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Licensing standard-essential patents in the IoT – A value chain perspective on the markets for technology

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ABSTRACT

Innovative industries need efficient markets for technology (MFTs). One determinant of MFT efficiency neglected until now is licensing level—that is, the level in the value chain where patents are licensed. Patents may be licensed upstream, to firms that put the patented knowledge into practice. I refer to this as integrated licensing. Alternatively, patents may be licensed further downstream in the value chain, in particular to makers of final devices. I call this bifurcated licensing since it separates intellectual property rights from the technical knowledge they cover. I study the licensing level of essential patents on communication standards such as LTE and Wi-Fi in relation to the Internet of Things (IoT). The choice of licensing level in this context is currently a hotly debated topic. To show how bifurcated licensing affects MFT efficiency, I present empirical evidence from a qualitative study comprising interviews with 30 individuals from 22 diverse firms, focusing on startups. IoT device makers clearly find the uncertainty regarding infringement, patent validity, and the licensing process hinders efficient licensing, which is compounded by the large number of IoT device makers and, for SMEs and startups, by resource constraints. As a theory contribution, I show that a patent's licensing level need not correspond with the implementation level of the patented knowledge—in other words, licensing may be bifurcated rather than integrated. I develop a model of how licensing level affects MFT efficiency. Implications for practice are that device-level licensing of standard-essential patents (SEPs), if broadly implemented, would have a negative effect on innovation and entrepreneurship in the IoT. Policymakers should ensure that SEP licensing is simplified.

1. Introduction

Markets for technology (MFTs) provide various benefits for society. They can mitigate the static inefficiency of patents, facilitate a division of labor between innovators and implementers (Bresnahan and Trajtenberg, 1995; Arora et al., 2001a), and reduce the dynamic inefficiency of patents in sequential innovation (Gambardella et al., 2007, p. 1165). These benefits depend on MFT efficiency (Teece, 1988; Arora and Gambardella, 1994; Lamoreaux and Sokoloff, 1999; Gambardella, 2002; Gans and Stern, 2003).

Studies of MFTs and their efficiency often consider the licensing of patents and the transfer of knowledge they cover as one and the same, even taking patent licensing as an indicator of MFT transactions (Lamoreaux and Sokoloff, 1999; Gambardella et al., 2007; Serrano, 2010). However, a distinction can be important (Arora, 1995), particularly if the recipient of technical knowledge is not the licensee of the patents covering this knowledge ((Fischer and Henkel, 2012, p. 1531). I refer to such a situation as *bifurcated* licensing, in contrast to *integrated* licensing, where the recipient of technical knowledge is also the licensee. Bifurcated licensing has become widespread for “standard essential patents” (SEPs) on communication standards such as LTE and Wi-Fi. For end user products, SEPs are commonly licensed to end product manufacturers (e.g., SEPs Expert Group, 2021, p. 78), even though the standard's technology is mostly implemented upstream in a component.

This approach works reasonably well if, as in the case of mobile phones, end product manufacturers are relatively few and homogeneous, large, and knowledgeable about the focal technology. However, this is not the case with the Internet of Things (IoT), where makers of final devices are numerous, mostly small, and not knowledgeable about communication technologies. I thus ask: How does bifurcated licensing affect MFT efficiency in the IoT space and in general?

The above observations suggest adding *licensing level* as a contingency factor to the issue of MFT efficiency. How the choice of licensing level affects efficiency raises further questions: To what level of the value chain *should* technology creators license patents on their technology in order to maximize efficiency? Do market mechanisms lead to an efficient choice of licensing level, in particular facilitating

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downstream innovation in the IoT? And if not, is there scope for policy intervention?

These questions are of theoretical as well as practical interest, and are subject to intensive debate concerning what should be the value chain level for licensing SEPs (e.g., Geradin, 2020; SEPs Expert Group, 2021). Theoretically, the level where IoT SEPs are licensed, discussed in recent legal and antitrust studies (e.g., Hovenkamp and Simcoe, 2020; Borghetti et al., 2021; Heiden et al., 2021), is an important contingency not yet considered in the analysis of MFTs. Practically, policy reports (SEPs Expert Group, 2021) and high-profile litigation cases, for instance between Nokia and Daimler (Reuters, 2021), reflect the relevance of licensing level in the IoT. However, there is hardly any empirical work on the topic. It is not known, for example, whether device-level licensing or upstream licensing lead to higher transaction costs—both claims have been made (Geradin, 2020, pp. 17, 21).

This study contributes to the discussion by providing empirical evidence on IoT SEP licensing. I focus on startups and SMEs as potential licensees since they play a central role for innovation and entrepreneurship in the IoT. I draw on a qualitative study based on interviews with 30 individuals from 22 firms, totaling 20 h, complemented by documents. The sample comprises firms of various sizes, industries, countries, and roles in SEP licensing, including device makers, a module manufacturer, and SEP licensors. Based on the results, I inductively extend the MFT theory by adding patent licensing level as a contingency and derive implications for policymakers.

The main empirical finding is that device-level SEP licensing in the IoT is hindered by uncertainty due to lack of information. Device makers have no knowledge of IoT technologies and related patents, do not know which or how many licensors could approach them, and lack an understanding of SEP licensing rules. SMEs and startups additionally face resource constraints that limit their opportunities to acquire technical and legal advice, and suffer even more than large firms from cost and legal uncertainty. SEP licensors, on the other hand, expect to realize higher royalties when licensing downstream, thanks to the higher value of final devices compared to baseband chips or network access devices. Furthermore, they consider device-level licensing the only approach that allows price differentiation (as often practiced with SEP licenses for mobile phones), which they deem necessary to generate a fair return on their investments.

Policy implications are that device-level licensing of IoT SEPs, certainly as practiced nowadays, is not feasible. It leads to inconsistent licensing and hold-out, and jeopardizes innovation and entrepreneurship in the IoT. Policymakers such as the European Commission and national governments should ensure that IoT SEP licensing is simplified in such a way that device makers can procure fully licensed IoT modules, and should commission studies that address open technical questions regarding SEP licensing.

Contributing to theory, transaction costs, resource constraints, and price differentiation are the main determinants of licensing level efficiency. Dyad-level transaction costs unambiguously rise, due to uncertainty and information asymmetry, in bifurcated licensing, i.e., if a patent is licensed downstream from the value chain level where the underlying knowledge is put into practice. Industry-level transaction costs increase with bifurcated licensing if the downstream layer is more fragmented, which is plausible and particularly likely with general purpose technologies such as communication standards. Price differentiation in license fees based on the contributory value of a technology should in principle be facilitated by bifurcated licensing if final devices are heterogeneous, but higher product complexity downstream complicates determining this value.

This paper is structured as follows. Section 2 provides background on MFTs and licensing of IoT standards, Section 3 describes the data and methods. Section 4 presents empirical findings. I develop a theoretical model of MFTs in Section 5, derive policy recommendations in Section 6, and present conclusions in Section 7.

2. Background

2.1. Patents and markets for technology

Markets for technology (MFTs) (Arora et al., 2001b) allow for specialization and a division of labor, and can thus improve the efficiency and effectiveness of the innovation process. MFTs have acquired high relevance for innovation-intensive industries (e.g., de Marco et al., 2017). Patents play an important role in MFTs: they facilitate trade by creating transferable assets (de Rassenfosse, 2012; Spulber, 2015), mitigate the risk of expropriation (Teece, 1986; Lamoreaux and Sokoloff, 1999; Arora et al., 2001b; Arora and Ceccagnoli, 2006; Gans et al., 2008), and reduce information costs (Hegde and Luo, 2018). Importantly, they help licensors generate royalty income (Robbins, 2006).

For licensees, MFTs create options for follow-on innovation. This is particularly so if the out-licensed technology is a general-purpose or enabling technology for many downstream markets (Rosenberg, 1982; Bresnahan and Trajtenberg, 1995; Arora et al., 2001a).[1] Conti et al. (2019) find that developing broadly usable technologies and making them available to downstream firms through MFTs are often practiced in conjunction, a strategy they call "specialization in generality." Teece (2018) and Gambardella et al. (2021) discuss the challenges of profiting from enabling technologies. Since an enabling technology can be employed in many markets, the innovator cannot own all the complementary assets required to profit from the technology in the product market, so must rely on MFTs.

MFTs are often hampered by transaction costs (Gambardella et al., 2007) of different origins: (a) The risk of expropriation if the recipient of a technology transfer can avoid paying the originator, who will consequently be less likely to engage in MFT transactions in the first place. Milgrom and Roberts (1992, p. 29) refer to such transaction costs as "motivation costs." Patent protection can be a solution (Arora, 1996; Nakamura and Odagiri, 2003; Arora and Merges, 2004). (b) Uncertainty regarding potential transaction partners, in particular for non-codified knowledge (Arora and Gambardella, 2010). (c) Commercial uncertainty (Rosenberg, 1996) regarding a technology's applicability and value. (d) Information asymmetry in favor of the technology seller (Akerlof, 1970; Zeckhauser, 1996).

In Milliken's (1987, p. 136) typology, the above sources of transaction costs are instances of *state uncertainty*, a lack of understanding of "*how components of the environment might be changing;*" what also emerged in the empirical study are *effect uncertainty* (a lack of an "*individual's ability to predict what the impact of environmental events or changes will be on his/her organization*"), and *response uncertainty* ("*a lack of knowledge of response options and/or an inability to predict the likely consequences of a response choice*").

Importantly, if the recipient of a knowledge transfer is not the licensee of patents covering this knowledge, as frequently with SEP licensing, the two parties face transaction costs for different reasons. If the technical knowledge relates to a standard such as LTE and Wi-Fi, whose specifications are publicly available, then the recipient and implementer of this knowledge faces commercial uncertainty (c). The licensee, in contrast, faces uncertainty regarding potential transaction partners (b), commercial uncertainty (c), and information asymmetry (d), as will become clear.

2.2. Mobile communication standards

The IoT relies heavily on mobile communication standards such as LTE and Wi-Fi. Most of these are developed under the auspices of standards development organizations (SDOs), whose members

[1] General-purpose technologies are closely related to enabling technologies, which "can be thought of as junior GPTs, [...] not necessarily having measurable economy-wide impacts" (Teece, 2018: 1369).

collaborate to create new technologies. Examples of SDOs are ETSI and 3GPP for recent cellular technologies and IEEE for Wi-Fi. The standard specification is implemented at the highest level of the value chain, in a baseband processor or "chipset," which then, together with other components, is integrated in a network access device (NAD). The NAD in turn is built into the final device, either directly or as part of another intermediate product. A firm may be active on one or more levels of this value chain.

Patents on inventions that are indispensable for implementing a standard (including optional features) are referred to as "standard essential patents" (SEPs). To prevent hold-up by individual SEP holders once a standard is widely adopted, SDOs typically require contributors to commit to licensing SEPs on (fair), reasonable, and non-discriminatory ((F)RAND) terms.[2] Some SDOs, in particular 3GPP but not IEEE, also require contributors to a standard to notify the organization of specific patents they own that they think "might be essential" to the respective standard (ETSI, 2021, 4.1). However, many or even the majority of these "declared SEPs" are not actually essential, and determining essentiality requires time and expertise (Bekkers et al., 2020). The number of declared SEPs and parties declaring SEPs for a given standard can be large. IPlytics (2019) found, as of November 2019, 22,604 patent families declared as essential for 5G, by at least 300 different entities.[3] SEP numbers for 3G and 4G are lower, but still four-digit.

2.3. SEP licensing for the Internet of Things

Mobile communication standards constitute enabling technologies, and so their creators need to rely on licensing to capture value (Teece, 2018; Gambardella et al., 2021). For cellular standards and Wi-Fi, no licensor offers all SEPs, despite the existence of patent pools. Rather, the licensor landscape is fragmented[4] and SEP infringement litigation is frequent.[5]

Obvious licensee candidates are the makers of baseband processors and NADs since these encapsulate the communication function. Such upstream licensing is sometimes practiced, for example by Huawei and Sharp.[6] Yet for mobile phones and Wi-Fi devices such as tablets, it has largely become the norm that SEPs are licensed downstream, to end product manufacturers (SEPs Expert Group, 2021, p. 78). In these industries, downstream licensing works reasonably well since end product manufacturers are telecommunications and electronics firms, relatively homogeneous, few in number, typically large, and many of them such as Huawei, Samsung, and LG are important SEP holders. Thus, they are well positioned to engage in SEP licensing negotiations.

The IoT scenario is starkly different. As devices are highly heterogeneous, ranging from toys to trucks, royalty setting rules developed for mobile phones cannot easily be transferred to IoT devices. Furthermore, IoT device makers are numerous and often small and medium-sized enterprises (SMEs) or startups. Based in diverse industries, they are typically unfamiliar with the inner workings of communication technologies.

Thus, the advent of the IoT has added new momentum to the debate among policymakers, industry players, and scholars, regarding where SEPs should be licensed in the value chain (e.g., Geradin, 2020; SEPs Expert Group, 2021). SEP holders tend to favor device-level licensing, while device makers prefer upstream licensing, at the NAD or baseband processor level (e.g., Schneider, 2020, p. 4).

Much of the licensing level debate has acquired a legal or antitrust perspective (Kappos and Michel, 2017; Rosenbrock, 2017; Gautier and Petit, 2019; Kühnen, 2019; Dornis, 2020; Geradin, 2020; Hovenkamp and Simcoe, 2020; Borghetti et al., 2021), and most studies are theoretical or conceptual in nature. Some authors do mention the practical difficulties of device-level licensing for licensees and in particular SMEs (Pohlmann, 2017; Geradin, 2020, p. 17; Schneider, 2020; Borghetti et al., 2021, p. 4; SEPs Expert Group, 2021, pp. 42, 158). However, there is hardly any empirical work on licensees' circumstances, in particular those of SMEs and startups, despite their key role for innovation in the IoT.

Proponents of device-level licensing argue that it allows royalties to be linked with the patented technology's contributory value to the end product, and thus practice price differentiation. Price differentiation, in turn, is purportedly needed for licensors to generate a fair return on their R&D investments (e.g., Teece and Sherry, 2016). Indeed, a Wi-Fi baseband chip arguably creates more value in a laptop computer, where it is used for several hours per day, than in a household device operated once a week, and so makers (and buyers) of laptop computers should have a higher willingness-to-pay for Wi-Fi functionality. Furthermore, with uniform pricing, SEP royalties may be too high to serve market segments where the respective standard creates only little value, implying a welfare loss (e.g., Tirole, 1988, p. 139). On the other hand, the contributory value of a standard to a final device may be difficult to determine due to the device's complexity. Moreover, it will arguably contradict FRAND principles if higher willingness-to-pay for a standard is not down to a higher contributory value, but a higher price of the end product attributable to other features (such as a brighter screen for phones) (e.g., Muris, 2019; Geradin, 2020, p. 17). Also, there may be ways to practice price differentiation upstream (see Section 6.2).

Furthermore, some advocates of device-level licensing claim that it leads to lower transaction costs than upstream licensing. Teece and Sherry (2016) argue that licensing at chipset level would be difficult to monitor and enforce. Borghetti et al. (2021, p. 3) state that device-level licensing would imply "*transaction costs savings achieved in negotiations with one group of licensees*" compared to a situation where actors on various value chain levels may request a license.[7] Also, licensing to baseband chip makers would not capture all SEPs if, as some authors

[2] While the actual meaning of FRAND was unclear for a long time (e.g., Rysman and Simcoe, 2011), in recent years court rulings, decisions by the European Commission, and established industry practice have created some level of certainty at least in the area of mobile phones (Geradin, 2020). In the U. S., the term "RAND" is employed.

[3] See Table 1 in IPlytics (2019). The top 32 declaring organizations account for 19,808 declared SEPs, or 87.6 %. The remaining 2794 are accounted for by organizations with 11 or fewer declared patent families each, yielding a minimum number of 254 and, given the characteristics of long tails, a likely number of >500 additional SEP holders.

[4] Licensors of LTE SEPs include patent pools (Avanci, Sisvel, Via Licensing), practicing entities (e.g., Ericsson, Nokia, Philips, Qualcomm, Interdigital), and patent assertion entities (e.g., Cellular Communications Equipment, Intellectual Ventures, IPCom, Optis, Unwired Planet). Licensors of Wi-Fi SEPs include patent pools (e.g., Sisvel, Via Licensing), practicing entities (e.g. Ericsson, Qualcomm), patent assertion entities (e.g., Innovatio, Intellectual Ventures, MOSAID, Ozmo Licensing), and research institutions (e.g., Caltech).

[5] Google searches (3 January 2022) for "'patent litigation' 'mobile phone'" and "'patent litigation' 'Wi-Fi'" yielded numerous examples of litigation and 296,000 resp. 73,000 hits.

[6] See Documents D6, D7, Table A.1. In June 2022, Huawei furthermore announced a component-level IoT SEP licensing deal with Nordic Semiconductor related to LTE-M and NB-IoT (Wild, 2022).

[7] These authors argue for an approach, somewhat misleadingly (Müller, 2021) labeled "access to all," that leaves the choice of licensing level to licensors (which mostly prefer device-level licensing). The alternative is "license to all," where each party requesting a license, irrespective of its value chain level, would be entitled to a FRAND license. The authors discuss various ways how upstream implementers could get "access," though not a proper license, to the patented standard. Kühnen (2019, p. 965) dismisses all of these except one as exposing upstream firms to legal uncertainty and thus creating transaction costs.

claim, some SEPs are not, or not only, implemented in the chipset.[8] As I discuss in Section 5.1, these arguments do not appear convincing.

Summarizing, IoT device makers' circumstances as SEP licensees are likely rife with uncertainties and lack of knowledge regarding the technology, the SEPs covering it, and the licensing process. The empirical study presented here shows how these factors play out in reality.

3. Methods

Since the process of SEP licensing to IoT firms is poorly understood, I chose an exploratory qualitative research design (e.g., Miles et al., 2014), allowing inductive theory development (Edmondson and McManus, 2007). I opted for an in-depth interview study since information on licensing is typically confidential and otherwise unattainable.

3.1. Study setting

The unit of analysis is the process of SEP licensing to startup IoT device makers from the licensees' perspective. Thus, my sample included independently owned firms founded in 2011 or later, with fewer than 500 employees, and that implement in their devices a communication standard for which SEP licensing is important (i.e., cellular standards and Wi-Fi). Given that the IoT's technical potential enables applications in numerous fields, I included makers of IoT devices in various industries. Geographically I focused on Europe while ensuring heterogeneity in terms of countries.

Complementing the sample of European IoT device maker startups with four other groups of firms ensured I captured as wide as possible perspectives and obtained a balanced picture.

3.2. Sampling approach

I employed a purposeful sampling strategy to generate "information-rich data" (Patton, 2015, p. 401), relying on database searches (Crunchbase, Pitchbook), publicly accessible Internet sources, and professional contacts. I contacted 35 European IoT device startups, of whom 12 (S1 to S12) agreed to an interview.[9] This approach allowed me to cover firms of different sizes, countries, and industries, comprising medical technology, industry automation, predictive maintenance, and smart homes (see Table A.1 for a complete list).

In addition, I interviewed three large, established implementers (E1 to E3); one small mobile phone manufacturer (P1); one communication module supplier (M1); and five SEP licensors (L1 to L5). The number of licensors should be sufficient for my study since the licensor side is far more concentrated and homogeneous than IoT device makers. The other groups of firms are not central to the SEP licensing process and were added to provide additional perspectives.

3.3. Data sources

I conducted 22 semi-structured interviews with 30 individuals from 22 firms. I also analyzed court proceedings, press releases, and legal publications (D1 to D8). Interview partners from entrepreneurial firms were mostly founders and CTOs or CEOs, and senior IP managers at the other firms. Five of the interviews with large firms were with several interviewees, at the request of the respective firms. Tables A.1 to A.3 in the Appendix provide an overview.

Having developed an initial interview guideline based on theory and literature, I adapted it iteratively to account for emerging topics, for instance licensors' use of NDAs, and no major changes were required (see Appendix A.4). I triangulated interview findings with document analysis, and discussed earlier versions of this study with peers and industry participants, among other things by presenting my findings at public webinars on SEP licensing.

Interviews took place between April 2020 and December 2021, via videoconference (20) or phone (2), and lasted between 0:18 and 1:31 h, totaling 19:58 h. Nineteen interviews were recorded and transcribed; in three cases the interviewees did not grant permission for recording and so notes were taken. Two interviews were complemented by email exchanges.

The twelve IoT startups in the sample employ a variety of wireless communication standards, mostly several standards in parallel. As shown in Table A.1, ten use Wi-Fi, eight use LTE, and all use at least one of these standards. They also apply Bluetooth, 2G, 3G, as well as less common standards such as ZigBee. As suppliers of baseband processors, the startups mentioned the firms Avnet, Cypress, Decawave, Gemalto, Intel, Marvell, Qualcomm, Quectel, Texas Instruments, and u-blox.

SEP holders had approached four of the twelve startups, requesting them to take out a license. Three had been approached by a large SEP holder (a practicing entity), two by a larger patent management platform and several patent assertion entities.

3.4. Data coding and analysis

I analyzed the transcribed interviews, the notes from the non-recorded interviews, and the supplementary documents using the MaxQDA 12 software package. I developed codes and categories inductively. I developed an initial version of the coding scheme and adapted it iteratively while open coding the first twelve interviews. I reviewed and modified the coding scheme while coding the remaining ten interviews, and checked consistency of each coding with the final coding scheme. In the following axial coding step, I grouped the first-order codes into second-order categories. For example, I merged the codes relating to unawareness of IoT communication technologies, pertaining patents, and the licensing process into the category "Lack of knowledge regarding technology, patents." The final step was grouping second-order categories into aggregate dimensions. I reviewed the resulting scheme in light of the emerging theory, modifying it where needed. For example, I listed "information asymmetry," originally an independent aggregate dimension, under "uncertainty." This was because despite information asymmetry, what mattered for the startups was not so much the difference in information between them and the licensor, but rather their own lack of information, which leads to uncertainty. Also, "cost" (e.g., of legal advice) was initially a separate dimension, but I found that what matters is cost relative to resources, now captured in the dimension "resource scarcity."

The resulting coding scheme has nine top-level nodes, 29 second-level nodes, 39 third-level codes, and 298 codings. Fig. 1 shows the emerging data structure. It contains five aggregate dimensions focusing on small IoT device makers' circumstances as SEP licensees. The nine top level nodes in the coding scheme comprise these five dimensions as well as four additional topics that are purely descriptive (standards employed, suppliers used) or not directly related to the startups' position (suggested solutions, SEP owners' perspectives). The interviewees reviewed and authorized all verbatim quotes.

[8] Surprisingly given the topic's prominence, there is considerable disagreement on what share of (LTE) SEPs is implemented in the baseband processor. Claims range from "most, if not all" (Continental and Denso, 2019, p. 19; Valenti, 2016), to "few" (Vary and Warne, 2020, p. 3), though based on a legal rather than a technical argument. Putnam and Williams (2016) report for a sample of 122 Ericsson SEPs that 71 % of them were realized in the baseband processor, but all also referred to other components.

[9] Despite the wide adoption of IoT technologies, it proved difficult to find firms willing to be interviewed. This reluctance may be due to the sensitive nature of the topic. Licensed device makers are typically bound by an NDA, while unlicensed firms may prefer to keep a low profile. SEP owners are typically large firms and generally secretive about licensing.

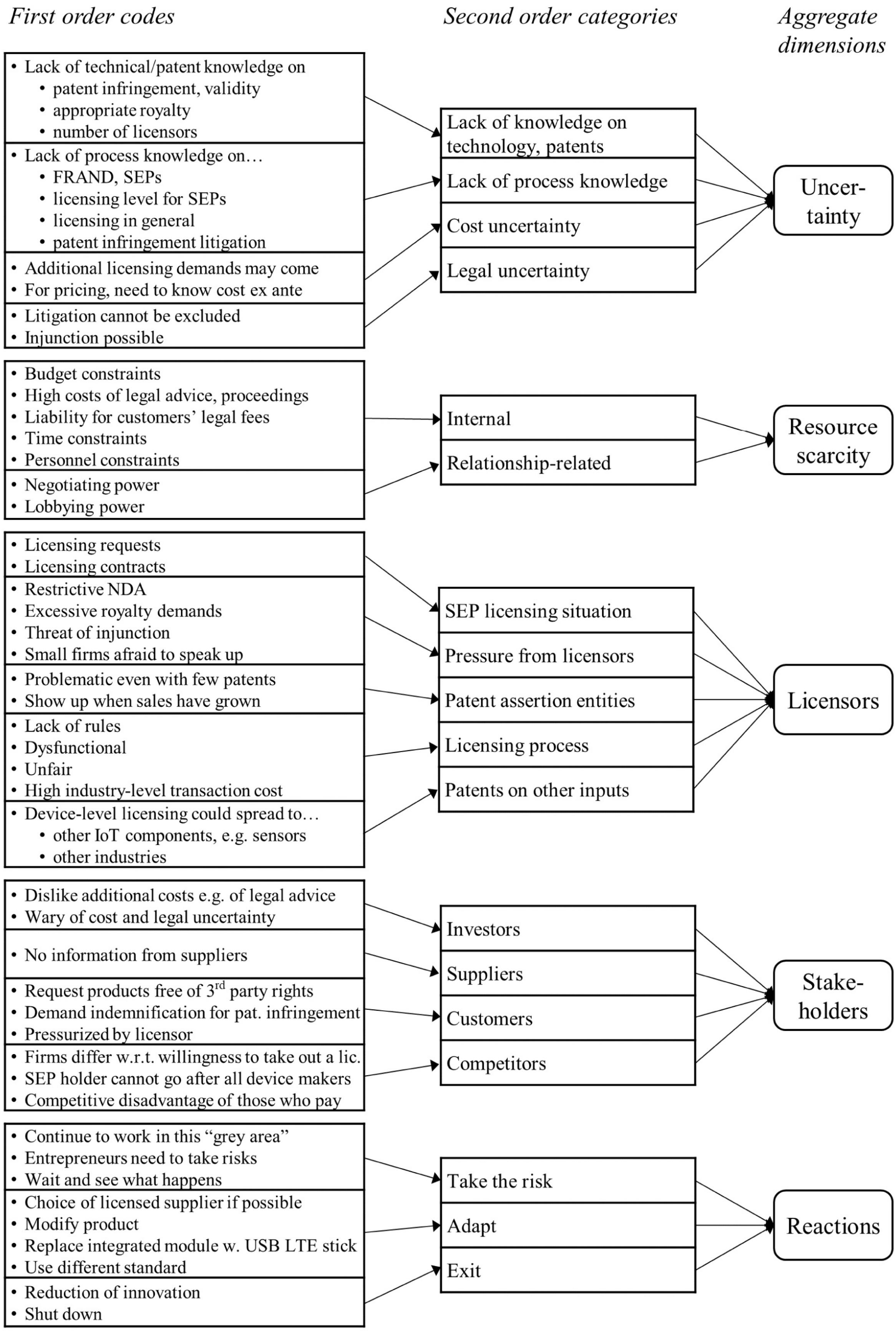

Fig. 1. Emerging data structure.

4. Small IoT device makers' circumstances as SEP licensees

Interviewees were asked openly about their (actual or hypothetical) reaction to licensing demands. The issues they raised were unprompted, and so some fields in the data table (see Appendix A.5) are blank. While interviewees emphasized different aspects, they had largely consistent views on the topics of uncertainty and resource constraints. In particular, there were no apparent differences between small and medium-sized firms (less/more than 50 employees), nor between the IoT device startups (S1 to S12) and the small phone maker (P1); size seemed to matter more than type of device. Differences existed between firms that did or did not receive licensing requests from SEP owners (S1, S5, S9, S11, at the top of Table A.5), mostly regarding concrete experiences. The main differences were device makers' reactions to licensing demands.

My data suggests that for small IoT device makers, uncertainty and resource constraints hinder device-level licensing. Licensors and stakeholders' actions are moderating factors.

4.1. Uncertainty

As my interviews show, small IoT device makers as potential SEP licensees lack knowledge of IoT technologies, patents, the SEP licensing process, costs, and legal exposure. Their minimal understanding about the potential outcomes of licensing interaction, much less about the probabilities, means these device makers face Knightian uncertainty (Knight, 1921). Applying Milliken's (1987) typology, we can identify state, effect, and response uncertainty. Information asymmetries vis-à-vis prospective licensors matter, but the device makers' lack of knowledge appears to be the dominant issue. Consequently, licensing to device makers implies high dyad-level transaction costs.

4.1.1. Lack of knowledge about IoT technologies and patents

Facing the general obligation and even concrete demands to take out a license for IoT SEPs, startups felt incapable of assessing whether their products indeed infringed these patents. They lack an understanding of IoT communication technologies, the respective standards, and applicable patents. They face state uncertainty (perceived environmental uncertainty). During the interviews they said[10]:

> "[…] it is for startups […] impossible to find one's way in this jungle. Because for example I completely lack transparency as to which patents the technology of a Qualcomm modem in my device actually uses." [S3]

> "[…] for us it would be enormously difficult to understand the thousands of patents on our module […]" [S3]

> "[…] how would we know all these things, I mean it's an incredibly high number of things we would have to look at proactively, when we don't even know sometimes how far we will go with one specific technology." [S6]

> "[…] on this module there are probably three million chips and three million patents infringed. Even at TI [Texas Instruments] nobody can assess that. And we as the final device maker definitely not. So we have [number] employees, I could probably keep half of them busy with checking patents and would still not get anywhere." [S1]

> "How many patents are in my PCB [printed circuit board] or the different elements? No clue!" [S9]

> "[…] if I'm using a Wi-Fi module, even if it is an SEP that is essential for the entire Wi-Fi standard, maybe I am not using that piece of technology, maybe that SEP relates to I don't know, automatic reconnection and I'm not doing that automatic reconnection. Am I using their IP or not?" [S10]

They also felt incapable of assessing patent validity, and the reasonableness of the entire offer:

> "So validity of all this stuff is yet another question. We as a small firm cannot possibly check this." [S1]

> "as a startup, […] as a small company, I have no way really of evaluating the legal validity of what they [licensors] say or not. I have no way of knowing is this reasonable, or not reasonable when they actually say how much money they want, I have no idea whether it is the same as anybody else or it's specific to me, is that fair, there is no way of judging. So I have no way of actually evaluating their request on any kind of merit." [S10]

An interviewee from a large, established implementer shared the startups' concerns:

> "One cannot expect that, for instance, a manufacturer of some electrical instruments that now integrates a communication unit informs itself about communication patents." [E1]

Even large firms face these problems, as the Association of Global Automakers and the Alliance of Automobile Manufacturers (D3, 2019, p. 5) stated:

> "The whole benefit of vertical specialization is that a manufacturer need not worry about how the products it buys were made. But without patent exhaustion, it must worry. It must either take additional time intensively investigating components outside its area of expertise, or else take X's word about what royalties it should pay." [D3]

An interviewee from an SEP licensor [L1] expressed the view that a device maker's claim not to know if SEPs proposed for licensing are essential, infringed, or valid would probably be an excuse to reduce royalties. My interviews with startups contradict this allegation; the concerns they expressed seemed plausible and genuine.

4.1.2. Lack of process knowledge

Interviewees displayed a lack of process knowledge regarding SEP licensing, FRAND rules, and litigation. Again, this constitutes state uncertainty. Several including the small phone maker did not even know there were issues with SEP licensing, assuming that the modules they procure were fully licensed:

> "we thought that when our company purchased IoT modules from [module maker] […] that the modules were already pre-licensed. We just assumed and we didn't even think to question which licenses had not been covered – and we didn't even know to ask." [P1]

Ignorance about the licensing process in general is another challenge most firms face:

> "… how do you work with licensing stuff, I don't even know. We have never done that, we just buy and create a system […]" [S7]

Several interviewees expressed concerns about the unknown and potentially large number of SEP owners seeking royalties:

> "5 euros would not harm us, but if this is only 5 percent and then all the others also demand 5 euros for their share, of course you get to a level where it has significant effects on the margin." [S2]

> "Yes, we would do this rather than getting into serious problems in court. Grudgingly, but relative to our size this is doable. Sure, it would be problematic if now 100 of those came and it gets around, 'go to this firm, they pay' […]" [S3]

[10] Quotes from interviews conducted in German were translated into English by the author.

> "[…] we cannot deal with so many patent holders. It is going to be difficult for them as well, you don't want to deal with a small company, as I said, you won't get much, so it is not worthwhile." [S6]

> "After investing our very limited resources as a small company in R&D, manufacturing, marketing, and distributing our products to customers, not only would we not have funds to negotiate a FRAND licensing fee after the product has already been delivered, but at that point in the process we wouldn't have enough margin to be able to absorb even a couple of dollars per unit in order to pay for a licensing fee. Further, even if we could somehow absorb the impact of one company coming after us for a licensing fee, we certainly wouldn't be able to absorb it if another company – much less additional companies – came after us for licensing fees." [P1]

One of the large SEP licensors [L1] claimed that only about ten LTE SEP owners actually licensed their patents while all others were dormant. While indeed not all SEP holders license their patents, the number of active licensors is clearly greater than ten (footnote 4 names 13 publicly known LTE SEP licensors). And even dealing with ten holders of SEP portfolios would be unfeasible for an SME device maker. Furthermore, uncertainty remains regarding potential further royalty demands.

Engaging in SEP licensing requires an understanding of FRAND principles, and startup interviewees were unaware of the FRAND concept and the FRAND licensing process. The following quotes illustrate this point.

> "[…] in our case, I don't know how a court would decide regarding appropriateness. If this was much more than one to two Euros, then many IoT devices would not work at all. Also, I do not know the legal practice, if in the case of FRAND licensing a court can say, 'this specific patent is monopolistic and you cannot demand a royalty of 5 euros because then the firm XY could not build any device at all." [S3]

> "Who has the burden of proof? Does [large SEP holder] have to prove this, or do we? I mean, anyone could come along. Or do we have to prove, no, we do not use any of your patents?" [S3]

> "With startups, you don't have the background, the budget, and you may not even have heard about standard essential patents, unless your startup has a technical person attending meetings." [M1]

4.1.3. *Uncertainty regarding cost and legal exposure*

The issues described above create effect uncertainty (Milliken, 1987) for device makers as licensees, who cannot assess the potential cost and legal consequences. During the development of an IoT device, it is unknown which demands for SEP royalties will surface later, so innovators cannot make reliable cost calculations. While they could add an extra margin for potential royalty requests down the road, doing so would put them at a disadvantage vis-à-vis competitors who are less cautious. Interviewees' statements reflect these concerns:

> "[…] right now, it is certainly a problem because there are no rules and we cannot solve this problem in advance, but are as a small buyer in the end at the mercy of the patent owners. So we cannot fully invest in the technology today, without considering this and asking, 'okay, what is the risk that we take and how much do we have to pay in the end for individual devices and how can we pass it on to the customer'. We have no financial control whatsoever." [S4]

> "[…] if I make an agreement today, I am signing with any kind of partner downstream. I'm signing an agreement that if I'm selling a product that is violating a patent […] it's on me, right, to cover the cost." [S5]

One interviewee pointed out the legal exposure to SEP infringement and the fact that most small firms are unaware of the consequences:

> "[…] the normal person, without legal training, would probably panic, because patent law has all sorts of cruelties that can hit an individual personally. […] in principle, as the head of development or possibly as the CEO you can find yourself in the dock […]" [S1]

4.2. *Resource scarcity*

Most issues related to uncertainty affect IoT device makers of any size. Compounding the situation for startups and SMEs are constrained resources, both internal (budget, time, personnel) and relationship-related (negotiating and lobbying power).

4.2.1. *Internal: Constraints on budget, personnel, time*

Several interviewees mentioned financial restrictions that obviate the evaluation of licensing offers:

> "Actually, no SME can afford that [to get informed about the merits of alleged SEPs offered for licensing]." [S1]

> "[By trying to evaluate a licensing offer] I would only delay my own innovation of the time to market and add a lot of cost I cannot afford to pay." [S5]

> "[…] for a startup, it's a substantial expense to get educated, because they'll have to reach out for expertise. […] It's a cost that you didn't plan for. It's also a liability that your financier may not appreciate […]" [M1]

> "for a small company it is like, the CEO is, we don't have budget, we don't have budget for that [assessing patents offered for licensing]." [S11]

Due to budget limitations, legal action is typically not an option for startups:

> "court arbitration and legal proceedings are not an option for small companies, we cannot afford to pay anything." [S11]

> "there is no way for us to fight it, we are too small to take on a large organization […]" [S12]

The required legal skills for evaluating licensing offers are usually not internally available:

> "[…] one of our replies to [licensor] was, can you tell us specifically which one and they said here is a list of all our patents and we said we are a small company, we don't have a lawyer who can tell us which one [we are infringing]" [S5]

Even if the firm has the required expertise, these people are typically busy with their main job:

> "The CTO is like, no but give me a break, I don't have time […] I don't have time to review, look at that list of patents." [S11]

An interviewee from one of the large SEP licensors [L1] stated that, to address the above issues, any licensee would have to call on external expertise. This view, however, appears unrealistic given the SMEs' resource constraints, the large number of SEP families for a single standard, the technical complexity of standards, and the effort required assessing the essentiality of even a single patent (Bekkers et al., 2020). One of the other SEP licensors [L2] shared the SME device makers' concerns:

> "So what should a small to medium entity do, you know, a small startup which sells for very few million or so and if they suddenly get sued by dozens of companies, by dozens of patent owners, how should they handle that, they don't have the resources. And that is a very serious concern. Absolutely." [L2]

4.2.2. Relationship-related: Lack of negotiating and lobbying power

One interviewee pointed to SMEs' lack of negotiating power:

> "[…] we as a small buyer have no hold over the licensors. If one has a larger volume, then of course one has many more possibilities. For Tesla there would be other possibilities […] in the end we're speaking about [number] devices maximum, in that case one has no leverage over these firms, they are in the driver's seat." [S4]

> "we never sign any NDA, or we try not to sign because we don't have […] the power to negotiate. I had already discussions with large companies and they said we can manage to change some of the legal terms but those companies are big, big guys, so they have time and legal resources and power, we don't have this." [S11]

> An interviewee from a large device maker [E3], speaking about licensing negotiations with a patent pool, voiced the impression that not only their firm as the licensee, but also the licensor were largely ignorant regarding infringement, standard essentiality, and technical merit of the patents in question. While a few technical experts were consulted, the outcome seems to have been mostly determined by the parties' relative negotiating power. Again, SMEs and startups would be in a difficult position.

Also at the political level, SMEs are seen as disadvantaged due to their lack of lobbying power:

> "[…] one of the things about SMEs I have heard for years […]: 'We want to hear from the small and medium sized companies. We want your opinion, we want to know.' But I'll tell you what I've found while working with SMEs. The opposite is true. Most companies don't want to hear from SMEs. It's the Apples and Googles of the world, and Nokias of the world that control the conversation. And when you hear from an SME, you're gonna hear something very different, which tends to be suppressed, because SMEs don't have the budget to lobby, they don't have the budget to attend every policy meeting." [M1]

> "politically, it's like let's protect our big manufacturers, big companies, Nokia, Ericsson, […], let's protect those companies." [S11]

4.3. Licensors

Interviewees from firms that had received licensing requests spoke about their experiences, the pressure exerted by licensors, and the specific role of patent assertion entities. Other interviewees commented on the licensing process and potential spread of bifurcated licensing.

4.3.1. SEP licensing situation

Four of the interviewed startups had been approached by one or several prospective licensors (see 3.1). Only in one case was a licensing contract closed. The startups argued they had no understanding of the technology, that their suppliers would be more appropriate licensees, and that their revenues were still too low to make licensing worthwhile. After fairly lengthy exchanges, the SEP holders in most cases abandoned their licensing attempts, without indicating why. The startups were relieved, but felt uncertain if, when, and where further licensing requests might come from, and if other SEP holders might employ legal means.

The outcome of most of these licensing attempts shows that device-level licensing to startups is problematic not only for the prospective licensee, but also for licensors. If the former engages in hold-out, refusing to respond to licensing demands with a potential legal basis, the SEP holder does not benefit from legally enforcing its demands.[11] Some licensors may find it worthwhile to set examples in order to build a reputation for toughness, but there was no evidence of this in my sample.

4.3.2. Pressure exerted by licensors

Interviewees described some prospective licensors' approach as tough. SEP owners typically first ask the potential licensee to sign an NDA (non-disclosure agreement), which deprives the device maker of the opportunity to get information from peers and suppliers:

> "For instance, I am completely lacking transparency about which patents the technology of a Qualcomm modem in my devices actually uses. And under an NDA I might not even get this [information]." [S3]

> "So they asked us to sign an NDA and then we talked to our lawyer and he said, 'You know what, you cannot really sign that because then you cannot go and speak with [distributor] and [supplier] and you cannot talk to others that may be in the same position,' right. And because we wanted to do that, I mean, if we had signed that claim we would have been done, right? Because then we would only have been able to let's say communicate with [potential licensor] on their terms for this discussion. And so we wanted to say, you know we need to be able to talk to others than our lawyers about this." [S5]

> "It is a […] total lack of transparency, in order to get information, you have to sign an NDA, which is a Fort Knox NDA, it is like you cannot even breathe, because you are not allowed to breathe and so for small companies that's a real [problem] […] you need to partner with your customer, you need to partner with all companies, you need to share some information because otherwise you are dead, you cannot deal alone with that type of claim, it is impossible. From a legal standpoint, it costs a fortune […]" [S11]

The interviewed firms had refused to sign an NDA and did not face dire consequences. Still, other implementers may feel they need to sign, particularly if the licensor exerts more pressure, and the request alone can put a firm in a difficult position. There may also be a selection effect insofar as only firms that had not signed an NDA were willing to be interviewed (see footnote 9). Some licensors actually exert pressure on small firms not to go public with their experiences:

> "[…] there are not that many small companies able or willing to share their concerns because unfortunately they are afraid, they are really afraid. […] I know some companies which had to go backward and participate in fewer events and all this because they got some threats during negotiations […]." [S11]

One interviewee reported that a licensor had simultaneously informed their reseller and a customer to apply more pressure, while a patent assertion entity had threatened to seize infringing products. Another perceived the tactics as unfair and "bullying":

> "another threat is that in order to make sure they will have your full attention, it happened to me that they would send the same day a letter to my customer, my reseller and ourselves, […] because they know that you have indemnification under your reseller agreement, you have indemnification under your customer contract and so they send three letters. Just to make sure that you will have no choice but taking care—and even under such circumstances your NDA is not allowing you to share information with the reseller or your customer." [S11]

[11] This is consistent with Heiden and Petit's (2017, p. 180) finding, based on a survey of 12 SEP licensing executives, that "*small- to medium-sized enterprises […] seek to avoid payment altogether.*"

"One of the trolls [patent assertion entity] could manage to send us threat that they would seize the products to in Italy, thanks to Italian laws, which allow them to seize let's say products which are infringing […] that's a no-go, that's, you don't even try to negotiate, you just, you just go and pay and cry […]" [S11]

"We really felt like we are just being cornered and bullied by a big player here, right. I mean we felt completely outmaneuvered, we didn't have money for lawyers, we didn't have insights, this was not a fair game. The process was not a fair game, so even if they had a legitimate claim, all right, and they are frank, have principles and all this, just by approaching us, a small startup, for me it is unfair." [S5]

All interviewees acknowledged that owners of IoT SEPs should receive fair royalties for the use of the respective standard. Their critique was about the process, which makes it impossible for them to assess a licensing offer and determine if it is fair. In one case, an interviewee explicitly addressed the amount of royalties requested:

"And one more thing that I really find surprising, this is what people consider a [appropriate] royalty. What is considered 'normal' is quite high. […] if everyone who somehow owns such a patent comes along, there will be nothing left of the dough [profit margin], it becomes negative." [S1]

4.3.3. Licensing process

Most interviewees from device makers found IoT SEP licensing at the device level unfair and unsustainable for SME device makers. They were surprised that their suppliers were selling them unlicensed products and therefore infringing patents:

"I don't know the applicable law. Can the chipmaker use other parties' patents, sell its products, and then sort of say [to buyers], 'well, if I infringe on a patent or not is for you to find out'?" [S2]

"But conversely, this means that some other firm can sell me things it has not licensed, it can make money with these, but it leaves us holding the baby, or what?" [S3]

"I can apparently go to a huge chip manufacturer, buy a chip set and then further down the line be approached by [large SEP holder]. Because apparently, it's easier to go for the smaller companies then make a deal with a bigger one." [S5]

Interviewer: "[…] if you had received a letter saying, '[…] we need to speak about royalties.' What would you have done?"

Interviewee: "I would have put it in the bin. I wouldn't reply. I assume, ok, before being involved in the discussion with [omitted], I would have assumed it was a scam […] because I would have found it inconceivable that buying a Wi-Fi module and then being asked directly by the license owner to pay based on the chips in my product when I am already paying for the chip, I would find it inconceivable that they allow that."

[S10]

One interviewee perceived the current IoT SEP licensing process as "anarchy":

"[…] for me we are still in the machinery trying to get the patent holders to define some rules, because right now it's anarchy. It seems like anarchy. […] when you look at it as a newcomer, it just seems super dysfunctional and not sustainable." [S5]

Interviewees considered it would be optimal for their business and their innovation activities if they could procure fully licensed modules:

"As an innovative company, it would be useful for us to have the licensing requirements satisfied at the module OEM level, so that when we purchase a module from a manufacturer, the module is already pre-licensed and we can absorb the higher price from the start […] when we begin to develop our device which uses that particular module." [P1]

"But my expectation as a manufacturer at the end of the chain, is that the licensing is already taken into my purchase of the component and technology. I don't have to deal with that. It is not up to me to deal with that. It's the one at the very beginning of the chain to find the right business model with their partners […]" [S9]

4.3.4. Patents on other inputs

Interviewees also alluded to beyond their own situation, suggesting that not only IoT SEP owners but also owners of patents on other components may start engaging in device-level licensing. Such a development would border on the absurd:

"We don't just have communication chips on the device. For example, we also have [type of sensor]. Who knows what kind of measurement methods or whatever other patents there are. I think if we started with all sensors and chips on our device this would become infinitely complex, and would not be commensurate with our size." [S3]

"Now we are talking about the communication technologies, but could it be anything? Like, that the entire component industry is changing into, just to produce anything and then the producers of equipment are then actually the ones in touch with the licensor?" [S7]

"It will not work this way. This is also the issue that we have in the automotive industry, that we build a car from many thousands of components, and of course we cannot have the knowledge about each technology in-house, this would be insane." [E1]

4.4. Stakeholders

Small IoT device makers' difficult position as potential SEP licensees is compounded by the influence of stakeholders—investors, suppliers, customers, and competitors.

Investors loathe financial and legal uncertainty due to unclear licensing obligations:

"[Faced with a lawsuit, startups] will panic and their investors will get nervous and it just doesn't go as well for a true startup where you get 5 to 10 people or even up to 100 trying to make something work." [M1]

"It's very hard for me to squeeze it into a pitch [to investors], 'oh by the way there might be some patents out there that because I am over a mobile network, we might be liable in the future potentially for an IP battle, not because of what we have created but because of standards.' I am not bringing it up as a subject, but I think it is one of those things that during due diligence it would more than likely come out." [S12]

Some of the interviewees had approached their suppliers to understand the licensing status of the procured inputs. One supplier said clearly that their products were unlicensed, but others gave vague answers:

Interviewer: "One question about [supplier], when they sell you that chipset, do they say anything about the licensing situation?"

Response: "No, absolutely not. Well what we did do though was, we went back to understand how this could be our problem, right. So we talked to [distributor], who was the distributor of this [supplier] chip and they said: 'Hey, this has nothing to do with us and we are just selling that [supplier] chip.' And then we went to [supplier] […] I think it actually escalated, but he came back and said: 'We don't have any violations, we don't have any agreements.' […] So we followed the chain back but none of them felt it was their problem." [S5]

In a B2B context, customers usually expect that the products they procure are free of third-party rights, and demand indemnification in case of infringements. For IoT device makers, this increases the legal and cost exposure, which is particularly problematic for startups and SMEs:

> "[…] if I make an agreement today, I am signing with any kind of partner downstream. I'm signing an agreement that if I'm selling a product that is violating a patent […] it's on me, right, to cover the cost." [S5]

> "For a small company it is like, it is major, […] because you have several customers […] when you are working with [omitted], they ask for unlimited liability, indemnity, so have an unlimited indemnity, and when I say unlimited it is really unlimited. Direct indirect, consequential damages, legal fees, and in the U.S., this is something." [S11]

Finally, competitors matter because device-level licensing of IoT SEPs to SMEs will probably be inconsistent given that device makers differ in their willingness to take out a license. Therefore, actual cost will vary between rival device makers, penalizing firms that took out a license:

> "[…] at the end of the day it stacks up and my cost for the device has been increased because I pay that license and someone else did not. And that's a competitive disadvantage." [S5]

> "I think what will happen is that they will try this with 100 companies and maybe 20 will respond and one of the ones which responds, they will try to get something out of them." [S6]

> "[…] it is a bit unfair competition because […] we don't know if the others pay, because when you start paying like 30 cent per device, something like that, it does impact your margin. So, in fact, and you are thinking that maybe the other guy because he is bigger doesn't pay or doesn't pay the same price, but you don't have any idea." [S11]

In the same vein, one of the interviewed large SEP holders conceded that they are unable to ensure equal licensing of all smaller firms that use their technology.

4.5. Reactions

Interviewees commented on the consequences of establishing and enforcing device-level licensing for their own firm and for the IoT in general. Mostly, they were not sure about their response options and how effective they would be, so also experienced response uncertainty (Milliken, 1987).

Three interviewees, all from firms not contacted by licensors, stated that their firm would "*take the risk*" and "*continue in this gray area.*" The majority of interviewees would, however, *adapt their business* one way or another. Two said they would try to find a supplier that sells fully licensed modules, while one firm (contacted by a licensor) moved from a premium supplier to a cheap one because the former provided only minimal support regarding SEP licensing. For one interviewee, it would be an option to replace the integrated LTE module in their product with a pluggable USB LTE stick (only possible with large devices), for which the SEP licensing obligations lie with the manufacturer. This would mean accepting an inferior product design in order to circumvent patent licensing problems. Two interviewees stated they would modify the product to use a different standard, less encumbered by SEP licensing issues (again, the question is if this is possible). Two interviewees were more pessimistic, and considered device-level licensing could mean the end for their venture:

> Interviewer: "[…] if the Wi-Fi module you are buying, if that says 'patent licenses not included' […]. What do you do?"

> Interviewee: "I stop my business and tell you it is becoming so complex that, I mean it is already so complex to source components today […]" [S9]

> "Further, even if we could somehow absorb the impact of one company coming after us for a licensing fee, we certainly wouldn't be able to absorb it if another company – much less additional companies – came after us for licensing fees. We would have no choice then but to close the company entirely." [P1]

Three interviewees raised the point, unprompted, that the establishment and enforcement of device-level licensing would severely hinder innovation in small companies:

> "When I think about it, we built stuff that is challenging for very large organizations and it has taken us three, four years, something like that, from school boys like myself. And that is to some extent amazing, and […] it's only possible because of the technology we build into the sensor. So, it is an enabler to build the fastest [type of device] in the world, and it's done by school boys. And that's cool in the sense that we couldn't have done that with any sort of issues with licensing stuff and money upfront, we just bought a component for 3 Euros or whatever and put it on a PCB, so that [device-level licensing] would definitely kill that kind of movement." [S7]

> "if you do that, and this is one of the points I am making, you are going to stop innovation by small companies. You are going to concentrate everything in the hands of the big guys. Why? Because it will become so complex to initiate a business around technology, that only big money guys can start and jump into that, in fact." [S9]

> "it just has to be that you can as a small to medium sized firm, you can buy a fully licensed module and that's it. Plug it in and be free, otherwise we would really strangle the IoT innovation." [S10]

4.6. Industry-level transaction costs

A point that does not concern the individual IoT device maker as a licensee, yet is highly important for the efficiency of the SEP licensing market overall, is aggregate transaction costs across all licensees.

Even casual observations show that industry fragmentation increases steeply when moving downstream. Regarding baseband processors for cellular communication technologies, market studies address six manufacturers explicitly,[12] and a recent industry study put the market share of the top three firms in 2019 at 71 %.[13] At the other end of the value chain, the market for IoT devices is highly fragmented (see also SEPs Expert Group, 2021, p. 41) and heterogeneous.[14] It seems safe to assume that the number of IoT device makers will be large, plausibly five-digit globally, and grow substantially.[15] The intermediate market for network access devices (NADs) will likely be in between baseband processors and mobile IoT devices in terms of fragmentation; given the relatively low degree of differentiation compared to devices, this market should still be concentrated. Even if a licensing contract with a device

[12] These are Qualcomm, MediaTek, Intel, Broadcom, Spreadtrum, and ST-Ericsson. https://www.decisiondatabases.com/ip/38054-baseband-processor-market-analysis-report and http://www.marketsnresearch.com/global-baseband-processor-market-status-by-manufacturers-types.html.

[13] https://news.strategyanalytics.com/press-releases/press-release-details/2020/Strategy-Analytics-2019-Cellular-Baseband-Market-Share-5G-Basebands-Capture-2-Percent-Unit-Share/default.aspx.

[14] See, e.g., https://iot-analytics.com/10-internet-of-things-applications/ and https://iot-analytics.com/top-10-iot-segments-2018-real-iot-projects/.

[15] Wi-Fi or WLAN technology based on the IEEE 802.11 family of standards is also a key technology for the mobile IoT. The number of firms on various levels of the value chain is qualitatively the same as for cellular technologies, with few chipmakers and numerous device makers—probably even more than for cellular technologies owing to the lower cost and complexity of Wi-Fi.

maker will likely be simpler than with a baseband processor maker, the strong increase in potential licensees when moving from baseband processor to final device level means a high increase in transaction costs (see also Pentheroudakis and Baron, 2017, p. 29). With ten baseband processor manufacturers and ten thousand device makers, a thousand times as many licensing contracts will have to be closed when licensing at device level compared to processor level.

4.7. Summary

IoT device makers face a difficult situation as SEP licensees: uncertainty due to a lack of knowledge regarding IoT technologies, patents, and licensing practices, compounded for SMEs by resource constraints. They perceive prospective licensors as exerting undue pressure, and the process of licensing SEPs to SME device makers as unfair and unsustainable. The influence of investors, suppliers, customers, and competitors compounds these issues. Hypothetical reactions to the general establishment of device-level licensing differ, from "taking the risk," adapting the business, to closing it. Several interviewees expressed concerns that it would severely harm innovation in small IoT companies. Industry-wide, device-level licensing would create much higher transaction costs than upstream licensing due to both higher dyad-level transaction costs and the much larger number of licensees.

5. Model

5.1. Bifurcated licensing, transaction costs, and price differentiation

The empirical study suggests an MFT model that includes the value chain level where patents are licensed. As Fig. 2 illustrates, bifurcated licensing separates the usage rights covering a patented technology from the knowledge of the technology: the rights are licensed to the downstream device maker, while the knowledge is passed on to the upstream component maker. There may be additional value chain levels between the component maker and the device maker, such as the module (NAD) maker.

I argue that bifurcated licensing increases: (a) uncertainty on the part of the licensee, and thus dyad-level transaction costs; (b) the number of licensees (due to greater industry fragmentation) and thus industry-level transaction costs; (c) product heterogeneity, and thus the potential for price differentiation; and (d) product complexity, and thus the difficulty to actually carry out price differentiation. Mediated through these factors, the licensing level affects MFT efficiency. Fig. 3 illustrates this argument. The model combines the empirical results (uncertainty) with economic arguments (price differentiation) to provide a comprehensive picture of MFT efficiency.

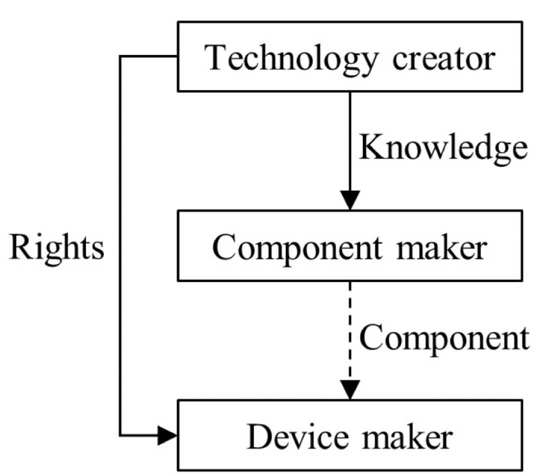

Fig. 2. Separation of rights from knowledge through bifurcated licensing.

5.1.1. Uncertainty: Dyad-level transaction costs

The empirical study has shown that IoT device makers as SEP licensees face state, effect, and response uncertainty, compounded for small firms by resource scarcity. For upstream firms that translate the standard's specifications into a component, each of the above types of uncertainty should be lower; also because firms are typically large and do not suffer from resource restrictions. Consequently, dyad-level transaction costs should be higher with bifurcated (device-level) licensing than with integrated (upstream) licensing.

Some authors name countervailing effects. Borghetti et al. (2021, p. 3) mention the "*efficiencies and ease of monitoring compliance with royalty payments and the use of products*" at device level, similar to Teece and Sherry (2016, p. 2). However, these authors assume a price differentiation of licenses based on using standardized technology in the final device, an argument I address in Sections 5.1.3 and 6.2. Ceteris paribus, it appears questionable if monitoring a small downstream firm is easier than monitoring a large upstream firm. Teece and Sherry (2016, p. 14) advance another argument against upstream licensing, "*[i]n some cases, we do not have actual transaction prices of the SSPPUs*"[16] (since the chip maker may also be the device maker). However, this argument criticizes applying the SSPPU price as royalty base; it does not oppose collecting royalties upstream. Finally, Borghetti et al. (2021, p. 3) state that device-level licensing would imply "*transaction cost savings achieved in negotiations with one group of licensees*" compared to a regulation allowing actors at various value chain levels to request a license. Given the heterogeneity of device makers and homogeneity of upstream firms, also this argument does not sound convincing.

The arguments for integrated licensing presented above generalize beyond the licensing of SEPs in the IoT context. A firm that puts patented knowledge into practice should have a better understanding of the technology and patents covering it than a downstream buyer of the component containing this technology. Similarly, a firm that integrates this component into a larger module should have a better understanding of these topics than the downstream device maker. These considerations suggest that uncertainty, and hence dyad-level transaction costs, increase the further down the patents are licensed in the value chain (relative to the knowledge implementation level).[17]

5.1.2. Licensing level fragmentation: Industry-level transaction costs

Dyad-level transaction costs add up over all dyads of licensee and licensor to yield industry-level transaction costs, and so the number of licensing relationships increases with the fragmentation of both the licensor and the licensee industry. For a given value chain, licensee fragmentation depends on the licensing level: in the IoT space, device-level licensing implies a considerably stronger fragmentation of the licensee industry than licensing upstream. Thus, at industry level, the transaction costs should be much higher for device-level licensing.

Some interviewees and authors (see footnote 8) claimed that not all SEPs were implemented in the baseband processor, and that generally speaking, no intermediate product practiced all SEPs. At least for NADs, the assumption appears implausible. And even if it was correct, the total number of upstream licensees should still be much smaller than IoT

[16] Acronym stands for "smallest saleable patent-practicing unit," and refers here to the baseband chip.

[17] Patent pools help to reduce the number of licensors and thus transaction costs. As of June 2022, the IoT licensing platform, Avanci, lists 49 licensors of 2G, 3G, and 4G SEPs (https://www.avanci.com/marketplace/#li-licensors). This is remarkable, but still not one-stop shopping. Huawei and Samsung, important LTE SEP holders, are absent from the list, and some patent assertion entities probably expect higher revenues from licensing individually rather than through Avanci. Also, judging by the list of licensees and pricing information provided, Avanci seems to be focused on vehicles. Thus, patent pools and licensing platforms could mitigate, but not solve the transaction cost problems for IoT device makers.

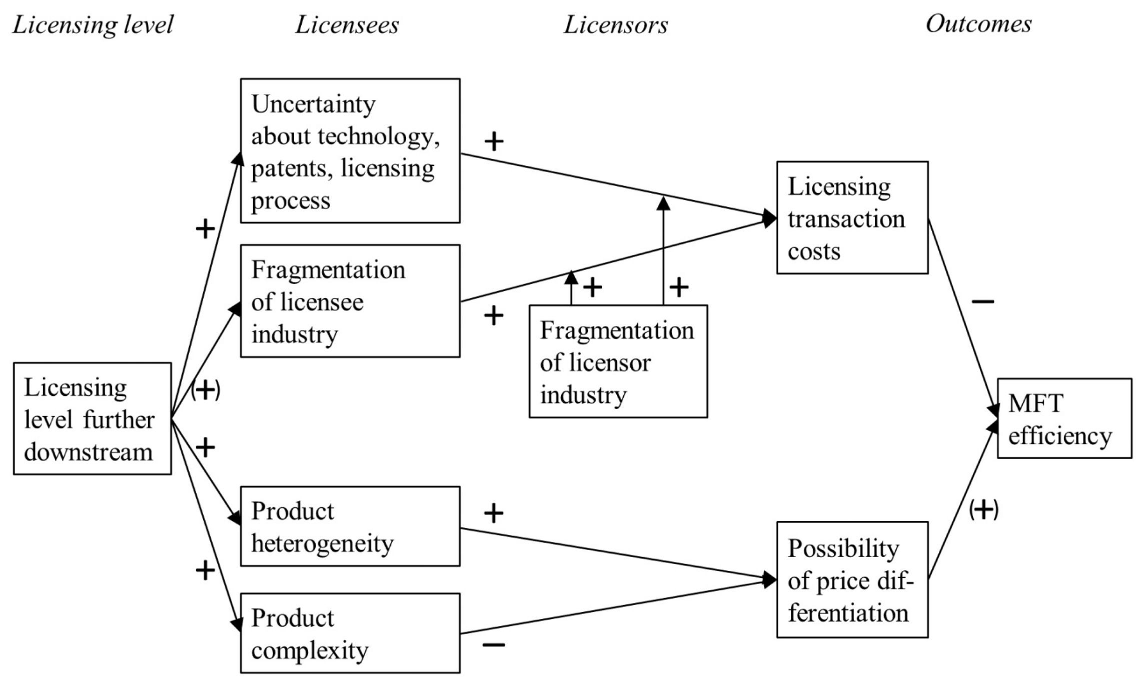

Fig. 3. Factors influencing MFT efficiency.

device makers.

Again, a generalization of the empirical findings beyond IoT SEP licensing suggests: If the downstream industry is more fragmented than the upstream industry implementing the patented knowledge—a condition that will often be fulfilled, in particular for general-purpose technologies—then ceteris paribus industry-level transaction costs are higher with bifurcated licensing.

5.1.3. Product heterogeneity: Potential for price differentiation

The value that a mobile communication standard contributes to a device depends on the type of device. This value should be reflected in the royalties paid: "*Determining a FRAND value should require taking into account the present value added of the patented technology*." (European Commission, 2017, p. 8). The heterogeneity of products in the IoT value chain is arguably highest at the device level. Thus, device-level licensing of SEPs should, at least in principle, facilitate accounting for what the patented technology contributes to the value of the final product (Sidak, 2014; Petit, 2016; Putnam and Williams, 2016; Teece and Sherry, 2016; Kappos and Michel, 2017; Gautier and Petit, 2019). Interviewees from licensors agree with this view:

> "And [the device level] is the best place to basically take into account the value of the technology that is incorporated into a product." [L2]

In general, two factors determine the feasibility of price differentiation in patent licenses. First, paid patent licenses are priced above marginal cost (essentially zero). Second, if products are heterogeneous, the contributory value of a patented technology will likely vary between products, and with it the product maker's willingness-to-pay for a license. Since product heterogeneity in most industries increases when moving downstream, so does the potential for price discrimination.

Price differentiation can have a positive welfare effect thanks to output expansion, since it allows serving market segments with a low willingness-to-pay, that with uniform pricing would remain unserved. A negative welfare effect results from the transaction costs that the enforcement of price differentiation causes (Leeson and Sobel, 2008). These contradictory factors are reflected in the Fig. 3 by the symbol "(+)".

5.1.4. Product complexity: Price differentiation challenges

Downstream along the value chain, products become more complex: A final IoT device is more complex than the NAD, which in turn is more complex than the baseband chip. Increasing product complexity poses a challenge for price differentiation of SEP licenses, since the more components a product has, the harder it becomes to identify a standard's contributory value. This is particularly important under FRAND conditions, which provide no justification for tying royalties to a product's price if this is driven by other components: "*[…] the present value added of the patented technology […] should be irrespective of the market success of the product which is unrelated to the value of the patented technology*." (European Commission, 2017, p. 8; see also Muris, 2019, and Geradin, 2020, p. 17).

The logic that product complexity increases when moving downstream should apply beyond IoT devices. Thus, while downstream licensing implies potential for price differentiation due to increasing product heterogeneity, the concomitant increase in product complexity makes its actual implementation more difficult.

5.2. Licensing level as determinant of MFT efficiency

Fig. 3 shows how licensing level affects the factors discussed above and how these, in turn, determine MFT efficiency. The uncertainty that licensees face, and likely also industry fragmentation, increase when moving downstream along the value chain. Both uncertainty and licensee fragmentation increase licensing transaction costs, effects that are positively moderated by fragmentation on the licensor side: the higher the number of individual licensors, the larger the absolute increase in transaction costs if licensee numbers increase. Licensing transaction costs, in turn, reduce MFT efficiency.

Licensing downstream also implies that the licensee landscape comprises higher product heterogeneity and product complexity, with countervailing effects on the possibility of price differentiation. In turn, price differentiation has a potentially positive effect on MFT efficiency, provided it leads to an output expansion not outweighed by increased transaction costs.

6. Policy recommendations

The empirical study and discussion suggest a number of policy recommendations. They could be brought to bear on the SEP licensing process through guidelines such as those published by the European Commission (2017) "*Setting out the EU approach to Standard Essential Patents*." I summarize these in Table 1 and discuss in the following.

6.1. Introduce new principles for IoT SEP licensing

The SEPs Expert Group (2021, p. 182) formulates three principles for licensing IoT SEPs in the value chain: "*(i) licensing at a single level in a value chain; (ii) a uniform FRAND royalty irrespective of level of licensing; and (iii) ability to pass down the value chain a FRAND royalty*." The Group furthermore makes detailed proposals (pp. 180–186) addressing the licensing process.

What is absent is an explicit endorsement of the European Commission (2017, p. 7)'s goal that "*[t]ransaction costs relating to the negotiation of a licence should be kept to the minimum necessary.*" In fact, some of the proposals ignore the device makers' and in particular SMEs' technology-related limitations as licensees. For instance, Proposals 51 and 53 require an SEP holder to provide the implementer with high level claim charts, and others would even increase transaction costs for device makers (e.g., Proposal 54 regarding an implementer's duty, under certain conditions, to "*proactively seek licences, prior to commercializing standard-compliant products*").

Furthermore, the goal to promote innovation and entrepreneurship by downstream firms in the IoT is not mentioned in the SEPs Expert Group's (2021) report. Any concerns about innovation refer to upstream innovation (pp. 22, 191), not device-level innovation—despite the abundant innovation possibilities in the IoT, provided SEP licensing is efficient.

My empirical findings show how the choice of licensing level affects transaction costs, downstream innovation, and entrepreneurship, thus suggesting two additional SEP licensing principles:

(iv) Licensing at a value chain level where transaction costs are minimal.

(v) Licensing in a way that promotes downstream innovation and entrepreneurship.

6.2. Explore possibilities of upstream price differentiation

Interviewees from SEP licensors found price differentiation indispensable. They claimed that it must be tied to the type of final device, which they considered impossible when licensing at the chipset level:

"[…] it's difficult or practically impossible to know, at the chipset level, what use that particular chipset will be put to, so we don't know how much to charge because we don't know what it is going to be used for." [L2].

However, baseband processors and even more so NADs implementing the same standard differ in their standard implementation performance.[18] Arguably, a standard's contributory value to a device is larger the better the standard implementation performs. Thus, performance might be a suitable basis for price differentiation that is not encumbered by the complexity of the downstream product. Consistent with these considerations, the SEPs Expert Group (2021, Section 6.2.4) proposes that "*SEP holders could license their SEPs at chipmaker level and charge different royalties for the different chips depending on the connectivity rates of these chips*."[19] For licensing at the NAD level, a forgery-proof version of the International Mobile Equipment Identity (IMEI) number could possibly be used to check if a given device is licensed. I recommend that policy makers and SDOs commission technical experts to explore the feasibility of upstream price differentiation in SEP licenses, at the chipset or module level, based on the standard implementation performance, and an improved IMEI for monitoring.

Table 1
Policy recommendations.

Recommendation	Implementation
Make "minimizing transaction costs" an SEP licensing principle	National governments; European Commission
Make facilitating downstream innovation an SEP licensing principle	National governments; European Commission
Commission a study on the feasibility of upstream price differentiation based on baseband chip or NAD performance	National governments; European Commission; SDOs
Commission a study on where SEPs are actually implemented in the value chain	National governments; European Commission; SDOs
Determine aggregate returns on standard development	National governments; European Commission

As discussed in Section 2.3, there is wide disagreement regarding the proportion of all SEPs that are realized in the baseband processor. Given the high relevance of this issue, the current lack of information is surprising. I recommend that policy makers and SDOs commission relevant technical studies.

6.3. Determine aggregate returns on standard development

SEP owners must receive an appropriate return on their investments in technology development and the risks, both for reasons of fairness and to maintain innovation incentives for generating future standards. On the other hand, they should not be over-rewarded.

In this context, we need to consider that 4G and 5G standards were and are developed through collaboration between all interested parties, without the "*competitive environment before the industry has been locked into the standard (ex ante)*" to which the European Commission's Guidelines on the Applicability of Article 101 TFEU refer in Article 289 when discussing methods to determine FRAND royalties. Such collaboration is typically accepted by antitrust authorities in the interest of efficiency, but under the assumption of competition in the downstream market. However, this competition is absent in the market for SEP licenses: sellers do not compete since, by definition, SEPs are complements, not substitutes. Thus, all relevant industry players collaborate without competing downstream—not a comfortable situation from an antitrust perspective. These considerations raise the question, what aggregate overall returns on standard development contributions are appropriate.[20]

Licensors prefer bifurcated licensing since it allows them to achieve higher royalty income; a Qualcomm executive referred to device-level licensing as "*humongously more lucrative*" than upstream licensing.[21] An analysis of aggregate returns on standard development could help

[18] The company u-blox, for instance, offers cellular modules implementing LTE-M, LTE Cat 1, and LTE Cat 4, with data rates in the kb/s range, 10 Mb/s, and 150 Mb/s, respectively (https://www.u-blox.com/sites/default/files/CEL-product_Overview_%28UBX-14001802%29.pdf). Telit offers similar differentiated products (https://www.telit.com/m2m-iot-products/iot-module-selector/).

[19] The proposal received mixed support, expressed as 3 out of 5 stars.

[20] Such a cost-based approach to FRAND valuation (Friedl and Ann, 2018) is in line with the Guidelines on the Applicability of Article 101 TFEU, Article 289. While the Article dismisses cost-based methods, it does so on purely practical grounds, "*because of the difficulty in assessing the costs attributable to the development of a particular patent or groups of patents.*" A calculation of *aggregate* costs and returns should, however, be possible and provide a valuable anchor for assessing the conformity of royalties to FRAND rules.

[21] A statement by a Qualcomm executive cited in the Court's Findings of Fact in the FTC's suit against Qualcomm (2019): "*But having – having to choose between one or the other then you're right, obviously the handset is humongously more … lucrative for a bunch of – a bunch of reasons.*" [D8]

show whether the actual profitability is in line with FRAND principles. I recommend that policymakers commission such an analysis.

7. Discussion and conclusions

There is intensive debate on where in the value chain standard-essential patents on standards such as LTE and Wi-Fi should be licensed, and the IoT has added new momentum. This study provides an empirical basis to the debate by exploring startup and SME IoT device makers' position as SEP licensees. Compared to upstream licensing, I find that device-level licensing creates higher transaction costs within the dyad of licensee and licensor, magnified by a larger number of licensees. For startups and SMEs, these challenges are compounded by resource constraints and pressure from licensors and stakeholders. The increased transaction costs of downstream licensing reduce MFT efficiency. The impact of licensing level on MFT efficiency through price differentiation possibilities is ambiguous.

Innovation and entrepreneurship in the IoT will probably be negatively affected by device-level SEP licensing once firms become aware of the risks and uncertainties to which the implementation of communication modules exposes them. So far, most seemed unaware of these issues. Facing the uncertainties and transaction costs identified in this study, especially SMEs and startups may delay or even shelve the adoption of novel IoT technologies; their innovation process may be slowed down; unexpected royalty demands may make a firm's business model unsustainable; investors may be reluctant to provide financing; and potential entrepreneurs may refrain from establishing an IoT device firm in the first place. IoT device makers may also avoid SEP licensing issues by using e.g. a USB LTE stick instead of an integrated component, thus accepting an inferior design that may impair the device's functionality, reliability, or even security. In contrast, the potential to acquire fully licensed IoT components should accelerate the innovation process by making the costs of such components and the associated licenses predictable, creating legal certainty, and allowing the implementation of IoT technology at low transaction costs. I derive policy recommendations that should promote innovation and entrepreneurship in the IoT.

Arguably the mechanisms observed in the IoT context and the consequences of bifurcated licensing hold more generally, and I develop a model of MFT efficiency that incorporates licensing level.

This study contributes to research on MFTs. The efficiency of MFTs is known to depend on various factors, including the possibilities to appropriate value (Arrow, 1962; Teece, 1986), the strength and scope of property rights (Teece, 1981; Gans and Stern, 2003), uncertainty (Rosenberg, 1996; Arora and Gambardella, 2010), and information asymmetry (Akerlof, 1970; Zeckhauser, 1996). My results show that licensing level is an additional determinant. In most industries, integrated licensing is the norm; patents are licensed at the value chain level where the corresponding inventions are first implemented. This is reflected, for instance, in the U.S. Uniform Commercial Code, which specifies that "*[u]nless otherwise agreed a seller […] warrants that the goods shall be delivered free of the rightful claim of any third person by way of infringement or the like […].*"[22] A recent exception is the licensing of SEPs on communication technologies and other ICT standards (SEPs Expert Group, 2021, pp. 77–79). Licensing level thus needs to be taken into account when studying MFTs.

Furthermore, this study contributes to research on designing patent systems. Widely discussed design choices are patent length (e.g., Gilbert and Shapiro, 1990), scope (e.g., Merges and Nelson, 1990; Lerner, 1994), and costs (e.g., de Rassenfosse and van Pottelsberghe de la Potterie, 2013). The licensing level, and more generally the value chain level at which patents can be enforced, have so far not been debated; the discussion reviewed in Section 2.3 is largely about interpreting existing law and ETSI policies. My study draws attention to licensing level as a potential design parameter in the patent system.

The study contributes to practice by providing empirical evidence as well as theoretically explaining the pros and cons of the various licensing levels for IoT SEPs. It may inspire SEP holders to rethink their mostly critical stance toward upstream licensing. It also points out the need to collect further data, for example about the level where SEPs are first implemented. These insights can help policymakers such as the European Commission, but also patent owners, to make an informed choice of licensing approach for IoT SEPs.

This study has limitations. As a qualitative study based on purposeful sampling, it enables us to uncover mechanisms but does not provide a quantitative picture. Specifically, it is difficult to assess how many IoT device makers have been approached by prospective licensors and by which type of licensors, what share actually took out a license, and to what extent IoT communication modules are available with SEP licenses included. A large-scale quantitative study should address these questions. In addition, there may be a selection bias in my sample since device makers that did take out a license are usually bound by an NDA and presumably reluctant to be interviewed. A large-scale study could try to overcome this limitation using appropriate selection models.

The IoT offers countless opportunities to innovators, entrepreneurs, and society. Ensuring an efficient market for technology around the IoT will help realize these opportunities.

CRediT authorship contribution statement

As the sole author of this paper I performed all steps of the research process myself.

Declaration of competing interest

Joachim Henkel reports paid expert testimony, non-public, in various court cases related to SEP infringement. In one case the involvement was public, where the author was retained by Apple in litigation with Optis. All cases are entirely unrelated to the submitted paper; there is no conflict of interest.

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[22] U.S. Uniform Commercial Code (§ 2-312 (3)). Similar provisions exist in the UN Convention on Contracts for the International Sale of Goods (CISG), Art. 42, and national laws ("*warranty of title*").

Appendix A

A.1. Demographics of interviewed firms (startups and established implementers)

Industry:	Automotive (1), diversified (1), industry automation (3), medical technology (1), predictive maintenance (1), routers (1), security technology (1), smart city (1), smart home (4), specialized smartphones (1), wearables (1)
Country:	Croatia (1), Denmark (2), France (2), Germany (7), Switzerland (1), Turkey (1), U.K. (1), U.S. (1)
Age:	Startups: founded after 2010 Established implementers: founded before 1970
Employees:	Startups: 2 to 400 Established implementers: >10,000
Wireless standards used:	2G (3), 3G (2), 4G (8), interested in 4G (1), interested in 5G (3), Bluetooth (6), LoRaWAN (1), ultra-wideband (1), interested in UWB (1), Wi-Fi (10), ZigBee (1)

A.2. List of interviews

Label	Date	Duration	# Interviewees
S01	12/05/2020	00:48	1
S02	16/06/2020	00:33	1
S03	19/05/2020	01:08	1
S04	15/04/2020	00:18	1
S05	08/06/2020	01:16	1
S06	17/07/2020	00:39	1
S07	16/11/2021	00:36	1
S08	26/11/2021	00:30	1
S09	19/11/2021	00:38	1
S10	18/11/2021	00:43	1
S11	24/11/2021	01:04	1
S12	19/11/2021	00:44	1
P1	02/12/2021	00:52	1
L1	03/07/2020	01:10	2
L2	06/08/2020	01:21	4
L3	13/09/2021	00:49	2
L4	06/10/2021	01:31	1
L5	04/10/2021	00:58	2
M1	19/08/2020	01:16	1
E1	18/06/2020	01:05	1
E2	29/07/2020	01:31	3
E3	19/02/2021	00:28	1

A.3. Documents analyzed

Label	Title	Author	Date	Available at
D1	Complaint for breach of FRAND commitments and violations of antitrust and unfair competition laws, Case No. 19-cv-2520	U.S. District Court Northern District of California	10/05/2019	https://de.scribd.com/document/471118863/Continental-v-Avanci-Complaint-pdf
D2	Findings of fact and conclusions of law, Case No. 17-CV-00220-LHK	U.S. District Court Northern District of California, San Jose Division	21/05/2019	https://de.scribd.com/document/411066615/19-05-21-FTC-v-Qualcomm-Judicial-Findings
D3	Brief of Association of Global Automakers and Alliance of Automobile Manufacturers as amici curiae supporting appellee	Association of Global Automakers, Alliance of Automobile Manufacturers	29/11/2019	https://de.scribd.com/document/437590521/19-11-29-AGA-and-AAM-automotive-acb-pdf#from_embed
D4	Brief of amici curiae Continental Automotive Systems, Inc. and Denso corporation in support of appellee Federal Trade Commission	Continental, Denso	29/11/2019	https://de.scribd.com/document/437590620/19-11-29-Continental-and-Denso-Acb#from_embed
D5	District court holds that Qualcomm patent licensing and other conduct violates the Sherman Act	Sullivan & Cromwell LLP	24/05/2019	https://www.sullcrom.com/files/upload/SC-Publication-District-Court-Holds-That-Qualcomm-Patent-Licensing-and-Other-Conduct-Violates-the-Sherman-Act.pdf
D6	Huawei reassures licensing commitment regarding certain IEEE standards	Huawei	30/05/2019	https://www.huawei.com/us/declarations/huawei-ieee-letter-re-802-11ax-et-al
D7	Setback for Daimler in connected cars dispute against Avanci pool members	Mathieu Klos, JUVE Patent	11/09/2020	https://www.juve-patent.com/news-and-stories/cases/setback-for-daimler-in-connected-cars-dispute-against-avanci-pool-members/
D8	After six years of attacks, Qualcomm finally sees stability return to patent licensing	Mike Freeman	23/09/2020	https://techxplore.com/news/2020-09-years-qualcomm-stability-patent.html

A.4. Interview guideline

Information collected from databases and the Internet: Firm name, founding year, business, other

- Introduction: The researcher, the study, permission for recording.
- Product offering:
  - o Do your firm's products or services make use of mobile IoT technologies?
  - o Please describe your firm's product or service offering in detail.
  - o Does the firm build and sell (or lease, or use) its own devices?
  - o Unit numbers per year? Revenues?
- Communication technologies:
  - o Which wireless communication technologies does your firm's offering use?
  - o What IoT components is your firm sourcing?
    - ▪ NADs, baseband processors?
    - ▪ From which manufacturer, over which distributor?
- Patent licensing:
  - o What do you know about patent licensing for the modules that you are sourcing?
  - o Do you have a license for the SEPs in the modules? If so, in what way?
    - ▪ Bought it fully licensed?
    - ▪ Own licensing contract with licensor?
  - o Have you been contacted by patent holders regarding royalty payments?
    - ▪ Yes:
      - Please describe the process in detail.
      - What kind of licensor: practicing firm, patent assertion entity, patent pool?
      - Were you asked to sign an NDA?
      - What were the implications?
    - ▪ No:
      - How would you react if you were contacted?
      - What do you think would be the implications?
  - o If in the future your firm could not buy fully licensed modules, how would you proceed?
  - o For your firm, what would be the best organization of SEP licensing?
- Do you see any additional points that are relevant in this context?

A.5. Data table

	Size (# people, 2021)	Demand by SEP holders?	Uncertainty	Resource scarcity	Licensors	Stakeholders	Reactions
Dimension comprises…			Subjective uncertainty about unknown facts; objective uncertainty about future events; information asymmetries vis-à-vis prospective licensor.	Constraints regarding internal resources and relationship-related resources.	Pressure exerted by prospective licensors; the role of patent assertion entities; the functioning of the licensing process.	Influence of investors, customers, suppliers, and competitors.	Reactions, actual or hypothetical, to SEP licensing demands; consequences for IoT device industry.
S1	> 50	yes	Impossible to find out if a patent is infringed or invalid.	Insufficient personnel to perform patent checks. High costs of legal advice and of patent assessment.	Excessive royalty demands. Patent assertion entities sent list of patents without much additional information.	Little support from module supplier.	Did not take out a license. Switched to cheapest supplier, since premium supplier did not provide support. Young firms often panic when threatened with legal action.
S5	< 50	yes	No knowledge if they infringed on any patents. Not clear how many other licensing demands might come. Would not know if they end up paying several times for the same patents.	Could not afford the additional cost of checking patents.	SEP holder just sent list of all its patents. SEP holder asked for signing an NDA. Firm perceives the approach of SEP holders as “unfair”, “bullying.” Perceives the process as lacking clear rules; “anarchy”, “dysfunctional and not sustainable.”	Customers demand indemnification for patent infringement. No information from module maker, distributor regarding licensing situation. Problematic for investors: uncertain royalty demands, also royalties above a certain units threshold. With license: competitive	Did not take out a license. Took position that prospective licensor should address module or chip maker. Ex ante, they would have made a different technology choice, i.e., picked a protocol not encumbered by SEP licensing.

(*continued on next page*)

(*continued*)

	Size (# people, 2021)	Demand by SEP holders?	Uncertainty	Resource scarcity	Licensors	Stakeholders	Reactions
						disadvantage vis-à-vis unlicensed competitors.	
S9	< 50	yes	No knowledge about number of patents on own device. Rules of licensing not known.	Licensing difficult for small firms; "big guy game".	"Very pushy approach" by licensor. High industry-level transaction costs with device-level licensing.	Suppliers also know very little about SEP licensing. Consistent patent licensing not ensured.	Did not take out a license. Device-level licensing would "stop innovation from small companies".
S11	> 50	yes	Uncertainty about which patents are infringed.	No time, no budget for reviewing patents. Court arbitration, legal proceedings not affordable. May have to pay customers' legal fees. No negotiating power. Lobbying: Politics is more about protecting big firms.	Strict NDA, prohibiting communication with suppliers, customers, but demanding a lot of information disclosure. Licensors provided little information, just a list of patents. Licensor sent letters also to the firm's reseller and customers. Patent assertion entity threatened seizure of products. Small companies afraid to speak up; some received "threats during negotiation".	Customers ask for liability, indemnity in case of patent infringement. Unfair competition because competitors might not pay royalties, or lower royalties.	In some cases, took out a license, in others not.
S2	> 50	no	Unknown how many potential licensors there are. No idea if module supplier would commit patent infringement.				Would switch to fully licensed supplier [apparently assuming that this would be possible]
S3	> 50	no	No knowledge re which patents infringed. Does not know who has the burden of proof re infringement. No knowledge about FRAND rules and royalties.	Considers one or two licensors doable, but not many more.	NDA might make it impossible to find out which patents are infringed. No understanding why supplier can sell unlicensed modules. Patent holders might start enforcing other component patents on device level.		Carry on in this "gray area," stating that they think that they procured fully licensed modules.
S4	> 50	no	No financial control due to potential future royalty demands. Cannot fully invest in a tech-nology without considering the risk of later royalty demands.	As a small-volume buyer, no negotiating power.			Take the risk of patent infringement. Considers that it hinders innovation if a firm has to take care of licensing component patents.
S6	< 50	no	Impossible to know about relevant SEPs ex ante. Often uncertain how far they will go with a specific technology.	Impossible to deal with so many patent holders.		Unequal licensing among competing device makers.	Approach to licensing: Wait and see what happens.
S7	< 50	no	No knowledge regarding licensing of module-level patents. Entire topic of SEP licensing was new to the firm.		Wonders what happens if the entire component industry changes to device-level licensing. High industry-level transaction costs; "hundreds" of IoT firms in interviewee's home city alone.		
S8	< 50	no	Do not know what to do if approached for SEP license.				Would switch to fully licensed supplier [apparently assuming that this would be possible]. Might replace LTE module with (fully licensed) LTE USB stick.

(*continued on next page*)

(*continued*)

	Size (# people, 2021)	Demand by SEP holders?	Uncertainty	Resource scarcity	Licensors	Stakeholders	Reactions
S10	< 50	no	No possibility to evaluate a licensor's request "on any kind of merit." Cost uncertainty of legal action.		Finds it inconceivable that after paying for a Wi-Fi chip the firm could still be approached by SEP holders for taking a license.		Options: Pay the licensor; or ignore the demand, risk legal action, and pay a lawyer. If an SME cannot buy a fully licensed module it "would really strangle the IoT innovation."
S12	< 50	no	Unclear how to work out which patents are credible.	For a small organization, no way to fight and take on a large organization.		Difficult to communicate to investors that there might be liabilities from patent infringement. Might come out in due diligence.	
P1	< 50	no	No knowledge about potential SEP licensing issues when acquiring module. No knowledge about possible number of licensing demands.	No funds to negotiate. No margin to absorb even small additional costs from royalties.			Having to pay additional fees after manufacturing would be "devastating"; we "would close the company."

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