**Technological Leadership and 5G Patent Portfolios:**
**Guiding strategic policy formulation[1] and licensing decisions**

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## I. INTRODUCTION

The global economy is now experiencing the roll out of a new paradigm in mobile connectivity designed to connect everyone to everything anywhere. Enabling this development is fifth generation wireless technology called 5G. It is a cluster of generally patent protected technologies embedded in wireless standards that enable faster throughput, latency, and data, which in turn, supports use cases that will help make possible services that could be imagined only in faint outline 20 years ago. These include autonomous driving, massive machine to machine communication, remote surgery, virtual reality, and hundreds of productivity enhancements in every vertical from agriculture to health care to construction.[4] 5G will change what societies do and how people work and play.[5] It will enable not just smarter smartphones, but thousands of other uses in various adjacencies.

Because of its economic and security significance, there are geopolitical issues associated with 5G technology. As a result, CEOs, and policymakers spend considerable time and effort trying to identify which countries and companies are leading in developing the technologies used in the foundational layer of technology. The foundational layer is the enabling layer.

Companies also want to understand the market or licensing value of intellectual property supporting the major paradigm shifts in the wireless world. Licensors and licensees both need valuation frameworks that can help them assess appropriate market-based royalties for 5G foundational technologies. Large amounts of money are at issue for significant portfolios of 5G patents.

Because of the number of new entrants entering the 5G ecosystem, and the lack of understanding of patents and standards development, there is sometimes very limited sophistication with how patent statistics are used by even respectable media outlets such as the Wall Street Journal. Citing patent analytics company iPlytics, the Journal recently announced that companies from China own “36% of all 5G standard essential patents” and noted that “US firms including Qualcomm and Intel hold just 14%.” The article went on to state rather naively that:

> “Chinese companies own such a significant share of the patents [that] the western companies need to pay to license from them, i.e., the net royalty payments will be from Western companies to Chinese companies.”[6]

This statement could only be true if the quality of Chinese patents is equivalent to or better than Western companies patents, or if the infringing sales based of Western firms is greater than that of Chinese firms. The licensing jurisdictions also need to be similar for such equivalences to be drawn.[7] The famous quote “not everything that can be counted counts and not everything that counts can be counted” (variously attributed to Albert Einstein and William Cameron) seems relevant in this context. Accordingly, an exploration into patent statistics and the context of patent licensing for 5G seems warranted.

An additional reason for executives and policy analysts alike to focus on standardization is the publication of "China Standards 2035." This initiative builds on "Made in China 2025" and seeks to take control of what is currently a decentralized private and substantially professionally-driven global standard development process, with far reaching consequences for international business and for national security. If successful, it will change the governance of global business and expand China's geostrategic power. In the last few years Chinese firms already have obtained substantial representation in the international standard setting process. Unlike Western representatives, Chinese representatives, whether corporate or government, are held accountable to nation state.

This paper's main focus is on why the size of patent portfolios for the upstream 5G foundational technologies held by particular firms, even when purportedly quality adjusted, are not good indicators of technology leadership and the (licensing) value of 5G patent rights that particular firms may own.[8] It endeavors to put patent data in proper perspective, with the goal of blunting any rush to use patent counts as technological leadership indicators and as the sine qua non of technical prowess or the value of patent portfolios. In doing so, it hopes to expose some of the mischief done through the misuse of patent statistics, particularly by commercial entities wishing to peddle patent analytics.[9] However, it is first important to understand the way in which enabling technology is assembled and how the foundational technology layer is created and standardized.

## II. THE GLOBAL OPEN STANDARDIZATION MIRACLE

a. Background

A very much overlooked and understudied topic in globalization is the process of standards development and standard setting, especially in mobile wireless. As the Swedish Institute of International Affairs recently noted:

> "For decades, and almost unnoticed by the general public and politicians, technical standards have been a driving engine behind globalization… they [now] run the risk of turning into a core subject of great power competition over high technology" (p4)

And goes on to note:

> "Europe emphasizes its commitment to rules based institutions in world affairs. Hence, it cannot simply adapt the new power approach to technical standards, since this undermines the existing institutional framework[10]…" (p5)

The report further noted China's state directed approach to standard development "radically breaks with both the US and European approaches that are both industry driven." Others sources draw attention to China, noting:

> "The CCP has seized on the importance of these [standard development] bodies for the dual and mutually reinforcing objections of increasing national competitiveness and building international influence on technology adoption[11]…"

Patents are particularly important in the mobile wireless ecosystem because patent licensing is how the global sharing and financing of new technology is achieved. Proprietary 2G, 3G, 4G, and now 5G foundational technologies have been made available via non-exclusive patent licenses to the whole world, generation after generation. This is a major reason for the success of mobile wireless over the past 30+ years. It is also a rather unique situation and unless continually attended to and protected, it may not continue much longer.

In the 1980's and 1990's the International Telecommunications Union (ITU) historically played a major role with standard setting for fixed line telecom. Under the ITU a new organization which orchestrated mobile wireless technology development was born: 3GPP. 3GPP stands for the 3rd Generation Partnership Project.

The 3rd Generation Partnership Project was put together in 1998 when the European Standards Institute (ETSI) partnered with seven other standards development organizations (SDOs) around the world to cooperatively develop technologies for 3G. It is functionally much more than a standard development and setting body. Today it is the de facto nexus for most remarkable combining the R&D outputs of the companies around the globe that are inventing 5G wireless technologies. 3GPP is akin to a global consortium that functions as the mobile wireless ecosystem's R&D arm for developing and assembling and then standardizing foundational technologies.[12] Tens if not hundreds of thousands of engineers around the world have been working in 5G foundational technologies. They are all loosely coordinated by the almost invisible hand of several standards development organizations (SDOs) that work with 3GPP. This amazing technology development program…costing billions of R&D dollars per year…is almost entirely privately funded and the technologies are combined by engineers operating under rules established by 3GPP/ETSI.

The 3GPP periodically releases documents incorporating many important new advances in the foundational technologies that have been garnered and gathered from the research activities of global mobile wireless technology companies. For example, release 16 was published in July 2020. It's usually at least a year or more after a release document is published before cell phone and other subscribers begin to have access to the fruits of the new technology. In order to get the benefits of these technologies, infrastructure companies like Ericsson, Nokia, Samsung, LG, Huawei, and Cisco have to design them into their equipment; and chip and device manufacturers like Samsung, Apple, LG, Motorola, and Huawei have to embed them in new modems and in new generations of their devices. Of course, the network service providers must also install the requisite equipment upgrades for benefits to be realized.

While now familiar to the mobile wireless industry, the type of governance that 3GPP affords is unique as to its global scale and scope. It is rule based and consensus driven.

Constituencies include technology developers, systems operators, device makers, and governments around the world.

3GPP epitomizes cooperative global technology development at its apogee. It is a corollary of the post-World War II liberal system of cooperative innovation and distributed economic organization. While 3GPP is the de facto R&D orchestrator of the mobile wireless ecosystems. With the rise of China, and China's expressed desire to dominate standard setting, this delicate organizational arrangement that has generated benefits for all may not last much longer. [13]

b. 5G Standards Development

It is important to note that the standardization of 5G technology involves not just achieving compatibility with all elements of the system; it also involves the incorporation of high performance technologies into the standard that are considered by the members to be the best. It's a merit-oriented competitive process.[14] Acceptable 5G technologies must not only be technologically advanced… they must also be commercially viable and tested through review by infrastructure builders and device manufacturers. Absent confidence that the user community is satisfied as to efficacy, the technology is unlikely to garner the votes necessary to be included in the standard.

With 5G, 3GPP has the difficult task of governing a collaborative effort amongst hundreds of different entities with somewhat different interests and incentives. It oversees an iterative, non-linear, consensus-based approach to technology selection and resultant standards development. Think of it as systems engineering managed privately and in a very decentralized manner. It has worked well. This is in part because the professionals involved are engineers, with little involvement by lawyers, economists, and politicians. An engineering culture is allowed to dominate and good work gets done.

With 3GPP, the mobile wireless industry has been able to provide a remarkable track record of developing a continuously evolving and improving interoperable systems, culminating in 5G. GSM, WCDMA, and more recently LTE are prior examples of successful technologies developed privately and separately but combined by 3GPP, using consensus driven governance, into a platform with massive economies of scale and scope. Technology development for 5G is done in a distributed manner with limited overall end-to-end supervision. A very few companies like Qualcomm and Ericsson work very hard to help ensure a high degree of end-to-end coherence. Without these special efforts, 3GPP could fail, as 3GPP doesn't have resources of its own to sponsor the development of "gap filing" technology that on a stand alone basis, may not be financially viable. The real contributions of individual members are hard to calibrate and are not measured by merely counting the number of technical contributions that are made or patents that are declared by particular companies.

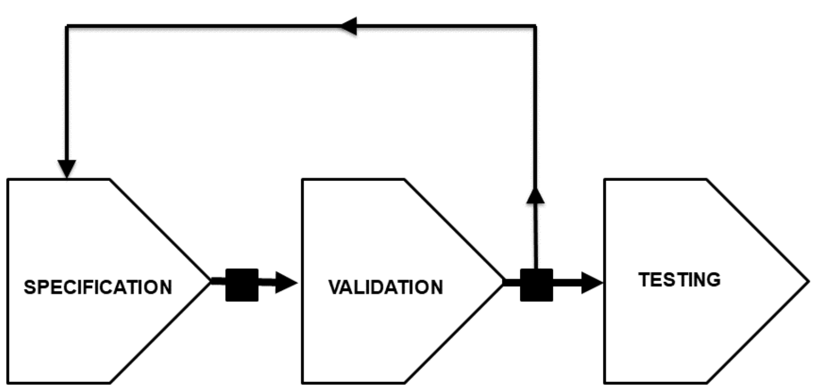
c. Standardizing on the Best Technologies

To understand the 5G licensing context, a brief description of the process by which technologies are woven into advanced high performance technical standards (such as 5G) is warranted. First, the development of technologies to go into 5G takes many years. Individual companies working in their own R&D facilities develop technological solutions to particular aspects of the technological challenge, which is laid out in ambitious goals for 5G. These companies then bring their technologies to meetings hosted by the standards development organization. At those meetings, members convince their colleagues of the applicability and utility of their technical solutions. Participants assume they are likely to be patented even if they are not currently patented.

Participating firms need confidence that each technology advanced for consideration is robust, has been or will be tested, can be manufactured, and that the requisite software and applications support will be available. Sponsors of technology are then required to demonstrate that the technology is or can be commercially viable. Hence, patented technology that becomes embedded in the standard has already undergone an early assessment as to commercial viability. Licensing execs need to understand this process, as it indicates that patents that are “truly essential” likely have passed a litmus test of commercial viability, and are thus likely to have value if indeed they are truly essential, and not just “declared essential” by the patent owner.

Standards also need to be designed for interoperability. Feedback from the validation and testing activities is critical and often leads to further development of the technology and/or changes in specification. This process is shown in Figure 1. Steps in validation include review, modeling, prototyping, and “plug tests/plug fests” where designers of equipment or software using the technology proposed for the standard test interoperability of products and designs with those of manufacturers. As standards go through various revisions, multiple firms may submit proposals and work together towards final adoption of the standard.

FIGURE 1. Standards Development Process



The standard setting process for 5G, like 4G, 3G, and 2G before it is a continuous process as updates are issued periodically. Licensing practices over the year have evolved to support the open interoperable mobile wireless ecosystem, with royalties being set in the marketplace via negotiation at levels sufficient to encourage at least a few companies to make the large investment required to develop new 5G technologies.[15]

## III. THE WIRELESS ECOSYSTEM: THE SALIENCE OF PATENTS AND PATENT LICENSING

a. Background

As outlined in the prior section, the process of standards development and standard setting in mobile wireless involves much more than just setting compatibility and interoperability rules. The standardization process involves selecting and anointing technology that will enable the entire ecosystem to function, and function well. Standard setting is almost a misnomer for what is involved. Ericsson has put it this way:

> "In the case of mobile telecoms standardization is, "a framework of agreements for all relevant parties in an industry to ensure the creation of well performing systems, products, and services in accordance with set guidelines. The objective is to maximize capability, interoperability, safety, repeatability, and quality."[16]

Private (for profit) technology developers are only willing to offer their technology for use in open (public) standards because of the existence of patent systems. The 3GPP governed innovation ecosystem would not be viable without private parties continuing to spend billions of R&D dollars on foundational/enabling technologies. Patent licensing fees are the way that these technology developers are financed.

While technology is adopted into the standards by vote of the members, developers who contribute patented technology do so only because of rules requiring (1) patent owners make licenses available (2) implementers/users take licenses and pay, rather than infringing willy nilly. I.e., everyone can have access to 5G standardized technology (at least for a reasonable period of time) through a patent license; but at the same time implementers/users must be willing to pay in royalties… which are not numerically set by ETSI. Commercial terms need to be negotiated and meet the criteria of being fair, reasonable, and non-discriminatory (FRAND). This two way commitment must be enforced for the open global R&D supra consortia that is 3GPP to be viable… otherwise free riding by implementers will cause it to collapse.

Over time, the open innovation model has become a bit fragile as there are thousands of downstream device manufacturers; but no more than a handful of firms provide 80% of the foundational technology that is incorporated into the standard. Apple's suit against Qualcomm over 4G royalty rates… which was eventually settled… was a classic case of "biting the hand that feeds you." Without Qualcomm's technology, Apple would run out of new cool features to put on its iPhone because the enabling foundational technology would not be there to support it. Apple has generally been quite supportive of its ecosystem partners… and it eventually did come to terms with Qualcomm… but it put the rather fragile global consortium for technology development at risk for several years. [17] The related attack by US FTC, perhaps inspired by Apple, compounded the problem.

b. Foundational Technology Patent Licensing

This paper focuses mainly on the licensing of 5G foundational or "enabling" wireless technology. As noted above, the collaboration innovation model used for upstream mobile technology requires a relatively smoothly functioning market for (non-exclusive) patent rights. As noted, 5G connectivity would not be possible without decades of upstream R&D on foundational technologies by companies like Ericsson, Nokia, Qualcomm, Samsung and LG as well as new players like ZTE and Huawei. While companies like Apple and Samsung that sell devices often receive credit in the public's eye, high-performance devices would not be possible without the technological inputs of upstream inventors, infrastructure developers, network providers, and many others.

What makes all patent licensing challenging for licensing executives, and for some policy makers to understand, is that patents are not self-enforcing. When patents are issued, the invention is exposed to the world through concurrent publication. The patented technology is protected legally but *un*protected practically, since there is no automatic monetary collection mechanism. To some (unscrupulous) industry participants, the publication of patents and associated standards is an invitation for unlicensed use of the patented technology because policing unlicensed usage is sometimes difficult and always costly.

Accordingly, just making licenses available does not guarantee that users will take a license and begin to pay royalties. The patent owner still needs to develop a licensing program and persuade non-licensed users to sign up and pay royalties, or face litigation. The SDO provides a licensing framework (FRAND) but no direct assistance to the parties. Courts must be prepared to enjoin infringers; otherwise, incentive are weak for unlicensed users infringers to seek a license. The patent owner is left "pushing on a string" unless courts or international trade regulators are able to block market access for infringers.

Despite difficulties, 5G technology licensing has already begun. Ericsson has announced commercial 5G deals with 12 service providers.[18] Nokia announced 63 commercial 5G deals.[19] Qualcomm has licensed eighty-five different companies. Hundreds if not thousands of licensing agreements for 5G standard essential patents (SEPs) are likely in the next decade. For this to continue amongst the plethora of new entrants expected, the economic principles of technology value determination need to be understood not just by licensing executives, but by policy analysts and also by courts and regulators.

Figure 2 and 3 show the sequencing of the development of standardized technology. This sequencing has important implications for licensing dynamics. Stage one investments are made (1) having no guarantees that they will be successful and (2) even if technologically successful, to some degree, the discoveries may not be good enough to go into the 5G standard. The fact that R&D to develop foundational technologies take place before the equipment and device makers invest puts the licensor in a rather weak bargaining position with respect to the implementees/licensees. This position is amplified by the fact that patents are not self-enforcing… it requires a court of law to back up the patent owner otherwise “strategic” or “unscrupulous” putative licenses will engage in “hold out.” As Delrahim has noted:

> “If the implementer holds out, the innovator has no recourse even if the innovation is successful. In contrast, the implementer has some buffer against the risk of hold-up because at least some of its investments occur after the royalty rates for new technology have been determined. Because this asymmetry exists, under-investment by the innovator should be of greater concern than underinvestment by the implementer.[20]

Put differently, implements can “hold-out” And not take a license and try to dodge paying royalties. This can make the job of the licensing executive difficult, a condition that some regulators around the world have only exacerbated.

FIGURE 2. Stages of Development of the (Mobile) Wireless Ecosystem

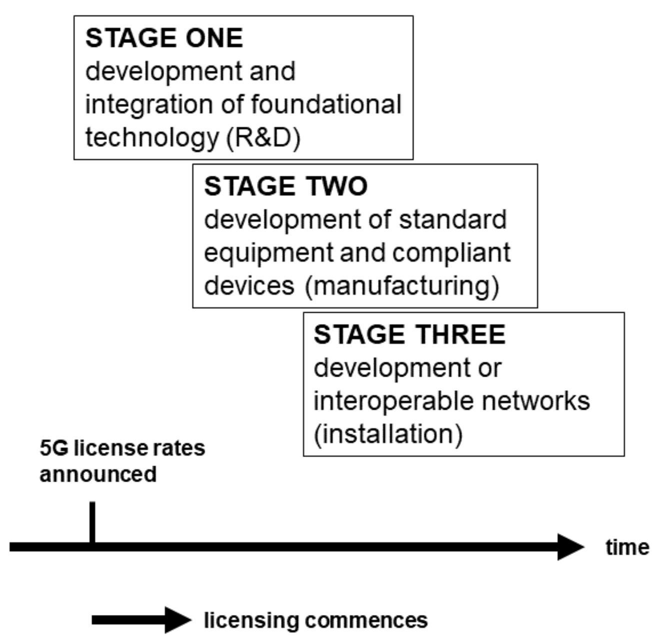
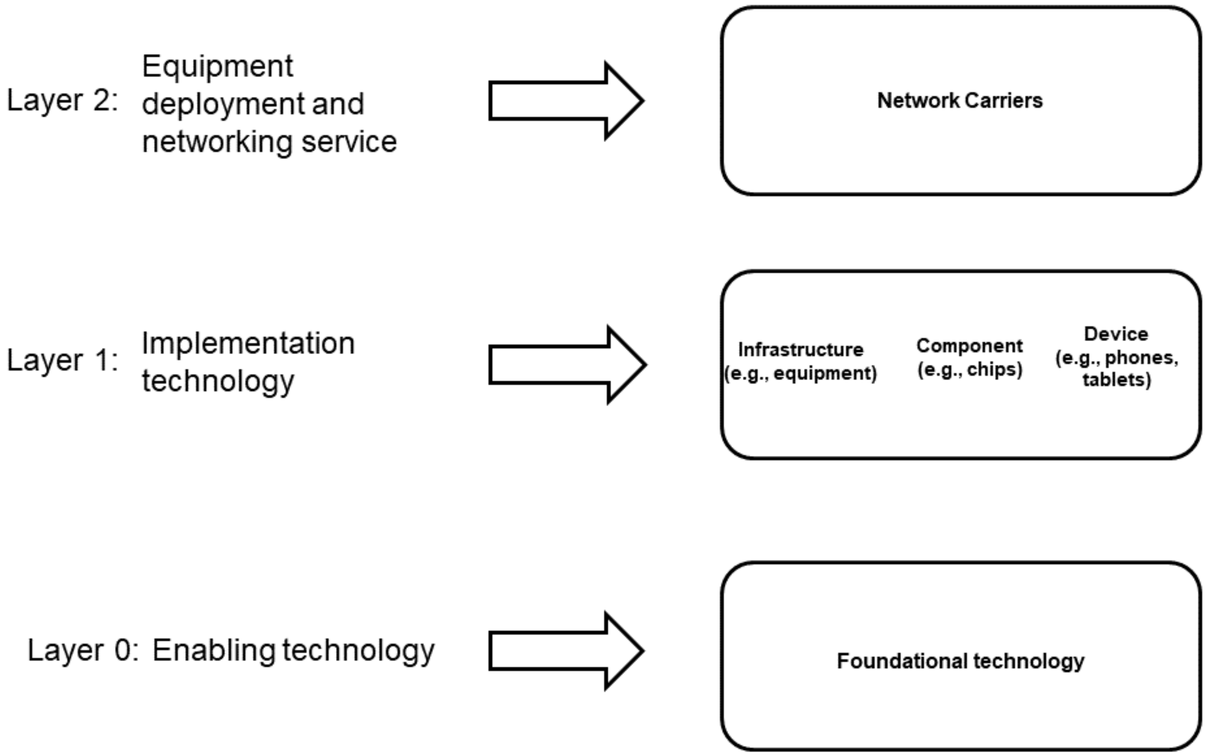


FIGURE 3. Simplified 5G Ecosystems




## IV. MEASURING TECHNOLOGICAL OUTPUT AND VALUE

a. Background

Clearly the field of licensing is complicated. Licensing executives need to be aware of this background while at the same time focusing on fundamental valuation principles. In that regard, the best indicator of value for anything is what parties pay in arm's length transactions in competitive markets.

However, market data on royalty payments doesn't always exist (or is not publicly available). Thus, even if some similar patent license agreements have already been struck, the per-unit price/royalty rate or lump sum payment for a portfolio might not be disclosed publicly, and therefor might be unknown to one or both sides negotiating a license.

In the absence of market data on royalty rates, some executives and policy analysts are tempted to focus on patent data that is now widely available in machine-readable form. Much of the rest of this paper will show that it is easy to be seduced by the numerosity of patent data. Arithmetic patent counting is hardly ever a good measure of value, as economists have known for many decades. Mark Schankermann has stated the situation quite succinctly:

> "The distribution of the private value of patent counts is sharply skewed in all technological fields, with most of the value concentrated in a relatively small number of patents in the tail of the distribution."[21]

This simplifies many license negotiations as one can focus mainly on the tail and get a good idea of the total value of the patent portfolio. Notwithstanding this shortcut, when there is ambiguity, technology managers and analysts seeking to determine a reasonable royalty or price for patented technology should never lose sight of the North Star: value in use. Whenever value in use is ignored, negotiations will drift off course, transactions are likely to fail, and costly litigation might ensue.

Naked patent counts are not particularly useful; such counts are not a proxy for the value of a firm's patent portfolio. Statisticians and econometricians remind us to use great caution when using proxies and this is particularly pertinent when patent counts are offered as a proxy for value. They are very "noisy" and likely also biased indicators of value for many reasons. As noted, there is great skewness in the distribution of patent values.[22] There are also problems when one is looking across industries, as patents differ in efficacy and utilization across industries/sectors.[23] There is also differences amongst firms in the proclivity to patent. Some of this is jurisdiction specific, making assessment even more difficult.

b(i). Patents as proxies for technological capability/value?

When a variable isn't directly observable, proxies can sometimes be found that are indirect measures of a desired fundamental variable. The focal variables that animate this study are technological capability, technological leadership, and especially value at the individual firm level. A good proxy is ideally correlated with the underlying variable of interest. The fundamental problem is that a patent is, at best, a rough proxy for what we usually are seeking: a measure of innovative output or technological capability and prowess.

Proxies are used when direct measures of the underlying variable are unobservable or unavailable, or measuring them directly is considered too costly. As noted by Hall and Jaffe: "In order to determine whether an indicator is meaningful and avoid being flummoxed, licensing executives need to assess both the data that are used, and the manner in which those data are summarized."[24]

Griliches categorizes data quality according to: extent, reliability, and validity. Extent refers to scale and scope of data sets. Reliability refers to inherent reproducibility of the data-collection process. Validity refers to the extent to which the data are generated and collected in a manner corresponding to the underlying concept of focal concern.[25] Patents fall short particularly with respect to validity. They are set to meet criteria of inventiveness, with no reference to commercial value, which is a focal concern in this paper.

The market or licensing value of a patent depends on how the patent holds up in court. Valuation is a function of not only the underlying technology but of how well the patent is written and defended, and of how the technology covered by the patent performs relative to the next best non-infringing alternative.

Unfortunately, simple patent counts are an imperfect and unreliable metric of either technological leadership or portfolio value. Using them may create an aura of accuracy; but it is a false and unscientific kind of accuracy. Ericsson's Christina Petersson notes:

> "The question of who is leading the development of 5G is of immense interest to businesses and to politicians….we conclude that many published studies are over simplistic and unreliable … company rankings are highly sensitive to: the assumptions; the analyst's data; and the metrics used … Depending on the precise inputs, European, South Korea, China, and US companies can all claim top spot(s) …"The true story of 5G patent leadership is much more complicated than the prevalent media narrative." [26]

Patents tell little about who is winning or likely to win the 5G race. One country could dominate patent counts, while other countries could dominate the development and deployment of services that run on top of 5G. Most licensing executives understand that it is improper to use patent counts to measure technological prowess and/or portfolio value.

Econometricians will go further and point out that the unobserved but true values of a variable of interest $X^*$and its observed but mismeasured counterpart $X$ can be related through $X = X^* + \Delta X$ when $\Delta X$ denotes the measurement error. Often, identification of the model will rely on the availability of a vector of other observed (proxy) variables.[27]

b(ii). Patent Counting: Precision but not Accuracy

In scientific inquiry, precision refers to how close the measurement of a variable is to what is being measured. Precision is independent, and can create a false sense, of accuracy. It is possible to be precise but highly inaccurate. Accuracy is more important than precision and is about how good a measure is of the true underlying variable.

Patent counting, while often precise, doesn't meet the criteria of accuracy.[28] Sometimes this is because of ambiguities as to patent scope. For instance, sometimes standards are at issue, with patents "reading on" or being "essential" to one or more technical standards. However, there may be ambiguities around how many patents in a given portfolio are essential, versus simply declared essential by the owner or some third party.

Researchers are sometimes smitten by the presence and munificence of publicly available machine-readable data. Leading scholars generally display considerable care with respect to not drawing too much from the statistical and econometric analysis of patent data. This care is less evident regarding for-profit patent analytics companies.

Writing[29] about SEP declarations, J. Baron and Tim Pohlmann note that "there is no verifiable information on how many of the declared SEPs are "truly essential" and how many "truly essential" patents may never have been declared." Declared SEPs don't meet Griliches' validity criterion. However, the authors' care seems to evaporate in commercial versions of their work.[30] Strong claims are also made in commercial publications, such as, "patent declaration information is the best source for understanding the potential 5G patent landscape."[31] Most experts would find that statement wrong or highly controversial.

b(iii). Patent Counts: Noisy or biased measure of value?

Noise has errors that generate assessment and decision risk and uncertainty. As Nobel laureate David Kahneman explained, "noise is like arrows that miss the mark randomly while bias misses the mark consistently."

Patent scholars have long stressed that patents are a very noisy measure of patent value. They are also likely a very biased measure. Whereas in behavioral economics more generally "we have too much emphasis on bias and not enough on random noise,"[32] it is likely that with respect to patents we have too much emphasis on noise and not enough on bias. Bias and noise are, of course, additive. Indicators can be noisy, biased, or both. Patent metrics as indicators are often both.

There is at best a skimpy literature in the context of patents which indicates the nature of bias, but all scholar quickly "tip their hats" to the presence of noise…and try to find more independent variables to reduce it…but then generally proceed to draw conclusions without a full discussion of bias, in part because bias is complicated and multifaceted.

With respect to patents, there is no evidence that biases one way negate biases the other way. In part this is because there has been too little attention given to biases in patent counts and in SEP declarations and in technical contributions. However, as pointed out in this paper, the entry of new players onto the field of SEP's has created new issues. So long as some decision makers input some level of importance to patent counts, and technical contributions, there is an incentive for all to artificially inflate statistics. Also, if some players see patent statistics as more meaningful than others, they will behave accordingly. Hence, the amount of bias (inflation/deflation) in patent statistics is likely to be firm specific, and possibly nation specific too.

Licensing executives with deep technological background who are close to 5G know who has the leading (patented) technologies and who does not. It requires quite some skill and experience to understand the many layers of technology, and who has contributed to the most important breakthroughs.

## V. THE STRATEGIC MANIPULATION OF PATENT DATA

Patent statistics would be difficult enough to make sense of were they the result of honest efforts to calibrate value. The problems are multiplied when patent statistics are manipulated deliberately.

Patent statistics/counts can be manipulated in many ways, leading to both bias and noise. Few scholars and licensing executives seem aware, despite longstanding warnings. For example, thirty-five years ago, Keith Pavitt noted that the propensity to file a large number of patents of low value varied considerably among firms as a function not just of ex ante expectations as to monetary value, but according to "the number of patent agents employed by the firm."[33] Pavitt was prescient in recognizing that a source of bias in patent data is "differences amongst firms in the propensity to patent the output of innovative activities."[34] Pavitt saw the remedy to this bias lying in part with "the judgement of technological peers on the innovative performance of specific firms and countries."[35]

In the semiconductor industry, increases in patenting in the 1990s revealed a paradox: higher patent propensities uncorrelated with R&D expenditures. Researchers looked into this development[36] and concluded that some firms were propelled by "strategic motives," which included "gaining leverage in license negotiations."[37] Individual companies can pump up their patent applications; nation states can bias patent statistics too.

One way governments can impact/manipulate patent counts is through patent subsidies.[38] The rapid increase in patent applications in China can be explained in part by China catching up with the West. However, government subsidies of the patenting process are also a major factor. In China, the subsidies are usually provided by local government.[39] Perhaps the reason is to stimulate innovation in China, pursuant to broader national policy goals?[40] Perhaps it is to develop respect for intellectual property? Less forgivable reasons also come to mind, as noted above. The result, according to one observer, is that

> "Raw patent filing numbers are a useless way of measuring the value of a technology. That applies especially to Chinese companies that receive official encouragement to build patent holdings."[41]

Subsidies promote not just the patenting of inventions but the invention of (low-quality) patents. Subsidies introduce more than noise into patent data; they introduce bias through the presence of many low-value patents. Licensing executives and analysts need to be alert to such biases[42].

The issues associated with the (strategic) manipulation of patent statistics that are discussed above are somewhat understood by scholars (and also by seasoned licensing executives), often leading to the articulation of caveats regarding the use of patent data in academic research. However, commercial purveyors of patent analytics and junior licensing executives are often unskilled as producers and consumers/users of such data and associated summary statistics. Further, commercial purveyors are disincented to reveal inadequacies in the data to potential and actual customers,[43] resulting in "black box" analytics. This aspect of many SEP counting and weighting exercises compounds the difficulty of understanding the value of patented technology. The non-robustness of popular patent rankings is also noted; small changes in definitions of variables produce different results.

## VI. RELEVANCE OF PATENT STATISTICS TO 5G LICENSING FRAMEWORKS

Because 5G technology is complex, the possibility of confusion as to the relevance and meaning of patent statistics is real. In particular, differentiating between patents that are truly essential to 5G standards and those that are not (though they might be tangentially related) leads to measurement errors. There are incentives to invent patents and to over declare (amplified by SDO penalties for under declaring), biasing declarations upward. Moreover, there is no reason to believe that all companies will over declare for the same reasons and by the same amount. Also, companies may declare their patents at different times. The absence of rules requiring disclosure according to a common procedure and clear criterion for "essentiability" renders counts of SEPs rather meaningless.

In this section, I critically examine five metrics that commercial patent analytics purveyors put forward as candidates for licensing executives to employ as an indicator of patent (portfolio) value. I pay particular attention to the extent to which the variables in question are exposed to strategic manipulation by one or more industry participants. I make preliminary assessments regarding the relative utilities of certain metrics.

1. 5G family counts

A patent family is a group of patents taken in various countries to protect a single invention (i.e., the same invention disclosed by a common inventor(s) and patented in more than one country). A patent family covers the same or similar technical content disclosed by common inventors.[44] Analysts who talk about patent counts generally are referring to counts of patent families.

Most analysts treat a patent family as a black box. Different definitions of patent families may produce different results.[45] The interest in patent families in recent years might reflect the interest in patent portfolios. Families avoid the double counting of single inventions, help neutralize the home-country advantage of applicants, and focus on the internationalization of technology markets.

Using SEP patents as a proxy for innovative activity requires an understanding of why they are filed, how they are administered, whether they are valid, and how they are enforced. Inventors apply for multiple patents for the same innovation partly in response to the legal rules prevailing in each national patent system and on decisions made by inventors/innovators.

Patent families may include several patents within particular national jurisdictions and at the international level. These filings include divisional or continuing applications. Divisionals are guaranteed by the Paris Convention and are sought most often when just one patent application would describe more than one invention (i.e., it would otherwise lack "unity of invention"). An applicant typically has the right to divide the first application into several divisionals, so long as the parent application is still pending.

Sometimes divisionals are imposed by examiners; more often they are sought by applicants. They are useful to the applicant when they identify new ways of claiming different versions of an invention. Narrower patents can result in a large number of patent applications and usually of granted patents. However, patent family linkages reflect patenting strategies. "Patent constructionism" or "patent invention" is not an unknown phenomenon.

A count of patent families is not a good indicator of technological prowess or patent value. It indicates involvement in and with certain technologies, and some amount of inventiveness, but the quality threshold is low.

| Assessment: Easy to manipulate; not a meaningful indicator.[46] |
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2. Forward cites[47]

A patent citation reflects that an invention may be based partly on an earlier patented invention. Citations for patents are grounded technologically, as inventor applicants in the USA are required to disclose relevant prior art (which restricts the scope of their own patent). But applicants don't want to cite other patents unnecessarily. Some applicants try to wash away prior art by citing marginal contributions. However, there is perhaps a little more discipline to the process than with scientific/academic publications, where authors are somewhat free to cite as they choose.[48] Patent cites can be weighted linearly or nonlinearly. A citation could be considered worth as much as a patent (i.e., the weights are linear) or worth more or less than a patent.

Particularly novel inventions will not typically have much prior art to cite. A fundamental invention will typically receive many cites from other inventions that build on it.

Generally, the number of (forward) citations a patent receives mirrors the technological importance of the patent to the development of follow-along technologies, which in turn should be related to economic value.[49, 50] However, Kuhn, Younge, and Marco[51] cast doubt and suggest great care regarding interpreting even this most respected of quality measures: patent citations. They may reflect technological achievement but not commercial value.

Lerner and Seru note that recent research calls into question a straightforward interpretation of patent citation data, as citations may suffer from considerable noise and measurement error.[52] They claim that "failing to correct for time period, technology, and geographic region can introduce significant bias into an analysis."[53] In their view, biases in the data cannot be ignored, as they do not add up to classic measurement errors; the biases are strongly correlated with firm, technological, and regional characteristics. Central challenges they identify are the import of time, technology class, region, and firm-level aggregation. They note that truncation problems are complex when patents are aggregated at the firm level. They find that results are not robust to various adjustment methodologies. Even if this bias doesn't exist or is removed, translation into commercial value remains problematic.

The issues outlined above are compounded by strategic behaviors. One genre is what Lerner and Seru call "misleading patent assignment…with patents sometimes being put in holding companies offshore. Another is what they call “strategic citations.” Lerner and Seru offer a “checklist for researchers” to help guard against bias; but I am aware of no universal acceptance or adoption of such check list. [54]

Jaffe and de Rassenfosse[55] note pitfalls in using citation data. Even the identity of the patent office matters. For instance, there is a “duty of candor” in US patent law. Failure to report known prior art may lead to subsequent revocation of the patent. Jaffe and de Rassenfosse note there is no duty of candor in European patent law, and applicants do not have to submit a list of prior art. They see examiner-added citations as strengthening the possibility of patent value. However, it is impossible to adjust for the wide dispersion of patent values.

| |
|---|
| Assessment: Not easy to manipulate but not easily aggregated across jurisdictions; doesn’t always reflect commercial significance. |

3. Independent claims[56]

An independent claim contains a preamble and elements necessary to define the invention.[57] All patents will contain one or more independent claims. An independent (“standalone”) claim does not refer to an earlier claim. Any claim must be followed by one or more dependent claims concerning particular embodiments. A dependent claim is necessarily narrower than an independent claim.  A patent ends with one or more claims specifically setting forth the scope of the patented invention.

Technology fields are also likely to impact the number of claims per patent. As Lerner notes, the scope of patents is often associated with the technological and economic value of patents.[58] He observes that the technological breath of patents in a firm’s portfolio affects value significantly. He cites broad patents as being more valuable because they close off substitutes. However, in the context of 5G, they enable more downstream inventions.[59] Matutes, Regibeau, and Rockett[60] suggest that scope of a patent indicates a more fundamental and possibly more valuable patent.[61]

The number of claims contained in a patent depends largely on the jurisdiction and is influenced by the claim-related fee structure.

| |
|---|
| Assessment: Hard to manipulate; impacted by jurisdictions covered. |

4. Geographical coverage[62]

This metric shows the number of jurisdictions where 5G is active.[63] Geographic coverage is an indicator of the value of patent rights, because inventors tend to seek greater international coverage for more valuable patents.

The value of patents has been held to be associated with the geographic scope of patent protection (i.e., with the number of jurisdictions in which patent protection has been sought).[64] The rational is that applicants might be willing to accept additional costs and delays of extending protection to other jurisdictions if they deem it worthwhile; but this can be exposed to strategic manipulation too.

Assessment: Relatively costly to manipulate.

5. Number of technical contributions for the development of standards

Because it is easily measured, it is possible that interested parties or poorly informed academics might in the future be tempted to put this forward. However, it is clearly not a metric for quality and has not been suggested as such by any credible authority, to my knowledge. The ETSI Intellectual Property Rights (IPR) policy regarding 5G SEPs comprises the rules governing disclosure and licensing commitments of its members. ETSI members are obliged to self-disclose patents that are potentially essential to the standard. However, ETSI does not require members to carry out a patent search for the disclosure process or follow a formal process for determining the essentiality of patents. Some companies fail to identify accurately which patents are essential to the standards and declare their patents to an abnormally high number of 5G technical specifications.

Assessment: Not a metric of real contribution

**Table 4. Summary: Assessment of Certain Patent Metrics as Indicators of Technological Prowess**

| Metric | Assessment |
|---|---|
| 5G Family Counts | Easy to manipulate. Not a meaningful indicator |
| Forward Citation Counts | Not easily manipulated or aggregated across jurisdictions; but doesn't always reflect commercial significance |
| Number of Independent Claims | Hard to manipulate; impacted by jurisdictions covered |
| Geographic Coverage | Relatively costly to manipulate |
| Number of "Technical Contributions" to Standards Bodies | Not a measure of real contribution |

## VII. TOWARD VALUE-BASED APPROACHES

The infirmities and hazards of valuation approaches based on patent counts (and royalty caps) is apparent. Both bias and noise are present. Better approaches require paying attention to the fundamental economics of technology valuation.

As already noted, in the economy more generally, licensing is not the most common business model used by firms to capture value from the technology they develop. Generally, firms capture value by implementing technology themselves. Profits come through the development and sale of components and products into which the technology is embedded. Management then avoids the hazards of licensing as a lynchpin of a company's revenue and profit model.[65] However, firms with technology have a (theoretical) choice between productization and licensing.[66] Some companies may not productize their technology, and some may productize to a limited degree.

However, in the case of air interface communication technologies offered by firms for patented adoption by ETSI into 5G standards, patent licensing is mandated by the "FRAND commitment." The ETSI IPR policy states explicitly that ETSI "seeks a balance between the needs of standardization for public use in the field of telecommunications and the rights of the owners of IPRs."[67] The IPR policy doesn't prescribe a formula; merely that there must be "balance" to allow the ecosystem to flourish and support the continuous generation and adoption of new technologies.

The FRAND commitment is a contractual one to the SDOs, and users are third party beneficiaries. It does not require patent owners to offer technology to be incorporated into standards. But if technology is offered for consideration to the standard setting body, and is covered by patents, SDO rules typically require the patent owner to disclose the existence of the patent and also agree to FRAND licensing. While own use isn't foreclosed, it must be in conjunction with "making licenses available," "for some period of time, to technology implementers."[68]

Because of the world's adoption of the open innovation (i.e., "licensing") model for mobile devices, it is necessary to look downstream to ascertain the value of the upstream technology tendered for license. However, this isn't unique to mobile devices and the 2G, 3G, 4G, and 5G standards. Looking downstream to observe the patent technology at work is also what licensing executives do and what courts do when patent infringement disputes arise.

This value created by 5G in the IoT will differ across use cases and application areas. Licensing structures and royalty rules will need to recognize this heterogeneity. Use value may depend on how a "thing" is commonly used by its owner and the nature of the services provided to others. New and creative ways may be needed to monitor and measure the use of patented technology so that licenses can be structured in new and different ways. Such organizational innovation is evident in the formation of Avanci to simplify (through "bundling" and fixed rates) the licensing of wireless technology for the IoT.

Avanci licensors and licensees include well-known technology developers and OEMs that have endeavored to "streamline the technology sharing process" through a "fixed price royalty model." This approach "accommodates the wide range of uses in IoT" devices. It implements licensing through fixed-rate (i.e., per unit) royalty structure. Avanci notes, in the spirit of what is advanced in this section, that:

> "When it comes to valuing technology, context is everything. To address this reality, Avanci launched its platform with prices that reflect the value cellular connectivity brings to a specific application. Although there is no explicit formula, some of the considerations when determining the value of a license for a particular application include (1) the need for wide area connectivity (2) the amount of use and the required bandwidth."[69]

There are four classes of accepted methodologies for determining value:

a. The Gold Standard: Patent by patent analysis of leading ("Star") patents

As explained by Grindley and Teece in an earlier paper in the California Management Review, patent licensing and cross licensing is often facilitated by a focus on the key patents (sometimes called "star" patents or "proud" patents) in a portfolio.[70] When there are thousands of standard essential patents for consideration, they must be and can be reduced to a manageable list of the most salient patents. Sometimes sophisticated software can be used to create a short list for further hands-on screening and analysis. However, once a standard has been published, the list of truly valuable standards essential patents will be common amongst almost all licensees.

Once there is a manageable list, "the best method to accurately assess the importance of any given patent relative to a standard is for skilled professionals to employ their expertise to evaluate the patent in details…there is no simple metric or group of metrics that can substitute for human evaluation"[71] Kappos notes that his requires deep knowledge and experience of both specialized technology and highly specialized patent law. He concluded that "it should be no surprise that this is the predominant method used when patent license agreements are negotiated." (p7) Because skilled licensing professionals also understand how the technology is likely to be used, "patent license agreements truly embody assignment of the importance of a patent portfolio – the value transferred from the patent holder to the licensee." (p7)

Licensees negotiated at some length by skilled negotiators can then become a benchmark… what Schelling[72] might call a focal point or benchmark for subsequent negotiations, with each agreement further solidifying the market value of the patent portfolio.

All other methods are supplements to the work of skilled professional hopefully converging on a mutually acceptable valuation. When knowledgeable skilled professionals are all in the same room and left to themselves, they can usually converge quickly on value. When this doesn't occur, and the dispute ends up in court, there are four main approaches that are acceptable: comparable licenses, discrete natural experiments, choice experiments, and econometric approaches using aggregate choice data.

b.(i) Comparable licenses: running royalty licenses are likely the most reliable indicators of FRAND rates.

Comparable licenses lie in the shadow of the gold standard for benchmarking patent value. Market transactions conducted by sophisticated parties are the best indicators of patent value. Expert analysis that looks first at comparable market transactions and various indicators is likely the best indicator of technological contribution and value.[73]

The previous section assumed there were no market transactions and/or no comparable license agreements, or that this information wasn't available in the marketplace (but could be available in court). This may happen early in the development of new technologies. While licensing is occurring for 5G used in mobile devices and in autonomous or semi-autonomous vehicles, many market segments have not yet launched licensing programs. If and when comparable licenses exist, the task at hand is simplified—assuming the transaction is between unrelated partners and unencumbered by broader strategic issues. One is likely to find three types of licenses for air interface technologies: one-way running royalty licenses, lump-sum licenses, and cross-licenses.

Running (per-unit) royalties are a cleaner benchmark than lump-sum licenses. One complication with lump-sum licenses is that some part of the payment may reflect compensation for past use, which may be discounted or compounded. Discount for portfolio licenses can relate to time period, geography, or different patents in a portfolio.

License agreements and associated royalty rates may decline with the size or scale of the licensee. This cannot be explained well on strict competitive grounds, as no scale economics are associated with licensing an additional unit, as the marginal cost of licensing an additional unit is zero in almost all circumstances.

Volume or scale discounts, when they occur, usually reflect the considerable bargaining power of some licensees and their ability to bring unrelenting high-cost litigation against the patent owner.

Lump-sum licenses are considerably less reliable as an indicator of value, because they are driven often by idiosyncrasies of the situation and particularities of the parties. In theory, lump sums can be converted to an economically equivalent running royalty by calculating a royalty rate that, when applied to past and expected futures sales of royalty bearing units, would provide a licensor with cash flow whose net present value is equal to the lump sum. The net present value is calculated as of the effective date of the license or whenever the lump sum is expected to be received. A discount rate for future sales is needed to complete this calculation.

Cross-licenses are more difficult to value, because any money that changes hands is likely to be for balancing payments. The value of a portfolio is not usually observable from the licensing agreement.

b.(ii) Discrete natural experiments[74]

As noted, the need to look downstream to vector in on the value of a technology is important in valuing technology. It is sometimes possible to glean the value of patents if there is a close association or linkage between the patented technology and a product feature.

If one needed to determine a (reasonable) royalty rate for certain Wi-Fi technology protected by patents, one would look to the market success of products using the technology at issue. The value of a patent (or a portfolio) can be gleaned sometimes if it's incorporated into an add-on feature or accessory that is priced separately in the market. For instance, Wi-Lan patented technology was provided the backbone of (Wi-Fi) 802.11 standards. Network interface cards (NICs) enabled users to access the patented technology (in an incremental sense) to boost network performance.

To the extent that other proprietary technologies are not also implicated in the NIC, the price of the NIC is a good indicator of the point at which to begin the exercise of calculating the contribution to profit made by the patented technology. Bargaining between the implementer/user and the patent owner will then determine how the gains might be split.[75] The exercise requires imputing a return to relevant complementary assets and complementary technologies used by the implementer.

b.(iii) Choice experiments

Most situations are complex, and no natural experiment can be observed directly. In some circumstances, one or more patented technologies might be critical to a particular service or performance feature of a product. The value consumers attach to particular features can be used as an indicator of the value of the patented technologies. The patented technology might support new and otherwise unavailable business models or revenue streams for the user. These can usually be observed and quantified. If multiple technologies are needed to support a particular functionality, that needs to be recognized to value device performance "with and without" a particular attribute.

In many cases, survey techniques can be used to seek assessments from respondents with respect to how they value product features. The survey design seeks assessments from respondents that are connected to the features supported by the patented technology. Once a change in WTP has been determined, this can be translated, under certain assumptions, into changes in price quantities and profits.[76]

b.(iv) Econometric approaches using aggregate (non-discrete) market-observed choice data

Aggregate data can be used and applied to the BLP methodology. It uses an economic model of demand, supply, and competition and offers an equilibrium framework. It employs price and quantity data from the actual market and simulates the profit impact of patented technologies.

The approach is highly technical and uses BLP, a random coefficient logit methodology.[77] According to Hiller et al.,[78] Berry, Levinsohn, and Pakes softens concerns about price endogeneity. It constructs "counterfactual markets where the potential patent infringement is absent and present."[79] The methodology takes price erosion into account and simulates prices, profits, and market shares in a scenario in which a particular firm did not have access to the patented technology in question.

The BLP methodology is data hungry and unlikely to be widely used, but is impressive in its power to illuminate the value of technologies. It might leave apportionment issues among patent holders unanswered if multiple patent portfolios support certain product features/attributes. Accordingly, as with other methodologies, it needs to be applied carefully.

A less-elegant econometric approach is hedonic analysis. This is a revealed preference method of estimating the value of certain attributes of a product. Those attributes are then connected to the patented technology that enables/allows the provision of those attributes. Coefficients are estimated that can help in the calibration of the value of the technology that underpins desired features/attributes of a device/final product

It isn't necessary or desirable to use patent-counting approaches. Methodologies exist from which one can infer the value of patented technologies should market transactions not exist or be unobservable to the analyst for proprietary reasons.

## VIII. SUMMARY AND CONCLUSION

There is a lot of complexity in the world of licensing for 5G foundational technologies. The paper has tried to provide a framework for licensing executives. There are 16 key points, outlined in the appendix, and sketchily summarized in table 5:

Patent counts are both very noisy and biased indicators of value and generally should be ignored for business and commercial purposes. Some noise can be eliminated by using forward citation counts as weights. The number of independent claims and the breadth of geographic coverage provide further (but weak) indications of value. Reviewing technical specifications per SEP family merely adds to the cacophony. Comparable licenses and/or value-based approaches are the only economically sound ways to determine value, whether in a commercial or a litigation context.

In the case of 5G and wireless technology, the contractual framework (FRAND licensing) that governs the 3GPP open innovation model is designed to support the ecosystem. That requires supporting the generation and implementation of new technologies. Patent-counting and top-down methods are proposed, it would appear, to steer regulators and judicial bodies toward focusing on reducing the financial costs of implementers, which shortchanges technology generators.[80] That approach will eventually hurt the implementees too—except possibly those with the capability to integrate vertically once the open innovation model collapses… and it may well do so.

There is considerable value in patent analytics regarding certain issues; but using such analytics to assess the market value or relative market values of patent portfolios is not one of them. Good scholars have generally shied away from trying to do so. Perhaps it is time to pause and take stock? Caveat emptor will not suffice. I have hesitated to offer a composite index, even on an experimental basis, because averaging the effects may conceal underlying problems and fuel the concerns that animate this paper.

Used properly, and deeply caveated, patent statistics can hint at value. For example, citation-weighted patents that are renewed can provide clues—but they cannot be the sole leitmotif of patent valuation, because they are untethered from commercial considerations relating to how the technology is used.

Understanding the role of standards bodies like 3GPP and the IEEE is needed in order to shape the evolution of technologies and markets. The technologies of the future that enable connectivity will rely not only on 5G and 6G and beyond, but also on subsequent versions of Bluetooth, RFID, Wi-Fi, and other standardized technologies. Licensing executives and top management need to get out in front if they want to be more in charge of their own futures. China and India will be important players in the future. New licensing models may well need to be invented.

No one country is the leader in 5G…and the whole concept of 5G leadership is difficult to define. Does one mean the foundational technologies; or the fixed infrastructure deployment; or device adoption; or new use cases? The answers remain unclear and are constantly evolving. However, with respect to the foundational (wireless) technologies, it is clear than Qualcomm, Ericsson, Nokia, and Samsung are amongst the major competitors. Huawei is a player too, but not to the degree suggested by patent counts.[81]

In addition to avoiding the pitfalls of overreliance on patent metrics, senior management and analysts struggling to understand the 5G space ought to recognize that the 5G ecosystem is built on foundational technology developed by just a very few firms. The foundational layer is what can be thought of as the enabling technology for the entire 5G ecosystem. If that layer isn't constantly improved, innovation downstream suffers. Hence, the skillful management of the licensing function and fair and reasonable behavior by firms in the 5G ecosystem is essential to the prosperity of national economics and the global economy.

Economist and former U.S. Federal Reserve Chairman, Alan Greenspan once remarked that it is better to be roughly right than precisely wrong. When it comes to patent value, the comparable market transactions approach, focusing on downstream value, can be put forward as being roughly right. Top-down and patent-counting approaches are usually precisely wrong. Whether they are a useful check on the methodologies is debatable and context specific. How wrong they are is never clear. It's not apparent that core methodological problems have been solved. Table 5 endeavors to distill a few heuristics that can guide executives and analysts.

**Table 5. 5G Patent Portfolio Heuristics**

| |
|---|
| Patent counts are very poor proxies for value |
| Chinese patents are often of low quality… and this is particularly so in 5G |
| Efforts to create quality adjusted indexes of patent data as proxies for individual patent holder value may well be  a fool's errand |
| Patent data provides a superficial aura of accuracy; patent counts are both noisy and biased statistics |
| The use of patent data requires nuance, skill, and a willingness to admit that noise and bias is commonplace |
| Licensing in both foundational and application layers for mobile wireless technologies will grow in importance along with Bluetooth, RFID, Wi-Fi, and other standardized technologies. |
| FRAND licensing rates for patent portfolios are negotiated, not mandated, and must be sufficient to draw forth the R&D investment needed to support both the creation and allow the adoption of next generation foundational technology. |

**APPENDIX: KEY TAKEAWAYS**

a. Geopolitical

a.(i). Patent counts are poor proxies of technological strength/value. There is a weak connection between even well-specified patent indices and the underlying economic value of a patent or a patent portfolio. If one is using just patent data, the "measure of our ignorance about value is very substantial."[82] Neither companies or countries can assert technological leadership based on the number of patents that they file and/or hold.

a.(ii). Using data on "declared essential" patent counts, it is not uncommon for the uninitiated to believe that China (and Huawei in particular) is the leader in 5G technology. However, as already pointed out, a "declared" essential patent doesn't make a patent essential, in any fundamental sense. Nor is contribution counting a reliable indicator of actual contribution. These metrics as inaccurate measures of the comparative strength of patent portfolios.  In short, patent counts are not just "noisy;" they are often biased indicators of value.

a.(iii). There is no clear evidence that Chinese firms are ahead in providing the leading technologies to 5G; but China is nevertheless trying hard to achieve that goal. It may look like its ahead on simple metrics like "technical contributions" and "patents"; but when these are adjusted for quality and salience, China is very unlikely to be in a global leadership position.

b. Valuation

b(i). There is great skewness in the distribution of patent values.[83] There are also problems when one is looking across industries, as patents differ in efficacy and utilization across industries and sectors.[84]

b(ii). Patent data might seem to become more reliable (as a proxy for value) when one accounts for independent claims, forward citation counts, and geographical coverage. Without considering such adjustment or weightings, patent counts are useless. At minimum, one must recognize measurement errors so large that the results are wrong in a way that is likely to be biased and misleading. In the hands of executives and analysts without knowledge of patent data sets, they will almost certainly be misused.

b(iii). Absent persuasive evidence that manipulation isn't occurring, patent counts are likely to be unreliable even if care is taken to develop reasonable forward-citation weightings. Many low-value patents can be generated without significant investment or inventive activity.

b(iv). While patent data can be strategically manipulated, purveyors of commercial patent analytics appear to be either unaware of or possibly engaging covertly in strategic manipulation. Patent data is not only noisy. It's also biased, although the nature of the bias is not always transparent.

b(v). The value of patented (enabling) technology cannot be decoupled from the value it helps create downstream. It is difficult to see how patent counting, unless coupled somehow with commercial (not technical) weightings, is linked to downstream usage value. Patent-counting and top-down methodologies are bereft of a way to touch, let alone quantify, fundamental value.

b(vi). Using patent data requires considerable technical skill and economic nuance. Leading scholars have mastered patent data to a modest degree, and their work is usually properly caveated and qualified. Commercial purveyors of patent analytics are less careful. Accordingly, clients and courts can be misled by such analytics and conclusions drawn from the data.

b(vii). Patent data creates a (superficial) aura of evidence-based scientific inquiry, but the data issues are so complex, and the link to value so tenuous, that precision can be mistaken for accuracy; obscurity can be mistaken for profundity; technological relevance can be mistaken for commercial relevance; and strategic manipulations can remain undetected. The result is unreliable "black box studies with results." The commercial relevance is highly questionable. Such "results" may be designed to mislead licensing executives and policy analysts, the courts, national security specialists, and the commercial intelligence world.

b(viii). When valuing intellectual property that "reads on" a standard, the numerical proportionality of SEPs is a poor measure of relative standing and absolute worth. It is unlikely to help measure and/or estimate the relative value of different patent portfolios. The problem is compounded by the fact that all forms of numerical proportionality top-down approaches require the determination of a "total value" associated with the patents that "read on" a standard. No one has come up with anything close to a sound methodology for doing so. Since it is technology implementers (not developers) that put forward such studies, it is likely that conclusions offered about patent value will be biased downward.[85]

b(ix). Trying to create quality-adjusted indexes of patent value from patent data sets is likely a fool's errand; but one should not expect to hear that from those capable and inspirational scholars who pioneered work in this area. It is now more than thirty years since the initial academics (Scherer/Griliches et. al.) work on this topic, and the additional sophistication brought by Hall, Trajtenberg, Pakes, Schankerman, and other scholars is commendable. However, the utility of patent statistics for valuation purposes is not yet, and may never be, secure.

c. Governance

c(i). 3GPP is a consortia of consortia built on cooperation, and failure to cooperate by dragging out negotiations (patent hold out) is a form of free riding which must be recognized and penalized in order to maintain the health of the mobile wireless ecosystem. With more and more players entering the arena it is more and more critical that private parties recognize their broader responsibilities and that 3GPP maintains proper due process. The 3GPP miracle could collapse because of its very success…if as more and more technology users enter they disregard established norms, due process is compromised, and/or if regulators clumsily intervene.[86]

c(ii). Patent licensing is a critical enabler to the proper functioning of the open innovation model in mobile wireless. Allowing royalties to be set at reasonable levels so that the critical enabling technology continue to attract the capital needed to support R&D required to recognize prior investments and keep technology evolving is part of the role of the licensing executive, whether the executive is representing the licensor or the licensee.

c(iii). There will be a panoply of uses for 5G not current foreseeable. There will also likely be a plethora of technology providers, suggesting the need in certain circumstances for segregating intellectual property rights, possibly through new associations of rights holders. Additional modalities and vehicles for licensing will be created. 5G will, in many cases, be licensed along with other technologies, simplifying licensing for both licensor and licensee.

c(iv). While the telecom industry is familiar with standards development and FRAND licensing, other sectors such as autonomous vehicles are just learning; and energy, medical, healthcare, consumer electronics, and manufacturing industries have little knowledge about connectivity standards and patent licensing. Licensing executives will need to be recruited and trained as domain knowledge must go beyond the foundational layer, which is the focus of this paper, to embrace various application layers too.

[1] Disclosure: Author has consulted with, advised, testified on behalf of, and been engaged to conduct research for numerous government agencies (including the Federal Trade Commission and the US Department of Justice) and technology companies in the US and abroad, including Qualcomm, Apple, and Intel, with respect to business strategy and technology licensing. He is also a long-term investor in Apple stock.

[2] This is an abridged version of "Patent Counts as a Proxy for Value and Technological leadership? The case of SEPs," April 2020.

[3] Thomas Tusher Professor of Global Business, Haas School of Business, University of California at Berkeley, and chairman, Berkeley Research Group. I wish to thank Dr. Bruce Guile and Kalyan Dasgupta for inspiration and three anonymous reviewers for helpful comments.

[4] All four prior generations of mobile networks used cell towers hundreds of feet tall and required considerable power to transmit over long distances. 5G uses a large number of smaller micro cells, together with cell towers, to create a blanket of very high-speed network coverage. For some users (e.g., virtual reality and gaming) 5G is all about speed ; for others such as industrial, agricultural, and commercial use cases its about high capacity and minimal lag. 5G also unlocks remote monitoring as never before.

[5] 5G is considerably more ambitious than what went before it. After a 2019 official launch, it is gaining momentum globally, ramping faster than previous generations of mobile wireless. It not only endeavors to deliver higher levels of efficiency and performance to enhance already developed broadband services. It also aims to expand mobile services into many other domains and become a unifying connectivity fabric for a wide range of applications. Like 4G, and 3G before it, 5G is not a fixed standard; it is evolving. 5G standards have embedded within them patented technological solutions to many of the hard engineering problems required for data optimization and voice and video transmission over a very limited amount of radio frequency spectrum…more limited in some countries than others.

[6] Don Strumpf "Where China Dominates in 5G Technology" Wall Street Journal, Feb. 6, 2019

[7] Ibid.

[8] Patent scope is also worthy of mention with respect to the value of standards essential patents. What matters here with respect to scope is whether a patent touches the standard. It's zero or one; so scope is less essential than it otherwise might be. A patent either reads on the standard or it does not. The paper is about patent licenses for SEPs… to use with respect to implementing a standard, and not something else. The fact that a patent might, say, both (1) read on the 5G standard and (2) it is also important for transmitting signals to satellites does not impact it's license value for 5G… as 5G licenses are limited, unless the licensee takes a license to cover 5G and other technologies as well… which they sometimes do.

[9] A longer version of this paper, "Patent Counts as a Proxy for Value and Technological leadership? The case of SEPs," goes into some of these issues in greater detail.

[10] "Technical standardization, China and the future international order: A European Perspective" Tim Nicholas Ruhling, Swedish Institute of International Affairs, Stockholm. Feb 2020

[11] Law Fare "The US needs to get into the Standards Game… with likeminded democracies" April 2, 2020

[12] See Teece D.J. "Profiting from Innovation in the Digital Economy" Research Policy 2018

[13] Examined more closely, 3GPP is actually a cluster of national and regional telecommunication standards organization. It organizes it's work into three different streams: Radio Access Networks, Services and System Aspects, and Core Network and terminals 3GPP develops the technical specs. These are then converted into standards by seven regional standards setting organization (SSOs) that form the 3GPP partnership.

[14] Technology selection in an SDO is a bit like journal acceptance for research papers… except the performance improvements thresholds over the status quo are so much higher, and the referees include not just technology development peers but also downstream implementers and device makers.

[15] Qualcomm alone spends (over $5B a year mainly on foundational wireless technologies.

[16] www.erisccon.com Setting Standards

[17] It was clear from company earnings calls that Time Cook, Apple's CEO, didn't quite understand critical issues relating to 4G technology and FRAND royalty rates.

[18] Ericsson extends 5G leadership with new agreements. Feb 25, 2019

[19] Nokia highlights momentum with 63 commercial

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[23] See Levin, Richard C., Alvin K. Klevorick, Richard R. Nelson, and Sidney Winter, "Appropriating the Returns from Industrial Research and Development," Brookings Papers on Economic Activity – Special Issue on Microeconomics 18:3, 1987, 783-832.
[24] Hall, Bronwyn H., and Adam B. Jaffe, "Measuring Science, Technology, and Innovation: A Review," *Annals of Science and Technology Policy 2*:1, 2018. 1-74.
[25] Griliches, Zvi, "Economic Data Issues," Chapter 25 in *Handbook of Econometrics Vol III* (ed.: Zvi Griliches and Michael Intriligator), Amsterdam: North Holland, 1986, 1465-1514.
[26] Petersson, Christina, "Why you shouldn't believe everything you read about 5G patents," Ericsson Blog, October 11, 2019, https://www.ericsson.com/en/blog/2019/10/5g-patent-leadership (downloaded June 4, 2020). Petersson is head of Ericsson IP Licensing. Peterson was referencing a study by the law firm Bird and Bird: Noble, Matthew, Jane Mutimear, and Richard Vary, "Determining Which Companies Are Leading the 5G Race," IAM Media, July-August 2019, https://www.twobirds.com/~/media/pdfs/news/articles/2019/determining-which-companies-are-leading-the-5g-race.pdf (downloaded June 4, 2020).
[27] Roach, Michael, and Wesley M. Cohen, *Lens or Prism: Patent citation as a measure of knowledge flows from public research*, National Bureau of Economic Research Working Paper No. 18292, August 2012.
[28] This might be thought of as false precision—because it's not accurate.
[29] Baron, Justus, and Tim Pohlmann, "Mapping Standards to Patents using Declarations of Standard-Essential Patents," *Journal of Economics and Management Strategy 27*:3, Fall 2018, pp. 504-534.
[30] IPlytics, "Who is leading the 5G patent race? A patent landscape analysis on declared 5G patents and 5G standard contributions," November 2019, https://www.iplytics.com/wp-content/uploads/2019/01/Who-Leads-the-5G-Patent-Race_2019.pdf (downloaded June 4, 2020).
[31] Id., p. 1
[32] Cited in J. N. Matias, "Bias and Noise: Daniel Kahneman on Errors in Decision-Making," medium.com, October 17, 2017, https://medium.com/@natematias/bias-and-noise-daniel-kahneman-onerrors-in-decision-making-6bc844ff5194

[33] Pavitt, Keith, "Patent Statistics as Indicators of Innovative Activities: Possibilities and Problems," *Scientometrics* 7:1-2, January 1985, 77-99, at 82.
[34] Ibid.
[35] Id., p. 95.
[36] Hall, Bronwyn H., and Rosemarie Ham Zeidonis, "The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry, 1979-1995," *The RAND Journal of Economics* 32:1, Spring 2001, 101-128.

[38] I.e., the cost of applying for a patent (i.e., drafting, filing, and negotiating with a patent office).
[39] Li, Xibao, "Behind the recent surge of Chinese patenting: An institutional view," *Research Policy* 41:1, February 2012, 236-249.
[40] Dang, Jianwei, and Kazuyuki Motohashi, "Patent Statistics: A good indicator for innovation in China? Patent subsidy impact on patent quality," *China Economic Review* 35, September 2015, 137-155.

[41] Clark, Robert, "Who rules 5G patents? It depends how you ask," Light Reading, January 14, 2020, https://www.lightreading.com/asia-pacific/who-rules-5g-patents-it-depends-how-you-ask/d/d-id/756790 (downloaded June 4, 2020).
[42] Ana Maria Santacreu & Heting Zhu note that "many Chinese patent applications could not withstand international evaluation" see "What Dias Chinas Rise in Patents Mean? A look at Quality vs Quantity" Economic Synopses (St. Louis Fed No 14 2018). See also Jonathan Putnam, video presentation, Hudson Institute, "5G Leadership – the IP side of the story" December 11, 2020
[43] Ziedonis, Rosemarie, "Intellectual property regimes and firm strategy: putting Hall and Ziedonis (2001) in perspective," in *Advances in Strategic Management* 26, *Economic Institutions of Strategy* (ed.: Jackson A. Nickerson and Brian S. Silverman), Sept 2009, 9. Ziedonis also mentions "hold up," but no evidence has ever been presented to establish the actual existence of hold-up in any patent situation. Hold *out* is more common. Hall, Bronwyn, "Exploring the Patent Explosion," *The Journal of Technology Transfer* 30, February 2005, 35-48, likewise noted the strategic nature of patenting by some business firms.
[44] A (simple) patent family, according to the European Patent Office, is a collection of patent documents that are considered to cover a single invention. The technical content is considered to be identical. The INPADOC (International Patent Documentation) is an international collection of extended patent families that is recognized worldwide to include very similar but not necessarily identical technologies.
[45] The two definitions: (1) INPADOC patent family: An extended patent family is a collection of patent documents that cover a technology. The technical content covered by the applications in one extended patent family is similar but not necessarily the same. Patent applications that are members of an extended patent family will have at least one priority in common with at least one of the other members – either directly or indirectly. (2) DOCDB simple patent family: A simple patent family is a collection of patent documents that are considered to be covering one single invention. The technical content covered by the applications in one simple patent family is considered to be identical. Patent applications that are members of one simple patent family will have all priorities in common with all of the other members. See European Patent Office, *Patent familes at the EPO*, July 2017, http://documents.epo.org/projects/babylon/eponet.nsf/0/C9387E5053AA707BC125816A00508E8D/$File/Patent_Families_at_the_EPO_en.pdf (downloaded June 4, 2020).
[46] In order to inflate their counts, Chinese firms often declare patents that have nothing to do with the standardized technology.
[47] See Falk, Nathan, and Kenneth Train, "Patent valuation with forecasts of forward citations," *Journal of Business Valuation and Economic Loss Analysis* 12:1, February 2017, 101-121; Kogan, Leonid, et al., "Technological innovation, resource allocation, and growth," *The Quarterly Journal of Economics* 132:2, May 2017, 665-712; Hall, Bronwyn H., Adam B. Jaffe, and Manuel Trajtenberg, "Market value and patent citations," *RAND Journal of Economics* 36:1, Spring 2005, 16-38.
[48] Trajtenberg, Manuel, "A Penny for Your Quotes: Patent citations and the Value of Innovations," *The RAND Journal of Economics* 21:1, Spring 1990, 127-187. Trajtenberg suggests the analogy that patents are like working papers: easy to produce if you have some level of research going on. He also suggests that patents are more like an input measure than an output measure. "[A] mere count of working papers written does not say much about the value of scientific contributions made; for that, one would need information on whether and where they get published, the number of citations they receive over time, etc."
[49] Ibid.
[50] Hall, Jaffe, and Trajtenberg (2005).
[51] Kuhn, Jeffrey M., Kenneth A. Younge, and Alan C. Marco, *Patent Citations and Empirical Analysis*, working paper, July 2017, http://sites.bu.edu/tpri/files/2017/07/Patent-Citaitons-and-Empirical-Analysis-Kuhn-Young-Marco-July-2017.pdf (downloaded June 4, 2020).
[52] Gambardella, Alfonso, Dietmar Harhoff, and Bart Verspagen, "The Value of European Patents," *European Management Review* 5:2, 2008, 69-84; Roach, Michael, and Wesley M. Cohen, "Lens or Prism? Patent Citations as a Measure of Knowledge Flows from Public Research," *Management Science* 59:2, February 2013, 504-525.
[53] Lerner, Josh, and Amit Seru, *The use and misuse of patent data: Issues for corporate finance and beyond*, National Bureau of Economic Research Working Paper No. 24053, November 2017.

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[55] Jaffe, Adam B., and Gaétan de Rassenfosse, "Patent Citation Data in Social Science Research: Overview and Best Practices," *Journal of the Association for Information Science and Technology* 68:6, June 2017, 1360-1374.

[56] See Marco, Alan C., Joshua D. Sarnoff, and Charles A.W. deGrazia, "Patent claims and patent scope," *Research Policy* 48:9, November 2019, 103790; Lanjouw, Jean O., and Mark Schankerman, "Patent Quality and Research Productivity: Measuring Innovation with Multiple Indicators," *Economic Journal* 114:495, April 2004, 441–465; Tong, Xuesong, and J. Davidson Frame, "Measuring national technological performance with patent claims data," *Research Policy* 23:2, March 1994, 133-141.

[57] A claim defines the invention and what aspects are legally enforceable. It must conform to the invention as set forth in the remainder of the specification. Terms and phrases used in the claims must find clear support or antecedent basis in the description so that the meaning of the terms in the claims are clearly understood by reference to the description. An independent claim refers to a standalone claim that contains all the limitations necessary to define an invention.
A dependent claim refers to a previous claim and must add a further limitation to the previous claim.
A claim in dependent form incorporates by reference all the limitations of the claim to which it refers.
See US Patent and Trademark Office, Invention-Con 2017 Claim Drafting Workshop slides, https://www.uspto.gov/sites/default/files/documents/Website%20PDF%20-%20Invention%20Con%202017%20Claim%20Drafting%20Workshop%20-%20OPLA.pdf (downloaded June 4, 2020).

[58] Lerner, Josh, "The Importance of patent scope: An empirical analysis," *The RAND Journal of Economics* 25:2, Summer 1994, 319-335.

[59] Ibid.

[60] Matutues, Carmen, Pierre Regibeau, and Katharine Rockett, "Optimal patent design and the diffusion of innovations," *The RAND Journal of Economics* 27:1, Spring 1996, 60-83.

[61] See also Marco, Alan C., Joshua D. Sarnoff, and Charles A.W. deGrazia, "Patent claims and patent scope," *Research Policy* 48:9, November 2019, 103790.

[62] See Cremers, Katrin, Dietmar Harhoff, Frederic M. Scherer, and Katrin Vopel, "Citations, family size, opposition and the value of patent rights," *Research Policy* 32:8, September 2003, 1343-1363; Hall, Bronwyn H., Grid Thoma, and Salvatore Torrisi, "The market value of patents and R&D: Evidence from European Firms," *Academy of Management Proceedings*, Vol. 2007, No. 1; Squicciarini, Mariagrazia, Hélène Dernis, and Chiara Criscuolo, *Measuring patent quality: indicators of technological and economic value*, OECD Science, Technology and Industry Working Papers 2013/03 1-69, https://www.oecd-ilibrary.org/science-and-technology/measuring-patent-quality_5k4522wkw1r8-en (downloaded June4, 2020).

[63] Ibid.

[64] Lanjouw, Jean O., Ariel Pakes, Jonathan Putnam, "How to count patents and value intellectual property: Uses of patent renewal and application data," *Journal of Industrial Economics* 46:4, January 1996, 405-432.

[65] This is how Samsung and Apple benefit from the impressive array of technologies they have developed and assembled (both from inside Apple and from outside, including those funded by the government).

[66] This was discussed in Teece, David J., "Profiting from Technological Innovation," *Research Policy* 15:6, December 1986, 285–305; Teece, David J., "Reflections on 'Profiting from Innovation,'" *Research Policy* 35:8, December 2006, 1131– 1146; Teece, David J., "Business Models, Business Strategy and Innovation," Long Range Planning 43:2-3, April-June 2010, 172–194; and Teece, David J., "Profiting from Innovation in the Digital Economy: Enabling technologies, standards, and licensing models in the wireless world," *Research Policy* 47:8, October 2018, 1367-1387.

[67] ETSI IPR policy clause 3.1.

[68] The patent exhaustion doctrine allows, as a practical matter, for a licensor to select the place in the value chain (e.g., components or devices) to collect royalties; it does not allow such rights to be exercised at multiple levels.

[69] Avanci website. https://www.avanci.com/

[70] See Grindley & Teece "Managing Intellectual Capital" California Management Review, Winter 1997

[71] See David Kappos "Comparing the Strength of SEP Patent Portfolios: Leadership Intelligence for the Community" 5-6

[72] Thomas Schelling "The Strategy of Conflict" 1960

[73] There is quite a bit of information in a patent beyond its mere issuance in a particular field in a particular year. A patent also identifies the inventor and the patent classes to which it has been assigned, and it cites previous patents and sometimes scientific articles to which the particular invention may be related. Because patents cite prior art, citation counts can be investigated, as can the claims of the patents, the patents' geographical coverage, and the renewal fees paid (if any).

[74] Allenby, Greg M., Jeff Brazell, John R. Howell, and Peter E. Rossi, "Valuation of Patented Product Features," The Journal of Law and Economics 57:3, 2014, 629-64, applied standard choice methods.

[75] See Reed-Arthurs, Rebbecca, Michael P. Akemann, and David J. Teece, "Resolving Bargaining Range Indeterminacy in Patent Damages after VirnetX," *Research in Law and Economics*, forthcoming (2020).

[76] Assumptions might include monopsonizing competitive markets, linear demand (in the region of interest), and constant marginal cost within the region of interest. These are standard simplifying assumptions used by many economists.

[77] See Berry, Steven, James Levinsohn, and Ariel Pakes, "Automobile Prices in Market Equilibrium," *Econometrica* 63:4, July 1995, 841-890.

[78] Hiller, R. Scott, Scott J. Savage, and Donald M. Waldman, "Using Aggregate Market Data to Estimate Patent Value: An Application to United States Smartphones 2010 to 2015," *International Journal of Industrial Organization* 60(C), September 2018, 1-31.

[79] Id.

[80] This is especially true the more enabling the patented technology. See Teece, David J., "Profiting from Innovation in the Digital Economy: Enabling technologies, standards, and licensing models in the wireless world," *Research Policy* 47:8, October 2018, 1367-1387.

[81] David Kappos, former head of the USPTO, has noted are a wildly inaccurate measure of technological position.

[82] Gambardella, Harhoff, and Verspagen, (2008).

[83] Gambardella, Alfonso, Dietmar Harhoff, and Bart Verspagen, "The value of European patents," *European Management Review* 5:2, Summer 2008, 69-84; Giuri, Paola, et al., "Inventors and invention processes in Europe: Results from the PatVal-EU survey," *Research Policy* 36:8, October 2007, 1107-1127; Schankerman, Mark, "How valuable is patent protection? Estimates by technology field." *The RAND Journal of Economics* 29:1, Spring 1998, 77-107; Scherer, Frederic M., and Dietmar Harhoff, "Technology policy for a world of skew-distributed outcomes," *Research Policy 29*:4-5, April 2000, 559-566; Silverberg, Gerald, and Bart Verspagen, "The size distribution of innovations revisited: an application of extreme value statistics to citation and value measures of patent significance," *Journal of Econometrics* 139:2, August 2007, 318-339.

[84] See Levin, Richard C., Alvin K. Klevorick, Richard R. Nelson, and Sidney Winter, "Appropriating the Returns from Industrial Research and Development," Brookings Papers on Economic Activity – Special Issue on Microeconomics 18:3, 1987, 783-832.

[85] Accordingly, one would have to be desperate to use it as a valuation methodology, even if merely as a cross-check.

[86] See Teece D.J. "5G and the Global Economy: How Static Competition Policy Frameworks Can Defeat Open Innovation" Competition Policy International (September 23, 2019).