONSENSUS* 160 (C. Bradford Biddle, Jorge L. Contreras, Brian J. Love & Norman V. Siebrasse eds. 2019); Rahuk Vihj, *Understanding Damages Calculation in SEP Litigation*, IP WATCHDOG (Jan. 30, 2021), <https://www.ipwatchdog.com/2021/01/30/understanding-damages-calculation-sep-litigation/id=129501/> [<https://perma.cc/VWE9-F8BH>].

⁶ Anne Layne-Farrar & Koren W. Wong-Ervin, *Methodologies for Calculating FRAND Damages: An Economic and Comparative Analysis of the Case Law from China, the European Union, India, and the United States*, 8 JINDAL GLOBAL L. REV. 127, 129 (2017).

⁷ Gregory K. Leonard & Mario A. Lopez, *Determining RAND Royalty Rates for Standard-Essential Patents*, 29 ANTITRUST, no. 1, 2014, at 86, 88.

⁸ Richard A. Epstein, F. Scott Kief, & Daniel F. Spulber., *The FTC, IP, and SSOS: Government Hold-Up Replacing Private Coordination*, 8 J. COMPETITION L. & ECON. 1, 8-9 (2012); J. Gregory Sidak, *Apportionment, FRAND Royalties, and Comparable Licenses After Ericsson v. D-Link*, 2016 ILL. L. REV. 1809, 1833 (2016) [hereinafter Sidak, *Apportionment, FRAND Royalties, and Comparable Licenses*].

⁹ See, e.g., Vincenzo Denicolo et al., *Revisiting Injunctive Relief: Interpreting eBay in High-Tech Industries with Non-Practicing Patent Holders*, 4 J. COMPETITION L & ECON. 571 (2008); Edward J. Egan & David J. Teece, *Untangling the Patent Thicket Literature* 17 (Tusher Ctr. for Mgmt. of Intell. Cap. Working Paper, 2015), <https://hdl.handle.net/1911/92003> [<https://perma.cc/77NG,-XBYN>]; Epstein et al., *supra* note 8, at 13; Alexander Galetovic & Kirti Gupta, *The Case of the Missing Royalty Stacking in the World Mobile Wireless Industry*,

In fact, empirical evidence from industries that should be canonical cases of patent holdup and royalty stacking display outcomes that are completely at variance with the predictions of the theory.¹⁰

The core assumption of both bottom-up and top-down methods of royalty setting—that SEP holders are earning excessive royalties based on the market power conferred by being part of an industry standard—is simply an assumption of patent holdup and royalty stacking theory, not a fact that has ever been empirically established. On the contrary, when researchers examine the evidence, they find that SEP holders earn revenues inconsistent with the claim that they exercise market power.¹¹

Flawed theories generate errors when applied in real world situations. Bottom-up technique holds that courts should value SEPs as the incremental value of the patented technology compared with its next-best alternative (which was discarded) at the time that the SEP became

29 INDUS. & CORP. CHANGE 827, 828 (2020); Damien Geradin & Miguel Rato, *Can Standard-Setting Lead to Exploitative Abuse? A Dissonant View on Patent Hold-Up, Royalty Stacking and the Meaning of FRAND* 3 Eur. Competition J. 101, 107 (2007); Damien Geradin et al., *The Complements Problem within Standard Setting: Assessing the Evidence on Royalty Stacking*, 14 ALB. L. J. OF SCI. & TECH. 1, 2 (2008); Kirti Gupta, *The Patent Policy Debate in the High-Tech World: A Literature Review*, 9 J. COMPETITION L. & ECON. 827, 827 (2013); Anne Layne-Farrar, *Patent Holdup and Royalty Stacking Theory and Evidence: Where Do WE Stand After 15 Years of History?*, ORG. FOR ECON. COOP. & DEV. COMPETITION COMM., Dec. 2014, at 2, <https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=DAF/COMP/WD%282014%2984&doclanguage=en>; J. Gregory Sidak, *Tournaments and FRAND Royalties*, 1 CRITERION J. ON INNOVATION 101, 104 (2016); Jonathan M. Barnett, *Has the Academy Led Patent Law Astray?*, 32 BERKLEY TECH. L.J. 1313, 1313 (2018); Bowman Heiden & Nicolas Petit, *Patent “Trespass” and the Royalty Gap: Exploring the Nature and Impact of Patent Holdout*, 34 SANTA CLARA HIGH TECH. L.J. 179, 209 (2018).

¹⁰ Alexander Galetovic et al., *An Empirical Examination of Patent Hold-Up 2* (Nat’l Bureau of Econ. Rsch., Working Paper No. 21090, 2015), https://www.nber.org/system/files/working_papers/w21090/w21090.pdf; Alexander Galetovic & Stephen Haber, *The Fallacies of Patent-Holdup Theory*, 13 J. COMPETITION L. & ECON. 1, 1 (2017); Alexander Galetovic et al., *Is There an Anticommons Tragedy in the World Smartphone Industry?*, 32 BERKLEY TECH. L.J. 1527, 1527 (2019) [hereinafter Galetovic et al., *Anticommons Tragedy*]; Galetovic & Gupta, *supra* note 9, at 827.

¹¹ Galetovic et al., *Anticommons Tragedy*, *supra* note 10; Galetovic & Gupta, *supra* note 9, at 827.

part of an industry standard.¹² The technique cannot be operationalized: It requires that practitioners be able to identify, and know the market price of, a technology that was nearly identical to the technology adopted but that never came into existence because it was discarded.¹³ As a practical matter, it is not possible to know the price of something that did not exist.¹⁴

Top-down apportionment is an attempt to solve this problem in operationalizing the bottom-up technique, but it requires a court to make a series of arbitrary decisions that have no theoretical underpinning. The top-down technique requires that a court determine the aggregate royalty that it believes should be earned by an entire suite of SEPs, and then use an algorithm to apportion the fraction of that aggregate royalty that it believes should be earned by the litigated patents.¹⁵ There exists no reliable method to estimate either value—unless the court were to accept the observed market prices of the SEPs in question, rather than the prices that it believes should be earned as a normative matter. We will explore this point below, but the basic issue is that such apportionment exercises require courts to violate a key concept in price theory—the standard theory of value and distribution in mainstream economics—which holds that the value earned in any particular stage of a production chain is not independent of, and not separable from, the value produced across the entire production chain.

Ultimately, our main point is that in adjudicating the value of SEPs, courts should do what they do in pricing other classes of assets or the flows of income they produce: rely on information from the market about the value of comparable assets or their rental rates. The logic for

¹² See Layne-Farrar & Wong-Ervin, *supra* note 6, at 150; Leonard & Lopez, *supra* note 7 at 88.

¹³ See Layne-Farrar & Wong-Ervin, *supra* note 6, at 150-51.

¹⁴ J. Gregory Sidak, *Misconceptions Concerning the Use of Hedonic Prices to Determine FRAND or RAND Royalties for Standard-Essential Patents*, 4 CRITERION J. ON INNOVATION 501, 504 (2016) (Sidak points out that the incremental value approach is not based on observable data and is ultimately a speculation, which renders it inadmissible as evidence in front of a court); *id.* at 505 (according to Sidak, as of August 2019 no court has used the ex-ante incremental value approach to calculate a FRAND royalty or determine whether an offer was FRAND).

¹⁵ Leonard & Lopez, *supra* note 7, at 89.

doing so is that a royalty is simply the rental price of an asset created by investments in research and development (“R&D”). It is no different from other assets that courts value by inquiring about their market price, such as real estate, inventories, art collections, music catalogues, or personal business assets. In short, they should inquire about the observed royalty base and rate charged in the market by a SEP licensor to a different licensee, or by other similar licensors, and make adjustments to account for differences in circumstance, such as the timing of the license. This comparables technique of valuation, unlike bottom-up and top-down, is based on price theory.

An approach based on price theory confers an additional advantage: It allows a court to distinguish between the observed royalty rates that emerge from a competitive market and those that emerge from a monopolized market. It is therefore a necessary step for courts to employ when assessing claims by a plaintiff that a particular SEP holder is exercising monopoly power.

This Article proceeds as follows. In Part II we explain the fundamentals of price theory. We realize that price theory is a basic building block of microeconomics. The fact that antitrust authorities and the experts upon whom courts rely often ignore price theory requires, unfortunately, that we return to the basics. We illustrate the power of price theory by examining a canonical SEP licensing industry: smartphones. In Part III we explore the bottom-up approach to royalty setting. We explain why it is based on a flawed theory, why it cannot be operationalized as a practical matter, and why its application would lead courts to up-end virtually any market where there is a standard, including those where a single firm is the de-facto standard. In Part IV we turn to the top-down technique, and its Smallest Saleable Patent Practicing Unit (“SSPPU”) variant. We show that it is not only based on the same flawed theory as bottom-up approaches, but that attempts to operationalize it require courts to accept an expert’s claim that he or she knows how changes in the price of any input will affect the prices charged, and the quantities produced, by all other firms in the production chain. Given that it is a precept of price theory that production systems work in spite of the fact that no

single agent needs to have—or can have—this knowledge,¹⁶ courts should be wary of accepting such claims. Part V concludes.

II. The Comparables Technique

The comparables technique starts from the premise that observed royalties are the market rental price of assets, in this case the SEPs.¹⁷ These market rates can be used to value similar transactions. That is, if implementers A, B, and C pay on average a royalty of x percent for using the SEPs of firm Z, implementer D in the same market should either pay a similar royalty; or some royalty that departs from the average for observable market reasons.¹⁸

A. Price Theory: A Theory of Value and Distribution

The comparables technique is the method used by courts and experts to value virtually all classes of assets and determine their rental rates,¹⁹ and they use this technique because it is based on price theory. Price theory answers two key questions: 1) where does value come from and 2) how is value distributed among inputs in a production chain? Price theory shows that the market price is equal to the value created by the entire production chain at the margin. This is true whether the good or service is a pound of steak, a gallon of gas, or a personal computer. Price theory also shows that the total revenues of the producers of final goods in a market are distributed among input suppliers on the basis of the value their input adds to total revenues at the margin. Thus, the

¹⁶ See F. A. Hayek, *The Use of Knowledge in Society*, 35 AM. ECON. REV. 519, 526 (1945).

¹⁷ See Sidak, *Appportionment, FRAND Royalties, and Comparable Licenses*, *supra* note 8, at 1821.

¹⁸ An example will clarify what we mean by “observable market reasons.” Consider the market for natural gas. In an exporting country, the market price of natural gas at the head of the pipeline tends to be about \$4 less per million BTUs than the fob price of natural gas on a ship that will carry it overseas. This is because natural gas must be cooled and liquefied before it can be stored on a ship, and this process costs about \$4 per million BTUs. See Kenneth Engblom, *Cost of Natural Gas & LNG Logistics*, LINKEDIN (Mar. 19, 2017), <https://www.linkedin.com/pulse/cost-natural-gas-lng-logistics-kenneth-engblom/> [https://perma.cc/AVD5-CXRF].

¹⁹ See, e.g., *How to Determine Fair Rental Value*, CLERGY FIN. RES., <https://www.clergytaxnet.com/resources/knowledgecenter/how-to-determine-fair-rental-value/> [https://perma.cc/JJ6Z-HAVJ].

sum of payments made to input suppliers, including those supplied by the firm at the end of the production chain, exhausts the revenues earned by the sales of the final product. One important implication is that the total value that can be distributed among the input suppliers, including the firm at the end of the production chain, is bounded by consumers' willingness to pay, as reflected by the demand curve for that particular product.

A simple supply and demand graph based on the market for smartphones shows why all value stems from consumers' willingness to pay and how that value is distributed among input providers. Figure 1 shows a diagram of the observed equilibrium in the smartphone market in 2016. For simplicity, we parameterize a linear demand curve with market data, and assume that all consumers paid the average selling price of a smartphone.²⁰

²⁰ To draw the intercept of the linear demand curve on the price axis we used the fact that 2G phones, which were considerably inferior devices compared with a 2016 smartphone, were introduced at \$1,400 in 1992. Indeed, when 2G phones were introduced they lacked data service beyond SMS and could not send emails. Data services were not introduced until years later. See Galetovic et al., *Anticommons Tragedy*, *supra* note 10, at 1548. In practice, different consumers pay different prices for different models and brands. However, because they are free to choose among them, in equilibrium marginal consumers are indifferent and a quality-adjusted standard phone can be built by estimating the differential value of the characteristics of each phone.

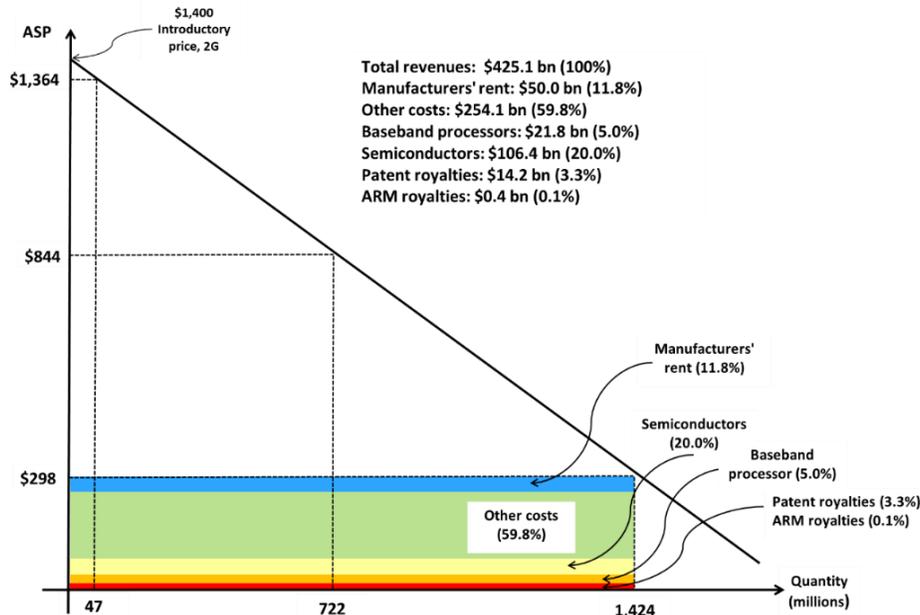


Figure 1: Value and distribution in the smartphone production chain, 2016

As can be seen in Figure 1, in 2016 phone manufacturers sold 1.42 billion smartphones for \$425.1 billion, at an average selling price of \$298.²¹ Because consumers are free to buy a phone or not, the demand curve shows how much consumers value a smartphone at the margin. That is, \$298 represents how much the least willing consumer in 2016 was willing to pay for a smartphone. Figure 1 also shows that most consumers valued their phones at more than \$298 and obtained a net surplus when they bought a phone: the difference between their willingness to pay, as shown by the demand curve, and the market price. It follows that the total consumer surplus was equal to the area between the demand curve and the market price for phones. According

²¹ The August 2017 update of the database showing the sources and calculations in detail is available in an Excel workbook, which is available at <https://data.mendeley.com/datasets/z4nyyf867h/1>. See also Alexander Galetovic et al., *An Estimate of the Average Cumulative Royalty Yield in the World Mobile Phone Industry: Theory, Measurement and Results*, 42 TELECOMM. POL'Y 263, 266 (2018) (discussing the database and its construction) [hereinafter Galetovic et al., *Estimate of the Average Cumulative Royalty*].

to the demand curve depicted in Figure 1, consumer surplus in 2016 was equal to \$784 billion.²²

As Figure 1 also shows, the revenues generated by the sale of smartphones were distributed among phone manufacturers and input suppliers. Roughly 20% of the revenue from smartphone sales reached semiconductor manufacturers (\$85 billion; \$60 per smartphone, on average), 5% reached the manufacturers of baseband processors (\$22 billion; \$15 per smartphone, on average); and 60% of the revenues (\$254.1 billion; \$178 per smartphone, on average) reached the producers of other inputs, such as the firms that made the cameras, Gorilla Glass, and housings, as well as the firms, such as Foxconn, that actually assembled the phones. Roughly 12% (\$50 billion; or \$35 per smartphone) reached the firms that sold the phones as profits, most of which accrued to Apple.

Figure 1 also shows that just over 3% of the revenue generated by the smartphone market reached the owners of patents (\$14.2 billion, or roughly \$10 per smartphone). Most (\$12.4 billion) was earned by SEP owners. The remainder was earned by the owners of other patents, some non-SEP, such as Microsoft (which earns royalties mainly on the patents on its Windows Phone OS), the patent pools that license audio and video codecs, and the patent assertion entities that own the patents necessary to manufacture semiconductors.

On what basis were the \$425.1 billion in revenues from the sale of smartphones in 2016 distributed among the inputs along the production chain? The key is that all the firms in the production chain substituted away from more expensive inputs toward less expensive inputs. Thus, firms at the end of the production chain, which designed and marketed the phones (e.g., Samsung and Apple), combined inputs from many suppliers to minimize costs in order to produce the smartphones that consumers valued. Similarly, the firms that produced the intermediate inputs and intellectual property for those smartphones

²² This was equal to about 1% of world GDP. See *Global GDP This Year*, WORLDOMETER, <https://www.worldometers.info/gdp/#gdpyear> [<https://perma.cc/E3GV-RS23>] (listing global GDP by year and noting global GDP in 2016 was \$77,796,772,093,915).

(e.g., Corning, and Ericsson) also combined inputs from many suppliers to minimize costs. Those suppliers, in turn, purchased the necessary inputs from firms even further down the production chain, and so on. Each input in the production chain had its own demand curve. That is, the demand curve its producer faced was derived from the demand for smartphones, and the elasticities of each demand curve depended in part on the possibilities for substituting away from that input. Consequently, firms along the production chain equalized the value created by each input at the margin with the input's market price.

The share of each input in the \$425.1 billion in revenues in the smartphone market, therefore, was the equilibrium outcome of a complex process of cost minimization and profit maximization. Because the output of an upstream firm is the input of firms further downstream, and all value stems ultimately from consumers' willingness to pay, no stage of the production chain is independent of, and separable from, the others—prices are determined simultaneously in all of them.

What does price theory tell us about how to value the intellectual property necessary to produce a smartphone? The royalty is the rental price of intellectual property and is a function of the value that consumers were willing to pay for the capabilities created by those patented technologies, at the margin, and the possibilities that producers had to substitute away from using those intellectual property assets toward alternative technologies. To be concrete, the finding that the patent holders earned just over 3% of the value of the average smartphone in 2016 has two complementary interpretations. First, the purchaser with the lowest willingness to pay for the average smartphone valued those technologies at the equivalent of just over 3% of the price she paid for her smartphone. Second, there must have been alternative technologies that producers could eventually substitute toward. Had there not been, then the owners of the intellectual property would have operated as if monopolists and charged far more than 3% of the value of a phone, a point that we return to below.

We should note that the point of price theory is not to determine the “right” price for any final good or any input. Rather, price theory is an explanation of the process whereby equilibrium-relative prices for products and inputs emerge out of the complex adaptive system that economists call a market economy. It explains the systematic link between consumer tastes and costs of production. Consequently, price theory is a rich generator of testable implications that can be falsified with data—such as, is the market for a particular input a monopoly—but it is not a blueprint to build a machine to calculate prices and dictate the resource allocation that should emerge in a particular situation.

Price theory is not a blueprint to build a price-computing machine because no individual agent in the market—neither a consumer nor any particular producer at any particular point in the production chain—knows the entire production chain, the structure of demand, or the myriad non-linear feedback loops within the production chain (e.g., how price signals from a firm further up the production chain affect the decisions of firms further down the production chain) that would be necessary to calculate the “right” market prices.²³ This does not mean that individual agents in the market act blindly. It means that they make decisions by looking at prices. These price signals aggregate information about value and costs at other points in the production chain.²⁴ It is precisely because prices aggregate information that a consumer does not need to know the price of DRAM chips in order to determine whether she is paying the market price for a laptop computer, and the producer of the DRAM chips does not need to know

²³ Caroline Banton, *Theory of Price*, INVESTOPEDIA (Nov. 28, 2020), <https://www.investopedia.com/terms/t/theory-of-price.asp#:~:text=Key%20Takeaways-,The%20theory%20of%20price%20is%20an%20economic%20theory%20that%20states,reasonably%20consumed%20by%20potential%20customers> [https://perma.cc/4SBR-F8TF]; Kenneth J. Arrow, *Workshop on the Economy as an Evolving Complex System: Summary*, in *THE ECONOMY AS AN EVOLVING COMPLEX SYSTEM* 277-78 (Philip W. Anderson et al. eds., 1988) (providing a simple example to illustrate both positive and negative feedbacks in a decentralized market) (“[C]onsider a world with just two commodities, bread and butter. At the initial prices, suppose that the demand for bread exceeds the supply, while the supply of butter exceeds the demand for it. The price of bread rises, while the price of butter falls. But the demand for bread certainly increases when the price of butter falls, and it can happen that the net effect is to increase the demand for bread, thereby amplifying the initial deviation”).

²⁴ See Hayek, *supra* note 16, at 530.

the price of the chemicals necessary to make the liquid crystals in the laptop's LCD display. No agent needs to know the details of—or even can know the details of—every stage of production, the feedback loops among them, and how those feedbacks operate to meet consumer demand and distribute the value it creates. No calculation can expect to replicate it, precisely because a market economizes information.

B. Economic Rent and the Distribution of Value Across the Stages of the Production Chain

When total revenues in the production chain exceed total input costs in equilibrium, some producers along the production chain earn an economic rent.²⁵ One source of economic rent is monopoly and, more generally, market power—the owner of the input can increase its market price by restricting the quantity it sells in the market without inducing substantial substitution or market entry. Such monopoly rents are the primary concern of antitrust authorities. Another source of economic rent is scarcity: The market price of an input exceeds that input's opportunity cost because the total quantity of the input is fixed.²⁶ For example, during the first round of the expansion of the solar panel industry the price of the main input—polysilicon—increased ten-fold.²⁷ Until new producers of polysilicon entered the market, existing producers obtained a scarcity rent. Finally, there are Ricardian rents, which remunerate differential productivity: The ability to produce more revenue per dollar of input than the least productive producer in the market.²⁸

Scarcity rents and Ricardian rents are unrelated to market power.²⁹ In the smartphone example, the rent earned by smartphone manufacturers (roughly 12% of all phone revenues) mostly stems from the fact that

²⁵ On the types of rent, see Roger G. Noll, “Buyer Power” and Economic Policy, 72 ANTITRUST L.J. 589, 592-94 (2005).

²⁶ Margaret Sanderson & Ralph A. Winter, “Profits” Versus “Rents” in Antitrust Analysis: An Application to the Canadian Waste Services Merger, 70 ANTITRUST L. J. 485, 498 (2002).

²⁷ Polysilicon Price Trend: What is Driving the Roller-Coaster Ride of the Polysilicon Price?, BERNREUTER RES. (Mar. 3, 2021), <https://www.bernreuter.com/polysilicon/price-trend/> [https://perma.cc/95A3-5FRH].

²⁸ Sanderson & Winter, *supra* note 26, at 495; Noll, *supra* note 25, at 593.

²⁹ Sanderson & Winter, *supra* note 26, at 486; Noll, *supra* note 25, at 593.

one of them—Apple—is able to sell iPhones at about three times the price charged by other manufacturers, while its production costs are only twice as high.³⁰ Consumers value iPhones more than other phones, and thus Apple obtains more revenue per dollar of input than its competitors.³¹ That additional revenue per dollar of inputs is a Ricardian rent.

Regardless of the origins of the rents, the total revenues of an industry are equal to the sum of the payments to the inputs plus economic rent.³² This point is also a fundamental insight from price theory: In equilibrium, the rents earned by any firm, whatever their origin and wherever their location in the production chain, are bounded by the payments to other inputs and the willingness of consumers to pay for the final product.

One should stress that the division of the revenues of a production chain is an equilibrium outcome of a complex process involving multiple firms, some of which earn rents, and consumers who determine the value of the final product. Thus, any attempt by an expert to apportion value to any input—including a patented technology—must take into account consumer demand for the *final* product, the payments to *all* inputs across the entire production chain (not simply at one stage of the production chain), and the rents earned by all the firms in the production chain, including the implementer that sells the final product into the consumer market. It follows that revenues at any particular stage of a production chain are not a fixed pie that may be apportioned by a court without affecting both the rest of the production chain and the consumers of the final good. Any valuation method based on the premise that any stage of a production chain is independent of and separable from the others has no basis in economic theory.

³⁰ See Rachel Brown, *The Cost of Making an iPhone*, INVESTOPEDIA (Mar. 27, 2020), <https://www.investopedia.com/financial-edge/0912/the-cost-of-making-an-iphone.aspx> [<https://perma.cc/U3T7-FTPS>]; J. Gregory Sidak & Jeremy O. Skog, *Hedonic Prices for Multicomponent Products*, 4 CRITERION J. ON INNOVATION 301, 329 (2019) (estimating that Apple's brand adds between \$240 and \$300 to each phone, beyond the difference in functionality).

³¹ See Brown, *supra* note 30.

³² See generally GEORGE STIGLER, *THEORY OF PRICE* (4th ed. 1987).

Permit us to illustrate these facts by returning to the example of the smartphone industry. The source and limit of all surplus in the smartphone production chain is the value that consumers assign to the things that they can do with a smartphone; neither the technologies that make smartphones work nor the components used to manufacture them are valuable by themselves. On the contrary, they have value only because smartphones do things that consumers value, and smartphones cannot do those things without the technologies or the components that make them work. It follows that the royalties earned by the owners of the SEPs necessary to make smartphones work, *regardless of where they are earned in the production chain*, are capped by the difference between the willingness to pay of consumers for a smartphone and all the other costs of producing a smartphone across the entire production chain.³³ As can be seen in Figure 1, in 2016 the equilibrium outcome of this process was that patent owners, including those who owned SEPs and those who owned non-SEPs, received 3.3% of all revenues in the smartphone market.

C. Price Theory and Monopoly Power

A fundamental insight of price theory is that monopoly power is exploited by restraining output to raise the market price.³⁴ The key difference between a monopolist and a firm operating in a competitive market is that the monopolist can raise the price by reducing output.³⁵ Both the monopolist and the firm operating in a competitive market produce to the point that their marginal revenue equals their long run marginal cost, but from the point of view of the monopolist the demand curve is downward sloping (as it restrains output, the price rises), while from the point of a firm in a competitive market the demand curve is flat (as it restrains output, the price stays the same).

³³ Sidak & Skog, *supra* note 30, at 603.

³⁴ Thomas G. Krattenmaker et al., *Monopoly Power and Market Power in Antitrust Law*, 76 GEO. L.J. 241, 249 (1987). This can be called Stiglerian market power; market power can also be exploited by increasing rivals' costs—Bainian market power.

³⁵ *See id.* at 256.

A direct test for the existence of a monopoly is therefore to look at the prices charged by a firm: If any one of the firms that owns the patented technologies in your laptop, tablet, or smartphone is a monopolist, the royalty paid by the manufacturer to the patent owner would reflect that monopoly power, and it would be passed along to you by the manufacturer. Plainly put, laptops, tablets, and smartphones would be priced much in the same way as movie theater popcorn.

Price theory provides a technique to determine whether a firm in the market is exercising monopoly power: the famous Lerner formula.³⁶ Thus, if c is the long-run marginal cost of manufacturing, P is the price of the good, and η is the elasticity of demand, a monopolist will price so that profit margins will equal the inverse of the elasticity of demand.

More formally:

$$\frac{P - c}{P} = \frac{1}{\eta}$$

The Lerner formula condenses information about the entire production chain (in c), the demand for the final good (in the price elasticity η), and the equilibrium profit margin. It is deceptively simple for this reason, and many of its implications, both theoretical and practical, are often overlooked.

To see why, let us begin by discussing c , the long run marginal cost of production, which includes the long run normal rate of return on capital. As we have seen, the long-run marginal cost of producing a good is equal to the sum of payments made to all inputs across the entire production chain. It follows that it is not necessary to produce the final good to exploit monopoly power. On the contrary, any provider of an input for which there is no substitute and that is used in

³⁶ See A. P. Lerner, *The Concept of Monopoly and the Measurement of Monopoly Power*, 1 REV. ECON. STUD. 157 (1934); cf. Roger G. Noll, *supra* note 25, at 589.

fixed proportions to produce a final good in any part of the production chain can exploit final consumers by raising the price of the input.³⁷

Next, let us consider η , the price elasticity of the demand for the final good. The Lerner formula says that the less elastic the demand for the final good, the larger the profit margin. It is sometimes overlooked, however, that if any agent in the production chain exercises monopoly power, then the monopoly rents transferred from consumers to producers will be rather large. To illustrate, let us assume that the elasticity of demand for a final good is 2 (meaning a 1% increase in price causes the quantity demanded by consumers to fall by 2%), and some firm in the production chain operates as a monopolist. The monopoly margin would be 50% of the final price paid by consumers and all of it would accrue to the firm operating the monopoly, regardless of where it is in the production chain.³⁸ Thus, firms that enjoy monopoly power are very profitable, and cannot be difficult to spot.

Let us apply this reasoning to the example of the smartphone market and inquire as to whether the patent holders act as a monopoly. Figure 2 shows the same demand curve as Figure 1, but it assumes that patent holders act as a single profit-maximizing monopolist and uses the Lerner formula to see what will happen to patent royalty rates, the total output of smartphones, the average selling price of a smartphone, and the share of revenues earned by other input producers.

³⁷ See, e.g., Joseph J. Spengler, *Vertical Integration and Antitrust Policy*, 58 J. POL. ECON. 347, 352 (1950); JEAN TIROLE, *THE THEORY OF INDUSTRIAL ORGANIZATION* 174 (1988).

³⁸ As a practical matter, production chains that include a monopolist produce even greater monopoly rents than our illustration here, because the elasticity of demand for final goods are usually found by empirical studies to be close to 1 (a 1% increase in price produces a 1% decline the quantity demanded by consumers). See Richard Blundell, *Consumer Behaviour: Theory and Empirical Evidence*, 98 ECON. J. 16, 35 (1988) (stating price and income elasticities of consumer products including: food, 0.494; fuel, 0.747; clothing, 0.852; transport, 0.674; services, 0.767; and alcohol, 1.983).

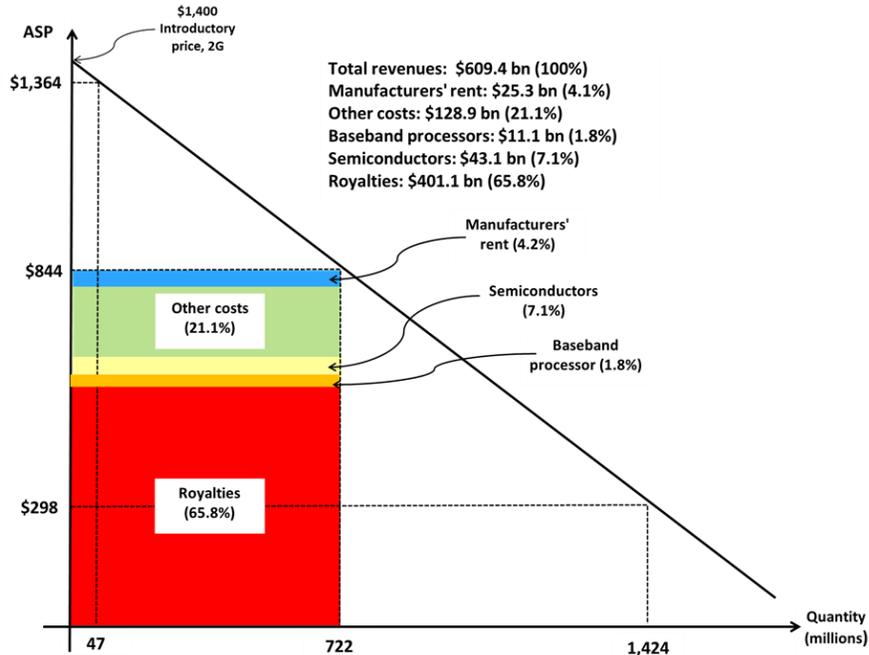


Figure 2: Value and distribution with a hypothetical patent monopoly in the smartphone production chain, 2016.

Figure 2 shows that instead of earning 3.3% of all smartphone revenues, the patent holders acting as a single monopolist would have earned 66% of the revenues. Those higher royalties would have driven up the average selling price of a smartphone from \$298 to \$844. As a consequence, the firms that design and market smartphones would have sold only 722 million units, instead of 1.42 billion. Even with the decline in unit sales, however, the higher prices would have pushed up total industry revenues from \$425.1 billion to \$609.4 billion. Because the origin of the higher market price would have been the exploitation of monopoly power by the patent holders, more than two-thirds of those revenues (about \$400 billion) would have been pure economic rent accruing to the patent holders—revenues that exceeded the long run cost of the inputs used to produce the patented technologies. The

profits of patent licensors would have been very large, of the order of 0.5% world GDP!³⁹

Once the price changes, the distribution of revenues and rents across the entire production chain would have to adjust radically to account for the fact that the patent holders are able to act as monopolists, taking two-thirds of all revenues. Everyone up and down the production chain is forced to adjust prices and output. Our rough estimates indicate that the revenues of semiconductor manufacturers would have fallen from \$85 billion to \$43 billion, and their share of total smartphone revenues would have decreased from roughly 20% to about 7%. Similarly, the revenues of the manufacturers of baseband processors would have fallen from \$22 billion to \$11 billion, and their share of total smartphone revenues would have decreased from roughly 5% to less than 2%. The revenues of the manufacturers of other inputs and the firms that assemble smartphones would have fallen from \$254 billion to \$123 billion, and their share of total smartphone revenues would have decreased from roughly 60% to about 21%. The profit margins of the firms that design and market smartphones would have fallen from roughly \$50 billion to about \$25 billion, and their share of total smartphone revenues would have fallen from 12% to about 4%.⁴⁰

³⁹ See *Gross Domestic Product (GDP)*, WORLDOMETER

<https://www.worldometers.info/gdp/#gdpyear> [<https://perma.cc/W5L6-LD8C>] (listing global GDP by year and noting global GDP in 2016 was an inflation-adjusted \$77,796,772,093,915).

⁴⁰ One might object to such an empirical test by claiming that the situation in SEP-intensive industries is complicated by royalty stacking (the existence of multiple SEP holders, each exercising monopoly power independently). No single SEP holder will be able to charge as if a monopolist, because her royalties are bounded by those imposed by other monopolists. Nevertheless, the same techniques that allow a researcher to identify whether a SEP holder is operating as a monopolist also allow her to test the hypothesis of royalty stacking by simply multiplying the single monopoly margin by the number of firms in the industry over the elasticity of demand. As a practical matter, with each additional firm in the royalty stack the total revenues of the patent holders increases, but the share of those revenues per monopolist falls. See Galetovic & Gupta, *supra* note 9, at 827; cf. Galetovic et. al., *Anticommons Tragedy*, *supra* note 10, at 1532 (estimating that the 29 patent licensors in the smartphone industry would have charged a combined royalty of 79.5% if each of them had acted as a monopolist).

This simple illustration has an important implication for courts. The application of tools from price theory indicates that SEP holders in the smartphone production chain do not act as monopolists. Our calculations are admittedly rough, but the difference between an observed royalty rate of roughly 3% and a predicted monopoly royalty rate of 66% is non-trivial, to say the least. A court being asked to determine a FRAND royalty in this industry would not be advised to start from the assumption that the observed market prices reflect monopoly power, and thus that some apportionment method other than comparables needs to be employed. Prior to accepting bottom-up or top-down apportionment calculations from an expert, a court would be advised to inquire as to whether the expert had estimated a demand curve for the industry, calculated the actual average royalty rate earned by all SEP holders, and compared that royalty rate to the one predicted by the Lerner formula. We are well aware that courts have seldom, if ever, asked infringers to estimate the royalty that a monopoly patent holder would charge and compare it with actual royalties charged. This underlines the disconnect between current practice by courts in setting SEP rates and standard economics.

D. Royalties and Licensing Markets

In a market economy, firms operate with the expectation that they will make a profit. They therefore make investments in R&D with the expectation that they will be able to appropriate part of the value of the technologies they create. Indeed, the incentive to develop new technology, or to invest in the commercialization of that technology, largely evaporates without a property right that allows the firm to appropriate that technology's value.⁴¹ As Griliches and Jorgenson pointed out, "the accumulation of knowledge is governed by the same economic laws as any other process of capital accumulation."⁴² A patented technology is therefore just like any other type of capital

⁴¹ There are other mechanisms by which a firm may appropriate the value of its R&D, such as political lobbying for restrictions on entry that might allow it to earn a market power rent.

⁴² Jorgenson & Griliches, *supra* note 2.

asset: Its value accrues over time, and depreciates over time.⁴³ And its value is determined by the possibility of substituting it at the margin.

As with any other capital asset, the owners of intellectual property will either use it directly or rent it in the market. In some cases, the owner of the patented technology will directly exploit it by producing a better input or a better final product. In those cases, no direct rental price for intellectual property will be observable; the rental price of the intellectual property asset will be implicit—that is, baked into the price of the physical product manufactured by the firm. In other cases, the owner of a patented technology will license it to others in exchange for a royalty, letting them produce the physical product. The market price for the intellectual property will be observable as the licensing royalty.⁴⁴

It follows that in an industry where specialized firms produce and license patented technologies to other firms in the production chain, royalties are the rental market price of an intellectual property asset.⁴⁵ As with any input, the equilibrium rental price of a given intellectual property asset is determined by the intersection of the derived demand for it and its supply. That derived demand is a product of two forces: the demand for the goods produced with the input, which consumers value, and the possibilities for other firms in the production chain to

⁴³ See, e.g., Alicia Tuovila, *Capital Asset*, INVESTOPEDIA (Nov. 12, 2020)

<https://www.investopedia.com/terms/c/capitalasset.asp> [<https://perma.cc/8WYW-RKGB>].

⁴⁴ STEPHEN JOHNSON, *GUIDE TO INTELLECTUAL PROPERTY* 198 (2015) (“A royalty is simply a payment of a fixed fee per item sold (\$5 per television set), or a percentage of the licensee’s list price for each item, or a percentage of the licensee’s receipts from sales”); see also *Meaning of Royalty in Oxfordify Dictionary*, OXFORDIFY, <https://www.oxfordify.com/meaning/royalty> [<https://perma.cc/WV8H-NFUB>] (“[A royalty is a] sum paid to a patentee for the use of a patent or to an author or composer for each copy of a book.”).

⁴⁵ Estimating the value of the services rendered by a technology at the margin is not straightforward when the user is also the supplier and owner of the intellectual property. As Jorgenson and Griliches point out, however, the same difficulty occurs when the user of a piece of physical capital is the same firm that invested in that piece of physical capital. Jorgenson & Griliches, *supra* note 2, at 275. When a particular piece of capital can be rented in a market, the market rental price is the accurate value at the margin of the services rendered by that piece of capital.

substitute away from it.⁴⁶ The substitutes may include different physical inputs or different intellectual property. In short, the rental price of intellectual property—the royalty—is the value assigned to it by the market at the margin.

Whether that rental market price reflects any monopoly power of the patent owner depends on substitution possibilities at the margin, not on the mere existence of an intellectual property right. At one extreme, the technology may be a unique way to achieve a given functionality, as is the case when a patented pharmaceutical is the only cure for a particular disease. In that case, the owner of the intellectual property is in the position to earn a monopoly rent, at least until a substitute, non-infringing pharmaceutical is developed, or the patent expires. Importantly, the source of the monopoly rent in that case is not the property right, but the absence of substitutes.⁴⁷

At the other extreme, the patented technology may compete with many alternatives. In that case, the premium that the owner of the patent earns is determined by the differential improvement of her technology over the alternatives. In both cases, however, value and its distribution will be determined by the same forces that determine value and its distribution in any market. It depends fully on substitution possibilities at the margin across alternative technologies. As price theory shows, whether a firm can exert monopoly power or faces substitutes for its technology can be empirically assessed by comparing actual royalties against those a monopolist would charge; no other test is needed.

⁴⁶ The rules governing derived demand have been known since Alfred Marshall's *Principles of Economics*. For a formal treatment see M. Bronfenbrenner, *Notes on the Elasticity of Derived Demand*, 13 OXFORD ECON. PAPERS 254 (1961); see also STIGLER, *supra* note 32; J. K. Whitaker, *Derived Demand*, in 2 THE NEW PALGRAVE DICTIONARY OF ECONOMICS 1345 (Steven N. Durlauf & Lawrence E. Blume eds., 2008).

⁴⁷ For example, when several patented pharmaceuticals compete in providing treatment to any given disease, the owners of those patents are not in a position to earn a monopoly rent.

E. How Can Courts Tell When There Is a Functioning Licensing Market?

How can courts determine whether there is in fact a functioning licensing market? Let us again return to the example of the smartphone industry. One hallmark of a functioning market is that there is a set of market-specific practices according to which firms behave. In the smartphone market, several licensing practices are well established.⁴⁸ To begin with, licensors and licensees typically negotiate royalties for portfolios of patents.⁴⁹ They do not write separate contracts for each patent.⁵⁰ In addition, the royalty is assessed on the average selling price of each phone.⁵¹ Blecker, Sanchez, and Stasik report, in fact, that holders of large patent portfolios have routinely licensed their entire portfolio for a single running royalty.⁵² Implementers and patent licensors also routinely grant each other cross licenses, which are less important than in other industries, because most licensors in the smartphone production chain are not downstream implementers.⁵³

A second indicator that a functioning licensing market exists for smartphone technologies is vertical separation along the production chain. There are numerous firms that specialize in developing and licensing the necessary technologies who do not manufacture smartphones. Ericsson and Nokia used to be handset manufacturers; as is well known, they are no longer in that business. Qualcomm has never been a significant phone manufacturer.⁵⁴ InterDigital never

⁴⁸ See generally Marvin Blecker et al., *An Experience-Based Look at the Licensing Practices That Drive the Cellular Communications Industry: Whole Portfolio/Whole Device Licensing*, 4 LES NOUVELLES – J. LICENSING EXECS. SOC'Y 221 (2016) (describing the history and evolution of licensing practices in the mobile phone industry); JOHNSON, *supra* note 44 (describing treatment of licensing practices); GREGORY J. BATTERSBY & CHARLES W. GRIMES, *LICENSING ROYALTY RATES* (2017 ed.) (describing treatment of licensing practices).

⁴⁹ See Blecker et al., *supra* note 48.

⁵⁰ *Id.*

⁵¹ The royalty may sometimes also include a lump sum payment. See, e.g., *id.* at 230.

⁵² *Id.* at 225-26.

⁵³ *Id.* at 227-28.

⁵⁴ Qualcomm deployed a full-fledged network in San Diego and manufactured handsets, but it did so in order to show that CDMA worked. Once it demonstrated the value of CDMA it exited phone and equipment manufacturing and concentrated on technology development and chip design and manufacturing, but did so without owning a chip manufacturing plant. See

manufactured a phone, and no longer produces any physical inputs; it develops technologies and earns all its revenues from licensing.⁵⁵ There are other firms that specialize in technology development and that license their technologies through patent pools, rather than bear the cost of maintaining a licensing division.⁵⁶

The high degree of vertical separation in the smartphone industry can be seen by the fact that the firms that design and market smartphones are not important contributors to the underlying technologies. The PricewaterhouseCoopers 2018 Global Innovation 1000 study provides data on R&D spending and revenues enumerated at the firm level for large firms covering the period 2011-17.⁵⁷ The study reveals that over the period 2012-17, Apple spent barely 3% of its revenues on R&D, while its major competitor, Samsung Electronics, spent approximately 7%.⁵⁸ The firms that licensed technologies to them outspent them by wide margins: Ericsson spent 14% of its revenues on R&D, Nokia spent 25%, Qualcomm spent 21%, and Rambus spent 42%.⁵⁹

Vertical separation and specialization even exist in the semiconductor industry, which provides one of the key inputs to smartphones.⁶⁰ The firm that designs the processor cores that power 95% or more of all smartphones—ARM—is a technology company that simply licenses

DANIEL NENNI & PAUL MCLELLAN, *FABLESS: THE TRANSFORMATION OF THE SEMICONDUCTOR INDUSTRY* 97 (Beth Martin & Amanda Ketchum eds., 2019).

⁵⁵ William Merritt, *InterDigital's Story: Fostering Industry Solutions and Profiting from Its Growth*, IPWATCHDOG (Feb. 6, 2014), <https://www.ipwatchdog.com/2014/02/06/interdigitals-story-fostering-industry-solutions-and-profiting-from-its-growth/id=47830/> [<https://perma.cc/74HN-ZWZE>].

⁵⁶ See Alexander Galetovic et al., *Estimate of the Average Cumulative Royalty*, *supra* note 21, at 265-66.

⁵⁷ *The Global Innovation 1000 Study*, PwC: STRATEGY&, <https://www.strategyand.pwc.com/gx/en/insights/innovation1000.html#VisualTabs1> [<https://perma.cc/LJV6-EAYK>].

⁵⁸ *Id.*

⁵⁹ *Id.* InterDigital, which is too small to be listed in the PwC 1000, spent 15% over the period 2011-16. Noel Maurer & Stephen Haber, *An Empirical Analysis of the Patent Troll Hypothesis: Evidence from Publicly-Traded Firms* 1, 41 (Hoover Inst. Working Paper Series No. 17003, 2018).

⁶⁰ See generally Jeffrey T. Macher et al., *e-Business and Disintegration of the Semiconductor Industry Value Chain*, 9 *INDUS. AND INNOVATION* 155 (2002).

the design of its processor cores through the foundries that manufacture semiconductors.⁶¹

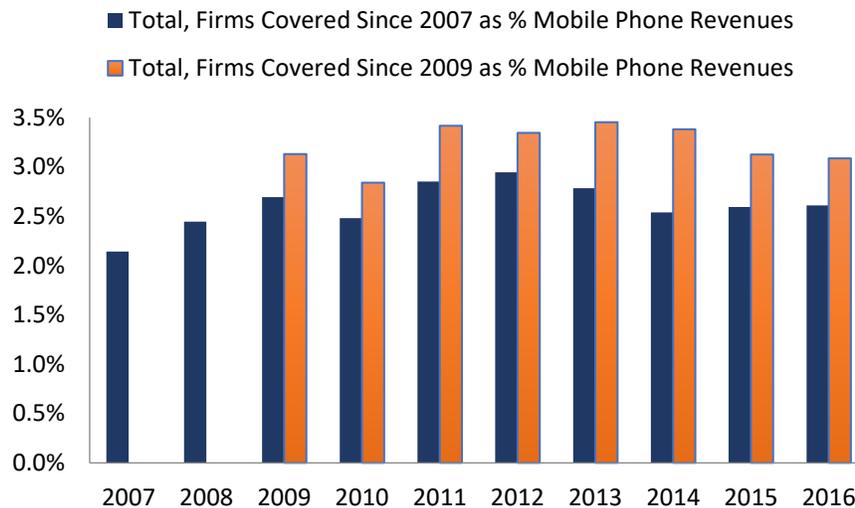


Figure 3: Patent royalties as percentage of the value of mobile (smart and feature) phones shipped, 2007-2016.

A third indicator of a functioning licensing market is stable royalty rates earned by the firms that specialize in technology development. If royalty rates did not follow a market logic, they would fluctuate dramatically year by year.⁶² Stable royalty rates are a feature of the smartphone industry.⁶³ Galetovic, Haber, and Zaretski estimated a time series of the average cumulative royalty yield in the smartphone industry covering 16 licensors that reported their royalty revenues since 2007 (which accounted for 78% of all royalty revenues in 2016); and for 22 licensors that reported their royalty revenues since 2009 (which accounted for 93% of all royalty revenues in 2016).⁶⁴ As Figure 3 shows, both series are remarkably stable.⁶⁵ “The average

⁶¹ See generally DANIEL NENNI & DON DINGEE, *THE ORIGIN AND EVOLUTION OF ARM PROCESSORS IN OUR DEVICES* (Shushana Nenni ed., 2015).

⁶² See Galetovic et al., *Estimate of the Average Cumulative Royalty*, *supra* note 21.

⁶³ *Id.* at 266.

⁶⁴ *Id.* at 272.

⁶⁵ *Id.*

cumulative royalty yield of firms with data since 2007 hovers between 2.1 and 3%; the average cumulative royalty yield of firms with data since 2009 hovers between 3 and 3.5%.”⁶⁶

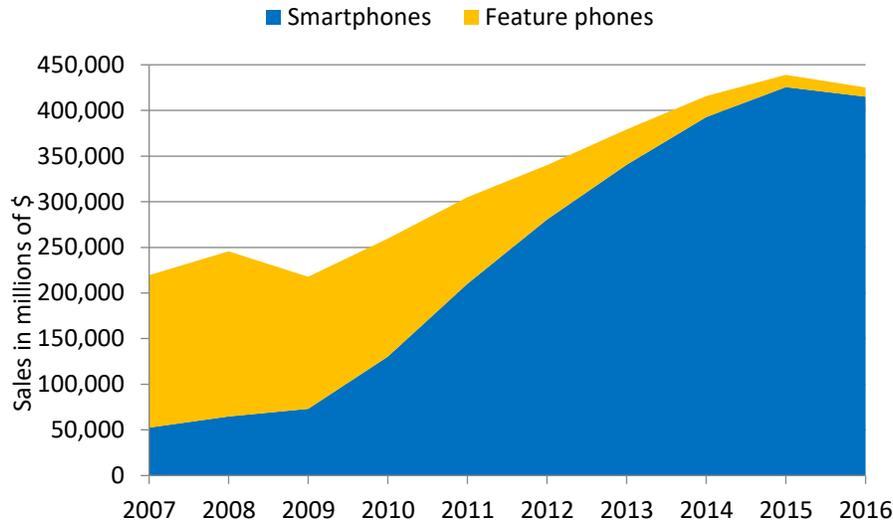


Figure 4: The composition of mobile (smart and feature) phone revenues, 2007-2016.

The stability of the average cumulative royalty yield over time is remarkable considering the large changes in the mobile phone market since 2007. As can be seen in Figure 4, smartphones almost fully substituted for feature phones, and the value of sales roughly doubled, yet the average cumulative royalty yield remained stable. This suggests the existence of a market operating in equilibrium.⁶⁷

III. The Bottom-Up Technique

While price theory provides a complete and logically consistent framework to assess the hypothesis that patent holders exercise monopoly power, experts, as well as antitrust authorities such as the

⁶⁶ *Id.*

⁶⁷ *See id.*

FTC and the DOJ, often advocate for a different technique for courts in setting FRAND royalties: “bottom-up.”⁶⁸

Underneath the bottom-up technique is the theory of patent holdup and royalty stacking, which posits that licensors are monopolists earning excessive royalties.⁶⁹ The argument runs as follows: When a group of downstream manufacturers chooses a particular patented technology as the standard for an industry, they knock firms that developed alternative technologies out of the market. The firms whose patented technologies are chosen to be part of the standard are now free to charge whatever price they like, and so, they price as monopolists. The manufacturers cannot refuse these outrageous demands. On the one hand, they are locked in by their own investments, which are specific to the selected standard. On the other hand, they are locked in by consumers who would balk at switching to products that use an alternative, non-compatible technology.⁷⁰ That is, the firms whose patented technologies have been chosen are now able, at least according to the theory, to “holdup” manufacturers and appropriate the value of standardization itself.⁷¹

⁶⁸ See U.S. FED. TRADE COMM’N, *supra* note 5, at 185-89; see generally Contreras et al., *supra* note 5; Vjih, *supra* note 5.

⁶⁹ See, e.g., George S. Cary et al., *The Case for Antitrust Law to Police the Patent Holdup Problem in Standard Setting*, 77 ANTITRUST L.J. 913 (2011).

⁷⁰ See, e.g., Suzanne Michel, *Bargaining for RAND Royalties in the Shadow of Patent Remedies Law*, 77 ANTITRUST L.J. 889, 889, 908 (2011); Jorge L. Contreras & Richard J. Gilbert, *A Unified Framework for RAND and Other Reasonable Royalties*, BERKELEY TECH. L.J. 1451, 1496 (2015).

⁷¹ Galetovic & Haber, *supra* note 10, at 42. The reader may notice that the theory of patent holdup and royalty stacking “conflates two different economic mechanisms: holdup and the exercise of market power. Holdup means that one firm appropriates another firm’s quasi rents—its revenues minus its short-run costs—through opportunistic behavior. A firm that is being held up, by definition, does not generate enough revenue to cover its long-run costs. Therefore, the firm will not reinvest once its capital wears out,” and it will exit the market. *Id.* at 11. An industry characterized by holdup is not in a long-run equilibrium; it should collapse. “Market power, by contrast, means that a firm can set prices such that it appropriates a monopoly rent from a market. The exercise of market power can be a long-run equilibrium because the downstream firms will cover their long-run costs and continue to reinvest as their capital equipment wears out. Thus, holdup and the exercise of market power are two different, mutually inconsistent economic mechanisms. One cannot simultaneously have a long-run equilibrium and not have a long-run equilibrium.” *Id.*

While there are many variants of this claim in the literature, Cary et al. provide a concise formulation:

Selecting a standard ordinarily requires an SSO to choose among competing technologies, and the process frequently results in a collective selection of a patented technology to the exclusion of other patented or non-proprietary technologies. Consequently, standardization necessarily entails the exclusion of alternative technologies Indeed, because the opportunistic conduct resulting in patent holdup specifically “concerns the inefficient acquisition of market power,” many commentators have “generally assumed that [such] opportunism in the standard-setting process is an antitrust problem.”⁷²

The claim is not simply a matter of academic theorizing but has been embraced by antitrust authorities. Renata Hesse, speaking as a DOJ official, articulated it as follows:

Once a standard becomes established, firms implementing the standard may find switching away more difficult and expensive. This lock-in confers market power on the owners of the incorporated patents. . . . Standards [sic] essential patent holders may seek to take advantage of the market power that standardization of their patented technology creates by engaging in hold-up. . . . This type of hold-up raises particular competition concerns when alternative technologies that could have been included in the standard were instead excluded from it.⁷³

⁷² Cary et al., *supra* note 69, at 914, 921.

⁷³ RENATA B. HESSE, IP, ANTITRUST AND LOOKING BACK ON THE LAST FOUR YEARS 16-17 (2013).

The theory of patent holdup and royalty stacking claims, in addition, that such opportunistic behavior can be practiced simultaneously by many firms, giving rise to a phenomenon termed royalty stacking. As Lemley and Shapiro state in their seminal paper: “As a matter of simple arithmetic, royalty stacking magnifies the problems associated with injunction threats and holdup, and greatly so if many patents read on the same product.”⁷⁴

The purpose of bottom-up apportionment is, therefore, to remove the undue monopoly power of the SEP holders by restoring the competitive situation that prevailed before a technology became the industry standard. That is, a court should “[identify] the set of alternatives that would have been available prior to standardization and then [determine] the incremental value, if any, of the SEPs relative to those alternatives.”⁷⁵ The FTC is quite explicit that this is the appropriate basis by which courts should set royalties:

Courts should recognize that when it can be determined, the incremental value of the patented invention over the next-best alternative establishes the maximum amount that a willing licensee would pay in a hypothetical negotiation. Courts should not award reasonable royalty damages higher than this amount.⁷⁶

A. Assumptions Instead of Empirics

The bottom-up technique is, however, fraught on a number of grounds, some empirical and some theoretical. Let us pursue them systematically.

The first stage of the bottom-up technique should be to demonstrate SEP holders exercise monopoly power. This stage should take place because the entire exercise of bottom-up apportionment is based on the claim that royalties are excessive.

⁷⁴ Mark A. Lemley & Carl Shapiro, *Patent Holdup and Royalty Stacking*, 85 TEX. L. REV. 1991, 1993 (2007).

⁷⁵ Leonard & Lopez, *supra* note 7, at 88.

⁷⁶ U.S. FED. TRADE COMM’N, *supra* note 5, at 189.

As we discussed in Part II, the claim that patent holders exploit monopoly power can be tested by comparing the royalty rate that would be charged by a monopolist with the observed royalty rate in the industry.⁷⁷ Such exercises are not, of course, exact—but when predicted values are larger than observed values by an order of magnitude or more the rules of scientific inquiry would require the rejection of the monopoly power hypothesis.

This is not, however, how the technique of bottom-up apportionment proceeds. Practitioners simply assume that royalties are excessive because the theory of patent holdup and royalty stacking claims that it must be so. By assumption, any observed royalty is the product of monopoly power.⁷⁸

B. Excessive Royalties and Additional Market Power

Recall that the bottom-up technique is designed to mitigate patent holdup and royalty stacking. If that theory is logically inconsistent or logically incomplete, then the basis for conducting a bottom-up exercise vanishes.

One of the core constructs of the theory of patent holdup and royalty stacking is that SEP owners obtain market power from two sources: 1) the “legitimate” market power that comes from the patent itself, a consequence of the right to exclude; and 2) the additional market power that comes from the inclusion of the patent in an industry standard.⁷⁹ The combination of the two produces an “excessive” royalty, because the SEP holder is appropriating the value created by standardization, in addition to the value created by the patented technology.⁸⁰ Indeed, in *Ericsson v. D-Link Systems*, the court stated

⁷⁷ Galetovic et al., *Anticommons Tragedy*, *supra* note 10, at 1550-51.

⁷⁸ See Galetovic & Haber, *supra* note 10, at 30.

⁷⁹ See *id.* at 34-36.

⁸⁰ *Id.* at 34-35.

that SEP holders can charge royalties only for the technology, but not for the value of standardization itself.⁸¹

As the authors have previously explained, however, the idea that standardization itself creates monopoly power is wrong, because standards and technologies are not separable and the only source of value is what consumers are willing to pay for what the technology does.⁸² A patented technology (or any input, for that matter) only has value if consumers obtain utility from, and therefore demand, its inclusion in the final good. Standardization permits a technology to operate across multiple manufacturers and generations of the consumer product; it is necessary to realize the value created by the technology, but it is not separable from the technology. It is precisely for this reason that it only pays to standardize technologies that do things that are valued by consumers; a standard for a useless technology is of no value at all. And, once a technology produces something consumers value, it is almost tautological that the technology will be more valuable the more users adopt it.

Because they are not conceptually separable, the value of a technology and the value of the standard in which it operates cannot be determined independently of one another. If they were, in fact, separable, researchers would be able to observe market transactions in standards that are independent of the patented technologies. To the best of our knowledge, no one has ever recorded such a transaction.

A thought experiment illustrates why the value of standardization cannot be separated from the value of the technologies themselves. Imagine a consumer that has a choice between a computer that can send an email and a computer that cannot. She will value the email-capable computer over the alternative. Now imagine that even though

⁸¹ 773 F.3d 1201, 1023 (5th Cir. 2014). Only U.S. courts compel SEP holders to separate the value of standardization itself from the value created by the technology. Outside the United States it is not the law that the SEP holder may not recover through its FRAND or RAND royalties a part of the value of standardization. Jonathan Putnam et al., *Roundtable: Essential Reading*, IAM (Nov. 4, 2020), <https://www.iam-media.com/frandseps/roundtable-essential-reading> [<https://perma.cc/E54Q-RXM7>].

⁸² See Galetovic & Haber *supra* note 10, at 41-42.

the computer can send an email, that email cannot be read by anyone else because there is not a standardized email protocol. From the consumer's point of view, the patented email technology inside the computer is useless, and thus has zero value. Now flip the situation on its head: Imagine that there is a standard protocol for email, but that no computer company has developed a technology that allows anyone to send an email. What value would our rational consumer put on a standardized email protocol? The answer, again, would be zero.

In short, asking what portion of the economic surplus created by consumer demand for a standardized technology is caused by standardization itself, and what portion is caused by the SEPs is akin to asking what portion of jackrabbit speed is due to the fact that coyotes hunt them, and what portion is due to the fact that jackrabbits live on flat, open terrain. For a biologist, this is a meaningless question: Jackrabbits, coyotes, and the mixed shrub-grasslands that they inhabit co-evolved; each is an emergent property of a complex adaptive system that biologists call a grassland ecosystem. So, it is with patented technologies, technical standards, and the consumer products that require compatibility and interoperability: They co-evolved; each is an emergent property of a complex adaptive system that economists call a market.

Conceptual errors tend to generate wrong implications. The world is full of standards. Some are developed by multiple firms that both cooperate and compete with each other in a Standard Development Organization ("SDO"), which is the case in the smartphone industry.⁸³ Others are developed by a single firm whose technology is *the* de facto standard. Intel and its family of x86 processors is a canonical example.⁸⁴ Once one holds to the proposition that it is possible to separate the value of a patented technology from the value of standardization, then the same logic about patent holders appropriating the value of standardization must also apply to a single firm whose technology emerged as the de facto standard. Both standards, after all,

⁸³ RON SCHNEIDERMAN, MODERN STANDARDIZATION: CASE STUDIES AT THE CROSSROADS OF TECHNOLOGY, ECONOMICS, AND POLITICS 253-54, 262 (2015).

⁸⁴ SEN-CUO RO & SHEAU-CHUEN HER, 1386/1486 ADVANCED PROGRAMMING 3 (1993).

came about through a process of competition, and, according to the theory of patent holdup and royalty stacking, the firms that developed them are in a position to levy monopoly prices that are being passed along to consumers.

Let us consider the case of Intel to explore where this line of thinking leads. At the beginning of the personal computer industry, Intel was not the only designer and manufacturer of microprocessors.⁸⁵ Circa 1981, five companies competed, each of which had their own designs: Intel, Motorola, Texas Instruments, Zilog, and Mostek.⁸⁶ In 1978, IBM chose Intel's 8088, a member of the x86 processor family, for its personal computer.⁸⁷ By virtue of being chosen by IBM, which had brand recognition and marketing capability, Intel's x86 instruction set—the set of instructions that software uses to command a CPU—became the standard in the PC industry.⁸⁸ The competing technologies of Motorola, Texas Instruments, Zilog, and Mostek were largely knocked out of the market, even though some prominent industry observers argue that Motorola and Zilog were technically superior.⁸⁹ Intel quickly came to dominate the market for PC CPUs.⁹⁰ Programmers wrote software that worked with Intel's instruction set, because that is what powered the standard PC platform, and consumers demanded Intel-powered computers because they ran the software

⁸⁵ Graham Singer, *The History of the Microprocessor and the Personal Computer*, TECHSPOT (Oct. 1, 2020), <https://www.techspot.com/article/874-history-of-the-personal-computer/> [https://perma.cc/AW69-MMHD].

⁸⁶ Peter Swann, *A Decade of Microprocessor Innovation: An Economist's Perspective*, 11 MICROPROCESSORS & MICROSYSTEMS 49, 52 (1987); see generally G.M.P. Swann, *Product Competition in Microprocessors*, 34 J. INDUS. ECON. 33 (1985) (discussing the history of the microprocessor up to the mid-eighties).

⁸⁷ Walden C. Rhines, *The Inside Story of Texas Instruments' Biggest Blunder: The TMS9900 Microprocessor*, IEEE SPECTRUM (June 22, 2017), <https://spectrum.ieee.org/tech-history/heroic-failures/the-inside-story-of-texas-instruments-biggest-blunder-the-tms9900-microprocessor> [https://perma.cc/HF6Y-LQ93].

⁸⁸ Wesley Fenlon, *10 Most Popular Computers in History*, HOWSTUFFWORKS, <https://computer.howstuffworks.com/10-most-popular-computers-in-history.htm> [https://perma.cc/U7K4-XFX3].

⁸⁹ Wally Rhines, *Chapter 8 – Value Through Differentiation in Semiconductor Business*, SEMIWIKI.COM (Aug. 30, 2019, 6:00 AM), <https://semiwiki.com/wally-rhines/274559-chapter-8-value-through-differentiation-in-semiconductor-businesses/> [https://perma.cc/M9EU-4YMG].

⁹⁰ Fenlon, *supra* note 88.

applications that had been designed to that standard.⁹¹ The only alternative was Apple. As of this writing, around 80% of personal computers run on Intel's standard.⁹² The process by which Intel knocked competing technologies out of the PC market was repeated in the 1990s, when Intel's x86 instruction set became the standard in server processors,⁹³ and yet again in the early 2000s when Intel's x86 instruction set became the standard in high-performance computers.⁹⁴ Importantly, Intel chose not to license its x86 instruction set; rather, it used the roughly 1,600 patents on its instruction set to prevent entry into CPU manufacturing.⁹⁵ In fact, Intel made it clear that it would pursue infringers.⁹⁶

If one takes the logic underpinning the bottom-up approach seriously, then one must conclude that Intel must be appropriating the value of standardization itself in the PC, notebook, and server markets. Intel does not, of course, willingly license its technology, and therefore does not earn licensing royalties.⁹⁷ But that is irrelevant: the value of Intel's patented technologies is included in the price of its x86 CPUs, and that value must include the value that came from standardization, as well as the value of the patented technologies. If one were to take the logic of patent holdup and royalty stacking seriously, Intel should now be forced to price its CPUs on the basis of the price differential between

⁹¹ *Computer History 101: The Development of the PC*, TOM'S HARDWARE (Aug. 24, 2011), <https://www.tomshardware.com/reviews/upgrade-repair-pc,3000-4.html> [<https://perma.cc/F6TS-ZJNC>].

⁹² See Joel Hruska, *Intel Claws Back Market Share from AMD in Desktop, Mobile*, EXTREME TECH (Feb. 3, 2021, 1:56 PM), <https://www.extremetech.com/computing/319731-intel-claws-back-market-share-from-amd-in-desktop-mobile> [<https://perma.cc/FVL4-XEU8>].

⁹³ Joel Hruska, *How Intel Lost \$10 Billion and the Mobile Market*, EXTREME TECH (Dec. 3, 2020, 2:03 pm), <https://www.extremetech.com/extreme/227720-how-intel-lost-10-billion-and-the-mobile-market> [<https://perma.cc/7B4V-4UZP>].

⁹⁴ *Id.*

⁹⁵ Steven Rodgers & Richard A. Uhlig, *X86: Approaching 40 and Still Going Strong*, INTEL (Jan. 27, 2021), <https://newsroom.intel.com/editorials/x86-approaching-40-still-going-strong/#gs.t1uvq4> [<https://perma.cc/FW8Y-GRR5>].

⁹⁶ *See id.*

⁹⁷ It does allow AMD to use its architecture under license, but that is a royalty-free license that Intel has disputed in court on several occasions. Greg Tang, *Intel and the x86 Architecture: A Legal Perspective*, JOLT DIGEST (Jan. 4, 2011), <https://jolt.law.harvard.edu/digest/intel-and-the-x86-architecture-a-legal-perspective> [<https://perma.cc/HRK8-JZTF>].

its initial 8086 chip, and those of Motorola, Texas Instruments, Zilog, and Mostek when all five were available in the market.

C. A Technique That Has Never Been Used

It is an irony that while the logic underpinning the bottom-up approach has been widely embraced by antitrust authorities, the technique itself has never actually been applied because “the incremental value of the patented invention over the next-best alternative” cannot be determined. It was not selected by an SDO to be part of a standard, and thus never came to market—and if it never sold in a market then there is no way to know what royalty would have been charged. Plainly stated, there is no way to determine the market price of something that never existed. Indeed, in *Microsoft v. Motorola*, Judge Robart wrote:

One flaw in Microsoft's approach is its lack of real-world applicability. Neither the IEEE nor the ITU specifies that RAND terms must be determined using an incremental value approach. Moreover, neither the IEEE nor the ITU require *ex ante* disclosure of RAND terms during the standard setting process. In fact, explicit multilateral *ex ante* negotiations cannot be conducted under the auspices of many SSOs, including the IEEE. . . . Another flaw in Microsoft's approach is its impracticability with respect to implementation by courts. In practice, approaches linking the value of a patent to its incremental contribution to a standard are hard to implement.⁹⁸

IV. The Top-Down Technique

The top-down technique is an attempt to deal with the fact that the bottom-up technique cannot actually be operationalized.⁹⁹ As Leonard

⁹⁸ 2013 U.S. Dist. LEXIS 60233, at *45-46 (W.D. Wash. Apr. 25, 2013) (citations omitted).

⁹⁹ See, e.g., Leonard & Lopez, *supra* note 7, at 89; Jorge L. Contreras, *Global Markets, Competition, and FRAND Royalties: The Many Implications of Unwired Planet v. Huawei*, 16 ANTITRUST SOURCE, Aug. 2017, at 11. The top-down technique has been used in *In re Innovatio IP Ventures*, *Apple Japan v. Samsung*, *Unwired Planet v. Huawei* and *TCL v.*

and Lopez explain it, the top-down approach is applied in two steps.¹⁰⁰ First, a researcher determines the cumulative royalty that should be received by an entire suite of SEPs. Second, the researcher uses an algorithm to apportion a fraction of the cumulative royalty to the litigated patents.¹⁰¹

A. A Pie of Fixed Size and of Unknown Origin

The premise behind the first step is that a researcher can find the cumulative royalty that SEP holders as a group *should charge* for the entire suite of SEPs. Experts have proposed a number of methods, all of which are arbitrary.¹⁰² In *In re Innovatio IP Ventures Patent Litigation*, for example, the court accepted an expert's opinion that the cumulative royalty paid by manufacturers of WiFi equipment using the IEEE's 802.11 standard should not exceed the profit per chip that embedded the standardized technologies.¹⁰³ The court therefore estimated that the "right" royalty should be equal to the profit margin: 12.1% of the price of a chip.¹⁰⁴ The court was explicit:

In summary, the Top-down approach starts with the average price of a Wi-Fi chip. Based on that average price, [calculate] the average profit that a chipmaker earns on the sale of each chip, thereby isolating the portion of the income from the sale of the chip available

Ericsson. Jorge L. Contreras, *Aggregated Royalties for Top-Down FRAND Determinations: Revisiting "Joint Negotiation"*, 62 ANTITRUST BULL. 690, 692-93, 695 (2017) [hereinafter Contreras, *Aggregated Royalties*].

¹⁰⁰ Leonard & Lopez, *supra* note 7, at 89.

¹⁰¹ *See id.*; *see also* Elizabeth M. Bailey et al., *Making Sense of 'Apportionment' in Patent Damages*, 12 COLUM. SCI. AND TECH. L. REV. 255, 262 (2011).

¹⁰² An exception is Sidak and Skog, who use a hedonic regression to estimate the incremental value of the technologies embedded in the LRDIMM 4 standard over the technologies embedded in the previous version on the standards *and which were still available in the market*. Contrary to the methods that have been used by courts, therefore, this one is based on an explicit and established theory of value: In a market's equilibrium, differential prices embedding different technologies are equal to consumers' differential willingness to pay at the margin for the best technology. Moreover, so far this is the only method that relies on observable market transactions and prices to estimate the value of the cumulative royalty. *See Sidak & Skog, supra* note 30.

¹⁰³ 2013 WL 5593609, at *39 (N.D. Ill. Oct. 3, 2013).

¹⁰⁴ *Id.* at *41.

to the chipmaker to pay royalties on intellectual property.¹⁰⁵

Thus, the court accepted the proposition that there is a fixed pie of revenue at each stage of a production chain that is independent and separable from the rest of the chain. That is, the court accepted the idea that value comes from WiFi equipment, rather than from the consumer demand for the final goods that use WiFi, such as a tablet, laptop, or smartphone. In so doing, it violated a key tenet of price theory: Total revenues in an industry are bounded by the demand curve for the final product, and producers at any stage of a production chain must adjust their prices and output to accommodate changes in price at other stages of the production chain.¹⁰⁶

Some antitrust authorities and the IEEE have carried this thinking about separable and independent stages of production chains to its logical conclusion by arguing that patent holdup and royalty stacking can be stemmed by forcing SEP holders to pick the smallest saleable patent practicing unit (“SSPPU”) as the royalty base.¹⁰⁷ This is a variant of the top-down technique in that it posits that there is a fixed pie of revenue at each stage of a production chain, and that an expert can apportion that pie of revenue.

¹⁰⁵ *Id.* at *38.

¹⁰⁶ Other examples include *Samsung v. Apple Japan*, where the Japanese Intellectual Property High Court held that the cumulative royalty for the 3G UMTS should be 5%; *Unwired Planet v. Huawei*, where the Court used announcement made by some patent holders about the cumulative royalties they expected to see; and *TCL v. Ericsson*, where the Courts followed the same method as in *Unwired Planet*. See Contreras, *Aggregated Royalties*, *supra* note 99, at 11; Press Release, Ericsson, Wireless Indus. Leaders Commit to Framework for LTE Tech. IPR Licensing (Apr. 14, 2008), <https://news.cision.com/ericsson/r/wireless-industry-leaders-commit-to-framework-for-lte-technology-ipr-licensing,c2246540>; Fei Deng, et al., *Comparative Analysis of Court-Determined FRAND Royalty Rates*, 32 ANTITRUST, no. 3, 2018.

¹⁰⁷ For critical assessments of the SSPPU, see generally David Kappos & Paul R. Michel, *The Smallest Saleable Patent-Practicing Unit: Observations on Its Origins, Development, and Future*, 32 BERKELEY TECH. L.J. 1433 (2017); Axel Gautier & Nicolas Petit, *Smallest Saleable Patent Practicing Unit and Component Licensing: Why \$1 IS NOT \$1*, 15 J. COMPETITION L. & ECON. 690 (2019); Anne Layne-Farrar, *The Patent Damages Gap: An Economist’s Review of U.S. Statutory Patent Damages Apportionment Rules*, 26 TEX. INTELL. PROP. L.J. 31, 35 (2018) [hereinafter Layne-Farrar, *The Patent Damages Gap*].

Even if one accepts the mistaken notion that there is a fixed pie of revenues at each stage of a production chain, it is not possible, as a practical matter, to determine the stage at which a patented technology should be valued for the calculation of SSPPU. As Bailey et al. point out:

[C]onsider a patent related to a microprocessor incorporated into mobile phones. A chip that provided some improvement (in speed, efficiency, etc.) may enable other functionality on the phone, such as an improved touchscreen interface, software applications with greater capability, greater video functionality, or improvement of other features of the phone. While apportionment would recommend that the royalty base be limited to the chip “portion” of the phone, this delineation may miss synergies between the patent at issue and the other features of the mobile phone. It would be incorrect to attribute all such synergies to the infringing company (or, for that matter, the patented feature).¹⁰⁸

More generally, the point is that, as Layne-Farrar points out, the smallest salable component where the technology is implemented may not coincide with the part of the device where the technology creates value.¹⁰⁹ The price of the component, in turn, will not reflect the value of the intellectual property, if market participants do not use the price of the component as the royalty base.

B. Conceptual and Practical Flaws of the Top-Down Approach

Several techniques have been used in the second step, all of which share the characteristic that they are rather arbitrary.

¹⁰⁸ Bailey, et al., *supra* note 101.

¹⁰⁹ Layne-Farrar, *The Patent Damages Gap*, *supra* note 107.

Some courts have simply accepted an estimate of the number of SEPs and calculated the share of the SEP holder in the total. For example, in *Samsung v. Apple Japan* the Japanese Intellectual Property High Court used a research report that claimed that there were 529 patent families involved, and then calculated Samsung's share.¹¹⁰ In *TCL v. Ericsson* the court determined the value of Ericsson's SEPs as a percentage of the total number of SEPs claimed to be relevant.¹¹¹ That is, the court decided that all SEPs were the essentially of equal value.¹¹²

Some courts have recognized that not all patents are equally valuable and have therefore tried to estimate the differential value of each SEP.¹¹³ In *Innovatio*, for example, the court accepted an expert's opinion that "the top 10% of all electronics patents account for 84% of the value in all electronics patents."¹¹⁴ The expert obtained this number, however, from a 1998 paper that estimated the distribution of value of all French patents granted in 1970, using information from patent renewals in France between 1969 and 1982.¹¹⁵ The court then allocated the share of the cumulative royalty by making a judgement about the importance of *Innovatio*'s patents by assuming that they were in the top 10% of all 802.11 standard essential patents.¹¹⁶ In *Unwired Planet v. Huawei*, experts proposed to apportion the cumulative royalty based on quality-adjusted patent counts, where quality was measured based on the number of contributions to the

¹¹⁰ See Chiteki Zaisan Kōtō Saibansho [Intellectual Prop. High Ct.] May 16, 2014, Hei 25 (ne) no. 10043, Chiteki Zaisan Kōtō Saibansho Haketsu Shōkai Hanrei Kensaku [Chizai Kōsai Web] 1 .

¹¹¹ *TCL Commc'n. Tech. Holdings Ltd. v. Telefonaktiebolaget LM Ericsson*, 943 F.3d 1360, 1369 (Fed. Cir. 2019), *cert. denied*, 141 S. Ct. 239 (2020).

¹¹² *Id.*

¹¹³ See, e.g., Leonard & Lopez, *supra* note 7, at 89.

¹¹⁴ *In re Innovatio IP Ventures, LLC*, 2013 WL 5593609, at *43 (N.D. Ill. Oct. 3, 2013).

¹¹⁵ See Mark Schankerman, *How Valuable Is Patent Protection? Estimates by Technology Field*, 29 RAND J. ECON. 77 (1998).

¹¹⁶ *Innovatio*, 2013 WL 5593609, at *43.

standard setting process.¹¹⁷ Sidak and Skog proposed to apportion value with a weighted index of SEPs forward citations.¹¹⁸

There is no shortage of metrics for apportionment that have been proposed by experts. None, however, is based on any theory of economics. Consider, for example, an apportionment metric based on a patent's share in a citation-weighted index. There are some empirical papers that link forward citations with different measures of patent value.¹¹⁹ One problem, however, is that there is no theory that explains the link between the number of forward citations and the value created by a SEP. Indeed, as Katznelson explains, a patent is cited in order to limit the scope of the claims of the citing patent.¹²⁰ The number of times a patent is cited is, therefore, not necessarily related to the value that consumers may assign to the technologies associated with the patent. This is not to say that forward citation may not signal social value. Indeed, when Hall et al. estimated regressions of the number of forward citations on the stock market value of a firm's stock of intangible knowledge they obtain R²s¹²¹ of between 0.1 and 0.3.¹²² Similarly, Gambardella, Harhoff, and Verspagen found that around

¹¹⁷ See Deng et al., *supra* note 106; *Unwired Planet Int'l Ltd. v. Huawei Co. Ltd.* [2017] EWHC (Pat) 711 [¶ 187-90] (Eng.) (Huawei used a counting technique called "Huawei Patent Analysis." Unwired Planet's patent counting method is called the Modified Numeric Proportionality Approach.).

¹¹⁸ Sidak & Skog, *supra* note 30, at 669.

¹¹⁹ See, e.g., Manuel Trachtenberg, *A Penny for Your Quotes: Patent Citations and the Value of Innovations*, 21 RAND J. ECON. 172 (1990) (describing the relation between citation counts and social surplus created by a patented technology); Jesse Giummo, *An Empirical Examination of Patented German Inventions Using German Employee Inventor Compensation Records* (Mar. 29, 2001) (Ph.D. dissertation, University of California at Berkeley) (ResearchGate) (finding that the royalties received by inventor/patent holders at nine major German corporations under the German Employee Compensation Act of 1957 correlated positively with the number of forward citations received by the patent); Bronwyn H. Hall et al., *Market Value and Patent Citations*, 36 RAND J. ECON. 1, 16-38 (2005) (describing the relation between the number of forward citations and a firm's stock market value).

¹²⁰ Ron D. Katznelson, *Patent Continuities, Product Lifecycle Contraction, and the Patent Scope Erosion—A New Insight into Patenting Trends 20* (presented at Southern California Law Associations Intellectual Property Spring Seminar) (June 2007), <https://obamawhitehouse.archives.gov/sites/default/files/omb/assets/omb/oira/0651/comments/460-patent.pdf>.

¹²¹ Amy Gallo, *A Refresher on Regression Analysis*, HARV. BUS. REV. (Nov. 4, 2015), <https://hbr.org/2015/11/a-refresher-on-regression-analysis> [<https://perma.cc/6FZE-WLEJ>].

¹²² Hall et al., *supra* note 119, at 16-38.

10% of the social value created by the patented technologies could be explained by forward citations.¹²³ However, while R^2 s of 0.1-0.3 may be large as a matter of furthering our understanding of the value of patents, they are insufficient to apportion value among different technologies, because 70 to 90% of the variance in the value of the stock of intangible knowledge remains unexplained, and the “explained” part does not rest on a theory.

In practice, because there is no guiding theory under such exercises, there is no agreement among experts about what should be measured, and how it should be measured. Mallinson, for example, compared two studies commissioned by industry participants that purported to count the number of essential patent families owned by major SEP holders in mobile phones.¹²⁴ One study claimed to have relied on “industry experts that included physics PhDs, wireless engineers, patent legal specialists, and former patent office employees.”¹²⁵ The other study claimed to have accumulated six years of experience assessing essentiality.¹²⁶ If determining essentiality were an exact science, both studies should have allocated the same number and share of SEPs to each patent holder and a plot of the data in a two-dimensional graph should have accumulated data points on a 45° line. Mallinson found, however, that the correlation between both studies was exactly zero.¹²⁷ Mallinson added six more studies to his original two and found that the correlation between pairs was generally below 0.5.¹²⁸

¹²³ Alfonso Gambardella et al., *The Value of European Patents*, 5 EUR. MGMT. REV. 69, 80 (2008).

¹²⁴ Keith Mallinson, *Valuing IP in Smartphones and LTE*, IP FIN. (Nov. 8, 2011), [<https://web.archive.org/web/20210123234647/http://www.ip.finance/2011/11/valuing-ip-in-smartphones-and-lte.html>] (PDF can be downloaded by clicking on hyperlink in archived article).

¹²⁵ *Id.* at 4.

¹²⁶ *Id.* at 3.

¹²⁷ *Id.* at 7.

¹²⁸ Keith Mallinson, *Do Not Count on Accuracy in Third-Party Patent-Essentiality Determinations*, IP FINANCE (May 12, 2017), <http://www.ip.finance/2017/05/do-not-count-on-accuracy-in-third-party.html>.

C. Top-Down and Apportionment

We should stress that we are not criticizing courts for apportioning the value of a technology, nor for picking a particular stage in the production stage to set the royalty base. Since *Garretson v. Clark*, courts have been given the task of determining the value created by a patented technology in damage cases.¹²⁹ Moreover, there are cases in which the end product's revenue is not the appropriate royalty base.¹³⁰ In fact, there are markets where the equilibrium that has emerged is for patent royalties to be levied further up the production chain. That fact, however, is exactly the point; courts should take their cue from the practices and prices in the market, not try to engineer a market based on the faulty assumptions that there is a fixed pie of revenue at each stage of a production chain, and that an expert can accurately apportion that pie of revenue.

V. Conclusion

Given that both bottom-up and top-down methods of royalty apportionment are not based on any theory of mainstream economics, that bottom-up cannot be applied as a practical matter, and that top-down can only be applied by accepting arbitrary criteria, what should courts do? The answer is that in adjudicating the value of SEPs, courts should follow the same practices as when they price other classes of assets or the flows of income they produce: rely on information from the market about the value of comparable assets or their rental rates. The logic for doing so is straightforward: A royalty is simply the rental price of an asset created by investments in R&D.

Some may argue that the method of comparables cannot be used because every SEP portfolio, and every SEP transaction, is different. Courts will also hear that the terms of individual licensing agreements are typically not publicly disclosed. Both claims are true—but those

¹²⁹ See generally *Garretson v. Clark*, 111 U.S. 120 (1884); see also J. Gregory Sidak, *The Proper Royalty Base for Patent Damages*, 10 J. COMPETITION L. & ECON. 989, 1008, 1025 (2014).

¹³⁰ See Layne-Farrar, *The Patent Damages Gap*, *supra* note 107.

claims are also true about many other classes of assets in which courts employ the technique of comparables to estimate value, such as real estate, art collections, brand names, music catalogs, privately-owned business enterprises, and even the flow of income from a professional career. In those cases, courts rely upon four sources of market information: list prices, average market prices compiled by trade publications, appraisals done by experts, and market prices of similar assets.¹³¹ Many SEP licensors, in fact, post list prices. Estimates of average royalties can be readily obtained from the financial statements of licensors.¹³² Expert appraisers certainly exist in the market for SEPs, because firms in high technology industries routinely hire them when purchasing or licensing SEP portfolios from one another. Last, a court can look at the royalty rates received by similar intellectual property owned by other patent holders.

An approach to royalty adjudication based on price theory confers an additional advantage: It allows a court to distinguish between observed royalty rates that emerge from a competitive market versus those that emerge from a monopolized market. It is therefore a necessary step for courts to employ when assessing claims that a particular SEP holder is exercising monopoly power.

¹³¹ See, e.g., *Summit 6, LLC v. Samsung Elecs. Co.*, 802 F.3d 1283, 1296 (Fed. Cir. 2015) (explaining that “[t]his court has recognized that estimating a reasonable royalty is not an exact science. . . . A party may use the royalty rate from sufficiently comparable licenses, value the infringed features based upon comparable features in the marketplace, or value the infringed features by comparing the accused product to non-infringing alternatives.”) (citation omitted); *Georgia-Pacific Corp. v. U.S. Plywood Corp.*, 318 F.Supp. 1116, 1120 (S.D.N.Y. 1970), *modified sub nom.*, *Georgia-Pacific Corp. v. U.S. Plywood-Champion Papers, Inc.*, 446 F.2d 295 (2d Cir. 1971) (listing, among other royalty determination methods, “[t]he rates paid by the licensee for the use of other patents comparable to the patent in suit[,] . . . [t]he portion of the profit or of the selling price that may be customary in the particular business or in comparable businesses to allow for the use of the invention or analogous inventions” and “the opinion testimony of qualified experts.”).

¹³² See, e.g., Galetovic, et al., *Estimate of the Average Cumulative Royalty*, *supra* note 21; Mallinson, *supra* note 124; Sidak, *Apportionment, FRAND Royalties, and Comparable Licenses*, *supra* note 8.