

**Innovation policy within private collectives:
Evidence on 3GPP's regulation mechanisms
to facilitate collective innovation**

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1. Introduction

Innovation policy, aiming to enhance economic welfare benefits derived from innovation, has traditionally used three types of instruments: intellectual property rights (IPR), competition policy and budgetary incentives through taxes and subsidies. The logics behind these approaches are complementary: IPR is meant to protect innovators' financial incentives to innovate, whereas competition policy protects competition on the assumption that, once unleashed, competitive market forces constitute an effective mechanism to spur innovation. At the same time, governments regularly deploy taxes and subsidies to encourage innovative firms. Taken together, these instruments ensure that innovators, be they individuals or firms, can profit from commercializing their innovations (Teece 1986; Teece 2006), which feeds back into encouraging them to further innovate.

While these policy instruments have been developed in an economy largely reliant on manufacturing, today's economy raises different kinds of challenges with regards to innovation. In particular, innovations within the digital economy are parts of complex and interdependent technological systems, and mostly conducted in a distributed, collaborative manner (Yoo 2012). Digital industries are typically structured around platform-based ecosystems where firms collaborate and compete around modular components and interfaces (Gawer & Cusumano 2002; Sanchez 1995). As a result, the management of IPR under collaborative innovation regimes becomes far more nuanced than in traditional contexts (Shapiro 2001).

Collective innovation, which is pervasive in the digital economy, creates complex regulatory challenges (Gawer 2012), as well as increasing litigation over intellectual property rights involving firms (Economist 2012; FT 2012; Forbes 2013a) as well as governments (FT 2013). In response to these phenomena, recent literature calls for new innovation policies that (1) better integrate private interests with public policy (Howells 2006; Shapiro 2008; Morlacchi & Martin 2009; Flanagan et al. 2011) and (2) provide new instruments to regulatory bodies and firms facilitating collaborative innovation (de Jong et al. 2010; Ebersberger 2011; Levy & Reid 2011).

This paper aims to make progress on these issues, by focusing on a unique case study in the telecom sector. The Third Generation Partnership Project (3GPP) is a federation of organizations comprising of standardization bodies from Asia, Europe and North America, industry consortia, technology producers including large firms such as Ericsson, Huawei, Motorola, Nokia, Qualcomm, and small firms, as well as large technology consumers such as telecommunication operators.

Since its creation in 1997, 3GPP has aimed to stimulate collective innovation while promoting the private interests of a number of partners who may be competitors as well as collaborators. It has therefore faced for a number of years some of the complex challenges that the public regulator is starting to face when aiming to promote innovation in the digital economy. 3GPP has been largely successful in its efforts, with 90% of the 6 billion mobile subscribers using 3GPP-sponsored technologies (GSA 2013). Through a multi-method study combining interviews and a survey, we explore in this paper the regulation mechanisms through which 3GPP manages the trade-offs of: (1) aligning the private interests of the firms within the collective; (2) ensure that collective innovation does not weaken healthy competition.

We find that a combination of specific IP rights instruments is key to managing these trade-offs. Specifically, we find that the combined policies of essential patenting, FRAND, and maximum royalty rate help overcome the specific challenges associated with collective innovation within competitive contexts.

The paper contributes therefore to the literatures on private collective innovation and IP rights and helps bridge these literatures. Our contributions are the following. We contribute to the private collective literature as our paper is the first to our knowledge that explores empirically how the management of IP rights affects the ability of a private collective organization to both innovate and compete. We find that the manner in which IP rights instruments are implemented in practice has a profound impact on shaping the process and the outcome of collective innovation in private collective organizations.

Relevant to the IP rights literature, we extend this literature by assessing a study of the combination and the interaction of different IP rights mechanisms operate in the context of a private collective organization. Specifically, and contrary to results questioning the validity of FRAND (Treacy & Lawrance 2008), we find that this instrument is beneficial both at the firm level and the collective level. We find however that essential patenting, as currently implemented in 3GPP, does not work the way it has been predicted (Shapiro 2001; Lemley 2002, 2007) as is prone to subjective re-interpretation once standards and licensing agreements have been developed, which leads to possible hold-up situations and litigation.

We also contribute to the policy debate about IP rights in the context of collective innovation. Our empirical study reveals that a practical solution to the limitations of current essential patenting has been found and implemented in the context of 3GPP: it consists in associating essential patenting policies to an ex-ante maximum royalty rate policy, which limits ex-post opportunistic behavior. This practical solution raises some concerns however, given the possibility of maximum royalty rate to be interpreted as anti-competitive by current antitrust regulation. We therefore raise the question of re-examining the potentially negative impact of antitrust regulation on collective innovation. The adoption of this practical solution, currently advocated by a number of firms involved in 3GPP (LTE 2008), would require modifications in antitrust regulation and a more flexible approach to public policing of collective innovation. This paper therefore contributes to the innovation policy debate on the reform of the patent system and antitrust regulation (AMC 2007; Wright 2009; Zoettl et al. 2009) especially in the mobile sector (Balto 2004) by providing empirically-based insights in favor of examining the impact of competition policy on collective innovation challenges.

2. Theory and hypotheses

The private-collective model of innovation (von Hippel & von Krogh 2003) describes a model of technology development that combines established models of proprietary innovation with some collective aspects of innovation whereby firms relinquish ownership rights over resources to make them partially non-excludable (Alexy & Reitzig 2013). In the private-collective, firms contribute to the production of a common technology (e.g. mobile communications, open source software) exhibiting public good characteristics.

Private-Collective organizations can be considered a particular form of strategic alliance as firms engage in a web of agreements sharing the commitment to reach a common goal by pooling their resources and coordinating their activities (Teece 1992; von Hippel & von Krogh 2006; Enkel et al. 2009; Huizingh 2011). In a similar manner to other sorts of strategic alliances, firms within the private-collective collaborate in research and development (Hagedoorn et al., 2000; Yasuda 2005), technology standardization and technology commercialization.

A unique characteristic of private-collective, however, is the creation of pools of intellectual property rights (IPrights) which are made available to the community within the private-collective.

The creation of shared patent pools have profound implications on innovation as, by partially waiving IP rights, firms within the private-collective reduce search and licensing transaction costs, as well as potential, ex-post, litigation (Von Hippel & von Krogh 2003; Garud & Kumaraswamy 1993; Fitzgerald 2006; Lerner & Tirole 2002b).

By lessening licensing and litigation costs, firms within the private-collective are able to expand their strategic options for technology development; in addition to traditional appropriation mechanisms such as large portfolio patenting or technology manufacturing, firms are adopting alternative approaches focusing on developing a limited set of patents and contributing them to patent pools and standards with other firms (Fischer & Henkel 2013).

Therefore private-collective as a model of innovation allows firms to implement strategies based on asset and knowledge specialization and value-capture strategies based on full technology package commercialization and IP rights. Examples of this model of innovation can be found in the software industry (von Krogh et al. 2003; Osterloh & Rota 2007) as well as in service and manufacturing (van de Vrande et al. 2009).

In this sense the private-collective model of innovation is claimed by several authors as an effective organizational form to facilitate the development of markets for technology (Arora et al. 2004).

Firms, however, often fail to benefit from inter-firm partnering, especially in technological contexts riddled with complex intellectual property regimes (Somaya 2003; Somaya et al. 2011), information and power asymmetries (Das & Teng 2000; Osborn & Baughn 1990), opportunistic behaviour (Williamson 1998; Gulati 1995) and managerial complexity (Park & Ungson 2001).

Reasons for the high failure rates observed in inter-firm partnering are, among others: the performance and network ties (Olk & Young 1997), access to complementary resources, the evolution of the consortium itself (Hagedoorn et al., 2000; Hagedoorn 2002; Lunnan & Haugland 2008) and the location of other strategic partners relative to the focal firm (Adner & Kapoor 2010). This is especially the case in contexts in which transactions are established at a vertical level (e.g. supplier-provider) and at a horizontal level between competitors (e.g. cross-licensing).

As a result the firm's ability to create and capture value from partnering with others is contingent on its market power, internal resources, activities outside the private-collective (Leiponen 2008; Stuermer et al. 2009) and other firms, either internal or external, to the private-collective (Alexy & Reitzig 2003).

Also of relevance in determining the success of any strategic partnering is the IPrights regime operating, especially if there are processes for standards development (Lemley 2002; Rysman & Simcoe 2008) and large network effects involved in standards adoption (Shapiro 2008; Chiao et al. 2007; Schmalensee 2009).

Literature on standard settings and intellectual property rights find significant weaknesses in current regimes for the management of IPrights that can provide perverse incentives for patent licensing firms to seek excessive rates of return as well as for licensees to minimize the economic value of the innovation embedded in the patent (Lichtman 2010; Treacy & Lawrance 2008; Schmalensee 2009). This not only impedes efficient markets for technology (Arora et al. 2004) but at the same time exposes the private-collective to exogenous stakeholders such as governmental agencies, antitrust and other legal systems (Lemley & Shapiro 1991; Lemley 2002, 2007) whose decisions can have a profound impact on the firm's ability to innovate and extract economic value from it.

In this regard this paper aims to contribute to a further understanding of the context that makes private-collective a sustainable model of collaborative innovation. More precisely, this paper investigates: (1) internal mechanisms of governance of IPrights whereby private-collective institutions can develop technologies and the resulting ability of the firm to benefit from them, as well as (2) the interplay between cooperation and competition in the context of private-collective. The former aspect is developed in section 2.1 with the latter in section 2.2.

From a public policy perspective, providing insights on these matters is relevant given current debates on the reform of the patent system and antitrust regulation (AMC 2007; Wright 2009; Zoettl et al. 2009) especially in the mobile sector (Balto 2004).

From a strategic and managerial perspective a better understanding of private-collective as a model of collaborative innovation would help firms' managers to better assess positioning and coordination choices (Iansiti and Levien 2004), value chain configuration in the private-collective (Adner and Kapoor 2010) and the benefits, and risks, associated with adopting a private-collective model (Joshi & Nerkar 2011).

2.1. Coordination of innovation in the private-collective (First trade-off: coordination of collective innovation & proprietary innovation)

The development of technologies within a Private-Collective organization involves a combination of many different components each of which may be the subject of one or more patents. In the information technology sector in particular, high-technology products such as microprocessors, cell phones, or memory devices can easily be covered by dozens or even hundreds of different patents.

The fact that a large set of patents can affect a single technology creates a patent thicket (Shapiro 2001) in which a set of patents, owned by different firms, overlap around the same technology. This might lead to complex patent hold-up situations resulting in (1) injunction threats and (2) royalty stacking.

2.1.1: Injunction threats

Lemley (2007) shows that the threat of an injunction can enable a patent holder to negotiate royalties far in excess of the patent holder's true economic contribution, ideally represented as a reasonable royalty level.

The royalty rate that would be reasonable and expected in the ideal patent system, without any element of hold-up is contingent on factors such as the value of the patented feature for the downstream firm, the margin per unit earned by the downstream firm on its product, the strength of the patent, the cost to the downstream firm of redesigning its product to avoid infringing the patent claims as well as the bargaining skills of the patent holder among others.

The negotiated royalty rate, however, depends upon the downstream firm's best strategy in the event that negotiations with the patent holder break down. In the case of litigation the owner of the patent gains great bargaining leverage from its ability to threaten to force the downstream firm from the market if the patent is found valid and infringed (Shapiro 2008). An alternative would be for the accused infringer to avoid the risk of disruption in its business by redesigning the product even while litigating, particularly if the cost of redesign is relatively low in comparison with profits that the downstream firm would lose by withdrawing from the market while redesigning its product. In any case, the patent holder benefits greatly from the fact that the downstream firm's threat point in the negotiations involves incurring redesign costs.

The threat that a patent holder will obtain an injunction that will force the downstream producer to pull its product from the market can be very powerful. These threats can greatly affect licensing negotiations, especially in cases where the injunction is based on a patent covering one small component of a complex, profitable, and popular product (USITC 2013; Economist 2013). Some situations of this phenomenon can be found in the mobile industry in which Apple and Samsung, formerly engaged in collaborative innovation, have recently resorted to litigation over IP rights (Forbes 2013a).

A number of private-collective institutions have adopted open policies of IP rights management whereby firms abide to a complete waiver of their patents. In what is known as the open source movement, patents associated with actual, or derived, innovations remain open and free for everyone to use (Lakhani & von Hippel 2003; Lerner & Tirole 2002a). Arguably this model of IP right management greatly diminishes risks associated with injunction threats.

In other instances of private-collective modes of innovation the excessive bargaining power hold by patent owners is compensated via two mechanisms: Essential patents and FRAND licensing (Lemley 2007; Farrell et al. 2007).

Patents are considered essential if they are considered to be indispensable to manufacture a standard-compliant technology (Bekkers et al. 2011). More precisely essentiality is a characteristic by which it is not possible on technical grounds to make, sell, lease otherwise dispose of, repair, use or operate equipment or methods which comply with a standard without infringing on that IPR (ETSI 2013).

Essential patents not only address the injunction problem but also define technical interfaces required to ensure ex-post interoperability at a vertical (between subcomponents) and horizontal (among competitors) level.

Under a FRAND policy of licensing, firms within the private-collective abide to license on a Fair, Reasonable and Non Discriminatory (i.e., FRAND) basis. This mechanism is especially important in the case of essential patents as it effectively limits the monopolistic power which is granted to the owner of the essential patent (Lemley & Shapiro 1991).

2.1.2. Royalty stacking

Royalty stacking refers to situations in which a single product potentially infringes on many patents, and thus may bear multiple royalty burdens. The term “royalty stacking” reflects the fact that, from the prospective of the firm making the product in question, all of the different claims for royalties must be added or “stacked” together to determine the total royalty borne by the product if the firm is to sell that product free of patent litigation. The existence of such “royalty stacking” exacerbates the hold-up problem as downstream firms (1) face infringement claims from multiple owners and (2) are charged more than the marginal costs associated to each patent (Shapiro 2001). Moreover royalty stacking may lead to a situation in which output is depressed even below the level that would be set by a vertically integrated monopolist.

In regards to the royalty stacking problem, firms engaged in the private-collective establish a maximum royalty rate for the technology as a whole (e.g. smartphone) thus avoiding potential unsustainable situations (Franzinger 2003).

These three mechanisms (Essential patenting, FRAND licensing and maximum royalty rates) make possible the implementation of pools of IP rights within the private-collective upon which collaborative innovation can take place¹. We contend therefore that these mechanisms are critical for the sustainability and effectiveness of private-collective modes of innovation.

In order to empirically test the influence of these mechanisms in the governance of private-collective modes of innovation, we suggest the following hypotheses:

H1a. FRAND licensing is positively associated with firms’ perception of their ability to develop technologies under Private-Collective contexts.

H1b. Essential patents are positively associated with firms’ perception of their ability to develop technologies under Private-Collective contexts.

H1c. Maximum royalty rate policies are positively associated with firms’ perception of their ability to develop technologies under Private-Collective contexts.

¹We note in passing that open sourcing can be considered as a particular instance of IP right pooling in which FRAND is a “de facto” policy and there are no royalties associated at all

2.2. Coordination and competition in the private-collective (Second trade-off: coordination of collective innovation & competition)

Previous section hypothesizes the relevance of Essential patents, FRAND licensing and maximum royalty rates in private-collective modes of innovation. These mechanisms can (1) nurture innovation and technology improvement and (2) promote compatibility at a horizontal and vertical level. In the case of mobile technologies a consumer can substitute one brand of smartphone for another in the same mobile network; in a similar manner smartphone manufacturers can be reassured that their products will operate across mobile networks (Hovenkamp 2007). In this sense section 2.1 contends the beneficial effect of the three mechanisms in reducing transaction costs involved in presence of overlapping IP rights (i.e. patent thickets).

These instruments however may run counter to competition, therefore raising antitrust concerns. Essential patents, a set of technical specifications agreed within the private-collective that provides a common design for a technology, may facilitate both collusion and exclusion (Lemley 2002).

Collusion is possible as an essential patent, by definition, minimizes differentiation and makes technologies readily observable which in turn facilitates the emergence of cartels (Hovenkamp 2005; Scherer & Ross 1990; Viscusi et al. 2005).

Conferring the status of essentiality to a certain set of patents arguably entails some exclusionary risks as owners of essential patents can exert excessive market power given the cumulative nature of technological development (ref to cumulative innovation), significant network effects (ref: network externalities) and patent hold-up (Lemley 2007). Previous section presented FRAND licensing as a counterbalancing mechanism to limit the exclusionary power granted by an essential patent.

Established competition rules on horizontal cooperation agreements explicitly prohibit agreements which have as their object the restriction of competition. For there to be restrictive effects on competition, essential patent and maximum rate policies must have, or be likely to have an appreciable adverse impact on at least one of the parameters of competition on the market, such as price, output, product quality and variety, or innovation (Whish & Bailey 2012; EC2013).

From a practical perspective established legal practises, e.g. the European Union (EC2013), implement four cumulative conditions which must be met for co-operation agreements to be considered beneficial in the sense of providing efficiency gains offsetting potential restriction on competition, (1) must lead to economic benefits, (2) restrictions must be indispensable to generate efficiency gains, (3) consumers must receive a fair share of the resulting efficiency gains, (4) the agreement must offer the parties no possible elimination of competition in relation to a substantial part of the products in question.

Hypotheses H1a to H2c partially apply these four criteria to test any potential restriction on competition due to essential patenting, FRAND licensing and maximum royalty rate policies. Based on the analysis above, we contend that:

H2a. FRAND licensing is positively associated with firms' perception of their ability to compete in Private-Collective contexts.

H2b. Essential patenting is positively associated with firms' perception of their ability to compete in Private-Collective contexts.

H2c. Maximum royalty rate policies are positively associated with firms' perception of their ability to compete in Private-Collective contexts.

3. Data collection and analytical methods

Our hypotheses require the identification of a setting in which firms federate around a private-collective organizational form for the purposes of technological development and commercialization.

To adequately characterize the impact of IPrights mechanisms on innovation (hyp.H1_{a-c}) we need data corresponding to private-collectives that have formal mechanisms in place, patent licensing firms and patent licensees. In order to do a similar analysis, this time applied to competition (hyp. H2_{a-c}), we also need an instance of a private-collective in which firms engage in collaborative research whilst competing in subsequent stages of technology commercialization.

3.1. The setting: 3GPP

The third Generation Partnership Project (3GPP) provides a setting that uniquely lends itself to the test of our hypotheses is the third Generation Partnership Project (3GPP). It is composed of standardization bodies from Asia, Europe and North America (ARIB, ATIS, CCSA, ETSI, TTA, TTC), market representation partners (IMS forum, IPv6 forum, UMTS forum, GSM association) as well as patent-intensive multinationals (Ericsson, Huawei, Motorola, Nokia, Qualcomm), technology consumers (e.g. telecommunication operators) and small technology-intensive firms.

In this domain, as documented in 3GPP (2007) and Leiponen (2008), 3GPP produces Technical Specifications, to be transposed by relevant Standardization Bodies into appropriate deliverables (e.g., standards).

3GPP inherited most of its operating procedures from the European Telecommunications Standards Institute (ETSI), retaining their approach to open membership, mechanism for the management of intellectual property rights, committee structure and working procedures, ETSI (2013). Contrary to ETSI, however, 3GPP is a clear departure from the government-led approach to technical standardization as in this case technological development is led by private firms.

Mandated by the International Telecommunications Union (ITU), 3GPP members start working collaboratively on the development of a new set of technical specifications (e.g., 4th generation mobile) which are in turn transposed by standardization bodies into formal standards. With standards in place private firms are able to start competing in the market mostly based on price and value-added offerings (service and support, complementary technologies).

Market figures seem to support 3GPP as an effective institution to develop technological markets with circa six thousand million mobile subscriptions globally using 3GPP systems which makes 90% of the total mobile market today (Economist 2012b; Forbes 2013b; GSA 2013)

3.2. Data

Initially a list of firms involved in 3GPP for the past decade was collected in order to conduct an analysis of their research intensity, as measured by number of conventional patents, essential patents (Bekkers et al. 2011; Phelps & Milone 2012) and engineers assigned to work on 3GPP-related technology development (3GPP 2013b).

A preliminary analysis of the dataset reveals the existence of three different groups based on the number of engineers firms commit to developing technologies within 3GPP, the number of total patents related to mobile technologies, the number of essential patents and the number of years that the firm has been involved in 3GPP. Table 1 depicts a clear separation in three categories: (1) firms exhibiting high research intensity (measured in terms of patent portfolio, essential patents and engineers); (2) firms with lower levels of research intensity but similar periods of involvement; (3) firms with shorter periods of involvement and resources committed, (see Table 1).

Further analysis, reveals that group 1 corresponds to large firms (e.g. Ericsson, Samsung, Nokia) specialized in developing and commercializing new mobile technologies whereas group 2 corresponds to large firms (e.g. Japan Telecom, China Unicom, O2) whose main business model is based on providing mobile services to end customers. The third group is consisted of small firms with specialized technologies (e.g., security, geopositioning) and lower capacity for research.

Table 1 Initial analysis of firms participating in 3GPP

Group	Number of mobile related patents	Number of mobile related essential Patents	Number of engineers involved	Number of Years Involved
Large Producers	5105.826	30.60606	21.48485	6.909091
Large Consumers	1294.444	.	8.714286	5.142857
Small Producers	40	.	2.5	2.833333

A multivariate analysis of variance (MANOVA, Wooldridge 2012) confirms the existence of three different categories, according to the p-values obtained ($0.0282 < 0.05$) (see Table 2).

Table 2 MANOVA analysis of firms involved in 3GPP

Number of obs = 32
W = Wilks' lambda
P = Pillai's trace

L = Lawley-Hotelling trace
R = Roy's largest root

Source	Statistic	df	F(df1, df2)	=	F	Prob>F
Groupmember	W 0.6780	1	4, 27		3.21	0.0282 e
	P 0.3220		4, 27		3.21	0.0282 e
	L 0.4749		4, 27		3.21	0.0282 e
	R 0.4749		4, 27		3.21	0.0282 e

Residual 30
Total 31

e = exact, a = approximate, u = upper bound on F

3.3. Interviews

For the purposes of triangulating among different sources of evidence, in addition to a quantitative analysis, a series of one-to-one interviews were arranged with relevant stakeholders. In total 6 in-depth interviews with managers from Ericsson (2) and ETSI (2), a civil servant at the European Union involved in antitrust matters and one engineer formerly involved in standardization processes at 3GPP.

The interviews offered a rich perspective of 3GPP confirming the existence of several mechanisms formally established among the 3GPP community: Essential patent mechanism, FRAND licensing obligation in the case of essential patents and consensus-based decision making among others. Maximum royalty rate policy is a mechanism which, if not formally made explicit in 3GPP's procedures, is broadly agreed among firms in parallel negotiations according to experts interviewed.

3.4. Survey

Given the existence of three groups of firms with potentially conflicting interests (see Table 1) we conduct three different surveys, one for each group identified (large producers, large consumers, small producers). Preliminary interviews conducted prior to the survey lead us to be attentive to the difference between managerial roles (e.g. legal, strategy) and technical roles (e.g. engineers).

The survey was circulated electronically to a total of 205 representatives of the large producer category (e.g. engineers working at Nokia, Ericsson, Qualcomm, Alcatel-Lucent), 123 representatives of the large consumer category (e.g. Vodafone, ATT, France Telecom) and 40 from the small producer category. The response rate was 28.3%, 23.6% and 0.05% respectively. Unfortunately, the lack of sufficient responses from the small producer category leads us to eliminate this group from subsequent analysis.

3GPP, in a similar manner to other Private-Collective organizations, needs to address two main trade-offs for sustainable technology developments and subsequent diffusion to market: on the one hand it must find an adequate balance between coordination of collective innovation and firm's private interests, on the other hand it must ensure that collective innovation does not impede competition (and thus avoid antitrust concerns).

In regards to the first trade-off, we ask to a representative sample of the 3GPP community their preference, on a Likert scale, for each IPrights mechanism in terms of diffusion of the focal firm's innovations (Q3), as well as innovation activity resulting within the private-collective (Q4). Refer to Table 3 for more details on the questionnaire.

In regards to the second trade-off, we ask to the same set of respondents how they find the three coordination mechanisms under consideration in terms of the ability of the firm to compete (Q1), to protect their innovation (Q2), the ability of the private-collective to develop new markets (Q5), the ability of the private-collective to protect innovations from external infringement (Q6) and facilitating the development of alternative technology offerings (Q7).

Finally respondents rate, on a Likert scale, their overall perception of 3GPP as an effective institution in terms of innovation and competition (Q8,Q8',Q9'Q9'). This approach is in the tradition of earlier empirical studies that relied on subjective assessments of the effectiveness of appropriability mechanisms (Cohen et al. 2000; Fisher & Henkel 2012).

In addition to controlling for the firms' strategic positioning (via the categorization into three categories), the results of preliminary interviews justified defining another variable (Role) controlling for the role played by the respondent in the firm (i.e. technical versus managerial). Finally a third variable, "Layer", controls for the respondent's experience in lower layers of 3GPP (e.g. radio transmission) versus higher ones (e.g. charging and billing, internet) (please refer to Annex A).

4. Empirical results

4.1. Coordination of innovation

Table 3 reports summary statistics for the variables considered in regards to coordination of collective innovation, measured via questions Q3, Q4, Q8 and Q8'. The results as described below provide evidence supporting FRAND, essential patenting and maximum royalty rate policy as beneficial for innovation purposes in 3GPP (hyp.H1).

The preliminary analysis of data presented in section 3.3 revealed a large heterogeneity of members involved in 3GPP with three main groups: large technology producers, large technology consumers and small firms (the latter not being considered due to lack of sufficient data available). In order to test for any significant difference we entertain an ordered logit regression controlling for the variables Group, Layer and Role. Thus Table 4 represents the proportional odds ratios for a one unit increase in the control variables Role, Layer and Group on the dependent variables (Q3, Q4).

Table 3 Impact of mechanisms for Coordination of innovation in 3GPP (descriptive analysis)

	Variable	N	Quantile				
			Min	.25	Median	.75	Max
Essential patents (private)	Q31	87	2.00	3.00	3.00	4.00	5.00
Essential patents (collective)	Q41	87	2.00	3.00	4.00	4.00	5.00
FRAND (private)	Q32	87	3.00	3.00	4.00	4.00	5.00
	Q33	87	3.00	3.00	4.00	4.00	5.00
FRAND (collective)	Q42	87	2.00	3.00	4.00	4.00	5.00
	Q43	87	1.00	3.00	4.00	4.00	5.00
Maximum Royalty rate (private)	Q34	87	2.00	3.00	3.00	4.00	5.00

Maximum Royalty rate (collective)	Q44	87	2.00	3.00	4.00	4.00	5.00
3GPP and innovation	Q8	87	2.00	3.00	4.00	5.00	5.00
	Q8'	87	3.00	3.00	4.00	4.00	5.00

Table 4 Influence of the control variables Role, Layer, Group (ordered logit)

Control variable	Essential Patents		FRAND				Maximum royalty rate		Overall perception: 3GPP and innovation	
	Collective level (Q31)	Firm level (Q41)	Collective level (Q32)	Firm level (Q33)	Collective level (Q42)	Firm level (Q43)	Collective level (Q34)	Firm level (Q44)	Q8	Q8'
Role	32.1*** (28.1)	22.5*** (17.3)	12.7** (10.9)	98.5*** (97.5)	18.6*** (16.0)	10.7*** (7.4)	4.21** (3.0)	7.04*** (5.1)	6.16** (4.2)	40.8*** (33.5)
Layer					1.79** (0.54)					0.55** (0.15)
Group	5.6*** (2.88)	2.4** (1.1)	5.6** (3.2)				3.7*** (1.8)	4.05*** (2.03)		
Prob> chi2	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.004	0.036	0.000

4.1.1. Essential patent mechanism

As far as the essential patent mechanism is concerned the results presented in Table 3 indicate a general consensus on its relevance for innovation purposes for the collective (Median $Q4_1=4$) with less support at the firm level (Median $Q3_1=3$).

We note a statistically significant influence of being a manager and a high scoring of the essential patent mechanism as an innovation enabler at both the firm and the collective level (32.1 and 22.5 respectively) (see Table 4). There exists some differences between the type of company under consideration as large technology consumers (e.g. telcos) exhibit larger odds of scoring essential patent as an important mechanism compared to technology producers (5.6 and 2.4 respectively).

According to an interviewee “The existence of essential patents is a two-edged sword. It is good that patents are classified as essential as then limits can be set on the amount of money that are charged for those patents (via FRAND). The problem with essential patents is that companies spend time in 3GPP trying to get their essential patents adopted, whether that is for the common good or not. This slows down the agreement process (as companies will hold out to the last to get their patented technology accepted)... the 3GPP process can be glacial because of essential patents and some odd decisions are made because of them”.

Associated costs to essential patenting are mostly borne exclusively by the large producer group (the owners of essential patents) whereas large consumers benefit from a well-defined legal and technological context delineated by the essential patent mechanism, this would support the different perception observed in relation to the essential patent mechanism.

According to the results of the research the essential patent mechanism seem to play several roles in the process of collective innovation, (1) provides a legal instrument to ensure a return on investment on innovations, (2) delineates intellectual property rights around precise bundles of technologies (e.g. LTE in 4th generation), (3) ensures technical interoperability by defining a technological standard. Hence we obtain support for the mechanism of essential patent as a relevant enabler of collaborative innovation in 3GPP (H1.b).

4.1.2. FRAND mechanism

The results presented in Table 3 reveal a strong support of FRAND as a relevant mechanism for facilitating innovation within 3GPP both at the firm level (Median: $Q3_2=4$, $Q3_3=4$) and the collective one (Median: $Q4_2=4$, $Q4_3=4$).

The interviews conducted reveal that FRAND plays an important role in ensuring a collaborative environment in which innovation and technology development can take place.

As mentioned by one of the ETSI member interviewed “...3GPP tries to balance the private interests of the firms and the collective mostly via consensus-based decision making and FRAND licensing policies... if someone is not prepared to license an essential technology following a FRAND policy then that technology is removed from the standard”.

This official policy of establishing compulsory FRAND licensing in the case of essential patents emerges as a key governance mechanism within 3GPP to avoid hold-up situations such as the one documented in (ref. Rambus). Also compulsory FRAND licensing provides a limit to the power extended to any essential patent holder.

In this sense we observe a clear complementary role between the FRAND mechanism and the essential patent mechanism as both are required to overcome hold-up situations (Shapiro 2001, 2008) and thus foster collaborative innovation in private-collective contexts.

Based on the results presented in Table 4 we notice a statistically significant influence on the control variable Role on the odds of a high scoring of FRAND at a firm level (12.7, 98.5) and at a collective level (18.6,10.7). This result suggests that managers involved in 3GPP exhibit stronger appreciation than engineers for FRAND as a strategic mechanism for innovation in the private-collective.

As far as the other control variables Layer and Group are concerned, the results lead us to conclude that there are no statistically significant differences neither among the type of company (technology producers vs. technology consumers) nor the layer in which the interviewee has been involved (5.6, 2.4).

Both empirical results and personal interviews conducted among experts in the field support FRAND as an innovation enabler in private-collective contexts (H1.a), moreover it seems to be a general consensus among firms and technological contexts on the importance of this mechanism.

4.1.3. Maximum royalty rate

Maximum royalty rate policies are not part of the 3GPP model of governance in order to avoid potential antitrust measures. Moreover all of the people interviewed who are directly involved with 3GPP, EU legislation and ETSI employees, preferred not to comment on the implications of having maximum royalty rates. However some of them indirectly expressed the necessity of limiting the potential of licensing revenues accruing for an essential patent: “You have to make sure that the cost of IP of each product or technology is not excessive. You need to make sure that the total cost of the product does not become excessive because of the intellectual property rights involved.”

Two managers from a large technology vendor explicitly confirmed that maximum royalty rates are usually agreed during licensing negotiations among companies to avoid royalty stacking specially in the case of patent pool licensing: “Our company usually pursues royalty rates agreements at around 8% of the total cost of the product, for instance a smartphone”.

A policy of limiting royalty rates accrued from the licensing of essential patents (i.e. maximum royalty rate mechanism) is considered beneficial especially at the collective level (Median $Q_{4_4}=4$) with less support at the firm level (Median $Q_{3_4}=3$).

Managers exhibit stronger valuations for maximum royalty rate mechanism both for their firms and the collective (5.45, 10.85) according to Table 4. On a similar manner, technology consumers exhibit larger odds of scoring maximum royalty rate as an important mechanism compared to technology producers (3.7, 4.05), clearly reflecting the beneficial effect of having a cap on the expected costs associated with acquiring the rights to have access to patent pools. All of the above indicate support for Hypothesis H1.c.

4.2. Collaborative innovation & competition

Table 5 reports summary statistics for the mayor variables considered in regards to competition, measured via questions Q1,Q2, Q5,Q6,Q7,Q9 and Q9’.

Table 5 Impact of mechanisms for competition in 3GPP (descriptive analysis)

	Variable	n	Quantile				
			Min	.25	Median	.75	Max
Essential patents (private)	Q1₁	87	3.00	3.00	4.00	4.00	5.00
	Q2₁	87	3.00	3.00	4.00	4.00	5.00
Essential patents (collective)	Q5₁	87	2.00	3.00	3.00	4.00	5.00
	Q6₁	87	1.00	3.00	3.00	4.00	5.00
	Q7₁	87	2.00	3.00	3.00	4.00	5.00

	Q1₂	87	3.00	4.00	4.00	5.00	5.00
FRAND (private)	Q1₃	87	2.00	3.00	4.00	4.00	5.00
	Q2₂	87	3.00	3.00	4.00	4.00	5.00
	Q2₃	87	2.00	3.00	3.00	4.00	5.00
	Q5₂	87	3.00	3.00	4.00	4.00	5.00
FRAND (collective)	Q5₃	87	1.00	3.00	4.00	4.00	5.00
	Q6₂	87	1.00	3.00	4.00	4.00	5.00
	Q6₃	87	1.00	3.00	4.00	4.00	5.00
	Q7₂	87	2.00	3.00	3.00	4.00	5.00
	Q7₃	87	2.00	3.00	3.00	4.00	5.00
	Q1₄	87	2.00	4.00	4.00	4.00	5.00
Maximum Royalty rate (private)	Q2₄	87	2.00	3.00	4.00	4.00	5.00
Maximum Royalty rate (collective)	Q5₄	87	2.00	3.00	4.00	4.00	5.00
	Q6₄	87	1.00	3.00	4.00	4.00	5.00
	Q7₄	87	1.00	3.00	3.00	4.00	5.00
3GPP and competition	Q9	87	2.00	3.00	4.00	4.00	5.00
	Q9'	87	3.00	3.00	4.00	4.00	5.00

4.2.1. Essential patents mechanism

Results of Table 5 indicate that, essential patents which are considered beneficial at the firm level (Median: Q1₁=4, Q2₁=4), are however, not perceived as beneficial at the collective level (Median: Q5₁=3, Q6₁=3, Q7₁=3). This latter result indicates some potential causality between the essential patent mechanism and the inability of 3GPP as a collective to compete against other technologies provided by the market.

In order to further investigate this phenomenon collected market information on essential patents, also specific questions during the interviews were formulated.

Our interview data analysis suggests reasons why this might be the case. A number of interviewees with relevant positions in 3GPP (technology delegates) pointed out that the process of defining which patent becomes essential is cumbersome and subject to large negotiation processes, "... this slows down the agreement process and causes 3GPP to stall in the definition of new technologies and products...", "...The process of defining what becomes an essential patent has worked incredibly well in some parts of the mobile ecosystem (radio technologies) however it is not as efficient in other parts in which markets are much more dynamic... as is the case in internet services or end customer applications a clear example is Skype, a non-3GPP technology that has prevailed over 3GPP-defined alternatives".

A prominent member of ETSI stated that an overarching problem with the actual process of essential patenting is the fact that firms are free to claim essentiality to their patents as they see fit thus leaving room for an ex-post interpretation of essentiality (and royalties involved) and in many cases to litigation in court. Current reality around patent litigation in the mobile industry confirms this situation (Economist 2011, 2012; FT 2012; Forbes 2012, 2013a).

An analysis of the distribution of essential patents within 3GPP reveals a high concentration of this kind of patent in large, technology intensive, multinationals, in detriment to others such as small firms or technology consumers such as telecom operators or smartphone manufacturers (see Table 6). Therefore it is reasonable to believe in the existence of some power asymmetries within 3GPP induced by the ownership, or lack of, essential patents as well as the process of negotiating ex-post what is considered "essential".

Table 6. Essential patent distribution in 3GPP (LTE technologies)

	4th generation mobile families declared	Patents considered essential	Percentage
Nokia	102	57	54.29
Qualcomm	26	8	7.62
Ericsson	24	14	13.33
Nortel Networks	17	7	6.67
Sony Corporation	12	8	7.62
Interdigital	11	2	1.90
TI	6	1	0.95
LG	4	3	2.86
Huawei	3	1	0.95
ETRI	2	1	0.95
Matsushita	1	1	0.95
NEC	1	1	0.95
Alcatel	1	0	0.00
DirecTV	1	1	0.95
Totals	210	105	

One interviewee recognized the inherent asymmetries in the essential patent mechanism: "if two large vendors own essential patents they exchange them and everyone is happy..... however patent

purchasers need to pay for access to patent portfolios.... and this is where you get the tension... Essential patents are not perfect but it is the best mechanism we have at the moment”.

Hence we obtain partial support of the essential patent mechanism as a competition enabler in private-collective contexts (H2.b). More specifically the results of this section suggest that, being essential patenting relevant for competition purposes, the processes as defined in 3GPP slow-down technology commercialization as well as induce ex-post subjective interpretation (and hence litigation).

4.2.2. FRAND mechanism

FRAND licensing, which becomes compulsory in the case of essential patents, is a measure to counter the power granted to the owner of an essential patent. In this sense FRAND is a competition enabler as it precludes monopolistic practises by forcing companies to grant licenses on a similar basis to every firm, moreover the obligation to license on a FRAND basis is extended not just to 3GPP members but also to every external firm. The obligation to broaden the FRAND scope to external parties constitutes an important feature to enact the concept of open patent pools, an important requisite in antitrust legislation.

The results presented in Table 5 reveal a strong support of FRAND as a relevant mechanism to facilitate competition both at the firm level (Median: $Q1_2=4$, $Q1_3=4$, $Q2_2=4$, $Q2_3=3$) and the collective one (Median: $Q5_2=4$, $Q5_3=4$, $Q6_2=4$, $Q6_3=4$). The above presented results thus provide support for FRAND as a mechanism that is relevant in facilitating competition in private-collective institutions (H2.a).

4.2.3. Maximum royalty rate

In regards to the impact of maximum royalty rate policies on competition, the results provide support for hypotheses H2.c, both at the firm and the collective level (Median $Q1_4=4$, $Q2_4=4$) and ($Q5_4=4$, $Q6_4=4$, $Q7_4=3$) respectively. This confirms maximum royalty rate policy as a beneficial instrument that facilitates competition in private-collective institutions.

5. Discussion

As with every empirical study, our analysis is subject to several data-related limitations. First, our results are obtained in one large, albeit specific, context (3GPP). Further research on private-collective as a model of innovation could test the results of this paper in other settings for instance the internet engineering task force (IETF) or the Apache software community.

The lack of sufficient responses from small firms limits the conclusions of this paper to multinationals, antitrust authorities and standardization agencies. In this regard, we would suggest future analysis on the ability of small firms to protect their innovations and compete in private-collectives dominated by large multinationals.

In regards to the instruments for the management of IPrights within the private-collective, this paper only considers three of them (i.e. FRAND, essential patenting and maximum royalty rate), there are however other important mechanisms required to reach consensus and avoid negotiation stalling that would deserve further analysis.

Market data (GSA 2013), the results of the survey and interviews conducted provide evidence on the ability of 3GPP to compete worldwide against technological alternatives. An unexpected insight emerging from two interviews is the existence of two clearly separated technological families within 3GPP, one corresponding to technologies associated with radio communications (termed as the “lower layer”) and other corresponding with internet services and mobile applications (“upper layer”). Engineers expressed some concerns on the adequacy of the 3GPP model of innovation in the upper layer as, according to them, the rapid technological pace in the case of internet services rendered 3GPP not agile enough to respond to the market. This apparent inability of 3GPP to compete in agile markets might have some relationship with the observed lack of small firms involved in 3GPP compared to other private-collectives such as the open source movement (von Hippel & von Krogh 2003, 2006 ; von Krogh et al. 2003) or Android (Tilson et al. 2012).

5.2 Implications for Management theory

This study contributes to the private collective literature as it is the first, to our knowledge, that explores empirically how the management of IP rights affects the ability of a private collective organization to both innovate and compete. We have found that the manner in which IP rights instruments are implemented in practice has a profound impact on shaping the process and the outcome of collective innovation in private collective organizations.

The literature on the management of IPrights has focused mostly on standard-setting organizations, and the majority of these studies focus on single mechanisms, which do not allow researchers to explore the interaction between these IP rights mechanisms. Our results reveal strong complementarity between FRAND, essentiality and royalty revenue structures. Moreover we have found that the manner in which these mechanisms are implemented in practice (i.e. before or after standard adoption takes place) have a profound impact on their effectiveness.

Previous research (Treacy & Lawrance 2008) has highlighted inherent weaknesses in the FRAND mechanism, focusing on its inherent ambiguity. The results of this paper however support FRAND as an effective mechanism in the way it is currently implemented in 3GPP. In this 3GPP case, participants concerns lie not in FRAND but in the ex-post interpretation of essentiality by licensees. This would reinforce the necessity of integrative perspectives in order to gain a complete understanding of current regimes for collaborative innovation (and their shortcomings).

Following Gulati (1998) the governance structure of the private-collective can be defined as the formal contractual structure participants use to formalize the partnership. Choices of governance structure are moderated by appropriability concerns (Pisano et al. 1988; Pisano 1989; Balakrishnan & Koza 1993) as well as coordination costs resulting from the extent of interdependence expected by the partners.

The results of our research confirm both appropriability and coordination costs as determinants in the choice of governance structure and the ability to innovate. In addition, we find that power

asymmetries due to firm's size or IP right ownership do also play a moderating role in how the governance structure is designed.

As far as the 3GPP is concerned, its governance structure could be assimilated to a contractual alliance whereby members of the partnering firms work together within their organizational boundaries (Gulati 1998). 3GPP facilitates unidirectional agreements such as licensing, second-sourcing, distribution agreements as well as bidirectional agreements such as joint contracts and technology exchanges.

Unlike conventional contractual alliances though, the 3GPP provides administrative hierarchies with rules and responsibilities for each member of the private-collective (e.g. FRAND regime for essential patents) thereby resembling a joint venture mechanism of innovation. In this case administrative hierarchy is provided via consensus-based processes for technology development and well defined (albeit not necessarily well enforced) policies for the management of intellectual property rights.

Our paper thus provides insights on the challenges arising in governance structures within federations of innovators which are also competitors, and inform related scholarly conversations on the importance and difficulty to formulate and implement governance structures that maintain incentives to innovate privately as well as collectively, in the face of technological and relational uncertainty.

The results of our study also hold implications for the various literatures that are addressing the issue of collective innovation. Task modularization (Sanchez 1995; Baldwin & Clark 2000), the pervasiveness of information and communication technologies, combined with the wide global distribution of skills and knowledge, are displacing the locus of innovation from within firms to networks of innovators (Baldwin & Von Hippel 2011; Chesbrough 2003). Beyond the literature on private collective models, literatures on technological platforms (Gawer & Cusumano 2002; Gawer & Henderson 2007; Gawer 2009, 2014; Boudreau 2010; Boudreau & Hagiu 2009; Eisenmann 2008; Eisenmann et al. 2011, Nambisan and Sawhney 2011; Tiwana et al. 2010), innovation ecosystems (Adner & Kapoor 2010), ecologies of innovation (Dougherty & Dunne 2011) and meta-organizations (Gulati et al. 2012), all examine the modalities of organization, management, and governance of network of innovators.

5.3 Implications for policy makers:

As revealed in the case of 3GPP some forms of private-collective can mitigate limitations of current regulation of intellectual property rights (e.g. patent system) and effectively articulate sustainable regimes for collective innovation. Antitrust authorities are acknowledging the important role played by private-collective modes of innovation in complex technological regimes by explicitly granting legal coverage (AMC 2007; Balto 2004).

The results of the interviews conducted and the survey support 3GPP as an institution that nurtures innovation (medians: Q8=4, Q8'=4) while allowing competition both within 3GPP and in external markets (medians: Q9=4, Q9'=4). 3GPP though, seems to have a tendency to impede technology differentiation from firms involved within the private-collective (medians: Q7₁₋₄=3). This phenomenon, which is inherent to any standardization process, whereby technological consensus is needed may force firms to compete just on price rather than on technological performance.

Therefore private-collective institutions need to establish a delicate balance between two extremes: complete ex-ante specification versus dynamic ex-post consensus building. Remaining on the first extreme would lead to lower innovation rates and competition based on price whereas the second extreme would lead to competition based on features (and increased litigation which, if excessive, might become counter-productive to innovation).

According to some of the experts interviewed, current regulation of the mobile industry can slow down the development of new technologies as, in contrast to the internet industry, mobile services are required to have extremely high levels of reliability. In this sense policy making could differentiate between critical technologies (e.g. radio access, antennae, basic communication services) and non-critical ones (e.g. mobile applications, multimedia services) in order to establish a tiered approach to mobile regulation.

The analysis of 3GPP reveals that small technological firms are practically absent in the development of mobile standards with only 30 small firms (out of 200 in total, 3GPP 2013) and no essential patents to negotiate with (Table 1). Recent results find an increasing role played by small parties in the resulting ability to innovate (Von Hippel & von Krogh 2003; Lakhani & von Hippel 2003, Lakhani et al. 2013; Boudreau 2012), further research could investigate why other instances of private-collective (e.g. software, internet, smartphone ecosystems) exhibit larger presence of small firms and if there exists any potential causality between the presence of small firms and the resulting innovation ability of the private-collective.

Related theory on standards and technology development supports the importance of the essentiality concept as a key mechanism to facilitate technical interoperability (and resulting economies of scale and scope). The results of our research, however present a more nuanced relationship between essential patenting and the resulting ability of the focal firm to innovate and compete. In the case of 3GPP essential patenting adequately helps firms to develop new technologies (hypothesis H1.b, section 4.1.1) on the other hand this mechanism seems to constrain the ability to compete, especially at the collective level (hypothesis H2.b, section 4.2.1).

The experience of 3GPP shows us that the manner in which IPrights policies are implemented in practice do have a profound effect on private-collective organizations. Contrary to FRAND licensing, which is completely specified and agreed prior to any technology commitment (i.e. standard development), the attribution of essentiality remains open to ex-post interpretation. Interestingly 3GPP does not mandate which patents become essential, as a result and according to a high level manager at 3GPP “almost every patent owner in 3GPP claim to have essential patents... the problem arises whenever a licensee does not agree on that essentiality status”. This would explain the increasing rates of litigation among firms in the mobile industry with prominent examples such as Samsung versus Ericsson (WSJ 2012; 2013), 3GPP participants, or Samsung versus Apple (Forbes 2012).

Litigation mechanisms, not necessarily indicative of a dysfunctional innovation regime, at present time are being over-abused specially by firms with no real involvement in technology development or commercialization. In this sense the 3GPP could, (1) adopt a more active role in the assertion of the essentiality aspect of patents in order to avoid ex-post interpretation by firms and (2) implement more efficient mechanisms to ensure transparency of patent ownership in the spirit of section 4 of the new innovation act (HR2013).

We have revealed that a practical solution to the limitations of current essential patenting has been found and implemented in the context of 3GPP: it consists in associating essential patenting policies to an ex-ante maximum royalty rate policy, which limits ex-post opportunistic behavior. This practical solution raises some concerns however, given the possibility of maximum royalty rate to be interpreted as anti-competitive by current antitrust regulation, and its traditional condemnation on both sides of the Atlantic in standard-setting processes (Schmalensee 2009).

We therefore raise the question of re-examining the potentially negative impact of antitrust regulation on collective innovation. The adoption of this practical solution, currently advocated by a number of firms involved in 3GPP (LTE 2008), would require modifications in antitrust regulation and a more flexible approach to public policing of collective innovation.

While the paper does not propose a definitive answer to his question, it contributes to the innovation policy debate on the reform of the patent system and antitrust regulation (AMC 2007; Wright 2009; Zoettl et al. 2009) especially in the mobile sector (Balto 2004), by providing empirically-based insights in favor of limiting the potentially negative impact of some aspects of competition policy on specific collective innovation challenges. This is a topical issue, as, in response to requests from relevant organizations (IEEE 2002) public bodies, especially in the USA, are starting to explore alternatives to conventional antitrust enforcement by suggesting among others an obligation on those firms submitting technologies to state the maximum royalty that will be sought in respect of any patents held (Barnett 2006, 2007; Masoudi 2007; Sidak 2008). In parallel, a number of firms in the mobile industry are leading initiatives aiming to supersede current limitations by explicitly suggesting maximum aggregate royalty levels for essential IPRs (e.g., single-digit percentage of sales price in the case of handsets and single-digit dollar amounts in the case of notebooks, LTE 2008).

The analysis presented in this paper, indicating that 3GPP members considered maximum royalty rate policies as beneficial, supports a more relaxed public policy in regards to maximum royalty rate negotiations and supports Schmalensee (2009) who suggests that, provided certain safeguards relating to the extent to which private-collective members can actually discuss the licensing terms are in place, it should be acceptable for standards bodies to solicit provision of maximum royalty rates when a patented technology is submitted.

Avenues for future research include further empirical studies and the development of game-theoretical models exploring the extent to which establishing predictable and more transparent maximum aggregate costs for licensing intellectual property rights might alleviate the problem of subjectivity in an ex-post interpretation of the essentiality concept either by firms (Wright 2009; Forbes 2012, 2013a, 2013b) or by governments overruling a court's decision (FT 2013).

6. Conclusions

The results of this paper extend existing theory on the private-collective model of innovation by characterizing how collective innovation takes place in current technological contexts, such as the Internet and mobile. As far as technology development and commercialization are concerned these technological contexts present two specific characteristics: (1) innovations involve a combination of many different components each of which may be the subject of one or more patents, (2) innovations can step on several patents, owned by different firms, at the same time. As a result the

management of intellectual property rights becomes a critical aspect in collective innovation contexts.

Earlier work on private-collective models of innovation (von Hippel & von Krogh 2006; Alexy & Reitzig 2013; Boudreau 2012) has not examined empirically the extent to which IP rights policy implementation affected members ability to innovate and to compete. Our study highlights the importance of three mechanisms: FRAND, essential patents and maximum royalty rate to overcome patent fragmentation and patent holdup.

In this sense this paper reveals a set of mechanisms whereby private-collective organizations effectively manage two trade-offs: (1) the conflicting interests between the private (i.e. firms) and the collective (e.g. standards setting and its adoption by the market) as a whole, and (2) conflicts of interest between collaborative innovation and antitrust authorities.

With regards to the first trade-off, essential patenting is a mechanism providing legal and technical context upon which private value capture and technological development can occur whereas compulsory FRAND licensing and maximum royalty rate policy as mechanisms required to ensure value creation at the collective level via cumulative innovation (Bessant 1998) and the development of patent pools (Lerner & Tirole 2002b).

With regards to the second trade-off, the limiting power of both FRAND compulsory licensing and maximum royalty rate policy lead to economic benefits and efficiency gains within the collective, moreover the fact that compulsory FRAND applies also to external firms constitutes an open patent pool system whereby non-affiliated firms can license technologies developed by the private-collective.

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Annex

Table 7. Survey instrument

Variable	Sub variables	Dimension measured	Unit of analysis	Values
Q1	Q1 ₁ ,Q1 ₂ ,Q1 ₃ ,Q1 ₄	Impact of each mechanism on the firm's ability to compete		
Q2	Q2 ₁ ,Q2 ₂ ,Q2 ₃ ,Q2 ₄	Impact of each mechanism on the firm's ability to protect their innovations		

Q3	Q3 ₁ ,Q3 ₂ ,Q3 ₃ ,Q3 ₄	Impact of each mechanism on the firm's ability to diffuse their innovations	Private	5-point likert scale (strongly disagree-strongly agree)
Q4	Q4 ₁ ,Q4 ₂ ,Q4 ₃ ,Q4 ₄	Impact of each mechanism on the ability of the collective as a whole to solve important technical problems?	Collective	
Q5	Q5 ₁ ,Q5 ₂ ,Q5 ₃ ,Q5 ₄	Impact of each mechanism on the ability of the collective as a whole to collectively create new markets		
Q6	Q6 ₁ ,Q6 ₂ ,Q6 ₃ ,Q6 ₄	Impact of each mechanism on the ability of the collective as a whole to protect internal innovations from infringement or unfair competition		
Q7	Q7 ₁ ,Q7 ₂ ,Q7 ₃ ,Q7 ₄	Impact of each mechanism on the ability of the collective as a whole to facilitate different technology offerings from competing firms?		
Q8		Does 3GPP stimulate innovation and technology development in the mobile industry.		
Q8'		Does 3GPP help firms to innovate and develop technologies in the mobile market ?		
Q9		Does 3GPP stimulate competition in the mobile market ?		
Q9'		Does 3GPP help my firm to compete in the mobile market ?		
Group		Firm's strategic positioning (technology producer, technology consumer)		
Role		Respondent's role in the company (technical versus managerial)		(0,1)
Layer		Respondent's experience in 3GPP (lower layer, upper layer, both)	(0,1,2)	