Component vs. Product Competition and the Licensing Level of Standard Essential Patents

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WORKING PAPER

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JEL Code: L24, L41, L43, L62, K21, L12, L13

Keywords

Standard Essential Patents, Licensing Level, Automotive Industry, SEP regulation, TTBER

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27 April 2026

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1 Introduction

In recent years, technical innovations in mobile connectivity, such as the development of 5G, have made it possible to connect multiple devices with different functionalities, such as mobiles, vehicles, traffic-lights and home-appliances. Together with technical developments in computer power and algorythm design, they have made it possible for interconnection among these devices to take place without human intervention. In order for such an "Internet of Things" to be implemented, manufacturing industries need to implement cellular wireless connectivity standards, such as 5G.

Standards are usually developed by private firms participating in the work of Standard Setting Organizations (SSOs).[1] Also called Standard Development Organizations (SDOs), these are private organizations whose main goals are to create standards that meet market needs and to promote the

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[1]Borghetti, J. S., Nikolic, I., & Petit, N. FRAND licensing levels under EU law, at 2.

implementation of these standards as widely as possible.[2] There are several SSOs around the world, such as the European Telecommunications Standard Institute (ETSI) that develops standards for mobile communication.

Standardized technologies such as 5G are, and in most likelyhood will be, covered by an increasing number of Standard Essential Patents (SEPs).[3].These are "technically necessary to implement a standard."[4]. As a consequence companies in the manufacturing industry need to be licensed in order to implement these communication technologies in the devices they produce.

Most of these SEPs for wireless technology are owned by firms that operate in the communication industry and did not traditionally participate in the value chain of devices such as cars or home appliances. At the same time, manufacturers of devices that will need to be connected in the "Internet of Things" did not usually participate in the works of the SSOs. This is very different from the past, when mobile phone manufacturers, needing to implement SEPs related to communication technologies, often had participated in the works of SSOs and held relevant SEPs.

Hence, when it comes to the implementation of SEPs for the Internet of Things, there is likely to be a strong separation between SEP holders and SEP implementors and potentially a divergence of interests.

Partly as a result of this separation, in recent years, a discussion arose regarding the proper level of the value chain at which licensors have to license for the implementation of their patents: on the one hand, patent holders of wireless technologies tend to prefer to license to final producers, as it had been common practice in the mobile communication industry for years; on the other hand, the first manufacturing industries to implement these technologies, such as the automotive industry, claim that patent holders have to license at the level at which these technologies are implemented first, i.e. at the component suppliers' level, as it has always been the case for previous SEP in the industry. This different view on the proper licensing level has already lead to many litigations involving SEPs holders and firms operating in the automotive industry.

One of the main issues in the litigations is related to the obligations related to a patent being part of a standard. In order to promote the implementation of standards, SSOs adopt policies aimed at protecting not only SEP holders' rights, but also implementers interests: SSOs require their members to give licenses on fair, reasonable and non-discriminatory (FRAND) terms.[5]

However, FRAND royalties and terms are not established by law because the royalty value depends on several factors, such as technology that the SEP covers, the standard to which such SEP is purportedly essential or the existence of alternative technologies pre-standardisation.[6] This implies several litigations between high tech companies: they cover fundamental issues, such the optimal level of FRAND royalties, the optimal royalty base for FRAND royalties or the concept of non-discrimination.[7] One of the most interesting issues linked with FRAND royalty is the debate on licensing level.

In fact, one of the litigated issues is whether FRAND commitments impose SEP owners to license every implementor which requests the licence or allow SEP owners to license their SEPs at the level of the production chain they prefer.

This debate has been particularly important in the automotive industry. It has already brought to two high-level court cases, namely *Daimler v. Nokia* in the EU and *Continental v. Avanci* in the US. While patent holders want to license exclusively to car manufacturers, component suppliers and

[2]Baron, J., et al. Group of Experts on Licensing and Valuation of Standard Essential Patents, at 23.

[3]According to Geradin and Katsifis, "Standard Essential Patents are patents that are essential to a standard in that an implementer cannot comply with the standard without infringing on the patent." Geradin, D. & Katsifis, D. End-product- vs Component-level Licensing of Standard Essential Patents in the Internet of Things Context, at 2.

[4]Borghetti, J. S., Nikolic, I., & Petit, N. FRAND licensing levels under EU law, at 2.

[5]Borghetti, J. S., Nikolic, I., & Petit, N. FRAND licensing levels under EU law, at 3.

[6]Grasso, R. Standard Essential Patents: Royalty Determination in the Supply Chain, at 3-4.

[7]Borghetti, J. S., Nikolic, I., & Petit, N. FRAND licensing levels under EU law, at 3.

car manufacturers want patent holders to license at the level at the component suppliers, as it has been the case for previous SEP in the automotive industry so far. Interestingly, both the automotive industry and SEP holders claim that their position on licensing level determination is crucial for their businesses being successful and, hence, for the implementation of cellular wireless connection technologies in the automotive industry.

The outcome of these litigations and, more generally, of the debate on the SEPs licensing level in the value chain is likely to be crucial for the implementation of cellular connectivity standards in IoT industries.

In addition, shedding light on the economic relevance of the debate may be of guidance for an evaluation of the now (momentarily?) withdrawn Standard Essential Patents Regulation and the recently revised Technology Transfer Block Exemption Regulation (TTBER)in the EU. While the SEP Regulation proposal did not give indications on the SEP licensing level, according to the Technology Transfer Guidelines accompanying the TTBER, a patent pool of SEPs should be ready to license, upon request, to *all potential licensees* on FRAND terms if it wants to benefit from the safe-harbour against a violation of antitrust law provided by the TTBER itself.[8].

This paper contributes to the debate by analyzing to what extent, under standard microeconomic assumptions on the functioning of the industry, the licensing level of SEPs in an industry changes market outcomes and, if it does, whether the impact on market outcomes depends on the degree of competition at the different levels of the value chain. We show that, contrary to common expectations, in our model the level of the value chain at which the licensee operates does not affect the profits of the firms, the level of the royalty and the price of the final product, irrespective of the degree of competition in the component and product markets. We then highlight that the crucial element in the model is the assumption that one and only one license is needed per unit of the final product. Our paper thus suggests that regulatory interventions should address the issue of the required number of licences rather than issue of the level of licensing.

The paper proceeds as follows. In Section 2 we give some more details on the licensing level debate in the automotive industry. In Section 3 we review the existing economic literature on the licensing level for SEPs. In Section 4 we build a simple model of the value chain of an industry in which component suppliers sell their products to manufacturers and the licensor chooses the level of the value chain at which it licenses. We then analyze whether the licensing level chosen by the licensor affects profits of the firms in different competitive environment of both the component and the product markets. In Section 5 we highlight what our neturality result depends upon and discuss the implications of our findings for the debate on the licensing level.

2 The licensing level debate in the automotive industry

The development of autonomous vehicles is one of the most ambitious goals set by the automotive industry for the next decade and is giving rise to several expectations. One of them is an increase in vehicles' safety.[9] In fact it is expected that this type of vehicles will reduce traffic accidents, which cause about 1.3 million deaths and about 20-50 million people non-fatal injuries every year.[10] Another important factor that pushes the automotive industry to develop self-driving cars is that this type of cars are expected to reduce traffic jams by allowing vehicle to select the best itinerary for the passenger according to the traffic situation. Reducing traffic congestion will reduce pollution, since traffic is responsible for about a third of vehicle carbon emission in the US.[11] Finally, self-driving cars

[8]Botta, M. *et al.* (2024) Support study for the evaluation of the Technology Transfer Block Exemption Regulation, at 97-99.

[9]Martinez, I. The 5G Car, at 51.

[10]World Health Organization. Road traffic injuries.

[11]Umar Hamid, et al., Current Collision Mitigation Technologies for Advanced Driver Assistance System – A Survey, at 85.

are expected to benefit drivers by endowing them with additional free time (inside the car). All in all, autonomous vehicles are expected to improve driving experience by allowing passengers to enjoy the flexibility of traveling by car without being forced to drive and in a safer and more efficient way.

In order to develop self-driving cars, the automotive industry needs to develop a vehicle able to connect with its current environment.[12]. Many thus call a self-driving car a “connected car”: a vehicle that does not only connect to other vehicle (V2V) but also to the infrastructure and the broader network, thus featuring the so called “vehicle-to-everything” communication (V2X), [13]. One should thus consider the network of ”connected cars” as a part of the Internet of Things. What many studies call the “Internet of Vehicles” (IoV) allows vehicles to share sensory data, risk data or environmental perception data between them.[14]

A crucial role for the development of ”connected cars” is expectd to be played by cellular wireless connectivity technologies, in particular by 4th generation (4G), 5th generation (5G) and further future generations.[15] These standardized technologies are covered by an increasing number of standard essential patents (SEPs).[16] In the recent years the number of declared patents that mention a vehicular application increased: among all different generations of wireless communication technologies standards, the number of standard-essential patents (SEPs) which may be implemented in vehicles is particularly high for 5G technology.[17]

Smooth licensing of SEPs is thus necessary for the development of self-driving cars.

2.1 The automotive industry’s vs the mobile communication device supply chain

In order to understand the debate regarding the appropriate level of licensing of SEPs in the value chain, one first needs to realize that the automotive industry is composed of thousands of firms that operate at different levels of the value chain. The car manufactures are the downstream producers of the value chain. In practice, a car is composed of more than 30.000 components[18]).

The automotive industry’s supply chain is usually described as consisting of three levels of suppliers. Tier 3 suppliers are the upstream producers of the automotive industry: they provide raw or close-to-raw materials to automotive industry, such as plastic or metal. Tier 2 suppliers are then the component manufacturers that transform the raw materials obtained by Tier 3 suppliers in components for the vehicle, such as windows, radio units or handles. Finally, Tier 1 suppliers provide to car manufacturers assembled parts, like door systems or infotainment consoles. The reason for this segmentation of the supply chain is that the production of a single component requires high technological knowledge by the component makers and components that are assembled in a car are often very different among each other.

Car manufacturers traditionally request Tier 1 suppliers to guarantee, by means of indemnification agreements, that componenents they assemble in vehicles do not infringe patent law .[19]

[12] Martinez, I. The 5G Car, at 50.

[13] Heiden, B. The Value of Connectivity in the Automotive Sector–A First Look., at 6.

[14] Hamid, U. Z. A., et al. Internet of vehicle (IoV) applications in expediting the implementation of smart highway of autonomous vehicle: A survey, at 141.

[15] Pohlmann, T. The Role of Standard-Essential Patents for the Auto Industry.

[16] Syrett, T. & Pous, N. INSIGHT: The Developing Landscape of Internet of Things Standards for Cars, at 1.

[17] Pohlmann, T. The Role of Standard-Essential Patents for the Auto Industry.

[18] Geradin, D., & Katsifis, D. End-product-vs Component-level Licensing of Standard Essential Patents in the Internet of Things Context, at 10.

[19] Continental’s Complaint, *Continental v Avanci*, at 26.

Therefore, traditionally, car manufacturers rely on a system where hundreds of components suppliers procure licensed parts, combined with a system of patent-indemnity that car manufacturers use to protect themselves from patent infringements of component suppliers.

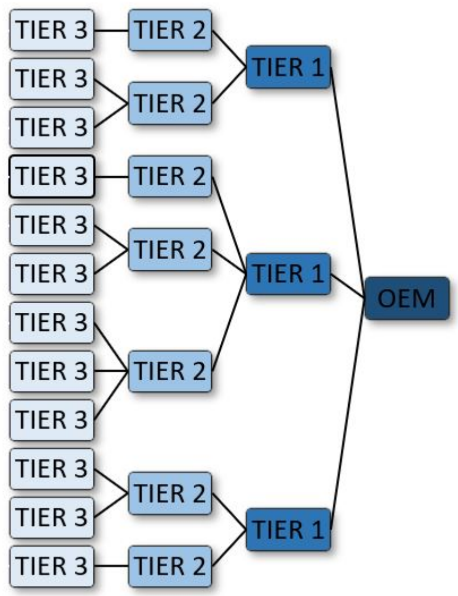

Figure 1: Automotive industry's supply chain.

Turning to the industry for mobile communication devices, such as cellular, smartphones or tablets, there are many similarities but also some important differences. As in the automotive industry, also the smartphone and the tablet's industry is composed of thousands of firms that operate at different levels of the value chain. The device manufactures are again the downstream producers of a complex value chain. However, a smartphone, or a tablet, is made of fewer components, "only" up to 2000. Cellular phones had even fewer components.

Also the mobile communication devices supply chain is usually described nowadays as consisting of three levels of suppliers. Tier 3 suppliers provide raw or close-to-raw materials. Tier 2 suppliers are then the component manufacturers that transform the raw materials obtained by Tier 3 suppliers in components for the smartphone, such as chips or displays. Tier 1 suppliers provide to smartphone manufacturers assembled parts, like processors, display modules and camera modules. Once again, the rationale for this segmentation of the supply chain is that the production of a single component requires high technological knowledge which is also highly specialized.

However, traditionally, i.e. since the times of cellular phones, it has always been the manufacturers of the final communication device that get the licenses for the communication technology. Importantly, many of the main manufacturers were also present in the work of the SSOs.

2.2 Conflicting preferences on the licensing level

In line with the traditional practices in their respective manufacturing industry, holders of SEP for mobile connectivity, that often were manufacturers of mobile communication devices, want to license only to end product-manufacturers, while the automotive industry insists that licenses should be granted to component manufactures.

On the one hand, observing that the components level licensing approach was successful for automotive industry in the past decades, car manufacturers and component suppliers argue that this approach should be maintained also for essential patents for cellular wireless communication technologies.

In particular, according to component suppliers and automotive manufacturers, licensing component suppliers is more suitable to the automotive industry because it grants suppliers the possibility to fully design components without being afraid to infringe a large number of SEPs. Moreover, it guarantees car manufacturers that the components that they use in their cars are free of third-party rights.

The automotive industry also claims that component suppliers would be better positioned to negotiate licences with SEP holders because they have a better knowledge about these technologies. Hence, licensing car manufacturers might be inefficient because they would be unable to select proper patent useful for connected cars and to negotiate the royalty value of these SEPs. Also, according to the car industry, SEP holders seek to license car manufacturers in order to increase royalties, leaning on their lack of knowledge about cellular wireless communication technologies and their greater profit margins compared to component suppliers.[20] This may discourage the automotive industry to implement new cellular wireless communication technologies to cars, which, in turn, will have a negative impact on the development of the connected cars. Hence, licensing at component makers level will affect positively also SEP holders because it enhances the implementation of their patents in such an important sector as the automotive industry.

Component suppliers and car manufacturers finally claim that FRAND commitments require SEP owners to license every implementor which requests the licence, i.e. oblige SEP owners to license their SEPs at any level of the production chain at which there are requests (the "license-to-all" interpretation of FRAND).

On the other hand, observing that the practice of licensing at the level of the final product has been successful for the mobile communication industry so far, SEP holders argue that this approach should be maintained also for essential patents for cellular wireless communication technologies in the automotive industry.

According to SEP holders patent licensing practices played a crucial role in the development of the cellular communications technologies in the last two decades: licensing at end-product level simplified the licensing process for SEP holders and implementers and enabled the mobile communication industry to have an impressive technological development. Moreover, many companies entered in the market for cellular communications equipment that were not substantively involved in creating the foundation of communication technologies. Hence, SEP holders claim that licensing cellular wireless communication's SEPs at downstream production level may push the technological development in many IoT industries, even those which do not have a deep knowledge about these technologies.

SEP holders finally claim that FRAND commitments require them to grant access to the license to all final product manufacturers that request them (the "access-to-all" interpretation of FRAND).

2.3 From different preferences to litigations in court

The licensing level's disagreement in the automotive industry has not limited itself to the business community. There are several ongoing litigations between 2G/3G/4G SEP holders and automotive industry's firms in the US and in UE. The most discussed cases were *Continental v Avanci* and *Nokia v Daimler*. Both concerned the licensing approach of SEP holders (Avanci and Nokia espectively),

[20]Geradin, D., & Katsifis, D. End-product-vs Component-level Licensing of Standard Essential Patents in the Internet of Things Context, at 12-13.

which wanted to license only car manufacturers, but the actors that opposed to that were situated at different level of the supply chain: Continental is a Tier 1 supplier, while Daimler is a car manufacturer. In the next sub-sections we biefly discuss both cases.

2.3.1 *Continental v. Avanci*

In May 2019, Continental Automotive Systems sued several 2G, 3G and 4G SEPs holders and their licensing platform for the automotive industry, Avanci LLCm [21] , claiming that their SEPs licensing approach violated Sections 1 and 2 of the Sherman Act.

In particular, Continental claimed the need to be licensed directly by Avanci in order to be lawfully reassured over any possible patent infringement concerning its Telematics Control Units (TCUs) implementing 4G SEPs and it argued that Avanci's policy of licensing only car manufacturers violated the SEPs holders' FRAND commitments according to which a licensor shall grant SEPs licenses at FRAND terms and conditions to component suppliers as well.

Continental claimed also that Avanci preferred to license directly car manufacturers because of their inclination to accept more expensive royalties for their higher profit margins and that a similar approach harmed any component supplier due to the indemnity costs that OEMs demand to Tier 1 suppliers to purchase their TCUs - indemnities which eventually become the vehicles of royalties from downstream to upstream manufacturers. For these reasons Avanci's royalty of $15/vehicle for its SEPs covering 2G, 3G, 4G and E-Call, exceeding component suppliers' profit margins, had to be considered non-FRAND (Continental Automotive Systems v. Avanci, LLC 2019, 4).

As a reaction, Avanci and the other defendants moved to dismiss Continental's complaint for the lack of subject matter jurisdiction, for the lack of personal jurisdiction and for the failure to state a claim under Federal Rules of Civil Procedure 12(b)(1), 12(b)(2) and 12(b)(6).

Eventually, six months after the defendants motion to dismiss, the U.S. Department of Justice filed a Statement of Interest to the District Courtfor the Northern District of Texas in which it specifies that the Court should indeed dismiss Section 2 antitrust claims of Continental (Continental Automotive Systems v. Avanci, LLC 2020).

In September 2020, the District Court actually dismissed with prejudice Continental's antitrust claims under Sections 1 and 2 of the Sherman Act for its failure to plead antitrust standing, but it also dismissed Avanci's motion to dismiss for its lack of Article III standing and ripeness. Then, the Court also declined to exercise supplemental jurisdiction to the other declaratory judgment, breach of contract, promissory estoppel and unfair competition claims (Continental Automotive Systems v. Avanci, LLC 2020).

Ultimately, Continental appealed to the U.S. Court of Appeals for the Fifth Circuit and in February 2022 the Court of Appeals reversed the District Court decision and it remanded the case with the instruction to dismiss Continental's claims for the lack of Article III standing (Continental Automotive Systems v. Avanci, LLC 2022).

All in all, US courts appear to have taken a *laissez-faire* approach, thus inmplicitly favouring an "access-to-all" approach.

2.3.2 *Nokia v. Daimler*

Unlike *Nokia v. Daimler*, where the litigation involved a cellular wireless communication technologies' SEP holder and a car manufacturer, *Continental v. Avanci* concerned a patent pool licensor and a component supplier.

Pre-Litigation Nokia and Daimler engaged in protracted negotiations regarding licensing terms. Daimler contended that Nokia should grant licenses to Tier 1 suppliers, who would in turn ensure the sublicensing of SEPs to downstream entities such as Daimler. Nokia, however, maintained that Daimler, as the entity commercializing the end product, was the appropriate licensee.

[21] Avanci is a patent pool, as its aim was to offer one-stop shop option for SEPs to licensees; see Nikolic and Galli (2022) for a discussion of patent pools in 5G

Unable to reach an agreement, in 2019, Nokia initiated multiple lawsuits against Daimler in German regional courts, including Mannheim, Düsseldorf, and Munich. Nokia sought both declaratory judgments and injunctions to prohibit Daimler from selling vehicles incorporating Nokia's patented technologies without a valid license.

In 2020 the Mannheim Regional Court ruled in favor of Nokia, determining that Daimler had infringed Nokia's SEPs by integrating connectivity technologies without an appropriate licensing agreement. The court granted Nokia the right to seek an injunction against Daimler's infringing products, emphasizing the necessity of adhering to FRAND commitments.

In November 2020 Daimler then sought to escalate the dispute by requesting a referral to the European Court of Justice (ECJ), which was granted by the Düsseldorf Regional Court. Key questions included whether SEP holders are obligated to license patents to upstream suppliers and how FRAND terms should be interpreted in multi-tier supply chains.

Still in November 2020 the Munich Regional Court further reinforced Nokia's position by ruling that Daimler's utilization of Nokia's SEPs without a license constituted infringement. This judgment underscored the courts' inclination towards the "access-to-all" licensing model.

In the meantime Daimler's suppliers, notably Continental AG, filed complaints with the European Commission, alleging anti-competitive practices by Nokia for refusing to license SEPs at the component level. While the Commission launched an investigation, no definitive ruling was issued during the litigation.

Under mounting legal pressure, in June 2021 Daimler entered into a global licensing agreement with Nokia. The settlement granted Daimler the requisite rights to use Nokia's SEPs in exchange for royalties, bringing an end to all ongoing litigation. The settlement also prevented the ruling of the ECJ on the referred questions mentioned above.

The case emphasized the legal distinction between the "license-to-all" and "access-to-all" frameworks. By siding with Nokia, German courts appeared to endorse the latter, reinforcing the end-product manufacturer's responsibility to obtain SEP licenses.

3 The existing liteature on the licensing level of SEPs

The optimal licensing level of Standard Essential Patents is a debated issue also in the law and economics literature.

The main question studied has been whether the licensing level influences the behavior of firms in the value chain and thus affects the firms' profits, consumer surplus and social welfare.

Layne-Farrar et al.(2014) analyzed patent licensing in vertically disaggregated industries, where patent holders may license to upstream producers only, downstream producers only, or to both upstream and downstream producers. They study the welfare implications of the "first sale patent exhaustion" doctrine, that restricts a patent holder's ability to license multiple parties along a production chain. They also analyse whether a policy that restricts licensing to upstream manufacturers is desirable. They find that in a frictionless environment (where all information is public, firms are free to set prices for the goods they sell, and negotiation among firms jointly maximizes the benefits of the parties involved) how royalty rates are split along the production chain has no real consequence for social welfare. Even introducing some frictions they consider typically present in technology markets, they still find no economic justification for restrictions of the patent holders' ability to license multiple parties or to license to downstream producers only. They thus state a "royalty allocation neutrality principle".

According to Spulber (2020), the level of licensing for standard-essential patents should be determined by voluntary market negotiations between patent holders and implementers to maximize efficiency. Spulber opposes mandated "license to all" rules, arguing they create "patent run-around" inefficiencies, whereby implementers send SEP holders to negotiate with firms at other levels of the value chain as a means of diminishing or avoiding patent license royalties. and that flexible negotiations are pro-competitive and essential for 5G innovation. Consistently, Spulber (2021) argues that the level of licensing should be determined by private market negotiations between patent holders and technology implementers rather than regulatory or judicial intervention. He opposes mandatory ”license to all” (LTA) rules, contending they hinder innovation and create a ”patent run-around” that undermines the intellectual property ecosystem.

Also Langus and Lipatov (2022) study the question whether a SEP holder should be allowed to choose the level in the value chain at which to offer a license. They argue that the SEP holder, as the social planner, tends to choose the licensing level that, other things being equal, minimizes transaction costs. They also show that the SEP holder maximizes total output, which is often aligned with social welfare maximization by the planner. They argue that these two factors make it likely that a SEP holder chooses the efficient level of licensing. Hence, according to them to, there is no necessity to regulate the level of licensing.

Likewise, Llobet and Neven (2023) ask at which stage in the production chain patent licensing should take place. They show that a patent holder would be better off by licensing downstream, when the licensing revenue can depend on the downstream value of the product either directly or through the use of ad-valorem royalties. They also show that downstream licensing is also preferred by the patent holder when, instead, we assume that the downstream licensee is less informed about the validity of the patent. They find, that in most cases, downstream licensing increases allocative efficiency. However, they also find that it might reduce the manufacturer's incentives to invest and, thereby, decrease welfare. They finally characterize the circumstances under which a conflict arises between the stage at which patent holders prefer to license their technology and the stage at which it is optimal from a social standpoint that licensing takes place.

As in Layne-Farrar et al. 2014) we find no economic reasons to justify a restriction to SEP holders' licensing choices. Moreover, assuming that only one component per final product is needed, we extend the above cited work to many different market competition scenarios, using a conjectural variation approach. We eventually show in a very convenient and compact way that, in all cases, either profits and consumers' welfare are invariant with respect to the level of licensing.

Finally, the issue of the adequate level of licensing has also been investigated empirically. Baron et al. (2023) underlines the detrimental effects of SEP licensing issues on efficiency and welfare. Specifically, they present an empirical assessment of complexities and potential problems, such as multiple patents implementations, uncertainty regarding essentiality, validity and FRAND terms and eventually the impact of inefficient- and under-licensing. The study mainly relies on publicly available information such as court decisions, company announcements and mandatory disclosures. Henkel (2022) opts instead for a qualitative approach: by interviewing 30 individuals from 22 diverse IoT firms, mainly startups, the author highlights how device-level SEP licensing in the industry is hindered by uncertainty due to lack of information. It eventually concludes that ambiguity regarding infringement, patent validity, and the licensing process hampers the efficiency of the market for technology.

4 The model

4.1 The set-up

In this section, we build a stylized model of an industry, in which firms operate at two levels of a vertical supply chain, to investigate whether conflicting profit incentives may push SEP holders to license exclusively to product manufacturers and push component manufacturers and product manufactures to request that component manufacturers be licensed directly. In particular we aim to study if and to what extent divergent profit incentives depend on the different degrees of competition in the components market and in the product market.

At the upstream level of the industry our model features a duopoly of component manufacturers u_1 and u_2, producing and selling homogeneous components $q_{u_1}, q_{u_2} > 0$, with $Q_u \equiv q_{u_1} + q_{u_2}$, to a duopoly of product manufacturers d_1 and d_2 at a price $p_u > 0$.

At the downstream level product manufacturers operate as a duopoly d_1 and d_2, with constant

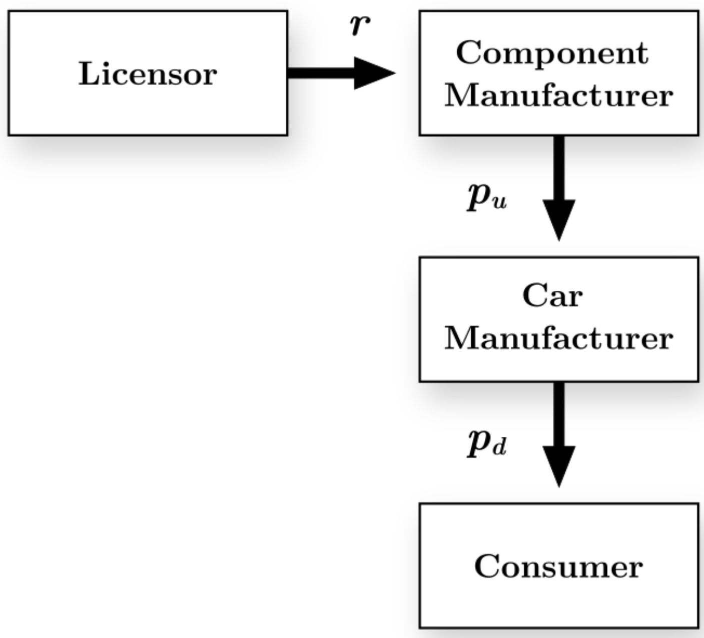

Figure 2: The structure of the model: case 1

returns to scale, assembling and selling homogeneous vehicles $q_{d_1}, q_{d_2} > 0$, with $Q_d \equiv q_{d_1} + q_{d_2}$, to consumers at a price $p_d > 0$.

Moreover, component makers sustain marginal costs $c_{u_1}, c_{u_2} > 0$ with $c_u = c_{u_1} = c_{u_2}$, while product manufacturers' marginal costs are $c_{d_1}, c_{d_2} > 0$ with $c_d = c_{d_1} = c_{d_2}$.

Finally, the model features a licensor l, operating as a monopolist, selling SEPs either to u_1 and u_2 (in case of upstream licensing) or to d_1 and d_2 (in case of downstream licensing) at a royalty $r > 0$, while bearing no marginal costs.

Hence, the model is a three stage model: in the first stage the licensor decides at which stage of the value chain to license its technology and sets its profit maximizing royalty rate; in the second stage component makers make their choices and in the third stage product manufacturers take their decisions. Figures 2 and 3 depict the structure of the model, when the licensor licensees the component manufacturers and the product manufacturers respectively.

For simplicity, we assume that each final product needs only one component that uses the licensed technology, thus $Q_d = Q_u = Q$ [22].

We also assume the inverse-demand function for final products by consumers is linear and it is $p_d = a - bQ_d$ [23].

Then, our analysis proceeds by backward induction: each player decides the price/royalty to be charged considering the best reply of the successive player. Hence, we start computing the best reply of the final product manufacturers, then we compute the best reply of the component suppliers and finally the optimal royalty charged by the licensor.

[22] That each final product needs only one such component is not crucial for our result. What is needed is that there is a fixed number of components and, more importantly, that, as a consequence, there is a fixed number of licenses needed per final product. We will discuss this further in the conclusions

[23] The linearity of the inverse-demand function does not affect the outcome of our model; indeed it can be proven that assuming a non-linear inverse-demand function, as for instance $p_d = \frac{a}{Q_d^2}$, does not change the results

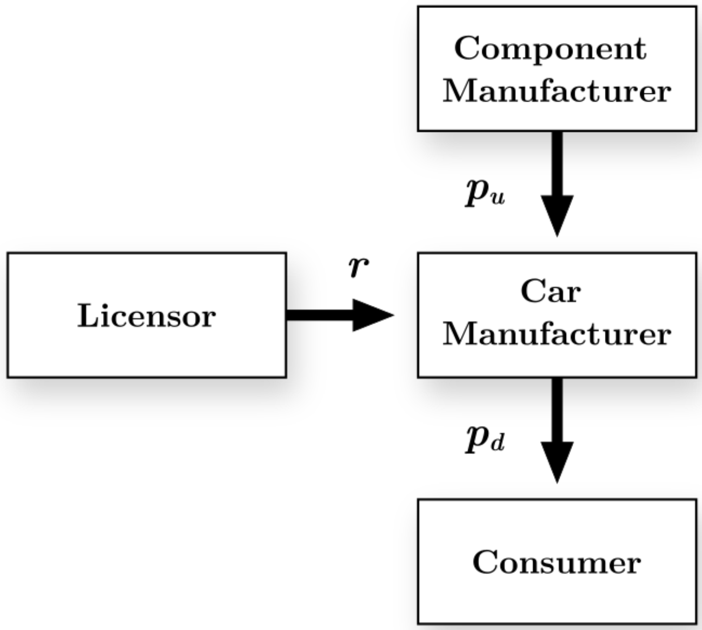

Figure 3: The structure of the model: case 2

In order to represent different competitive situations faced by component makers and car manufacturers in only one model [24] we adopt a *conjectural variations* approach as in Bresnahan (1981) and Perry(1982).[25].

We thus define, for $i, j \in \{1,2\}$ and $i \neq j$, $\frac{dq_{u_j}}{dq_{u_i}} = v_{u_i}$ and $\frac{dq_{d_j}}{dq_{d_i}} = v_{d_i}$. We assume $v_{u_1} = v_{u_2} = v_u$ and $v_{d_1} = v_{d_2} = v_d$, while v_u and v_d might differ. [26]

Our analysis proceeds as follows: we first study case 1, where the licensor licenses the car manufacturers, to eventually turn to case 2, where the licensor licenses the component makers. In both cases we calculate the profits of the firms involved to finally compare them and determine whether the licensing level matters.

4.2 Case 1 - The licensor licenses the product manufacturers

4.2.1 Product manufacturers

In a two levels vertical supply chain, when the licensor licenses the product manufacturers, in the second stage of the game both product manufacturers maximize the following profit function,

$$\max_{q_{d_i}} \pi_{d_i} = p_d q_{d_i} - (c_d + p_u + r) q_{d_i} = \left[a - b\left(q_{d_i} + q_{d_j}\right)\right] q_{d_i} - (c_d + p_u + r) q_{d_i} \tag{1}$$

[24]On each stage of the value chain our model encompasses Perfect Competition, Bertrand, Cournot, Stackelberg and eventually Collusion

[25]See also Cabral (1995) and Jullien et al. (2014)

[26]To represent a Cournot Duopoly one can set $v_{u,d} = 0$, to depict Perfect Competition or a Bertrand Duopoly $v_{u,d} = -1$, for Stackelberg $v_{u,d} = -0.5$ and eventually for Collusion $v_{u,d} = 1$

Assuming the existence of a unique solution to (1), and noting that $\frac{dq_{d_j}}{dq_{d_i}} = v_{d_i}$ and $v_{d_1} = v_{d_2} = v_d$, each FOC is

$$\left[a - b\left(q_{d_i} + q_{d_j}\right)\right] - b\left(1 + v_d\right) q_{d_i} - \left(c_d + p_u + r\right) = 0$$

We then derive the system of best reply functions of downstream firms

$$q_{d_i} = \frac{a - (c_d + p_u + r) - bq_{d_j}}{b\left(2 + v_d\right)} \quad \text{for } i, j \in \{1, 2\} \text{ and } i \neq j \tag{2}$$

yielding the quantity of each firm

$$q_{d_i} = \frac{1}{3 + v_d} \frac{a - (c_d + p_u + r)}{b}$$

Thus, the total quantity of the downstream level is [27]

$$Q_d = \frac{2}{3 + v_d} \frac{a - (c_d + p_u + r)}{b}$$

and, substituting it inside the inverse demand function $p_d = a - bQ_d$, we find the price of the downstream firms

$$p_d = a - \frac{2\left(a - (c_d + p_u + r)\right)}{3 + v_d}$$

Eventually, the profit of each downstream firm is

$$\pi_{d_i} = \left[\left[a - \frac{2\left(a - (c_d + p_u + r)\right)}{3 + v_d}\right] - (c_d + p_u + r)\right]\left[\frac{1}{3 + v_d} \frac{a - (c_d + p_u + r)}{b}\right]$$

4.2.2 Component makers

Turning to the component manufacturers we first note that as $Q_d = \frac{2}{3+v_d} \frac{a-(c_d+p_u+r)}{b}$ and $Q_d = Q_u = Q$, their price can be expressed as

$$p_u = (a - c_d - r) - \frac{b\left(3 + v_d\right)}{2}\left(q_{u_i} + q_{u_j}\right)$$

Hence the profit functions the two component makers aim to maximize is:

$$\max_{q_{u_i}} \pi_{u_i} = p_u q_{u_i} - c_u q_{u_i} = \left[(a - c_d - r) - \frac{b\left(3 + v_d\right)}{2}\left(q_{u_i} + q_{u_j}\right)\right] q_{u_i} - c_u q_{u_i} \tag{3}$$

Then, under regularity conditions that ensure the existence of a unique interior solution, and noting that $\frac{dq_{u_j}}{dq_{u_i}} = v_{u_i}$ and $v_{u_1} = v_{u_2} = v_u$, the FOC of each u is

$$\left[a - \frac{b\left(3 + v_d\right)}{2}\left(q_{u_i} + q_{u_j}\right)\right] - \frac{b\left(3 + v_d\right)}{2}\left(1 + v_u\right) q_{u_i} - \left(c_u + c_d + r\right) = 0$$

From these we derive the system of best reply functions of upstream firms

$$q_{u_i} = \frac{a - (c_u + c_d + r) - \frac{b(3+v_d)}{2} q_{u_j}}{\frac{b(3+v_d)}{2}\left(2 + v_u\right)} \quad \text{for } i, j \in \{1, 2\} \text{ and } i \neq j \tag{4}$$

[27]By setting $v_d = 0$ the usual Cournot outcome is achieved, similarly by setting $v_d = -1$ for Perfect Competition and Bertrand, $v_d = -0.5$ for Stackelberg warfare and $v_d = 1$ for Collusion

yielding the quantity of each firm

$$q_{u_i} = \frac{1}{3+v_u} \frac{a-(c_u+c_d+r)}{\frac{b(3+v_d)}{2}}$$

Thus, the total quantity of the upstream level is

$$Q_u = \frac{2}{3+v_u} \frac{a-(c_u+c_d+r)}{\frac{b(3+v_d)}{2}}$$

[28] and the price of upstream firms is

$$p_u = (a-c_d-r) - \frac{2\left(a-(c_u+c_d+r)\right)}{3+v_u}$$

Eventually, the profit of each upstream firm is

$$\pi_{u_i} = \left[\left[(a-c_d-r) - \frac{2\left(a-(c_u+c_d+r)\right)}{3+v_u}\right] - c_u\right]\left[\frac{1}{3+v_u}\frac{a-(c_u+c_d+r)}{\frac{b(3+v_d)}{2}}\right]$$

4.2.3 Licensor

Turning to the licensor, behaving as a monopolist l, it maximizes its profit function

$$\max_r \pi_l = rQ \tag{5}$$

Assuming as usual the existence of a unique solution, we denote by r^* the optimal royalty rate.

4.2.4 Equilibrium profits

We can now substitute r^* in the quantity of each upstream firm to obtain $q^*_{u_i}$ and Q^*_u. Then, we plug r^*, in the price of upstream firms to get p^*_u. Furthermore, we substitute r^* and p^*_u in the quantity of downstream firms to get Q^*_d and eventually p^*_d. Finally, we can compute π^*_l, $\pi^*_{u_i}$ and $\pi^*_{d_i}$.

Hence, equilibrium profits are:

$$\begin{aligned} \pi^*_l &= r^*Q^* \\ \pi^*_{u_i} &= \left[\left[(a-c_d-r^*) - \frac{2\left(a-(c_u+c_d+r^*)\right)}{3+v_u}\right] - c_u\right]\left[\frac{1}{3+v_u}\frac{a-(c_u+c_d+r^*)}{\frac{b(3+v_d)}{2}}\right] \\ \pi^*_{d_i} &= \left[\left[a - \frac{4\left(a-(c_u+c_d+r^*)\right)}{(3+v_d)(3+v_u)}\right] - \left[a - \frac{2\left(a-(c_u+c_d+r^*)\right)}{3+v_u}\right]\right]\left[\frac{2\left(a-(c_u+c_d+r^*)\right)}{b(3+v_d)(3+v_u)}\right] \end{aligned} \tag{6}$$

for the licensor, the upstream firms and the downstream firms respectively.

4.3 Case 2 - The licensor licenses the component makers

4.3.1 Product manufacturers

In the second case, when the licensor licenses the component makers, the first players moving are still the car manufacturers and each one of them wants to maximize the following, lighter, profit function:

$$\max_{q_{d_i}} \pi_{d_i} = p_d q_{d_i} - (c_d+p_u)q_{d_i} = \left[a - b\left(q_{d_i}+q_{d_j}\right)\right]q_{d_i} - (c_d+p_u)q_{d_i} \tag{7}$$

[28] Conditioning on the v_d chosen above, by setting $v_u = 0$ the usual Cournot outcome is achieved, similarly by setting $v_u = -1$ for Perfect Competition and Bertrand, $v_u = -0.5$ for Stackelberg warfare and $v_u = 1$ for Collusion

Assuming the existence of a unique solution to (7), and noting that $\frac{dq_{d_j}}{dq_{d_i}} = v_{d_i}$ and $v_{d_i} = v_{d_j} = v_d$, the FOC of each d is

$$\left[a - b\left(q_{d_i} + q_{d_j}\right)\right] - b\left(1 + v_d\right) q_{d_i} - \left(c_d + p_u\right) = 0$$

We then derive the system of best reply functions of downstream firms

$$q_{d_i} = \frac{a - (c_d + p_u) - bq_{d_j}}{b\left(2 + v_d\right)} \quad \text{for } i, j \in \{1, 2\} \text{ and } i \neq j \tag{8}$$

yielding the quantity of each firm

$$q_{d_i} = \frac{1}{3 + v_d} \frac{a - (c_d + p_u)}{b}$$

Thus, the total quantity of the downstream level is[29]

$$Q_d = \frac{2}{3 + v_d} \frac{a - (c_d + p_u)}{b}$$

and, by substituting this into the inverse demand function $p_d = a - bQ_d$, we find the price of the downstream firms

$$p_d = a - \frac{2\left(a - (c_d + p_u)\right)}{3 + v_d}$$

Eventually, the profit of each downstream firm is

$$\pi_{d_i} = \left[\left[a - \frac{2\left(a - (c_d + p_u)\right)}{3 + v_d}\right] - \left(c_d + p_u\right)\right] \left[\frac{1}{3 + v_d} \frac{a - (c_d + p_u)}{b}\right]$$

4.3.2 Component makers

As in case 1, turning to the component manufacturers we note that as $Q_d = \frac{2}{3+v_d} \frac{a-(c_d+p_u)}{b}$ and $Q_d = Q_u = Q$, their price can be expressed as

$$p_u = (a - c_d) - \frac{b\left(3 + v_d\right)}{2}\left(q_{u_i} + q_{u_j}\right)$$

Again, it is possible to formulate the profit function each component maker aims to maximize, but this time bearing r:

$$\max_{q_{u_i}} \pi_{u_i} = p_u q_{u_i} - (c_u + r)\, q_{u_i} = \left[(a - c_d) - \frac{b\left(3 + v_d\right)}{2}\left(q_{u_i} + q_{u_j}\right)\right] q_{u_i} - (c_u + r)\, q_{u_i} \tag{9}$$

Then, assuming the existence of a unique solution, and noting as above that $\frac{dq_{u_j}}{dq_{u_i}} = v_{u_i}$ and $v_{u_i} = v_{u_j} = v_u$, the FOC of each u is

$$\left[a - \frac{b\left(3 + v_d\right)}{2}\left(q_{u_i} + q_{u_j}\right)\right] - \frac{b\left(3 + v_d\right)}{2}\left(1 + v_u\right) q_{u_i} - \left(c_u + c_d + r\right) = 0$$

We then derive the system of best reply functions of upstream firms

$$q_{u_i} = \frac{a - (c_u + c_d + r) - \frac{b(3+v_d)}{2} q_{u_j}}{\frac{b(3+v_d)}{2}\left(2 + v_u\right)} \quad \text{for } i, j \in \{1, 2\} \text{ and } i \neq j \tag{10}$$

[29] See *Footnote 5*

yielding the quantity of each firm

$$q_{u_i} = \frac{1}{3+v_u}\frac{a-(c_u+c_d+r)}{\frac{b(3+v_d)}{2}}$$

Thus, the total quantity of the upstream level is [30]

$$Q_u = \frac{2}{3+v_u}\frac{a-(c_u+c_d+r)}{\frac{b(3+v_d)}{2}}$$

and the price of upstream firms is

$$p_u = (a-c_d) - \frac{2\,(a-(c_u+c_d+r))}{3+v_u}$$

Eventually, the profit of each upstream firm is

$$\pi_{u_i} = \left[\left[(a-c_d) - \frac{2\,(a-(c_u+c_d+r))}{3+v_u}\right] - c_u - r\right]\left[\frac{1}{3+v_u}\frac{a-(c_u+c_d+r)}{\frac{b(3+v_d)}{2}}\right]$$

4.3.3 Licensor

Turning to the licensor, behaving as a monopolist l, it maximizes its profit function

$$\max_r \pi_l = rQ \tag{11}$$

Under the usual regularity conditions that guarantee the existence of a unique interior solution, we denote by r^* the optimal royalty rate.

4.3.4 Equilibrium profits

We can now substitute r^* in the quantity of each upstream firm to obtain $q^*_{u_i}$ and Q^*_u. Then, we plug r^* in the price of upstream firms to get p^*_u. Furthermore, we substitute p^*_u in the quantity of downstream firms to get Q^*_d and eventually p^*_d. Finally, we can compute π^*_l, $\pi^*_{u_i}$ and $\pi^*_{d_i}$.

Hence, equilibrium profits are:

$$\begin{aligned}
\pi_l &= r^*Q^* \\
\pi_{u_i} &= \left[\left[(a-c_d) - \frac{2\,(a-(c_u+c_d+r^*))}{3+v_u}\right] - c_u - r^*\right]\left[\frac{1}{3+v_u}\frac{a-(c_u+c_d+r^*)}{\frac{b(3+v_d)}{2}}\right] \\
\pi_{d_i} &= \left[\left[a - \frac{4\,(a-(c_u+c_d+r^*))}{(3+v_d)\,(3+v_u)}\right] - \left[a - \frac{2\,(a-(c_u+c_d+r^*))}{3+v_u}\right]\right]\left[\frac{2\,(a-(c_u+c_d+r^*))}{b\,(3+v_d)\,(3+v_u)}\right]
\end{aligned} \tag{12}$$

for the licensor, the upstream firms and the downstream firms respectively.

4.4 The neutrality of the licensing level

Comparing the results of case 1 to the ones of case 2, we conclude that the licensing level does not affect the profits of the firms involved, as shown by (6) and (12). It also does not affect the profits of the patent holder.

In addition, since the equilibrium price of the final product is equal in both case 1 and case 2,

[30]See *Footnote 6*

$$p_d = a - \frac{4\left(a - \left(c_u + c_d + r^*\right)\right)}{\left(3 + v_d\right)\left(3 + v_u\right)}$$

consumers are not affected by the licensing level either.

Finally, because also equilibrium quantities in the downstream product market are equal in both cases, the adoption of the new technology is indifferent to the licensing level.

Importantly, this neutrality result does not depend on the level of competition of the markets in which component suppliers and product manufacturers respectively operate.

This resut also appears robust to the extensions to n firms, differentiated products and non-linear demand functions.

However, this neutrality result depends not only on the royalty being per-unit (as it was for instance the one set by *Avanci*) but also on the number of different components per vehicle being fixed and the needed licenses per vehicle being fixed and independent of the licensing level.

5 Conclusions

The outcome of the debate on the licensing level of the value chain in many IoT industries is expected to be crucial for the implementation of cellular connectivity standards in these industries.

We started by describeing the terms of the debate and highlight its relevance We then proceeded to analyze the case of the automotive industry. We first discussed this industry characteristics and the importance of cellular wireless connectivity standards for the development of autonomous vehicles. We then introduced the debate and the litigations about the level at which SEPs should be licensed in the automotive industry vertical supply chain. We focused in particular on two cases of litigation in court: the *Continental v Avanci* case, in which a component supplier of the automotive industry sued a patent pool that licenses many 2G/3G/4g SEPs for the automotive industry for refusing to license it and for licensing only downstream producer; the *Nokia v Daimler* case, in which a car manufacturer sued a SEP holder for refusing to license to component manufacturers and requesting the licence to be obtained by the car manufacturer.

We then set up to examine whether the licensing level affects the value of the royalty and the profits of firms operating in the automotive industry, as a possible explanation of *Continental v Avanci* and *Damler v Nokia*. To this aim, we built a model of a vertical supply chain of an industry in which component suppliers sell their products to manufacturers and the licensor chooses the level of the value chain at which it licenses. We analytically modelled two aternative licensing scenarios and in each of them we computed the royalty and profits of licensor, component supplier and car manufacturer: in the first scenario the licensor licenses the final product manufacturer, while in the second scenario it licenses the component maker. We later compared the results of the two cases in order to analyse whether and in which way the licensing level affects the profits of firms.

The aim of this paper was to determine whether SEPs licensing level actually shaped firms' profits and incentives and, as a conseuence, the adoption of the licenced technology. From our model we concluded that level of the value chain at which the licensor decides to license its patents does not affect the profits of the firms in the industry nor the profits of the licensor. Perhaps most surprisingly, in our model, this result does not depend the level of competition of the upstream and downstream markets in which component supplier and product manufacturers respectively operate.

We expect this neutrality result to be rebust to the extensions to: n firms, differentiated products and non-linear demand functions. To this regard, our results do not justify the introduction of norms that aim to fix or to level of licensing for SEPs.

However, this neutrality result crucially hinges not only on the royalty being per-unit (as proposed by *Avanci* but also on the number of components per final product being fixed and the number of needed licenses per vehicle being fixed and independent of the licensing level.

To this regard our model can be regarded as a benchmark model. Yet it also suggests that a regulatory intervention mandating the need for only one unit license per final product irrespective of the licensing level may reduce litigations and uncertainty and would also avoid double marginalization on the royalty rate. As a consequence, it would ensure the policy objective of a faster adoption of new communication technologies and development of the IoT.

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