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The Relationship Between Open Source Software and Standard Setting

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THE RELATIONSHIP BETWEEN OPEN SOURCE SOFTWARE AND STANDARD SETTING

TABLE OF CONTENTS

Contents

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ABSTRACT / FOREWORD / EXECUTIVE SUMMARY

Abstract

Standards and open source development are both processes widely adopted in the ICT industry to develop innovative technologies and drive their adoption in the market. Innovators and policy makers assume that a closer collaboration between standards and open source software development would be mutually beneficial. The interaction between the two is however not yet fully understood, especially with regard to how the intellectual property regimes applied by these organisations influence their ability and motivation to cooperate. This study provides a comprehensive analysis of the interaction between standard development organisations (SDOs) and open source software (OSS) communities. The analysis is based on 20 case studies, a survey of stakeholders involved in SDOs and OSS communities, an expert workshop, and a comprehensive review of the literature. In the analysis, we differentiate according to the governance of SDOs and OSS communities, but also considering the involved stakeholders and subject matter. We discuss the preconditions, forms and impacts of collaboration, before we eventually focus on the complementarity of the different Intellectual Property Right (IPR) regimes. Finally, we derive policy recommendations addressing SDOs, OSS communities and policy makers.

Foreword

This report has been initiated by the Digital Economy Unit of the European Commission Joint Research Centre (JRC). It was prepared in the context of the three-year research project on Research on Innovation, Start-up Europe and Standardisation (RISES), jointly launched in 2017 by JRC and DG CONNECT of the European Commission. The report was developed in the framework of the 2017 Communication of the European Commission 'Setting out the EU approach to Standard Essential Patents' (COM(2017) 712 final). This research builds on the previous work and expertise of the JRC gathered in the field of standardisation and intellectual property rights, namely the JRC reports:

- 2015 'Fair, Reasonable and Non-Discriminatory (FRAND) Licensing Terms; Research Analysis of a Controversial Concept' EUR 27333 EN.
- 2015, 'Intellectual Property and Innovation in Information and Communication Technology (ICT)' EUR 27549 EN.
- 2016 'Patent Assertion Entities in Europe; Their impact on innovation and knowledge transfer in ICT markets' EUR 28145 EN.
- 2017 'Licensing Terms of Standard Essential Patents; A comprehensive Analysis of Cases' EUR 28302 EN.
- 2019 'Making the rules. The Governance of Standard Development Organizations and their Policies on Intellectual Property Rights' EUR 29655 EN.

Executive Summary

Policy context

In the Communication of the European Commission "Setting out the EU approach to Standard Essential Patents", the Commission announced to fund a study to analyse complementarities, ways of interacting and differences between open source and standardisation processes and to recommend solutions for smooth collaboration between standardisation and open source communities. The Report "The Relationship Between Open Source Software and Standard Setting" aims at gaining a deeper understanding of the motivators and inhibitors of a closer collaboration between standards development organisations (SDOs) and open source software (OSS) communities. This report completes a series of JRC studies in the field of standardisation and intellectual property rights released in the last years.

Our report first reviews the existing literature focusing on the interface between OSS and standardisation (chapter 2) and continues to outline the results of 20 case studies focusing on the interaction between OSS and standards development (chapter 3) as well as the analysis of a stakeholder workshop and survey (chapter 4). The insights from the literature review, the case studies and the stakeholder survey have been used as input for a comprehensive analysis (chapter 5). We finally provide our recommendations.

Methodology

A comprehensive review of the scientific literature as well as publications by SDOs, OSS communities and governments, focusing on the general interface between OSS and standardisation in general and their licensing schemes in particular, revealed only a limited number of relevant publications and studies. However, the insights from the literature combined with suggestions from a steering committee served as guidance for the case study research design. The steering committee, including seven members, was set up with the aim to assure a balanced view with contributions from representatives from OSS, patenting industry participating in formal standardisation processes, and SDOs. The committee had the opportunity to comment on all parts of the study throughout the project. A series of preparatory interviews to the case studies has been performed to which organisations and individuals were openly invited to participate. Interviewees included representatives of European and international SDOs and major open source communities, standardisation consortia, umbrella organisations and Standard Essential Patent (SEP) rights holders. Twenty case studies have been selected so that they exhibit a relevant connection between standards and open source development based on an existing collaboration or interaction with a preference to collaborations that excel in essential community metrics, especially the number of participating entities and the amount of contributions raised, and a significant market impact. The case studies include major research and development collaborations that shaped the ICT sector in recent years, for example in the areas of cloud computing, programming languages or operating systems. A workshop with more than 50 experts representing all relevant stakeholder groups provided additional input to the further steps of the study. Following the workshop, a comprehensive online questionnaire was developed that builds upon literature, the results from the case studies and suggestions from the steering committee. The questionnaire contained questions about participating organisation's characteristics, including their intellectual property management, their activities in both standardisation and open source communities, and eventually the usage of licences and experienced conflicts. The stakeholder survey has been broadly distributed both among SDOs and OSS communities confirmed by more than 300 respondents answering at least parts of the questionnaire. The mix of empirical methods delivers a comprehensive picture of the interaction between SDOs and OSS communities in general and OSS and FRAND licensing related to certain fields of standardisation.

Key Findings

1. *Governance*

We find that **the role of governance is perceived very differently between SDOs and OSS communities.** Governance of SDOs develops – at least in Europe – primarily within the constraints of the legal framework of the European Union, the relationships within the integrated network of SDOs and the competition between them. OSS community governance refers to the coordination of individuals, corporates and organisations within an OSS development project to which they jointly and voluntarily contribute.

Moreover, the leadership of SDOs is more formally established and in a position to manage and implement the goals of the organisation and of policy makers, whereas leadership in an OSS community is more fluent and acts in a facilitating role since the community relies on voluntary participation.

Finally, the recognised status of SDOs enables them to make and implement decisions that an important minority may not agree with. In general, actors do not have the opportunity to realise a "fork", i.e. making a copy of an open source project and continues to develop it separately. In OSS communities, however, relevance depends on the ability of the community to represent the consensus of a critical mass of contributors in terms of both technical direction and governance norms. The case studies highlight that participants experience this as a strength of OSS communities, because it prevents the organisation from developing own interests that possibly diverge from the contributor interests.

However, formalized decision making in SDOs provides stability and acceptance, for example in the interaction with policy makers or anti-trust authorities. Voting rules and election processes differ strongly both between SDOs as well as between different OSS communities. We find that there are many commonalities, like the voluntariness of contributions, in the self-organisation, approaches to governance and culture between the OSS and standards development communities.

The comparison of key aspects of governance between SDO and OSS communities, however, also shows that as of now, significant differences exist that need to be bridged to achieve efficient collaboration. One key issue is that OSS communities as well as most SDOs cannot be directed to collaborate and also cannot direct their participants to do so. This currently acts as a barrier to collaboration, since most attempts apply a top-down approach. It is, however, also an enforcing corrective to make sure that collaboration only emerges where its benefit is apparently clear and convincing.

2. *Stakeholders*

The case studies and the survey reveal a large overlap of stakeholders involved both in standardisation and OSS.

The incentives to join standardisation activities and OSS development are quite similar but generally rated higher for OSS among the respondents of the stakeholder survey. For them, only the inclusion of own Intellectual Property Rights (IPR) is slightly more relevant for the participation in standardisation than for joining OSS. In addition, standards are obviously a more effective approach to specify regulations, in particular in the European Union in the context of a Council Resolution on the New Approach to technical harmonisation and standards in the internal market and meanwhile the New Legislative Framework.

The largest differences can be found for the incentive of lower and pooled cost for R&D and shorter development times which are found to be important drivers for joining OSS communities. In addition, the personal interest is assessed to be more relevant for the involvement in OSS. However, in addition to finding technical solutions, for the respondents of the stakeholder survey the free use of code under an open source licence, which is also connected to a positive return of investment in R&D, is more important for an involvement in OSS than the royalty free use of standards.

In summary, the analysis of the stakeholders involved in standardisation and OSS reveals some interesting complementarities. **In SDOs we find heterogeneous stakeholders with an overrepresentation of larger and patenting companies. Despite the very visible involvement of large multinational enterprises, OSS communities are also characterised by smaller companies without patents and by independent software developers.** SDO processes engage a broadly defined set of stakeholders. They are also integrated with industry and policy making,

in particular formal SDOs in Europe. In general, OSS communities mostly involve enterprises, other organisations and individual software developers without a systematic multi-stakeholder engagement. **There is a strong overlap of participants in standards and open source development especially for large enterprises.** Overall, most OSS processes are focused on the contribution of code and currently less accessible to policy makers. Therefore, it is difficult to influence OSS communities according to industrial and innovation policy goals.

3. *Areas and scale of collaboration*

Both in SDOs and OSS communities, collaborations exist that span hundreds or thousands of participants and produce complex, marketable outputs. They act as platforms for collaboration and consensus building as well as industry and personal networks.

SDOs and OSS communities complement each other and compete for relevance at the same time, but for different aspects of the functions they provide. They complement each other in the results they produce (specifications versus implementations). Both are challenged in handling large-scale ground-breaking research that requires significant upfront investments, like the development of pharmaceuticals or mobile communication protocols.

With the exception of international SDOs, like IEC, ISO and ITU and others, neither SDOs nor the wider open source community have developed truly global collaboration yet, even though benefits would be maximized by the widest possible adoption of a standard. Market actors pragmatically choose combinations of OSS with proprietary hardware and software. Today, such combinations are the norm and seen as the working model of most industrial OSS consortia, like the projects hosted by the Linux Foundation or the Eclipse Foundation. Technology areas with high cost of change as well as competitive, differentiating product features are favouring open source development models less. Voluntary participation also means that contributors are unlikely to choose such areas for their OSS development work.

The viability of collaboration between SDOs and OSS communities is influenced by the following three layers of interaction, i.e. cultural fit, governance models and legal framework in that collaboration has to be possible and to be preferable over working separately. Since neither side can instruct the other, collaboration probably needs to be envisioned as an integrated cyclic process with feedback loops between specification and implementation, and shared responsibility for both aspects between all participants.

Three archetypical scenarios, specification-first, implementation-first and parallel standardisation can be observed in the case studies. The specification-first approach declines in relative relevance but is still important in specification-driven technology areas. Some cases transitioned from a traditional specification-first to a parallel approach as the necessary collaboration methods became available. Especially the parallel approach to standardisation represents some of the successful interactions between standards and OSS development, e.g. due to the higher transparency, and can result in higher quality standards, more innovativeness and better implementations based on the insights from the case studies and the responses of the stakeholder survey.

Where SDOs and OSS communities' processes are combined, the processes and governance in the working groups and communities often converge. This may lead to parallel OSS development processes that incubate new features combined with standardisation processes to establish consensus, as well as a choice for participants of two alternative platforms for collaboration and consensus-building. It appears that a well-working relationship develops if standards developers and OSS implementers largely overlap and many entities potentially contribute to the development process. Where there is no such overlap or in situations where there is a strong concentration of few suppliers in the market, no cooperation develops, and the majority of market participants are merely (commercial) consumers of technology with no participation in standards development.

From the perspective of participants **in SDOs, the interaction with OSS communities is mutually beneficial and serves their interests in a specific technical area.** The OSS contributors help to incubate the developed technology and to test the specification, which supports maintaining high quality in standards. The partner OSS community often creates the first or only reference implementation, which might become the de-facto standard implementation later in the process.

Interaction with the OSS community also inspires the modernisation of SDO processes, e.g. through the adoption of new collaboration methods and platforms and increased transparency of decision making. Since experts in the specific market segments are rare, there is a noticeable overlap between the individuals involved in standards development and OSS implementation.

The SDO and OSS communities describe their mutual interaction as fruitful and productive. The collaboration and consensus building processes encourage the stability of specifications that would otherwise change quickly and cause interoperability issues. **OSS implementations sometimes overshoot the functionality specified in the standards based on the faster pace of development.** This may cause a shift in the scope of the technical development. In such cases, SDOs may be slower to update working group mandates and charters compared to the self-selection processes in OSS development.

There is no indication that the market pulls towards a situation where only open source solutions are used.

4. *The evolving role of standards*

Some of the larger collaborative projects do not consider the creation of multiple, standards-compliant implementations as useful, since they prefer all potential investments to be combined into a single project. While standards help achieve interoperability of proprietary products that do not share an implementation, **OSS users tend to choose a joint implementation for that purpose.** In such a scenario, the best interoperability can be achieved by reducing the number of implementations, ideally to one. Based on that, some cases explicitly exclude participating in standards development from their organisations remit.

The wider adoption of implementation-first and parallel approaches to standardisation influences the utility of specifications relative to the value of joint implementations. Where standards used to be considered necessary to achieve interoperability, at least the OSS development process now offers an alternative to achieving it. This changes the role of standards themselves as standards and OSS development are becoming alternatives in achieving market diffusion for a technology. Actors now have a choice regarding which process they consider more suitable to their business needs. OSS changes the landscape for managing innovation by immediately providing an implementation for newly developed solutions, eliminating the gap between invention and the availability of implementing products which used to be bridged by developing a standard. OSS provides innovative state of the art technology that at the same time is a commodity, which have traditionally been considered opposites.

Freedom to operate is a key precondition for contributors to participate in the development process. Confidence in access to the implemented functionality, e.g. through patent grants in OSS licences or contributor IPR policies, are considered necessary for a fast-paced development process. This confidence reduces investment risks and is expected to be achieved at the beginning of collaboration. The ex-ante acquisition of all required IPR from the contributors and the absence of later negotiation are key advantages of the OSS development process.

The combination of SDO and OSS processes may, however, lead to trade-offs, especially to a slower pace of development and lower innovativeness caused by the overhead of coordination, while especially in areas of high technical complexity, detailed specification in standards and working OSS implementation may support each other and lead to both higher quality standards and better code.

Even in an open source development collaboration, participants are uncomfortable with the possibility that other actors may use the OSS product, including their contributions, to create competing products. While permissive licences like the MIT licence do not provide any protection against such scenarios, reciprocal licensing terms have been mentioned repeatedly as a viable IPR regime that protects contributors from future competition based on their own investments. The risk of competitors creating commercial, proprietary derivative work is a relevant concern to those participants. An IPR regime based on reciprocal licences like the GPL is considered sufficient protection by those participants.

All three approaches, i.e. standards as input into OSS, OSS as input into standardisation and parallel development in addition to the general interconnectedness of standard development and OSS activities, are used based on the

assessment of respondents to the stakeholder survey. However, standards development and OSS activities are relatively much more interconnected for smaller organisations, which much more often transfer OSS as input into standardisation, whereas this transfer and even the parallel development is not so common for larger organisations. According to the responses from the survey to the question on the likelihood of the interconnection between standards development and open source activities, **small organisations contribute relative to their size much more to the integration of OSS and standardisation than large organisations**.

Comparing all the assessments about the interconnection on efficiency and results, it becomes obvious that **smaller organisations perceive knowledge flows from OSS to SDOs as providing the latter with new ideas as inputs for technical solutions. Larger organisations see advantages for SDOs from OSS in the implementation of technical solutions.** In contrast, smaller organisations experience positive impacts of standardisation on OSS on the validation and diffusion of technical solutions. There exists a complementarity of effects, which is explained by the size of the organisations.

5. *IPR regimes in OSS and SDOs*

An effective interaction of SEP licensing and open source software requires legal compatibility of open source licences with FRAND licensing of SEP, which is a key component for example of ETSI's standardisation activities in the area of mobile communication technologies. This is one important dimension of the interaction, since any directly contradicting terms in a specific combination of open source and FRAND licence would prohibit a combination of the two works in a product. However, **legal compatibility is a necessary, but not a sufficient condition for possible collaborations of SDOs and OSS. IPR regimes serve partially different purposes in SDOs compared to OSS communities.** OSS licences mirror and follow collaboration models and represent how participants envision the jointly created products to be used, resulting in the strong-copyleft, weak-copyleft and permissive classes of OSS licences. The governance within open source communities develops as a collaboration model first and is reinforced through a choice of licence, whereas IPR frameworks at SDOs regulate how participants engage and how conflicts are resolved. In both cases, the founders get together and agree on their mode of governance and IPR rules. Special attention is given to how participants may later exit the pre-competitive cooperation at SDOs and compete again on products that implement the developed standard.

Most commonly, participants adjust to the collaboration methods and IPR policies employed by the communities they engage with, entering into a trade-off between contributing own IPR in return for getting access to the aggregate contributions by the other participants. For activities at the boundary of standards and OSS development, this typically involves adopting a royalty-free patent licensing policy while being aware of the option of agreeing to various additional side conditions. This expectation of royalty-free licensing is considered acceptable and not to be a barrier to collaboration or to the development of relevant standards. Multiple parties mentioned as a precondition for this model to work well that all participants invest goodwill into making the collaboration work and are open and transparent about their intentions.

Only a smaller number of OSS licences are relevant in recent practice. The Apache License 2.0, the MIT License and the GNU General Public License (GPL 2.0) are quite popular followed by GNU General Public License 3.0 and the BSD License 2.0. In addition to the significant differences between the general attractiveness of the various OSS licensing models, there are discrepancies between larger and smaller organisations. The latter have much stronger preferences for both the GNU General Public License 3.0 and the GNU Lesser General Public License (LGPL) 3.0, whereas the former are inclined to the MIT License and the various versions of the BSD Licenses. In general, licence choices in communities follow the envisioned collaboration model of the contributors. More recent projects more often opt for licences with explicit, as in the Apache License 2.0 or the GNU General Public License 3.0 as opposed to implicit or absent patent licensing terms.

Regarding the existence of conflicts between the various copyright licences and the licensing models in standardisation, in particular FRAND, **both the GNU General Public Licenses GPL 2.0 and 3.0 and the GNU Lesser General Public License LGPL 2.1 and 3.0 are mentioned by the majority of the stakeholders.** For the BSD Licenses only one third report conflicts. Overall, small organisations report fewer conflicts. In the successful case studies, even if incompatibilities between OSS licences and SDO IPR frameworks may

theoretically exist, the participants always resolved these issues or worked around them driven by the common interest in the collaborative development of a standardised technology. **Licensing incompatibilities have not been observed as a practically relevant problem in the investigated cases.**

In case of conflicts, the strict separation between OSS and FRAND licensing is still the preferred option followed by negotiations to find solutions supported by the experiences reported in the case studies. If no solutions are found, in particular small organisations withdraw from standardisation. Another less popular option is the use of copyright-only licences explicitly excluding patent licence rights, which are negotiated separately.

Whereas there seem to be no convincing constructive solutions for conflicts between OSS and licensing models in standardisation in general, some approaches of collaboration between standardisation and OSS are more promising, in particular in the perspective of smaller organisations. First, the stakeholders ask for more tractable SDO patent policies. Secondly, new processes to integrate OSS in standardisation are suggested. Thirdly, not only more tractable patent policies are asked for, but some stakeholders even suggested that SDOs should explicitly offer a royalty free option. Below medium, but above low effectiveness we find new governance and conflict solution models, the use of copyright-only OSS licences explicitly excluding patent licence rights and finally a direct combination of SDOs and OSS communities. Finally, OSS licences should not include FRAND-based patent grants and definitions of OSS should not be more flexible, because both options are perceived by the stakeholders as being not very effective. Interestingly, larger organisations perceive these options as much more effective than smaller organisations.

Recommendations

We have structured our recommendations into three sections addressing SDOs, OSS communities and policy makers in general, but also the European Commission in particular.

Recommendations addressing SDOs

In principle, these recommendations address all SDOs, acknowledging however that individual SDOs have already implemented some of them or are currently addressing them.

1. **We recommend SDOs to consider addressing software and OSS explicitly within their IPR policies** in order to adequately handle the peculiarities of software in general and OSS in particular.

2. The elaboration of **more comprehensive IPR policies including software and OSS** requires a better coordination between SDOs and the consideration of the views of public authorities and other stakeholders.

3. Some SDOs depend on selling access to standards. The inclusion of OSS in standards might have an impact on SDOs' financing models. **We recommend these SDOs to consider this trend and to reduce their dependencies on revenues from selling standards.** This has been realised by some SDOs that apply open access solutions already or practice a closer collaboration with OSS communities.

4. Stakeholders and policy makers have complained about the limited speed of standardisation processes at SDOs. **We recommend a closer collaboration with OSS communities, because it might support SDOs in efforts to speed up the processes and to increase the agility of standards development.**

5. Small organisations, in particular SMEs, face problems in actively contributing to standardisation processes at SDOs. **We recommend SDOs to integrate in particular SMEs active in the software sector more effectively in their standardisation processes by closer collaboration with OSS communities.**

Recommendations addressing OSS communities

6. Despite existing attempts to define open source independently, **we recommend keeping and strengthening the existing Open Source Definition.** The definition is broadly supported by the OSS community as well as the overwhelming majority of industry actors and therefore the basis for possible collaboration between them and SDOs.

7. **Larger OSS communities should consider in engaging in the development of future strategies according to WTO standardisation principles**, which includes openness, consensus and transparency, because SDOs that develop standards must meet these governance requirements. In addition, standards that include software specifications may be referenced in legislation. Consequently, OSS communities have a choice to produce the specifications themselves or to collaborate with SDOs. We encourage OSS communities to collaborate with SDOs to benefit from their reach, brand, and network for that purpose.

8. Attempts to combine elements of OSS licences with conditions for FRAND licensing of SEP are in general of limited success. **We recommend both OSS communities and stakeholders active in SDOs to continue developing new models of collaboration and to test them in the market**. Innovative approaches may either be successful or provide new impulses to improve existing SDO and OSS processes. Market actors will indicate the usefulness of these new approaches by way of their decisions to participate.

Recommendations addressing policy makers

Since there is a general justification for public authorities to support both standards and OSS development, there are good reasons to improve the interface between SDOs and OSS. In general, the involvement of governments in markets should be justified by market or system failures.

9. Standardisation is utilised as a channel of knowledge and technology transfer for publicly funded research, development and innovation projects. **We recommend policy makers in the Member States and the European Commission in particular to promote OSS in addition to standardisation as a further channel of knowledge and technology transfer**. In this context, **the interface between OSS and standardisation must be defined and elaborated further as a parallel and complementary transfer channel** to exploit possible synergies and minimize redundancies and conflicts.

10. The current regulatory frameworks both related to copyright and patents neither reflect the relevance of standards nor software as such and OSS in particular. **Policy should consider OSS and standards in future revisions of European copyright and patent legislation.**

11. Public procurement as an important demand-side innovation policy is already recurring on standards, but in official policy documents rarely on OSS despite the already existing option to reference OSS in public procurement. **We recommend the explicit inclusion of OSS in public procurement policies, e.g. in updating the public procurement directives or the public procurement strategy. Equally, we recommend investigating the interrelation between standards and OSS in public procurement.**

12. The involvement of SMEs in SDOs is still limited. **Policy makers, in particular in Member States, should further promote SMEs' involvement both in SDOs and OSS communities within EU and national SME policies.**

13. SDOs and OSS engage in a healthy competition from the process perspective. **We recommend the European Commission to create a level playing field between SDOs and OSS communities** to foster innovation. This requires creating exchanges between the evolutionary selection process in OSS communities and the formalization within SDOs, but also may add additional obligations, like working with multi-stakeholder platforms or adherence to minimal standards for governance norms.

14. Policy makers have provided substantive guidance on the legal boundaries and requirements applicable to the substance of IPR policy choices of SDOs with the safe harbour approach defined in the guidelines to horizontal co-operation agreements. No such guidance exists with regard to OSS communities. **We recommend developing specific requirements for horizontal co-operation that apply to both SDOs and OSS communities and their collaboration.**

15. SDOs are already well-integrated into the European research and policy making frameworks, while for OSS communities such integration is still at the beginning. **We recommend integrating OSS communities into the European research and policy making frameworks where justified by their generation of positive externalities in the European Union.**

16. Today, OSS runs a large part of the technical infrastructure of an information and knowledge driven society. OSS should be considered as an infrastructure of the information age of similar importance to highways and bridges. It is worth investigating the benefit of public medium-to-long term investments into OSS infrastructure that supports European Union policy goals. **We recommend further evaluating policy options for the European Union to contribute directly to OSS.** This may require changing the regulatory framework or establishing European OSS development organisations either next to or integrated with existing European SDOs.

1 INTRODUCTION

1 | Introduction

With the generally accepted notion that innovation is essential for European welfare and economic growth, policies that aim to foster innovation have become a focal point of activity for policy makers for the last decades. Research and experience suggest that in order to obtain successful innovations – meaning innovations that are used in the markets – respective policies need to address more than just the funding of research and development (R&D), which has been traditionally at the heart of innovation and R&D policy. In this context, the interplay of different policies and herein the collaboration between the main institutions implementing these policies has grown in importance. The right "configuration" of these fields in relation to each other – which includes R&D funding, tax schemes, public (innovative) procurement, regulation, Intellectual Property Rights (IPR), technology transfer, open source software and standardisation – can be seen as key to success for an overall innovation (as well as industrial) policy.

This applies particularly to the two fields under investigation in this study, open source software and standardisation. The IPR system – comprised of the four main instruments of patents, trademarks, copyrights and designs – aims to foster innovation by providing time-limited monopoly rights for innovators to recuperate investments made into R&D. In the past, IPR has been a field of activity largely for lawyers and patent agents, mostly unconnected to other actors of innovation systems. However, broader usages of IPR than mere protection for the purpose of insuring against unlawful copying – e.g., for funding by venture capital firms, for directly generating licensing revenues, for allowing collaboration on joint R&D projects, for enabling new business models – have propelled a need for IP to become a topic to be dealt with in more strategic ways (e.g. Blind et al. 2006 for patents and Block et al. 2015 for trademarks). This also implies the integration of IP into other policy fields.

Framing of the study

In the context of current advances in technology, open source software (OSS) implementation is, in addition to standards, also driving innovation, and is becoming increasingly widespread, including in the area of ICT standards. Integration between open source projects and standards development processes is a win-win situation: on one side the alignment of open source and standardisation can speed-up the standards development process and the take-up of ICT standards (especially for SMEs) and on the other side standards can provide for interoperability of open source software implementations. Activities in this direction are taking place within different SDO.

Open source and standardisation processes both have similarities in common (e.g. collaborative open processes, contribution to innovation) and differences (IPR policies, agility, maintenance, transparency, balance of the processes etc.). There is therefore a need to pay attention to the interaction between open source community projects and SDOs processes.

The Commission supports open source solutions, i.e. through R&I projects funded under Horizon 2020. Flexible and effective interactions between standardisation and open source communities will promote and accelerate the uptake of advanced technology developments.

The Commission will continue to collaborate with stakeholders, open source communities and SDOs to promote an effective relationship between standardisation and open source. It will also fund studies to analyse complementarities, ways of interacting and differences between the two processes, and recommend solutions for smooth collaboration between the two communities.

Source: European Commission 2017.

Similarly, standards have seen a surge in relevance for innovation over the past years. They can support innovation by codifying and spreading the state-of-the-art in various areas, as well as by bridging the gap between research and end-products and services (Blind and Gauch 2009). In principle, information codified in standards is accessible to everybody, and so the different actors of the innovation systems can use this knowledge to adopt innovations or generate new ideas (e.g. small and medium-sized enterprises (SMEs) make obviously use of this source Blind and Mangelsdorf 2013, 2016). Another important benefit is in allowing for interoperability, an issue when products and processes supplied by various providers must interact with each other. This is especially relevant for the ICT industries (Blind et al. 2010). In such cases, standards allow for mutual compatibility between and among the interacting products and processes.

The intersection of IPR and standards occurs particularly in case a standard depends, for its functioning, to draw on several pieces of IP-protected inventions and works, such as different patented technologies (with the patents then being so-called standard-essential patents (SEPs)) or copyrighted pieces of software including open source software (OSS). Numerous challenges arise. In the case of patents, some of the challenges are the identification and selection of patented technologies relevant for standards, the adequate reimbursement of the IP holders and the maintenance of the standards due to technological dynamics, but also due to changes in the ownership of patents. A well-functioning interaction can generate large economic benefits for the owners (e.g. Pohlmann et al. 2016), but also societal impacts by providing access to digital technologies. A dysfunctional relationship can in the short run generate litigation costs both for patent owners and standards implementers, but also disincentives related to investments in research and innovation and contribution to standardisation processes. Therefore, the need to look at this intersection from a policy perspective has been agreed upon since at least a decade, however there is no agreement as of yet about the solutions to deal effectively with the challenges raised in order to maximize the benefits for innovators and for society as whole.

European policy has taken up the issue of interplay of standards and IP in several ways. At the highest level, in the Europe 2020 Strategy released 2010 (EC 2010), the flagship initiative "Innovation Union" aims to re-focus R&D and innovation policy on societal challenges. Understanding innovation as a complex phenomenon that requires the interplay of several until now more isolated policy fields, the strategy also aims to improve framework conditions for businesses to innovate. In this context, IPR and standards-related initiatives are explicitly mentioned. In addition to Europe 2020, the Investment Plan (EC 2014a) is also to be considered. Reacting to weak investment climate, the Investment Plan intends to remove obstacles to investment, to provide visibility and technical assistance to investment projects and to make smarter use of new and existing financial resources. The starting point of the plan is to improve the investment environment in the EU by fostering the predictability and quality of regulation and removing regulatory barriers in key sectors acknowledging the impact of regulation on innovation (Blind 2012, 2016).

Definition of standardisation, standards and technical specifications

Standardisation can take different forms, ranging from the adoption of consensus based standards by the recognised European or national standards bodies, through consortia and fora, to agreements between independent companies. We call all these organisations Standard Development Organisations (SDOs), but the recognised bodies formal SDOs.

Standard means a technical specification, adopted by a recognised standardisation body, for repeated or continuous application, with which compliance is not compulsory.

Technical specification means a document that prescribes technical requirements to be fulfilled by a product, process, service or system.

Source: European Commission 2011d. European Commission 2012.

In parallel, the Joint Initiative on Standardisation (JIS) adopted in 2016 aims to modernise the way standards are developed in Europe. It specifically focuses on promoting faster standards development, closing the gap between research priorities and European standardisation, clearer prioritization, and a stronger international presence.

More specifically and in relation to ICT, standardisation has a crucial role to play in increasing interoperability of new technologies within the Digital Single Market Strategy (EC 2015). The development of new technologies such as 5G wireless communications, digitalisation of manufacturing (Industry 4.0) and construction processes, data-driven and cloud-based services, cybersecurity, eHealth, e-transport and mobile payments are listed as examples and in general confirmed in the communication on ICT Standardisation Priorities for the Digital Single Market (EC 2016a).

Particularly in the context of ICT technologies, a strategic approach is needed according to the EC (EC 2016a). This is because

— There is a need to ensure that standardisation output, but also the stock of standards, keeps pace with the development of new technologies.
— There is a challenge for Europe, since standards development is increasingly taking place outside of Europe, threatening European companies' innovativeness and competitiveness.
— In this context, the fact that standardisation is driven "bottom-up" by industry players must be accounted for (i.e., the activity of industry-driven ICT fora and consortia) – whereas the implications for the citizens of the EU have to be considered, too.
— SEPs in particular have become an increasingly relevant feature in standardisation in the area of digital communication with increasing implications for the traditional manufacturing sectors (e.g. via Internet of Things or Industry 4.0) and crucial for the business models of research-focused companies and organisations.
— Finally, the increasing relevance of OSS calls for more use of open source elements by better integrating open source communities into SDOs' standard setting processes endorsed by the recent communication of the European Commission (EC 2017) on SEPs.

One important specific strategic response at the European level is the establishment of the EU Rolling Plan for ICT Standardisation. According to the 2017 edition of the Rolling Plan, the European Commission, with the Rolling Plan and in collaboration with a multi-stakeholder platform (MSP), "...provides a unique bridge between EU policies and standardisation activities in the field of information and communication technologies (ICT) and thus, it allows for increased convergence of the efforts of standardisation makers towards European policy goals in the ICT domain" (EC 2016a). Whereas as far as SEPs are concerned, the European Commission addresses in its Digital Single Market Strategy (EC 2015) and the recent communication on SEPs (EC 2017) the need for a framework to balance the interests between right holders and implementers of SEPs. In the 2018 edition of the Rolling Plan, patents are not mentioned any more. In contrast, the relationship to OSS was not yet mentioned in 2015, but only the "use of open source elements by better integrating open source communities into SDOs' standard setting processes" (EC 2016b). However, this communication concludes with the objective that "the Commission will work with stakeholders, open source communities and SDOs for successful interaction between open source and standardisation, by means of studies and analyses" (EC 2017, p. 13). The 2018 edition of the Rolling Plan announced that the European Commission in collaboration with SDOs and OSS organisations launched an action to analyse the impact of open source in the cloud standardisation process (EC 2018). As further action in this area, activities are foreseen to strengthen the interlock between standardisation and OSS in the area of Cloud and establish and support bilateral actions for close collaboration of open source and standardisation. Besides the area of cloud, the standardisation related to blockchain should be closer coordinated with open source projects in this area. In the past, robot operating systems have been developed and maintained as OSS by universities and research institutes without reaching yet the stability and maturity to become full standards. Here, no specific action is proposed.

The question then arises, coming from the general strategic vision, of how standards development can be supported in practice in order to reap the possible benefits of OSS. This also includes proper dealing with the relationship between IP and standards in general and OSS and standards in particular. One first requirement is that the positive economic benefits of standards, which also justify public support for their development process, e.g. in form of mandates, are only exploited if they are implemented at a large scale. Against this backdrop, public procurement plays an important role. Companies could be incentivised via public procurement (Blind 2008)

to implement the most recently developed standards. This could be achieved, for example, by catalogues of standards that guide public procurers in drafting their tenders. In addition to the promotion of standards, even including SEPs, via public procurement, the procurement of OSS based products could be promoted even further by standards relying on OSS addressed in the open source software strategy of the European Commission.

Other areas are the EU funded research, technological development and innovation (RTDI) and pilot projects, as well as Public Procurement for Innovation. The current European research and innovation program Horizon 2020 includes standardisation processes as transfer and implementation mechanism and standards as additional success indicators for innovation in addition to scientific publications and patents (European Commission 2011a, 2011b, 2011c). The EU Rolling Plan for ICT Standardisation 2016 provides input to H2020, as "...the impact of standards on R&I may be on different levels: R&I projects may contribute to standardisation work; standardisation may be a tool for adopting and exploiting new technologies; and standardisation may contribute input to R&I work or R&I activities may build on standardisation work that is available or in progress" (EC 2016b) as already elaborated by Blind and Gauch (2009). Consequently, in the Rolling Plan 2017 it is even claimed that "initiatives linking ICT standardisation and ICT R&I appear to be most effective when carried out at the research planning stage (see Goluchowicz and Blind 2011 on need of standardisation foresight). Standardisation awareness is therefore essential in the research life cycle. Standardisation bodies have partially set up links into research activities for facilitating the uptake of standardisation deliverables in research projects and the transfer of research results into standardisation" (EC 2016c). In addition, recent initiatives, like Responsible Research and Innovation (EC 2014b), ask for sharing research results, e.g. via open access, to improve research and innovation. Finally, Moedas (2016) promotes openness leading to the vision that in 2030 open source communities and others offer "free public access to all scientific data as well as to all publicly funded research". However, he also is aware that the EU has to preserve "its economic interests, notably as regards intellectual property rights and standards" despite open innovation, open science and international collaboration enabling "global standard-setting", allowing global challenges to be tackled more effectively, and facilitating participation in global value chains and new and emerging markets. Finally, "Europe needs to create the right regulatory environment that removes obstacles to innovation and encourages innovators and entrepreneurs, while rules and standard-setting must keep up with rapidly changing technologies". In summary, we face not only the tension between openness and intellectual property rights, but also the trade-off between developing global standards in rather complex and lengthy processes and adapting them to the increasing dynamics in science and technology in order to exploit their innovation promoting impact, as shown by Blind et al. (2016).

In parallel, the European Commission supports OSS with funding under the EU research and innovation funding programme Horizon 2020 and has called for greater use of open source elements by better integrating open source communities into SDOs' standard setting processes, notably for cloud computing (Open Forum Europe 2017b). It has a dedicated and publicly available open source software strategy in place for its own use.

The overall conclusion at the level of operational support is that standardisation is playing an increasing crucial role in Europe's innovation system by being more closely linked both to research and innovation programs, like within Horizon 2020, and to demand-driven innovation policies, like public procurement and regulation, e.g. via Public Procurement of Innovative solutions (PPI) and the New Legislative Framework, former known as New Approach, but also to the numerous general EU and specific ICT-related policy initiatives.

Having looked at the operational policies, we turn our attention now to the institutional level. In general, IPR regimes have to follow the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), which we have to take into account. However, the modernisation of the EU copyright rules, e.g. related to data bases, might have also implications on OSS being relevant for answering the research questions and the derivation of policy recommendations.

Standards are developed by various stakeholders within a process following the WTO (1995) criteria of transparency, openness, impartiality and consensus, effectiveness, relevance and coherence. Whereas traditional industries in manufacturing have been successfully triggered by national standards, already the development of mobile communication required at least a European approach illustrated by the successful GSM standard (Pelkmans 2001). Furthermore, the great success of the Internet has

only been possible by globally organised standardisation consortia like the Internet Engineering Task Force (IETF). Consequently, future developments in ICT, like the Internet of Things (NIST 2013) and the next generation of mobile communication, i.e. 5G, require global solutions, i.e. standards, to become globally successful innovations.

Consequently, such globally accepted standards require standardisation processes and SDOs, which are effectively and efficiently able to involve all relevant stakeholders. Changing existing rules, e.g. by opening standardisation processes, as well as effective governance of the agreed rules is necessary. SDOs are platforms representing the interests of their stakeholders or the countries they are accredited by, e.g. national SDOs. In order to achieve cooperation between the various SDOs requires coordination of the governance especially, related to the standardisation processes and their results, i.e. the coherence of standards and their contents, but also their accessibility.

Governance of standardisation processes in terms of coordination between SDOs, and particularly in view of IPR policies, is tricky. On the one hand, the treatment of IPRs, especially patents, requires a coordinated approach in order to avoid negative impacts of phenomena like forum shopping, e.g. both in standardisation and in IP litigation (Lerner and Tirole 2006). Besides the challenge of designing and implementing efficient patent policies, the interaction between patents and OSS is creating a further tension. On the other hand, the business models of SDOs are quite different. For example, some SDOs are funding their activities by asking for significant membership fees (mainly consortia). By contrast, the "traditional" national SDOs still generate a significant share of their revenues from selling standards documents, which might be challenged by OSS being an important input into the standards.

One important key aspect of SDO activities (and also a major issue for policymakers) is the balancing of competing objectives and interests. In the Communication "A strategic vision for European Standards" (COM (2011)311), the European Commission focuses on the five strategic objectives for European Standardisation:

— Quick availability of standards
— European standards to support the competitiveness of European businesses
— Standards to support EU legislation and policies
— Inclusiveness of the standardisation process
— Standards to support the competitiveness of European businesses at global level

There are inherent conflicts of objectives, not the least from an institutional point of view. For example, including all relevant stakeholders might not be compatible with increasing the speed of standardisation. Furthermore, standards are asked not only to support EU legislation, according to the New Legislative Framework defined in EU regulation 1025/2012 on European Standardization, but also EU policies in general, and programmes like Horizon 2020, as well as European business at the European and international level. Overall, a challenging set of objectives is expected from European standards.

The objective of the study is to identify possible commonalities and barriers for interaction between standardisation and opens source processes. The study should clarify the role of open source in the context of standard setting, in particular its interplay with proprietary knowledge solutions included in the standard (FRAND licensing) and should provide an overview of OSS and FRAND features in standardisation. The analysis should also provide clarification of the different concepts of openness: 'openness' in standards, 'open source', 'open standards' etc. It should consider in particular the following issues on the compatibility of OSS and FRAND licensing:

— The general compatibility of OSS licensing with FRAND licensing differentiated by type of OSS licensing (e.g. General Public License).
— What is the impact of GPL licensing and other OSS licensing forms (considering passing on the rights to next users of the software without need to obtain a licence from the original IPR owner) on interoperability?
— As to how far is the interplay of OSS and FRAND licensing directed by the borderline between software and hardware? Is this borderline shifting or vanishing over time?
— What is the relevance of software patentability in this respect? What is the degree of computer-implemented inventions (often called software patents) in relevant technologies (e.g. cloud computing; geospatial technologies)?
— To which extent do the different practices of software patentability in Europe, the US (and other countries/regions in the world) matter for shifting this borderline and for shaping the interplay of different licensing models?

In addition, the following issues should be addressed:

— Other possible barriers (beyond licensing issues) for interaction between OSS and standardisation processes.
— Differences in development processes of OSS Communities and SDOs.
— Stability, sustainability and maintenance of OSS projects supporting the standardisation process and OSS community building issues.
— Interoperability of OSS applications and products.

The study will provide a comprehensive overview of the relevant existing policies with SDOs and of existing collaboration actions between SDOs and OSS. It includes an overview of OSS/FRAND combining practices by industry in relevant sectors (namely cloud computing, 5G, IoT, cybersecurity, big data, geospatial technologies, robotics and others) and the feedback from a representative stakeholder dialogue. While taking into consideration the available literature in the field the analysis will in particular consider the following questions:

— What is the degree of participation of OSS projects, implementing standards with FRAND licensing?
— How do large companies combine open source and FRAND licences in their business models?
— How does this shape their contributions to standard setting?
— Is a combination of both concepts feasible also with SMEs (considering the risk of litigation and lack of resources to negotiate FRAND contracts)?
— What are the existing IPR policies combining OSS and FRAND practices at leading SDOs?
— How is OSS involvement into the standardisation process impacted by the standardisation maturity of the digital technology domain (e.g. standardisation in mobile networking), the speed of technology developments (e.g. cloud, IoT) and the market characteristics (e.g. intensity of competition)?
— Is there a need for regulation or other kind of public action at European or global level?

The final analysis will come up with a list of policy recommendations and a roadmap of future actions at EU level. It should compare policy objectives of OSS and FRAND licensing and it should provide a systematic overview of relevant IPR policies. It should analyse and compare best practice examples of OSS and FRAND licensing co-existence and develop policy guidelines therefrom.

The remainder of this study is organised as follows. In chapter 2, we summarise the insights from the review of the literature. In chapter 3, the insights from the case studies are displayed in a condensed form. Chapter 4 sumps up the results of the stakeholder survey. In chapter 5, we present the comprehensive analysis of our findings of the three approaches of our study concerning the governance architecture of SDOs. Finally, we derive policy recommendations in the last chapter. In the Annex, the complete literature review, the whole case study analysis and the detailed results of the stakeholder survey are presented.

2

LITERATURE REVIEW

2 | Literature Review

2.1. Methodology of the literature review

The literature review used two types of sources. On the one hand, we searched for all academic literature on Intellectual Property Rights (IPRs) and standardisation in information and communication technologies with a specific focus on patents and copyright issues, open source software in particular. On the other hand, we screened the publication of the standardisation organisations and other associations for recent publications related to open source software.

2.2. Results of the literature review

In order to structure our review of academic papers, we divide the studies into three categories following Lundell and Gamalielsson (2017), but also Clark (2016) without immediately considering the tension between OSS licences and the FRAND regime related to patents. First, we consider cases, which start as standardisation projects within formal or informal standardisation bodies but are eventually implemented as OSS projects. The second option is the initial implementation of software via OSS projects followed by a standardisation process. The third and final option is the parallel development of standards and their implementation as OSS.

FRAND Commitments

FRAND commitments are designed to ensure that essential IPR protected technology incorporated in a standard is accessible to the users of that standard on fair, reasonable and non-discriminatory terms and conditions. In particular, FRAND commitments can prevent IPR holders from making the implementation of a standard difficult by refusing to license or by requesting unfair or unreasonable fees (in other words excessive fees) after the industry has been locked-in to the standard or by charging discriminatory royalty fees.

Source: European Commission 2011d.

2.2.1. *Scenario 1: Standards implemented as OSS ("standard first")*

There are examples of the implementation of standards via OSS discussed in the literature. However, these standards are mainly developed in SDOs following a royalty free (RF) licensing scheme, for example at the Organization for the Advancement of Structured Information Standards (OASIS) and the World Wide Web Consortium (W3C). According to Phipps (2019), these SDOs are characterised by an implementation-led rather than a requirement-led standardisation approach. There are also some standards released by SDOs applying the FRAND regime. However, there are no declarations of SEPs related to these standards. Nevertheless, there is still the latent fear of conflicts with potential SEP holders, because of the general contradiction between the FRAND regime and OSS licences. In particular, the popular GPL is incompatible with FRAND, but there are several other OSS licences, like the MIT or BSD licences, being compatible with FRAND according to Kappos and Harrington (2019). However, there is no general consensus about this conclusion (see also EC 2012b), because others argue that they are just complementary, but not compatible (Phipps 2019). In addition, the notion of the incompatibility of the licensing regimes is endorsed by a significant percentage of open source programmers (Bekkers and Updegrove 2013). Due

to the highlighted relevance of standards implementation for their quality and success, the concerns of the OSS communities related to the ambiguity in the licensing conditions gain further in relevance.

2.2.2. *Scenario 2 OSS code as input into a standard ("software implementation first")*

The second scenario according to Lundell and Gamalielson (2017) is characterised by the initial implementation of software, which eventually leads into technical specifications of standards also called implementation-led standardisation by Phipps (2019). Under this scenario, a software implementation precedes the development and endorsement of the technical specifications of a standard released either by a formal and or informal SDO. According to Li (2017), it is in general more complex for SDOs to utilise open source working practice to develop standards. She differentiates between two sub-scenarios. On the one hand SDOs can use source code directly in specifications. One the other hand, specifications refer to the same functions they derive from open source projects. The direct use of running code requires at first the check of the copyright issue over this specification, because SDOs own the copyright of specifications, while in the open source project developers remain the right holder. The major problem is that it is uncertain whether SDOs still can claim the copyright if code is included as part of the specifications. This problem is confirmed by Lundell and Gamalielsson (2017), who conclude their paper not only with the open question of which open source licence should be used, but more important which organisation has or should have the copyright for the developed software in which the technical specification of the standard is implemented.

In the second sub-scenario presented by Li (2017), the code included in the specifications of the standards becomes essential, like patent-protected knowledge in the case of essential patents. Here, addressing the copyright issue becomes even more crucial. According to her analysis of ETSI, ITU and IEEE, none of them have a particular clause regarding essential copyright. The ETSI IPR policy even emphasizes that software embedded in specifications shall not be used as mandatory for compliance (ETSI 2017).

In addition to including software code in the technical specifications of standards, the functions from OSS code can also be adopted in a standard. Here, Li (2017) distinguishes between the licences applicable to the OSS code. If the OSS licence does not contain any patent clauses, the patent issue could only be left to the policies of the relevant SDO, which might eventually subject to the FRAND commitment (according to Li 2017). However, if an OSS licence includes a patent clause, the patent right is granted on a RF base. The open question is whether SDOs can require the patent owners who contribute patents to the standard to licence it under FRAND licence even if there is already an OSS licence with RF patent licensing. However, Li (2017) cannot find any entitlements for SDOs to do so in their current IPR regimes.

Since most SDOs have no specific rules regarding the licensing of OSS code integrated in the specifications of standards, Li (2017) concludes that the OSS licensing terms are the "only clear applicable rule". Consequently, granting RF licences should be applied to use the code in standard embedded technologies. However, such rules might be a strong disincentive for at least some patent owning innovators, because the option to collect royalties on SEPs might be one of the main incentives for many innovators to contribute standardisation (e.g. Lerner and Tirole 2015). However, in the survey by Blind et al. (2011) patent owning companies rate the relevance of the freedom to operate achieved by a standard as much higher.

In addition to the conflict regarding the licensing terms for OSS and patents, there is a systemic difference in licensing software according to the OSS licensing terms and patents according to FRAND. OSS licences follow a cascade effect, which restrict the implementers of OSS in other areas not applicable to FRAND (Li 2017). Although using patents for free, OSS licences contain in general a "patent retaliation" clause, which discourages recipients from litigating against the work that incorporates the patented contribution by terminating the patent right. The idea is to prevent implementers from filing lawful litigation, if they find their patents included in the same work have been infringed. However, the current IPR regimes of SDOs guarantee patent owners this opportunity.

In summary, the current frameworks of formal SDOs and informal consortia obviously allow the integration of OSS into their standard development process and standards.

SDOs, like W3C and OASIS, which have meanwhile more a RF culture related to patents and consequently rather limited number or no SEPs at all, are forerunners in starting proactive initiatives to include OSS in their standards. Despite the challenges for SDOs applying FRAND, the strict exclusion of OSS code in standards' specifications is certainly no sustainable strategy, because the available OSS code is already large and further growing. Furthermore, some OSS communities already claim to set de facto standards, which is challenging both formal SDOs and informal consortia (Updegrove 2015). Finally, both the increasing competition between SDOs and consortia and the additional competitors from the OSS communities as additional standard setters are likely to increase the pressure to cooperate with the latter. Industry standards may also be developed by competition between OSS communities, forgoing formal specification altogether.

2.2.3. *Scenario 3: OSS and standardisation in parallel ("standard and implementation of standard in parallel")*

Whereas in the previous two scenarios a more or less clear distinction between the starting point of the process and the transfer in the other area has been drawn, Scenario 3 represents the reciprocal action between the development of technical specifications of a standard together in parallel with the development of one (or several) implementations(s) of technical specifications of a standard in OSS software.

Lundell and Gamalielsson (2017) further developing Gamalielsson et al. (2015) analyse the bi-directional influences between the OSS project Drupal provided under the GPL licence version 2 being a copyleft type and the development of the RDFa (Resource Description Framework in Attributes) standard for the interchange of data on the Web at W3C. Support for RDFa 1.0 was achieved in the OSS project Drupal by its first implemented in the core of Drupal 7 (RDFa is implemented in a separate module in Drupal).

Summarizing the insights related to the third scenario of parallel developments in OSS and standardisation confirm on the one hand the observations related to the first and second scenario. In the early days of the Internet, IETF as a consortium driven by individual members, like OSS projects, has been involved in the development of an email format in parallel to OSS projects. However, the few cases of close interaction between OSS and standardisation are mainly focused on consortia, which have strict RF and rather patent intolerant licensing policies, i.e. W3C or OASIS. They have been already been identified as being in a good position to integrate input from OSS projects in contrast to formal SDOs applying the FRAND scheme. The recursive integration of inputs from standardisation respective OSS may lead to a virtuous circle of standards of higher quality and broader distribution. In contrast, the challenges for the FRAND based SDOs and consortia already elaborated for the unidirectional relations also will create difficulties for the parallel developments. In the long run, higher quality standards due to inputs from OSS and their broader diffusion via OSS will put further pressure on formal SDOs and informal consortia following the FRAND regime.

The limited focus of SDOs on copyright in general and software or open source software in particular has certainly economic implications in various dimensions. First, the few SDOs or consortia explicitly addressing software are able to develop a stronger profile in standardising topics based on software alone or on the combination of software and hardware. Here, the actors with standardisation needs obviously decide according to the perceived competencies of the SDOs including the governance related to software. Second, the FRAND regime relevant to the licensing of standard-essential patents established in traditional SDOs, i.e. members of ISO and therefore guided by the ISO/IEC/ITU IPR policy, is not necessarily attracting contributors to OSS, which are used by rather royalty free dominated licensing schemes. Therefore, a separation or division of work can be expected also in the future despite the significant efforts in particular by ETSI to find solutions for the coexistence of FRAND licensing and OSS licences as expressed by some of their members organised within the Fair Standards Alliance (2017). Secondly, the rather strict royalty free based policies of OASIS and W3C following the OSS licensing schemes facilitate the implementation of their standards. Third, the IPR policies of SDOs related to software are linked to their business models, in particular those that do not make their deliverables freely available. It seems more difficult to sell standards under a royalty free regime integrating OSS in standards. However, this tension has not yet been addressed in the publications of SDOs and consortia.

2.3. Summary

The background as presented in the literature review leads, first, to very general conclusions as regards the growing importance of standard setting processes and their use of IPR, not only patents, but also copyrights on software. The general assessment is, secondly, that standardisation has a multidimensional role. It intermediates between science and technology driven research and innovation and demand-sided innovation policies (OECD 2011) framed by various regulatory framework conditions. Patents and copyright-protected software including open source software are the major IPRs used as inputs for ICT-standardisation and also relevant for the accessibility of the output of ICT standardisation. Therefore, IPR utilisation in standardisation processes adds a further dimension.

In general, standards are developed by a number of different actors within a voluntary consensus-oriented process. Considering the accompanied increasing variety of interests of actors involved in standard setting, standard setting governance determines the success of SDOs in the sense of integrating the different interests at stake also asked for the European Commission. Effective rule setting and governance of SDOs are crucial for the successful development and eventually the implementation of standards. The IPR policy approaches developed by SDOs will have to consider not only specific rules and procedures for FRAND licensing relevant for patents, but even more for the treatment of open source software.

3

CASE STUDIES

3 | Case studies

3.1. Concept and methodology

The case studies report was developed following these steps.

First, insight into the specific area of interest was gathered through multiple open-ended, qualitative, in-depth interviews with representatives of key stakeholders, especially organisations that participate in standards development, open source activities or both, SEP rights holders, European and international SDO, and major open source communities, standardisation consortia and umbrella organisations. The interviews followed an interview guide approved by the European Commission and steering committee established to accompany the study. They are tailored to gain a deep understanding of the experience of the participants regarding the interaction between FRAND licensing and open source from a cultural, governance and legal perspective. The individual interviews are not targeted towards a specific case study. However, the exchange with the participants revealed interesting cases.

The interviews resulted in a set of findings and an initial understanding of the subject. Based on these findings, data about the case studies has been gathered in a second step, through field work, directed research and direct interaction with the case study subject entities. The interviewees had been informed about the selected cases and encouraged to provide more specific input if they can.

In the final step, the findings from the interviews and the case studies have been aggregated into informed insights about the motivators and inhibitors of SDO and OSS collaboration.

Types of OSS licences and relation to patents

The terms and conditions under which others can use Open Source code are defined in Open Source licences chosen by the authors. All Open Source licences give users the rights to use, study, modify and redistribute the code. The licences are anchored in the copyright of the authors; however, they establish an agreement that may include additional obligations, including patent grants. Reciprocal Open Source licences obligate the user to distribute their modifications under a similar licence. Permissive Open Source licences do not require reciprocity. Licences from both groups may or may not contain patent licensing requirements. Many Open Source licenses exist, however only few of them are widely used in recent practise. The choice of Open Source licence that a community makes strongly influences community governance and interactions with other stakeholders, including SDOs.

3.2. Results

3.2.1. *Motivators and barriers to collaboration*

The case studies indicate that all three layers of interaction identified in the expert interviews – cultural fit, governance models and legal framework – are relevant influences on the viability of collaboration between SDO and open source communities. Collaboration has to be possible and to be preferable over working separately. One key aspect to understanding this interaction is the principle of voluntary participation. Neither side can instruct the

other to perform certain tasks or to focus for example on implementation versus specification. Collaboration probably needs to be envisioned as an integrated cyclic process with feedback loops between specification and implementation, and shared responsibility for both aspects between all participants. A positive influence may be the match of the timelines for producing results between SDOs and open source communities, while businesses may be driven by shorter development cycles under time-to-market pressure.

3.2.2. *Business and collaboration models*

It is obvious that the availability of the product of the wider open source community partially disrupts existing business models, especially if they are built on the exclusivity of implementation details, trade secrets and patent protection of functionality that gradually grows to be implemented as a public open source good. Usually, this is the result of a well-functioning market with competition between different collaboration models, as long as this gradual shift is caused by market pull. Care should be taken if business models are made viable or invalidated by external push. Most of the presented cases developed without noticeable regulatory encouragement or investment, indicating that it can be assumed that the coordination of standardisation processes is achieved through competition in the market. Regulatory interventions into the market need to be assessed carefully for the balance of the possible positive effects and welfare losses.

3.2.3. *Collaboration models*

The assumption that committee work at SDOs is necessary to produce complex standards that cover a wide range of functionality across different technology areas, which was raised during some of the expert interviews, cannot be confirmed. Communities like Cloud Foundry or OpenStack produce comprehensive software platforms that require research and development investment, long-term commitment and effective governance norms and IPR regimes of similar or larger efforts compared to some standards development efforts. All these aspects have been found implemented in open source communities as well as in SDOs. The success of the development effort seems to depend more on momentum, the intention to overcome obstacles and work towards a common goal, and the personal motivation of the participants involved. The diligent review of specifications performed in SDOs has shown a positively stabilising effect that enables implementers to produce conforming products.

3.2.4. *Creating a level playing field*

The expectation that "open source is welcome to join but must accept our established SDO governance framework" illustrates that especially long-term participants in SDO activities assume a mixed perspective of peers in the standardisation process and authority. As peers in the standardisation process, they interact with others, including open source communities, as equal market participants that compete at eye level. When they assume a position of authority, they project the gravitas of the institution (usually the formally recognised SDO) they are embedded in and demand that potential collaborators accept its relevance and follow its IPR regime. The cases indicate that formal recognition (which with regard to this study currently only exists for SDOs) is helpful but not enough to entice parties to mutual collaboration. Other drivers for example are technical relevance, effective processes and a cultural fit.

Interfering with market forces to enable specific business models carries the risks of perpetuating historical developments or missing promising new approaches. Regulators usually attempt to create a legal framework for innovators that enables competition between alternative approaches and let different business models compete in the market for viability. From the perspective of the standardisation process, SDOs and open source communities should be considered peers and equal actors in a "standardisation market", especially because of their partially differing characteristics that cater to different market needs.

3.2.5. *Suitable IPR regimes*

Hardware and software exhibit different economics based on unit marginal cost being the equilibrium price in markets with efficient competition. The commoditisation and virtualisation of hardware functions in software does not just drive down prizes, they also transition functionality from physical to information goods. The growth of open source communities is one piece of evidence for this more general shift towards commoditisation and hardware function virtualisation. The case studies show that even in the same market segment, the IPR frameworks applied cannot easily be transferred from hardware to software implementations, as they will not necessarily be accepted by participants. Instead, a new set of separate and disjunctive behavioural norms for collaborative and competitive environments emerged. Where collaboration is the dominant model, the common expectation is that all contributing entities that form the community jointly act as a steward over the created technology and make it available to everybody. Where collaboration is not suitable, actors compete as before and focus on differentiating product features. Institutions have emerged that facilitate participation in the collaboration process, like the major open source umbrella organisations as well as SDOs, like IETF or W3C, and that create IPR frameworks representing the concept of joint stewardship in the collaborative environment, like the Open Invention Network.

3.3. Assessment of the interaction

Since networking and telecommunications technology are especially affected by the tensions between SDO and open source IPR regimes, stakeholders in these specific technologies have been particularly motivated to provide input to the case studies. However, the interaction between standards and open source development most noticeably affects software/software and software/hardware interfaces, so that the cases still describe a representative subset of the relevant subject matter for the study. The following paragraphs try to summarise a number of take-aways from the case studies.

First, fruitful collaborations between standards and open source development exist, as for example in the case of the White Rabbit project, the different programming languages or the Linux operating system. The processes applied by these collaborations evolved over time, and continue to do so, resulting in well-established governance models.

Open source approaches are suitable for the development of research and development heavy innovations that require significant up-front investments in large, diverse stakeholder networks. Open source communities are commonly driven by their own set of motivations mostly based on technical needs. Non-contributing entities have little impact on setting their technical roadmaps. Based on that, a collaboration between standards and open source development is difficult to enforce especially considering the generally voluntary nature of participation on both sides. Some projects even adopt implementation-only policies, which potentially leaves a gap where no specifications will be produced that can be referenced by regulators or other stakeholders.

While individual open source projects may serve a specific technical need and may remain relatively small in terms of contributor and contribution counts, with the adoption of their products they become part of a complex upstream/downstream network of continuously integrated open source technologies that develop in lockstep based on decentralized coordination and a normalised, negotiation-free IPR regime.

Different widely adopted open source projects have developed IPR regimes that combine source code licensing and patent licensing. They all however effectively implement royalty-free patent licensing schemes.

In cases where larger organisations decide to participate in open source development, the benefit from gaining access to the totality of contributions made by other collaborators commonly outweighs the potential gains from royalty-bearing patent licensing.

Once actors in a market segment congregate to establish open source collaboration for the provision of foundational software technologies for that segment, the focus of the collaboration sometimes shifts away from specification to joint implementation. The jointly developed solution effectively solves the interoperability and software quality problems.

Technology areas where specifications communicate the basic uses of the technology independent of the use of specific implementations, as in the case of the programming languages covered by the cases, remain standards-development driven, but adopt collaborative open source methods to develop new standard features. They may for example make draft specification or discussions of new features openly available, even if the balloted standards still need to be purchased for a fee.

In some cases, the wider open source community actively invests to prevent business-critical technology from being dominated by single or small numbers of companies. The number of independent contributing entities to a specific software product is an important metric of community health in practice.

Software-focused standards development projects rarely take the technical lead with specifications that are then implemented by the wider open source community as reference implementations. SDOs are usually not the entities developing new and innovative technologies. It is more common that vibrant open source communities incubate new technologies that then become candidates for standardisation.

One of the most successful software innovations in general, Java, provides an example where specification, reference implementation and test suite are jointly developed in presence of royalty-free licensed SEP, but outside an SDO.

Voluntary open source contributions and contributions generated through direct research and development investments of companies are complementary and can lead to similar results in terms of technical development underlining the argument that both are alternative approaches to the development of technical standards. Open source methods result in freely available implementations but depend on the willingness of contributors to create them. Proprietary research and development results in potentially patented inventions but can be funded through commercial investments. The approach selected for a specific scenario needs to take the composition and business models of the potential contributors to a new technology into account. Both approaches can be combined in a way that they compete for market share in the same market segment.

Innovative new technologies over time become commodity and tend to be collaboratively implemented as open source technologies. This open source implementation then demonstrates the state of the art and rarely leaves an opportunity for competitive inventiveness, since this would require a single inventor to compete with a consortium representing many of the relevant stakeholders in a market segment.

The traditionally separate assessment of SDOs and open source umbrella organisations becomes more difficult to maintain. Different aspects of standards development, like consensus building and ensuring interoperability and quality levels, are increasingly provided by open source umbrellas as well. Membership models of industry-driven open source organisations also show similarities to models applied by some SDOs. For a better understanding it may be necessary to assess the individual functions of standards development separately with a utilitarian approach and less focused on the established institutional framework.

In summary, fruitful collaboration between standards and open source development can be observed in the cases. Successful royalty-bearing licensing of SEP in combination with open source development cannot be observed. Most SDOs represented in the cases as for example W3C or OASIS have adopted royalty-free or FRAND-Z SEP licensing schemes over time. Through the evolution of open source governance towards standardised behavioural norms, the wider open source community continues to build a commons of freely available foundational software technologies and grows and extends it also through patent cross-licensing and the increasing adoption of open source licences that include patent grants.

4

STAKEHOLDER SURVEY

4 | Stakeholder survey

The aim of the stakeholder survey was to gather and analyse the views of a broad set of stakeholders on the topic of the interplay between patents and OSS within standardisation processes in general and FRAND and OSS licences in particular, hereby creating a robust empirical representation of the opinions and issues at stake.

4.1. Methodology

Based on the insights from the literature review, the case studies, which already followed a rather detailed interview guideline, an online survey was designed. In parallel, a database of experts being active in the field, who have for example the workshop performed in the context of the other projects related to patents and standards, has been built up. By the middle of November, these experts, but also the several mailing lists have been informed about the survey.

4.2. Results

In the following sections, we are presenting the man results of the stakeholder survey. Overall, 315 respondents started to complete the survey. However, the majority of the respondents did not continue to answer the following questions to the very end.

4.2.1. *Respondents*

More than 200 participants revealed their position in their organisation. On the one hand, around 20% are the Chief Executive Officers or in the top management. In general, responses from small organisations having below 250 employees or younger organisations are provided by their CEOs, which has to be taken into account interpreting the differences in the answers between small and large organisations. Overall and in particular in larger companies, members of the R&D department, members of the R&D departments, but also of the legal and standardisation department have responded to the survey. The location of the participants' countries is broadly distributed among 20 countries with around one third of answers from France and Germany, but also 20% from the United States and Canada.

The information provided about the basic economic characteristics of the organisation is rather limited. Whereas the information about the annual turnover is rather incomplete and skewed with a median value of just above EUR 3 million, the average number of employees is above 20,000, but the median at 80 employees. Therefore, we have a significant share of small- and medium-sized organisations, which enables us to split the sample in 31 organisations with more and 45 organisations with less than 250 employees. This distinction will be used for a differentiated analysis of the responses.

Around 20% of the organisations are providing software, another 10% are independent software developers mainly working for small- and medium-sized organisations. Another third of the respondents are representing mainly larger organisations producing final goods, supplying components, being systems integrators or network operators. In addition, almost 20% are employed by private or public research institutes or universities. Finally, respondents also represent organisations providing private or public services, i.e. the latter by governmental institutions.

4.2.2. *Use of Intellectual Property Rights*

Not even half, but mainly larger organisations has applied for global patent families. This share is higher than the ratio reported in the Community Innovation Survey. In contrast, almost 60% have registered trademarks, two thirds even claim copyrights and even three quarter have globally registered domain. Industrial designs have only been registered by a third of the organisations.

Since less than half of the organisations have applied for patents, consequently even a lower share of one third is licensing out or even selling patent families to third parties (Figure 1). If we just focus on those organisations applying for patents, 70% of them licence out their patents, which is a rather high share compared to value derived from the Community Innovation Survey. Regarding licensing in or buying patents, the share of organisations is almost identical at around one third. Obviously, there is a significant exchange of patent rights between the organisations owning patents, but the expected higher share of organisations licensing in patents cannot be observed.

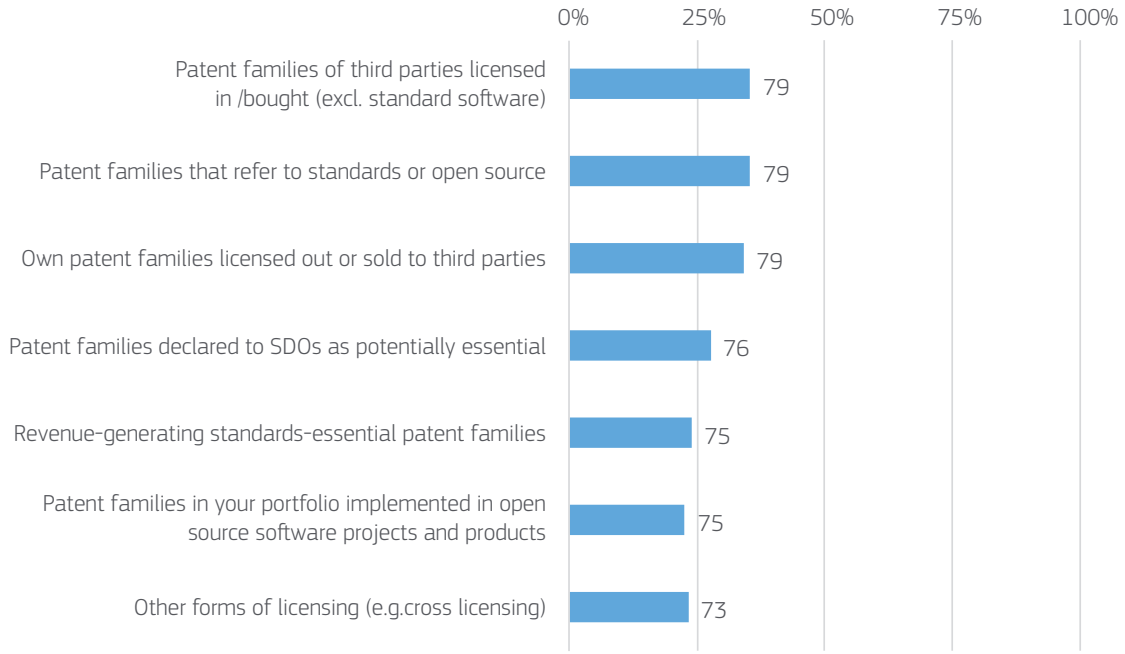

FIGURE 1*: LICENSING AND TRADING OF INTELLECTUAL PROPERTY RIGHTS BETWEEN 2015-2017.

One third of the organisations own patents which refer to standards and open source. A slightly lower share of organisations has declared patent families to SDOs as potentially essential. Only one quarter of the organisations, i.e. almost half of the patent owning organisations, generate revenues out of these standard-essential patent families. Slightly less than one quarter of the organisations have patents which are implemented in OSS projects and products. Finally, one quarter of the organisations are involved in other forms of licensing, in particular cross-licensing is mentioned. If we focus on the small organisations, then all the mentioned options are not used by more than 90% of the respondents. Only almost 15% of the small organisations mentioned that they licence in or buy patents and just above 10% own patent families which refer to standards or OSS.

In summary, the patent related activities of the responding organisations are concentrated at larger organisations, whereas the smaller organisations are almost completely excluded. However, the high licensing activities both inward and outward, which are much more than the number found in the Community Innovation Survey, are in line with both the high patent intensity of the sample and the need of the complex ICT industry to integrate technologies from producers of complementary products.

* Labels next to the bars in the figures indicate number of valid responses received in the survey.

4.2.3. *Involvement in standardisation and open source software*

Around one half and mainly larger organisations are active in at least one of the different types of standardisation organisations. On average, an organisation is active in almost three different types of standardisation organisation. Most common is participation in international consortia, like OASIS, the Open Geospatial Consortium (OGC) and W3C, but in summary the majority is active in formal standardisation bodies, in particular ETSI.

Whereas only around half of the respondents are active in standardisation, almost 90% of the responding organisations are currently involved in open source development activities. In general, all organisations are using OSS, in particular as input into the application level. Around 80% of the responding organisations are occasionally contributors to OSS projects. The differentiation in larger and smaller organisations reveals that larger organisations are, in general, more involved in all activities with one important exception. Small organisations claim slightly more often to be a regular contributor to OSS despite their size disadvantage.

In order to identify the motivations of organisations to join both standardisation activities and OSS development, the respondents were asked to assess the relevance of a set of incentives (Figure 2). Starting with the incentives to standardise, we find that developing standards of high quality, carrying forward the state of the art of technology and finding technical solutions are most relevant for the respondents. The following motives, like company interest, knowledge creation, establishing networks, increasing reputation, specifying regulations, knowledge seeking, and market access are slight above medium relevance. Only of low relevance is the inclusion of own IPRs in standards.

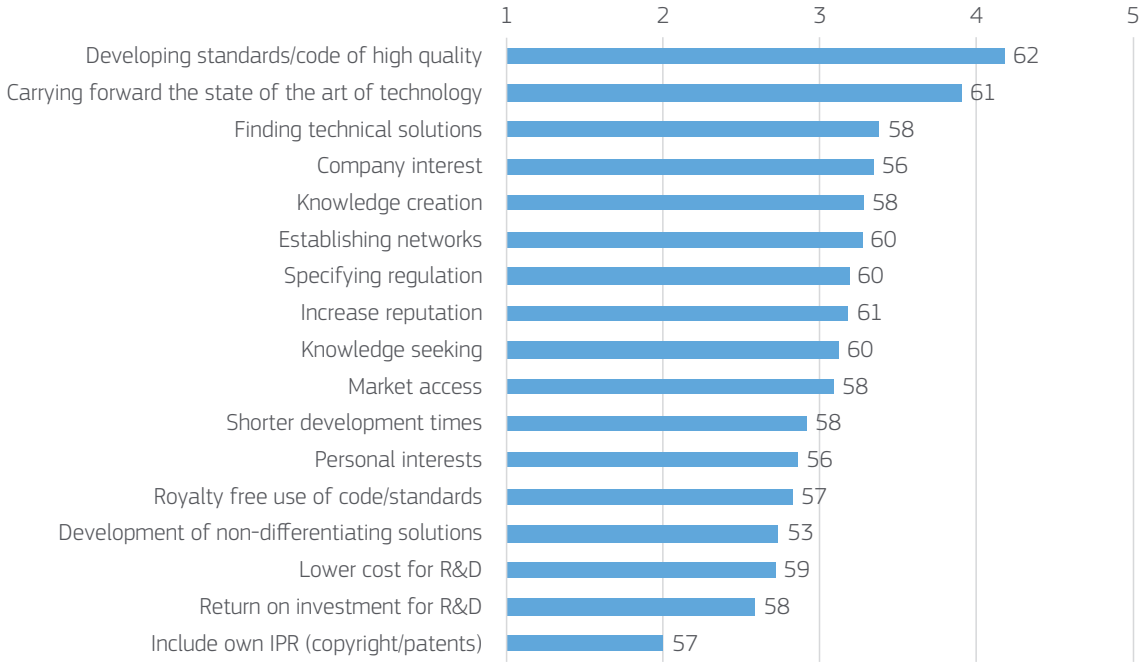

FIGURE 2: INCENTIVES TO JOIN STANDARDISATION ACTIVITIES (SCALE: 1 = "VERY LOW"; 2 = "LOW"; 3 = "MEDIUM"; 4 = "HIGH"; 5 = "VERY HIGH").

Looking at the motives to join OSS development (Figure 3), we find the two incentives of developing code of high quality and carrying forward the state of art of technology on the two top position reaching an overall assessment above high relevance. Slightly below high relevance ranks finding technical solutions, company interest, shorter development times, knowledge creation, personal interest, increasing reputation, lower cost for R&D and establishing network. Again, the inclusion of own IPR in OSS is rated below low relevance. In addition to the listed incentives, some respondents underline the relevance of interoperability to be achieved both by standardisation and OSS. Furthermore, the contribution to OSS is perceived as a strategy to prevent proprietary software solutions, which might create a vendor lock-in and consequently closes markets instead of opening them.

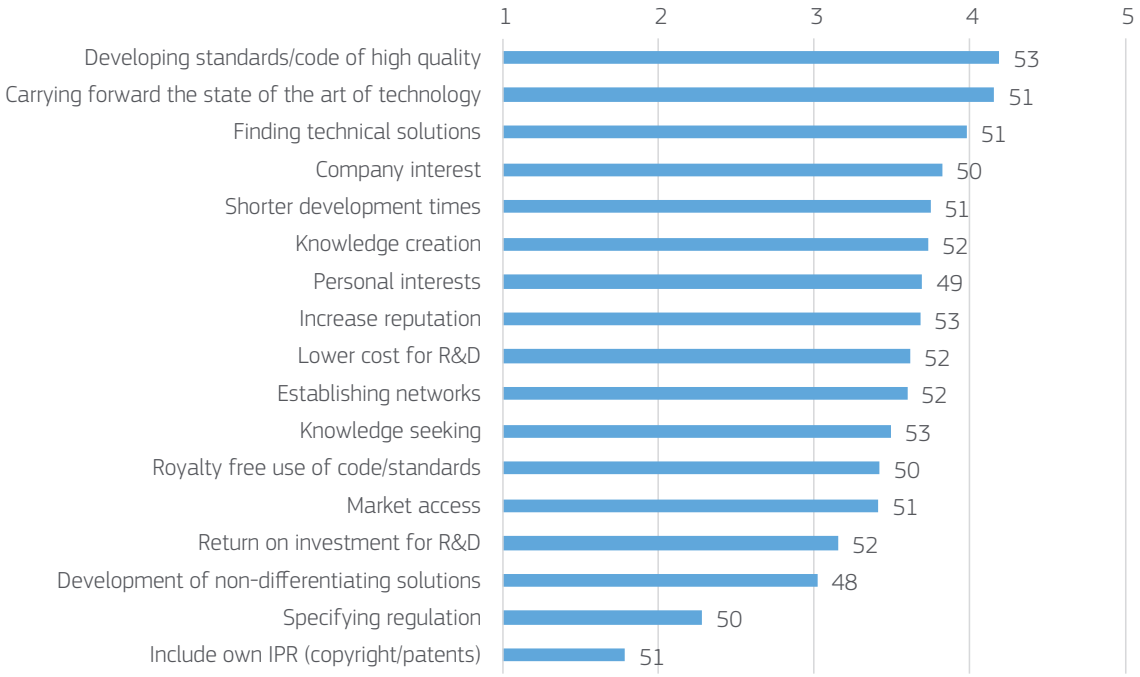

FIGURE 3: INCENTIVES TO JOIN OSS ACTIVITIES (SCALE: 1 = "VERY LOW"; 2 = "LOW"; 3 = "MEDIUM"; 4 = "HIGH"; 5 = "VERY HIGH").

If we compare the assessment of the incentives to join standardisation activities vs OSS development, we observe the following patterns. First, the relevance of almost all incentives are rated higher for OSS with two exceptions. The inclusion of own IPR is slightly more relevant for the participation in standardisation than for joining OSS. And standards are obviously a more effective approach to specify regulations, in particular in the European Union in the context of the New Approach. Secondly, the largest differences can be found for the incentive of lower cost for R&D and shorter development times, important drivers for joining OSS. In addition, the personal interest is assessed to be more relevant for the involvement in OSS. However, in addition to finding technical solutions the royalty free use of code, which is also connected to a positive return of investment in R&D, is obviously much more important for an involvement than the royalty free use of standards.

Finally, two thirds of the respondents expect an increase of importance of OSS compared to less than half related to standardisation. In the assessment of the current relevance, we observe a significant difference between large and small organisations related to the importance of standardisation. Whereas the two thirds of the former assess it as very important, this is the case for less than one third of the latter. This assessment is consistent with the lower participation of smaller organisations in standardisation bodies. Related to OSS, we observe not such a significant difference. Obviously, standardisation plays for small compared to large organisations a less relevant, whereas we cannot observe such a difference related to OSS. Related to the future, the expectations related to standardisation are overall balanced between an increased and constant relevance and quite similar between large and small organisations, whereas the majority of all organisations, in particular larger organisations, expects a further increase in the relevance of OSS.

4.2.4. *Interaction between OSS and standardisation*

Surprisingly, all three options, i.e. standards as input into OSS, OSS as input into standardisation and parallel development in addition to the general interconnectedness of standard development and OSS activities are perceived by the respondents to happen on average "sometimes". However, the distinction between large and small organisations reveals some more differentiated insights. Surprisingly, more than 50% of the organisations with less than 250 employees report that their standardisation and OSS development activities are always or often connected, whereas this is only the case for less than a third of the larger organisations. In particular, for more than half of the smaller organisations OSS is used as input for standardisation, whereas this is

only claimed by 15% of the larger organisations. Finally, more than a third of the small organisations claim parallel developments in standardisation and OSS, whereas this is claimed only by 15% of the larger organisations. Overall, standards development and OSS activities are much more interconnected for smaller organisations, which much more often transfer OSS as input into standardisation, whereas this transfer and even the parallel development is not so common for larger organisations. Obviously, small organisations contribute much more to the integration of OSS and standardisation than large organisations.

Following the identification of the different types of interaction, the respondents have been asked for their assessment of the interaction between OSS and standardisation on their efficiency and results. Starting with looking at the impacts on standardisation (Figure 4), we observe that the majority of the respondents expects a positive impact of this interconnection on standardisation. In particular, more than 70% of the respondents perceive a positive impact on the creation of specifications of technical solutions contributing to interoperability and only slightly less than 70% on the implementation of technical solutions. However, standardisation benefits less related to the ideation of new technical solutions, but also to their validation and eventually diffusion, because here only around 60% of the respondents expect positive impacts. Overall, less than 10% of the respondents expect negative impacts from the interaction on standardisation.

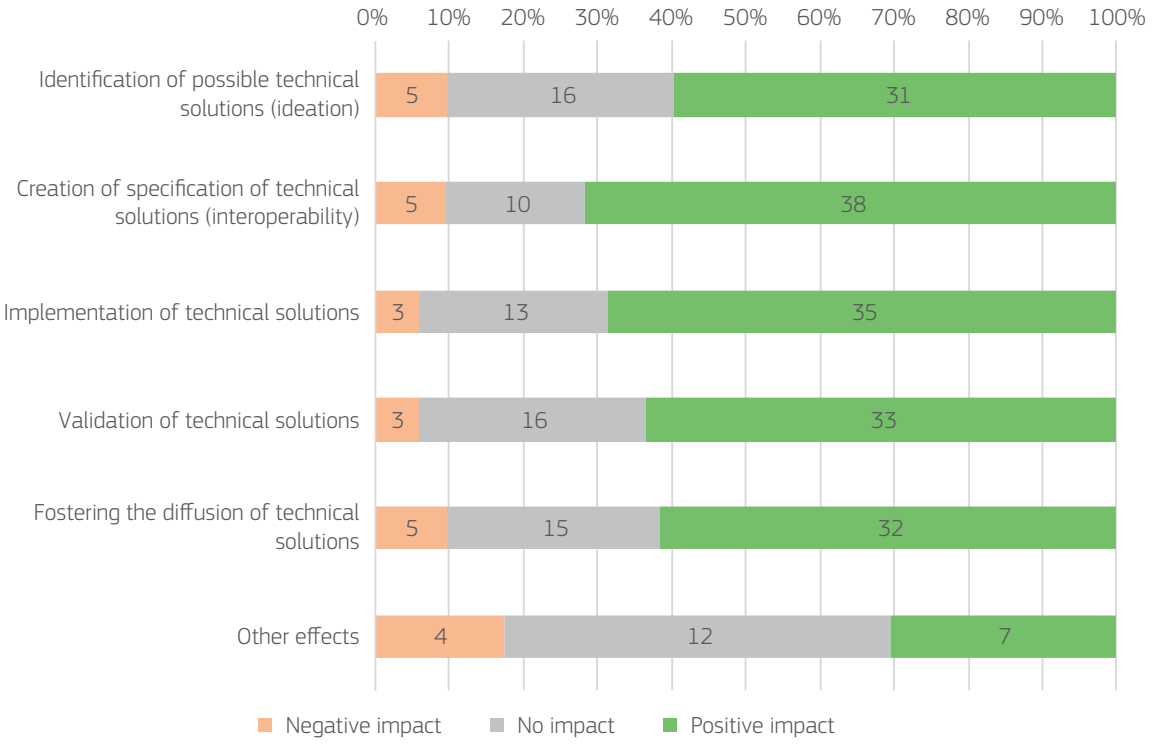

FIGURE 4: IMPACT OF INTERCONNECTION OF OSS AND STANDARDISATION ON EFFICIENCY AND RESULTS OF STANDARDISATION.

The differentiation between small and large organisations reveals that the former are more likely to expect positive impacts on the identification of possible technical solutions, i.e. the ideation, and the creation of specifications of technical solutions, i.e. interoperability, whereas the latter see the advantages in particular in the implementation of technical solutions.

If we turn to the impacts of the interaction on OSS in figure 5, we observe even higher shares of respondents perceiving positive impacts. Almost 80% expect positive impacts for the creation of specifications of technical solutions, in particular related to interoperability, and around 75% for the implementation of technical solutions. Whereas around 70% perceive positive impacts on OSS both for the identification of possible technical solutions and their diffusion, beneficial impulses for the validation of technical solutions are expected by less than 60% of the respondents. However, only around 5% perceive negative impacts.

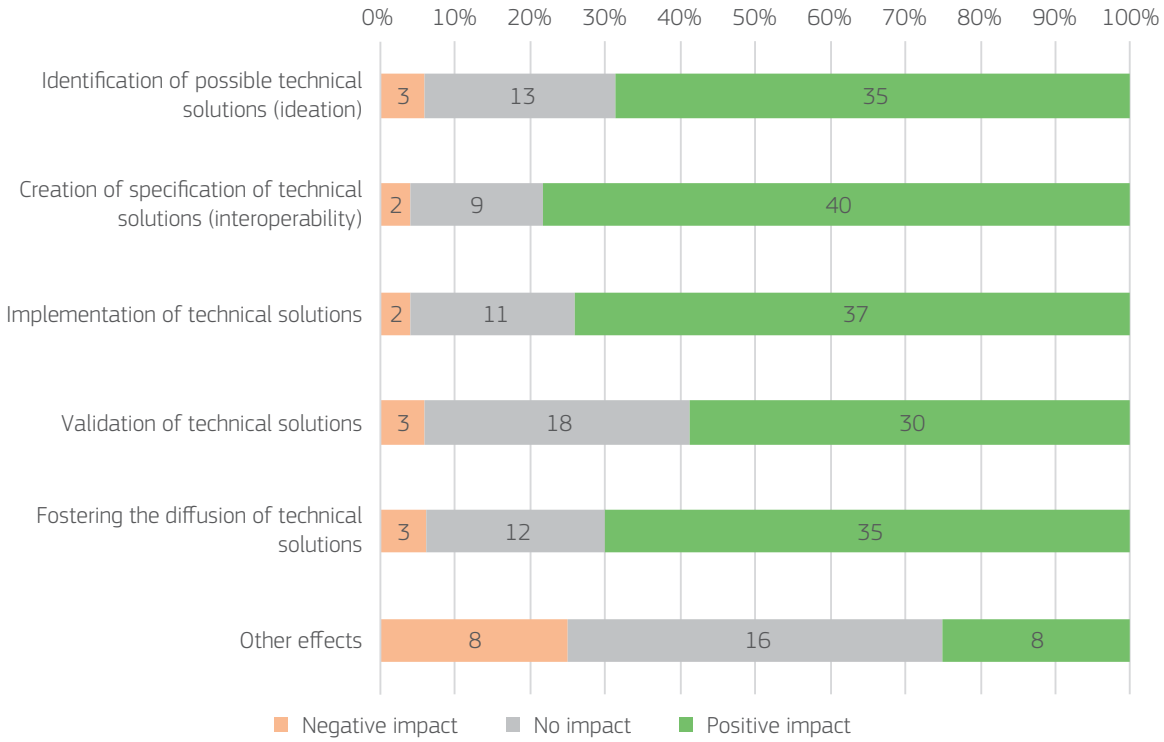

FIGURE 5: IMPACT OF INTERCONNECTION OF OSS AND STANDARDISATION ON EFFICIENCY AND RESULTS OF OSS.

The differentiation between small and large organisations reveals in contrast to the expected impacts on standardisation that the former are more likely to expect positive impacts on the validation and diffusion of technical solutions. Larger organisations see the advantages again in the implementation of technical solutions, but also in the identification of possible technical solutions in OSS.

Taking the latter insights of the interconnection on efficiency and results of OSS together with those on standardisation, it becomes obvious that smaller organisations perceive knowledge flows from OSS to standardisation as providing the latter with new ideas as inputs for technical solutions. Larger organisations see advantages for standardisation from OSS in the implementation of technical solutions. In contrast, smaller organisations experience positive impacts of standardisation on OSS on the validation and diffusion of technical solutions. Obviously, there exists a complementarity of effects, which is explained by the size of the organisations. However, it has to be mentioned that smaller organisations are also less involved in standardisation confirming previous studies.

Overall, the respondents do see that there is likely to be a positive impact for identifying, implementing, validating and fostering technical solutions through the development and use of OSS outside of an SDO, and that its limited use and development for particular purposes in an SDO might be helpful in certain situations.

In particular, analysing the impacts on open source projects, which build on standards developments, should require a differentiation according to the following three situations. First, when standards exist before open source initiatives, they can help to guide open source initiatives to create their technical specifications, which might be a positive impact. Secondly, standards created at same time as the OSS negotiations around the new standards might slow down the open source community to create its technical specifications. In addition, there is a risk that technical specifications in OSS advance more quickly than standards specifications and as the standard catches up, it 'forces' re-engineering of OSS. Both impacts could be negative. Thirdly, standards are created after OSS. Then, the standards might impact the existing ecosystem in reducing the variety in OSS. On the one hand, this might be negative, if this reduces the dynamic and 'creative' nature of many OSS teams competing in the parallel exploration of the search space to develop a winning or elegant solution. On the other hand, it might be positive in stabilising the subject area (hence, foster investment) and ensuring a level playing

field (hence promoting competition by allowing smaller players to have a chance). This positive impact is more likely, where interoperability is important. Especially during the consolidation after an initial phase of rapid exploration of OSS solutions, the aspect of standards needs to be considered.

4.2.5. *IPR Regimes in Standardisation and OSS*

In general, participation in standardisation activities applying royalty free schemes is much more common compared to FRAND. In particular, less than 20% of the respondents never participate in standardisation activities which apply royalty free schemes, this share is more than double in case FRAND is implemented. Complementary, more than 50% do always or often participate when royalty free is implemented, but less than 40% when FRAND is realised. In particular, small organisations are almost never involved in activities under a FRAND scheme, whereas the size of organisations does not correlate with the popularity of royalty free.

Looking at the most common OSS licensing regimes among the respondents in figure 6 the Apache License 2.0, the MIT License and the GNU General Public License (GPL 2.0) are the top three followed by GNU General Public License (GNU) 3 and the BSD License 2.0.

In addition, we can observe discrepancies between larger and smaller organisations. The latter have much stronger preferences for both the GNU General Public License 3.0 and the GNU Lesser General Public License (LGPL) 3.0, whereas the former are inclined to the MIT License and the various versions of the BSD Licenses.

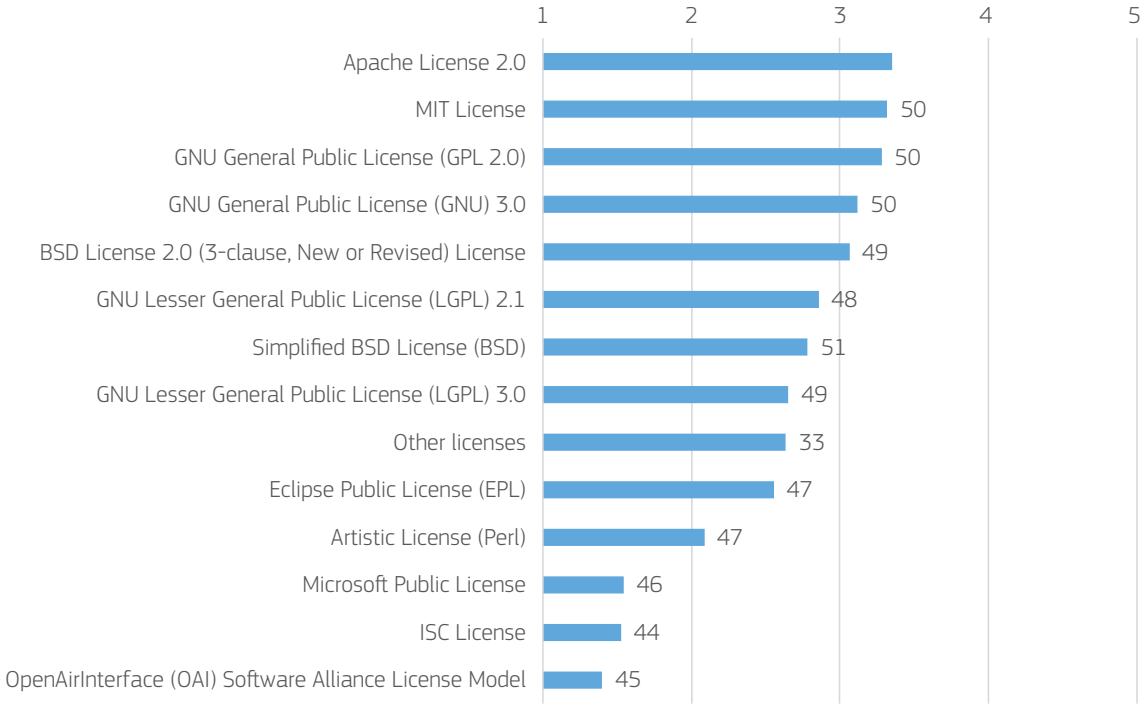

FIGURE 6: PARTICIPATION IN OSS ACTIVITIES WITH VARIOUS COPYRIGHT LICENCES (SCALE: 1 = "NEVER"; 2 = PARTICIPATION IN OSS ACTIVITIES WITH VARIOUS COPYRIGHT LICENCES (SCALE: 1 = "NEVER"; 2 = "RARELY"; 3 = "SOMETIMES"; 4 = "OFTEN"; 5 = "ALWAYS").

Finally, the respondents were asked for the existence of conflicts between the various copyright licences and the licensing models in standardisation, in particular FRAND. Here, it becomes obvious that both the GNU General Public Licenses GPL 2.0 and 3.0 on the one hand and the GNU Lesser General Public License LGPL 2.1 and 3.0 create conflicts for around two thirds of the respondents. For the BSD Licenses only one third report conflicts. Overall, small organisations report less conflicts.

The detailed descriptions of the experienced conflicts between the chosen OSS and the licensing models in

standardisation summarised under "Other licences" in the figures reveal the following positions. Some argue that OSS licensing and FRAND are in general incompatible and that only fully open licensing is acceptable, because FRAND excludes out small businesses and increases burdens on open source builders. Others explain the conflict as of commercial as opposed to legal nature, as reciprocal OSS licences like the GPL-3 require a royalty-free patent licence, while FRAND does not imply royalty free licensing. This may prevent the patent owner from monetizing their patent portfolio. Since the patent owner is free to choose a different business model, the issue is for some respondents not a question of legal compatibility.

In case of conflicts, there are – at least in theory – various options to solve them. Overall, the respondents have not very often experienced effective solutions. Most appropriate is the strict separation between OSS and FRAND licensing followed by negotiations to find solutions. If no solutions are found, sometimes organisations withdraw from standardisation. Another option is the use of copyright-only licences explicitly excluding patent licence rights, which are negotiated separately. Still more than rarely used are more flexible IPR models in SDOs, which allow case by case IPR schemes, and even the withdrawal from OSS, which is less likely than the withdrawal from standardisation.

In a final question, we asked for an assessment of the effectiveness of various general approaches of collaboration between standardisation and OSS. First, it is asked in particular by smaller organisations for a higher flexibility of SDOs' patent policy. Secondly, new processes to integrate OSS in standardisation are suggested. Thirdly, not only more flexible patent policies are asked for, but it is even suggested by many small organisations that SDOs change their patent policies towards royalty free.

4.3. Summary

Despite of the limited response to the stakeholder survey, the analysis of the responses reveals sound and internally consistent results. In addition, the results are also in line with the insights from methodologically similar analyses. The differentiation of the sample into large and small or medium-sized organisations, which is almost identical to a separation into patent owning and not patent owning companies, reveals interesting insights, which also guide the derivation of policy recommendations.

5

ANALYSIS

5 | Analysis

The literature review, case studies and survey report together deliver a comprehensive picture of the interaction between SDOs and OSS communities in general and OSS and FRAND licensing related to standardisation in particular that goes beyond the insights covered in existing publications. The results will be synthesised to analyse aspects of governance, relevant stakeholders, areas of innovation and collaboration versus competition between the wider OSS community and standard setting organisations. These insights will be used to derive policy recommendations presented in the final chapter.

We structure the analysis according to the general governance of SDOs and OSS communities, the involved stakeholders and the addressed topics and conclude with an intermediate presentation of their respective strengths and weaknesses. In a final section, we analyse their interaction starting with the preconditions, before we introduce the interaction in general followed by the three possible scenarios of possible interaction. Since the impact of the interaction is perceived to be positive, we conclude with the analysis of the compatibility respective complementarity of IPR regimes in SDOs and OSS, the core topic of the study.

5.1. Governance

It became clear early in the study that **legal compatibility of the IPR frameworks applied through open source licences and SDO terms of reference is necessary, but not sufficient to establish successful collaborations**. Once legal frameworks have been established that make it possible to collaborate on standards and open source development, a common understanding of organisational governance and stakeholder participation needs to be developed that causes a positive motivation of all parties to committedly contribute to a collaborative process.

R&D funding and IPR frameworks are key traditional angles of innovation and IPR policy (Edler et al. 2016). Existing publications focus on legal aspects and the impact of IPR frameworks on industrial innovation and growth. This includes potential growth and R&D allocation effects caused by the admission of patented technologies into newly developed standards. Meanwhile, a growing number of different technologies is necessary to build modern products, but this is also one reason for a rising complexity to secure licences to all necessary IPR. A wide range of components of different types like network communication, storage, computing or peripherals are being combined into more and more integrated ICT products. This gives rise to potential anti-commons situations that could inhibit or prevent the efficient adoption of innovative IPR protected technologies in the market (Heller 1998). How participants acquire licences to the IPR necessary to introduce their products into the market is of key importance to the efficiency of the innovation process. Licences may be gained through bilateral negotiations, FRAND commitments, automatic licensing offers that can be unilaterally accepted and other means. Insufficiently discussed in literature is the importance of *when* in the innovation process participants are able to secure licences. The stakeholder input to the case studies shows that **the ex-ante acquisition of licences to open source products without the need for later negotiation significantly reduces the inherent risk and potential of hold-up situations** caused by the stronger bargaining position of rights holders in later market-based negotiations, an aspect not yet covered in literature. Parallel to the requirement of technical interoperability, the question of which IPR frameworks are applied and how participants manage to combine them in marketed products becomes crucial for the competitiveness of the ICT single market.

The importance of the perception of governance is underlined by the continuing disagreement about the possibility to combine FRAND and OSS licensing terms. While multiple authors point out that from a legal perspective only a small number of open source licences contain terms contradictory to FRAND licensing of SEP, others underline the cultural opposition of OSS contributors to reserving rights to collaboratively developed products (Bekkers and Updegrove 2013), or the prohibitive effect of such terms on contributor motivation (Phipps 2019). This indicates a difference in the perception of the nature of governance that became evident in the case studies.

In an SDO environment, **governance is expressed in the terms of reference, including the IPR and**

pre-competitive cooperation frameworks applied by the organisation and accepted by the participants. At the heart of SDO governance is a multilateral legal agreement. For each participant, the SDO governance framework is an exogenous variable. How participants collaborate on the platform provided by the SDO follows from it. In OSS communities, it is more common that the model of collaboration emerges from the intentions of the participants. **OSS governance is endogenous to the community**. The collaboration model maps to different reciprocal or permissive approaches of product licensing. In recent years, licences are chosen from a small set of popular licences that each represent one of the common models of collaboration. The popular OSS licences provide a toolbox of flexible licence choices where different approaches may be combined even for the products of a single community.

5.1.1. *Governance of SDOs*[1]

5.1.1.1. *The standardisation ecosystem*

The governance of SDOs evolves within a comprehensive standardisation ecosystem. Consequently, it is constrained by several dimensions. First, **SDO governance is embedded in a legal framework**. Legal constraints arise from international trade law, competition/antitrust law, intellectual property law and public procurement law (Baron et al. 2019). In particular, the Agreement on Technical Barriers to Trade released by the World Trade Organization specifies transparency and openness, non-discrimination, impartiality, balance of interests and consensus-based decision-making as governance principles at least formal SDOs should follow, in order to avoid the creation of barriers to trade. Many consortia operate without considering this agreement.

At the EU level Regulation 1025/2012 sets the legal framework for SDO governance in general and the Guidelines of the European Commission to horizontal co-operation agreements in particular for competition issues related to standardisation. Secondly, the governance of formal **SDOs is also limited by the relationships with other SDOs**, in particular the vertical links in the top-down hierarchical structure between the established international, European and national SDOs. In addition, there are cooperative horizontal liaisons between these formal SDOs and informal SDOs and consortia, including OSS organisations. Finally, the **competition between SDOs has a restrictive impact on their governance**, e.g. in the context of forum shopping (Lerner and Tirole 2006). Baron et al. (2019) found some evidence of "voting with one's feet" by dissatisfied stakeholders to other SDOs in emerging areas, whereas with increasing maturity of technologies stakeholders are sticking to their SDOs due to switching costs, path dependency and even IPR linked to already existing standards.

The three types of constraints for SDOs governance vary depending of the type of SDO (Baron et al. 2019). The formal and established SDOs at the international, regional or national level are primarily constrained by the respective legal frameworks and the vertical relationships. In contrast, informal SDOs or consortia are in general in a fierce competition with other SDOs for members in general, contributors and implementers in particular. Furthermore, some are looking for accreditation or approval of their standards by formal or already more established SDOs, which might generate indirect legal constraints and restrictions by the SDOs they collaborate with. Well established informal SDOs with a strong technological profile are in general therefore both under less competitive pressure and less constrained by regulatory frameworks and vertical relationships to other SDOs.

In the context of public policy, **SDOs are embedded into a self-regulatory approach characterised by a limited involvement of public authorities** in the day-to-day functioning of SDOs and in the substance of their work. These autonomous and industry-driven processes are also endorsed by their stakeholders. Nevertheless, public authorities are in the position to monitor and enforce the above-mentioned legal constraints, in particular trade and competition policy instruments, on SDO governance and procedures to ensure that the results of their activities are contributing to public policy objectives. This procedural approach allows some diversity, which is in line with experimental approaches to regulation, like regulatory sandboxes (NESTA 2019).

[1] The governance of SDOs was not addressed in the terms of references of the study. However, it turns out that governance of both SDOs and OSS communities plays an important role for their interaction. Therefore, we summarise in this subsection the major findings from the executive summary of the report by Baron et al. (2019) as a benchmark for the comparison with the governance of the OSS communities.

Due to the different contexts of SDOs, Baron et al. (2019) observe some heterogeneity in the governance of SDOs. Internal institutions influence the way each organisation makes decisions within the three dimensions of constraints. They differentiate between leadership- and membership-driven models. The more formal SDOs tend to be following the later consensus-oriented model, because they have also to consider public interests. The informal industry driven SDOs put the technology in the focus of their work. Further objectives of the SDOs, which are mostly non-profit and non-governmental incorporated organisations, are depending on the governance, including the organisational form, the division of roles among governance bodies, the voting rules within these bodies, processes for selecting SDO leadership, and the role and responsibilities of SDO staff.

Members are organisations, including other SDOs, but mostly companies. Some SDOs have a large individual membership. Members can be grouped by commercial functions, level of participation or geographical origin. With respect to SDO leadership, in general, members of governing boards are recruited from their membership. The size and responsibility of permanent staff vary considerably between SDOs. The existence of a significant permanent staff with leadership functions is an element of a more leadership-driven governance. Staff typically participates in standardisation meetings but has no voting rights. In some SDOs, the staff also drafts policy documents, whereas in other SDOs with a strong membership representation on the board policymaking is in the board's responsibility. If individuals participating in SDO policy development are expected to represent a member or stakeholder, then governance is more membership driven. If individuals should act in the interests of the SDO itself or of society at large, then the autonomy of the SDOs towards its membership is strengthened and makes it more leadership driven.

SDOs follow different procedures to develop their rules and policies as compared to standards. Differences are found in voting rules (more majority voting instead of consensus), different decision-making bodies (the general assembly and the board instead of committees and working groups), eligible participants (formal members instead of any interested party), transparency (generally less than for standards development), and the duties of the participants (more emphasis on duties towards the SDO rather than towards the member). Most SDOs feature one or more of these differences.

In most SDOs, policy matters must move through many bodies, e.g. committees and boards. However, decision-making is quite heterogeneous between SDOs and even sometimes within an SDO depending on the topic. In general, where the central decision-maker for policy matters is the general assembly of members, policymaking is membership-driven. Where the central decision-maker is a board, policymaking can be more leadership-driven as long as the rules for board appointment and status give the board more autonomy vis-à-vis the membership. Where the central decision-maker is a specific policymaking body designed to balance stakeholder interests, here as well policymaking will tend to be less influenced by powerful members and more leadership-driven. Finally, where the ultimate decision-maker on policy is a non-elected director or board, policymaking is predictably leadership driven.

It should be noted that voting rules for policymaking are not always reflective of SDO practice. On paper, most SDOs have majority voting for policymaking, with voting thresholds ranging from simple to two-thirds majority. Individual votes are mostly kept secret. Some SDOs have specific voting rules designed to make it difficult to overrule significant stakeholders or stakeholder categories. However, in reality, votes are rare, and policymaking is mostly based on consensus. Policymaking might in theory lead to disputes between members. Most SDOs offer procedures to issue formal or informal interpretations of policies and allow for appeals of policy-related decisions. However, SDOs report few disputes, and generally show a strong aversion to intervening in disputes amongst members. The different features of SDO governance architecture combine to lead to a stronger role for SDO leadership or a greater emphasis on member or stakeholder consensus.

5.1.1.2. *Governance principles*

The governance principles in particular for formal SDOs arising out of the legal constraints were formulated focusing on standardisation activities. In contrast, policymaking at SDOs is generally less open than standards development, since participation tends to be restricted to SDOs members and membership is not free at most SDOs. As for transparency, different models co-exist with respect to standards development. Some SDOs are very transparent in the process of standards development but will then make the final standard available only against a fee. Other SDOs that rely on membership fees offer sometimes less transparency to the outside world in the course of development but make the final standard available for

free. When it comes to policymaking, SDOs tend to be far less transparent. A similar difference exists in volunteer-driven OSS communities, where the development process has been observed to be much more accessible and transparent than the community management process (Böhm 2019).

Balance of interests is a concern in policy making just as in standards development. Some formal SDOs seek to achieve a balance of interests, e.g. according to geographical and economic dimensions or public interests, in the bodies that decide on policies. Other more informal SDOs use ad hoc categorisations, defined per project. In practice, many SDOs experience difficulties in attracting sufficient representatives outside of the producer and implementer constituencies. In addition to balance in representation, a few SDOs also seek to balance voting, by having majority-per-category requirements.

Openness and balance are objectives that can be hard to attain at the same time. **Some SDOs privilege openness, others balance, and others emphasize openness in standard development and balance in policy-making matters**. An alternative path is to rely on the fiduciary duties of SDO leaders towards the SDO or the general interest of SDO members in order to dampen any adverse effects from openness or balance.

In the understanding of SDOs and their stakeholders, the consent of participants, as expressed through SDO decision-making, provides a substantial measure of **'internal' legitimacy** to SDO activities and decisions. The external legal constraints applicable to SDO procedures channel consent so as to avoid clashes with the policies underlying these laws. Still, from a public policy perspective, consent might not be sufficient, given the broad impact of SDOs activities and decisions beyond the SDOs and its stakeholders. Market discipline is more elaborate than previously thought and can also confer some legitimacy. While **SDOs** are not themselves democratic institutions, in certain cases (in the EU in particular) they do **receive delegated tasks from democratic bodies**, also contributing to their legitimacy. Finally, SDOs concentrate expertise, even though they sometimes deal with policy matters that lie outside of the typically technical expertise of the participants. Through the combination of all these sources, SDO activities and decisions can therefore aspire to sufficient legitimacy from a public policy perspective, warranting the self-regulatory approach described above.

5.1.1.3. *Governance and IPR policies*

In general, SDOs establish IPR policies, which are embodied in a range of documents, depending on the SDO. Stakeholders do care about these policies, and that they are material in their decisions relating to participation in SDO activities and decisions (Wiegmann et al. 2019). At the same time, product-centric and patent-centric firms diverge in their assessment of and expectation towards IPR policies, making this policy area both highly salient and highly challenging.

SDO IPR policies primarily regulate the management of copyright on the produced standards and rules on patent disclosure of potentially Standard-Essential Patents (SEPs), on patent licensing of such SEPs (often on the basis of commitments to Fair, Reasonable and Non-Discriminatory (FRAND) licensing) and on the transfer of such licensing commitments upon transfer of SEPs to another party. IPR policies are established and changed in interaction between the SDO and public authorities. Few SDOs in Europe are fully independent in this regard. They are subject to procedural approaches by public authorities, especially anti-trust and competition issues, in return for establishing a "safe harbour". In the European safe harbour approach, public authorities describe the general content of an IPR policy that would usually be deemed to comply with legal requirements applicable to SDOs. Observing this procedure establishes a "baseline policy" generally understood to be compliant with legal constraints. These baseline policies define basic requirements of IPR disclosure and licensing, without prescribing the exact implementation in detail. Many SDOs adopt baseline policies without adding a substantial additional framework to guide their participants in areas where patents are rare. FRAND licensing requirement are rooted in the criteria imposed by the baseline policies. Any additional SDO terms of reference beyond the baseline policy reflects the SDOs own choices of technical scope and internal governance (Baron et al 2019).

Explicit, written governance norms and IPR frameworks regulate the behavioural expectations towards participants in SDOs. For conflict resolution, most interviewees referred to these SDO frameworks as well-established guidelines that for the most part prevent conflicts by making the expected behaviour explicit and providing a platform for implementing those expectations. Participants orient themselves based on these SDO frameworks that usually

existed before they joined. They do not consider other conflict resolution methods necessary. Conflicts that cannot be solved by enforcing the widely accepted SDO IPR framework almost never occur in practice.

5.1.2. *Governance of OSS communities*

Where systematically different leadership-driven and consensus-driven models can be observed for SDOs, the **governance in OSS communities is more obviously shaped by voluntary participation of all contributors**. Individuals and organisations contribute to a community's development process only if it is in their self-interest. While some communities have decision making and conflict resolution procedures and functions in place, they cannot force a contributor to implement a community decision. A participant always has the choice not to contribute to the implementation of the decision or to leave the community altogether. Because of that, **open source communities generally aim for consensus similarly to SDOs when making decisions and are considerate towards minority opinions**. The role of steering committees and boards is primarily to moderate the process of finding consensus and to facilitate contributions. This makes it difficult to systematically compare the governance of SDO and OSS communities. For analytical purposes, we will still discuss the same governance aspects for OSS that have been detailed in the previous section for SDOs.

The **ultimate decision maker in an OSS community is the whole of all contributors, with each vote possibly weighted by the contributor's merit in the meritocratic organisation**. While in the past, concepts like a "benevolent dictator" veiled the fact that without voluntary participation there are no contributors and no community, in recent years governance norms of communities have increasingly normalised and common expectations established. Representative boards, either elected by the contributors or appointed based on financial contributions of organisations to the community, are tasked with day-to-day management, but can rarely take decisions even against an influential minority of contributors. There is also a common understanding that community management and technical leadership are separate concerns. Many community organisations separate between a governing board and a technical steering committee.

The voting rules reflect this ambivalent nature of leadership under voluntary participation. **Votes are typically assigned in a one-contributor-per-vote scheme or based on a tiered model where organisations that pay a higher membership fee gain additional votes and committee seats based on that status.** However, the composition of the representative committees only rarely translates to concrete influence over technical decisions. **Technical leadership emerges from concrete product contributions which often only partially overlaps with administrative project leadership.**

This means that the **election process is based on a mix of meritocracy and organisational status within the project**. The election process is also much less impactful. Since administration in OSS communities plays a subdued role as an enabler of product contributions, serving on a governing board or a technical steering committee translates more to responsibility than to privilege. If OSS projects elect representative functions, voting is performed either based on one-contributor-per-vote schemes or on tiered membership status.

The individual duties of the participants are focused on the overall goal of the community to enable and attract contributions. They require for all participating organisations to collaborate with other contributors in the interest of the project, regardless of competitive interest. Once communities grow to a size where formal organisation is necessary, details of these **behavioural expectations are often laid out in a "code of conduct" adopted by the project that aims at creating an inviting, non-discriminating, productive community conducive to attracting contributors and contributions**. Beyond explicit policies like a code of conduct, solidified implicit community norms reinforce professionality, acting in good faith and integration with parent umbrella organisations and the wider open source community.

The organisational form of OSS communities varies from small, auto-organised groups to formalized structure with appointed governing and technical representatives. **Voluntary participation dictates that these project representatives do not enjoy executive power over project contributors** and have only limited influence on the concrete technical

work. Some projects, however, employ technical and/or administrative staff. In such setups, the community organisations act similar to companies in carrying out the mission of the project. Only a small number of OSS communities are set up as independent legal entities. Most of the larger collaborations established in recent years are established under an umbrella organisation, such as the Eclipse Foundation, the Apache Foundation or the Linux Foundation that are legal entities, which provide administrative support, technical infrastructure and other functions like marketing and fundraising coordination.

The role of staff cannot easily be generalised, since the project setups vary significantly. In industry-driven communities staff typically focuses on community management and project representation. Key technical contributors, like release managers, are employed as staff in some projects. Some of the figureheads like Linux Torvalds, the creator of the Linux kernel, are employed as staff to enable them to work on their projects full-time. Overall, **staff headcount of OSS projects is typically small compared to the number of engaged contributors** and focuses on enabling and supportive roles. OSS community staff is usually not in a position to dictate governance, legal or technical decisions.

The case studies support this assessment and illustrate how OSS governance coalesces towards more common expectations based on pragmatic management of voluntary participation and meritocracy. The survey identifies that **especially SMEs benefit from the reduced barriers to entry and cost of participation and are motivated by this to contribute**.

Literature and journal publications are sparse on this aspect. The wider open source community has evolved beyond the earlier understanding of individual volunteer-driven communities reflected in Benkler (2002), Lerner and Tirole (2002) or O'Mahony and Ferraro (2007) towards a model of collaboration shaped by industry-driven continuous research and development cooperation. This development is not in contradiction to these earlier scientific observations, it marks a change in community composition that represents the adoption of OSS products and processes across the industry

Similarly, the **OSS ecosystem has evolved into the global upstream/downstream network that integrates the work of the various individual communities into a technology stack suitable for end-users and as software platforms for commercial products**. The term wider OSS community describes this global network of individual projects, developers, research institutions, business and any other entities that participate in the creation of open source software. **No central decision-making body exists to steer the work of the wider OSS community** in the global upstream/downstream network. Similarly, to different SDOs competing for the creation of relevant standards, the work of the wider OSS community is coordinated by way of competition between alternative solutions for downstream integration and adoption. Collaboration between the communities within the upstream/downstream network may emerge organically, with the support of companies acting as distributors of integrated products, like Red Hat, SUSE or Canonical, or facilitated by umbrella organisations. The case studies illustrate how and where collaboration decisions are made and what umbrella organisations act as supporters of the process.

5.1.3. *Comparative analysis of governance*

Where **SDO governance develops within the constraints of the legal framework, relationships within the integrated network of SDOs and competition between them, governance of OSS refers to "the means of achieving the direction, control, and coordination of wholly or partially autonomous individuals and organisations on behalf of an OSS development project to which they jointly contribute"** (Markus 2007, p. 152).

The **leadership of SDOs is more formally established** and in a position to manage and implement the goals of the organisation and of policy makers. **Leadership in an OSS community is more fluent** and acts in a facilitating role since the community relies on voluntary participation.

Decision making similarly differs both in scope and in process. The **recognised status of some SDO enables**

them to make and implement decisions that an important minority may not agree with. Except for possible competition between SDO and "forum shopping" behaviour of participants (Lerner and Tirole 2006), **actors do not have the opportunity to "fork" the community**. Similarly, should stakeholders be dissatisfied with the performance of a given SDO, **they can 'vote with their feet'** and take their standards development activities to another SDO, or even launch a new SDO. **In OSS communities, however, relevance depends on the ability of the community to represent the consensus of a critical mass of contributors in terms of both technical direction and governance norms.** Top-down enforcement of leadership decisions is not a promising proposition and cannot be observed in practice. The case studies highlighted that participants experience this as a strength of OSS communities, because it prevents the organisation from developing own interests that possibly diverge from the contributor interests. However, **formalized decision making in SDOs provides stability and acceptance, for example in the interaction with policy makers or anti-trust authorities**.

Voting rules and election processes differ strongly both between SDOs as well as between different OSS communities. For the interaction between standards and OSS development, they may be less relevant as they are mostly internal affairs of the organisation. One noticeable difference is in the acceptance of representatives that have not attained merit from contributing to the standards or OSS development process. In such cases, being an elected or appointed representative may not translate to having an influential voice in the collaboration. This issue is related to the individual roles and duties of participants that primarily represent the standards or OSS development organisation as opposed to the ongoing development process. While there is a role for career of standardisation staff members in SDOs, there is no such career (yet) within an OSS community. Open source umbrella organisations are more similar to SDOs in this respect than to individual OSS communities.

This comparison of key aspects of governance between SDO and OSS communities shows that as of now, **significant differences exist regarding all five criteria, i.e. ultimate decision maker, voting rules, election process, individual duties, organisational form and the role of staff**, that need to be understood and bridged to achieve efficient collaboration. A key aspect is that both **most SDOs as well as OSS communities cannot be directed to collaborate and also cannot direct their participants to do so**. This currently acts as a barrier to collaboration between SDO and OSS communities, since most attempts engage a top-down approach to it. It is, however, also an enforcing corrective to make sure that collaboration only emerges where its benefit is apparently clear and convincing. Policy makers can use this insight to influence the motivational environment to create, encourage and support convincing opportunities for collaboration.

5.2. Stakeholders

5.2.1. *Stakeholders in SDOs*

SDOs in Europe rely on voluntary cooperation between businesses, users, public authorities and other interested parties. These include market surveillance authorities, accreditation and certification bodies, universities research institutes and laboratories, legal experts (e.g. on IPR), academics, innovation agencies, insurers, trade/labour unions, NGOs and other groups representing specific sectorial, professional or societal interests (e.g. consumer interests, worker interests, environmental interests and SME interests). In addition, governmental institutions, regulators and public procurers (Blind 2008) have a specific interest in standardisation and standards, because they rely on them in executing their tasks. **At the European level, the standard setting process is based on consensus**, i.e. characterised by the absence of sustained opposition to substantial issues by any important part of the concerned interest and by a process that involves seeking to take into account the views of all parties concerned and to reconcile any conflicting arguments (see also ETSI 2019), and the other interested stakeholders. Overall, there are slightly less than 10% of the companies with more than 5 employees actively

involved in formal standardisation (Rammer et al. 2016). In addition, it has to be noted that despite representing 99% of all companies, SMEs appear to have individually very limited resources to invest in standardisation and therefore obviously experience difficulties in participating (Rammer et al. 2016), while their business can be highly impacted by standardisation work (e.g. Blind and Mangelsdorf 2013, Wakke et al. 2016). Furthermore, a strong overlap between companies active in formal standardisation and patenting can be observed (e.g. Blind and Mangelsdorf 2013). From a practical perspective, cooperation is needed between a broad range of stakeholders, including the EC, ESOs, industry, and the representatives of societal and other stakeholders.

In the stakeholder survey, **around one half of the responding and mostly larger organisations report to be active in at least one of the different types of standardisation organisations**. On average, an organisation is engaged in almost three different types of standardisation organisation. Most popular are international consortia. This dominance is further supported by the standardisation organisations mentioned under "Others". Here, we find further international consortia, like OASIS, OGC and W3C. However, taking all types of consortia plus the category "Others" sums up to slightly more than 42%, whereas the naming of the formal standardisation bodies accumulates to more than 57%. This ratio is certainly specific to the focus on information and communication technology in general and software in particular, because across all sectors German companies are five times more active in formal standardisation bodies compared to consortia (Rammer et al. 2016). Due to this specific focus, most organisations are active at ETSI followed by the international standardisation bodies ISO and ITU in addition to the involvement at the national standardisation bodies, which is a requirement for the participation at the European or international level.

5.2.2. *Stakeholders in OSS communities*

In contrast to the rather high heterogeneity of stakeholders in standardisation, **the stakeholders in OSS are concentrated on companies and independent software developers**. Recent studies have shown that companies are significantly using OSS, e.g. according to Nagle (2019b) more than 40% and even more than 65% according to Black Duck Software (2016).

Whereas only around half of the respondents to the stakeholder survey are active in standardisation, almost **90% of the responding organisations are currently involved in open source development activities**, which is significantly more than the share of the respondents of the survey conducted by Baron et al. (2019). Again, there is a strong bias of larger organisations being involved in particular in formal standardisation bodies. The involvement takes different forms. In general, **the organisations among all respondents to the stakeholder survey are using OSS** with a median value of 100 OSS projects. In particular, OSS is used by over 90% as input into the application level, slightly more than three quarter as input into the intermediate level, i.e. middleware, and around two thirds as input into base layer, i.e. into the operating system or the platform level. Here, the median number of OSS projects is 10. Around 80% of the responding organisations are occasionally contributors to five and regularly to ten OSS projects. It needs to be noted, however, that participation in OSS collaboration requires a smaller commitment of invested time and money.

The **case studies exhibited a strong overlap between the participants in standards and open source development**. Especially larger businesses engage on both. SMEs less often engage directly in standards development, as shown by the survey. The participant overlap may also be a result of the overwhelming representation of telecommunications operators and data network operators, original equipment manufacturers, equipment suppliers of different tiers, as well as ICT software vendors and service providers in the case study and survey data. These subsectors are characterised by strong market concentration for large enterprises combined with a network of service providers and suppliers. Based on the high level of interest in collaborating on the study, we assume the respondents to the survey to represent a representative cross-section of the stakeholders in the interaction of standards and OSS development.

5.2.3. *Comparative analysis*

SDOs as well as OSS umbrella organisations facilitate the participation of industry, individual contributors and academia in technical innovation. By providing widely accepted IPR policies or project charters, they help to normalise governance norms.

Other stakeholders that do not participate in the standardisation process, but may be affected by the produced results, as for example environment protection or civil rights groups, are not reported by the study participants to be involved in the cases and have not been responding to the stakeholder survey. Some SDOs provide multi-stakeholder platforms. Communities and SDOs are usually open for comments from outsiders already on drafts of standards. Beyond that, there seems to be no forum where outside stakeholders may formulate their interests. It is not clear from the cases whether or not participants see this as a situation that should be improved.

The **cases covered mostly represent industrial standards development and open source collaborations**. Both also accommodate the participation of volunteer contributors and academic institutions where it is applicable, which supports knowledge transfer.

Whereas we find in the literature no information about the overlap between the involvement of stakeholders both in standardisation and OSS, **the survey reveals that almost half of the respondents are involved both in standardisation and OSS**. Based on the insights of the case studies the stakeholders involved in the different cases are rather similar between standards development and OSS implementation focused projects. The key relationships are between telecommunications operators and data network operators as the commercial consumers of software and equipment, original equipment manufacturers, equipment suppliers of different tiers, software vendors and service providers. Other important stakeholders forming also the largest group of respondents to the survey are commercial and individual software developers that influence the adoption of technologies and academia and research organisations as a source of innovations.

The absence of variance in the set of stakeholders between cases underlines that standards and OSS development serve the needs of the same community. Other stakeholders, like environmental groups, civil society or government representatives have not been mentioned by the study participants. Obviously, they are not sufficiently interested in the topic.

The reasons for participating in standards development stated by the participants of the case studies match those identified in the literature (e.g. Blind and Mangelsdorf 2016). **Standards development provides stability to the technical innovation process by enforcing a disciplined approach and the creation of complete specifications.** The schedules and planning horizon of SDOs and OSS communities are similar and support each other, while businesses are often forced to plan from one release to the next. For some cases, standards are useful in their own right or as prerequisites for adoption, as in the cases of programming languages or mobile communication protocols. Standards support interoperability and are used as references for regulatory compliance. They also help overcome fragmentation in the market caused by diverging, incompatible or only partially standards-compliant implementations. Standards force vendors with strong market positions to open up for competition. The processes at SDOs facilitate consensus building embedded in a governance and IPR framework that allows for compromises between competitors.

The reasons stated by stakeholders contributing to the case studies for participating in open source development only partially overlap with the reasons for participating in SDOs. Overall, **participants in SDOs and OSS development share many values and convictions**. Participants aim at creating new technologies to overcome a dominant market presence of a single or a small group of vendors in a specific market segment. Collaborating on a joint implementation competing with incumbent businesses can help to re-establish competition, reduce prices, increase the variety of solutions offered in the market and rekindle innovation. In other cases, joint OSS implementation helped increase interoperability between existing or new solutions. Some study participants consider participating in OSS development a more suitable approach to develop industry standards if an implementation-first approach can be realised.

If we compare the assessment of the respondents to the stakeholder survey on the **incentives to join standardisation activities versus OSS development**,

we observe the following patterns. First, the relevance of almost all incentives **are quite similar**, but rated higher for OSS with two exceptions. The inclusion of own IPR is slightly more relevant for the participation in standardisation than for joining OSS. Secondly, standards are obviously a more effective approach to specify regulations, in particular in the European Union in the context of the New Approach. The largest differences can be found for the incentive of lower cost for R&D and shorter development times, important drivers for joining OSS communities. In addition, the personal interest is assessed to be more relevant for the involvement in OSS. However, in addition to finding technical solutions, the royalty free use of code, which is also connected to a positive return of investment in R&D, is obviously much more important for an involvement than the royalty free use of standards.

A further explanation for the higher assessment of the incentives to get involved in OSS compared to standardisation is the general **higher importance of being involved in OSS development compared to standardisation development**. This bias towards OSS is reinforced by the assessment that **two thirds of the respondents expect an increase of importance of OSS compared to less than half related to standardisation**. In the assessment of the current relevance, we observe a significant difference between large and small organisations related to the importance of standardisation. Whereas the two thirds of the former assess it as very important, this is the case for less than one third of the latter. This assessment is consistent with the lower participation of smaller organisations in standardisation bodies. A major reason for the difference is the cost of participation (in time and travel) in standards work compared to OSS. SMEs have a harder time justifying participation. Also, a software engineer can write and contribute code without additional knowledge and training over what they need for their day job. Standards participation requires time to develop the necessary skills. Most SMEs do not have the in-house expertise, and it is not easy to hire experienced standards employees. Related to OSS, we observe not such a significant difference. Obviously, **participation in standardisation plays a less relevant role for small compared to large organisations, whereas we cannot observe such a difference related to OSS**. Related to the future, the expectations related to standardisation are overall balanced between an increased and constant relevance and quite similar between large and small organisations, whereas the majority of all organisations, in particular larger organisations, expects a further increase in the relevance of OSS.

In summary, the analysis of the stakeholders involved in standardisation and OSS reveals some interesting complementarities. Whereas we find in formal SDOs a high heterogeneity of stakeholders with an overrepresentation of larger and patenting companies (Rammer et al. 2016), the OSS communities relatively involve smaller companies without patents and independent software developers. This is a complementarity, which offers synergies to be exploited via a closer collaboration.

5.3. Subject matter and scale of collaboration

During the initial interviews in preparation for the case study report, an assumption was mentioned by an interviewee that the recognised and elaborate organisation structure of SDOs enabled them to coordinate large-scale, industry-sector crossing standards development processes that required heavy up-front research and development investments, whereas OSS communities naturally focus on smaller-scale developments of individual programs with a low number of participants. If that assumption would hold, SDOs could provide a coordinating role to help smaller OSS projects to develop more complex products.

The observation from the case studies is, however, that **large-scale collaborations exist in both standards and OSS development**. From both perspectives, collaborations exist that span hundreds or thousands of participants and produce complex, market-ready products. While it is apparently true that larger, more complex collaborations require additional formalized organisational structures and processes, these functions are provided successfully by OSS umbrella organisations. There is no apparent need for a stronger formalization of OSS development processes. **A convergence can be observed in the functions provided by SDOs and OSS umbrella organisations to their respective communities.** Both act as platforms for collaboration and consensus building as well as industry and personal networks. While the purpose of individual OSS communities

is usually well-defined and implementation-oriented, it is possible that SDOs and OSS umbrella organisations converge further. This gives policy makers the option to engage with OSS umbrella organisations in the future similarly to how they engage with SDO today, which provides new policy options.

The case studies indicate that for the role of standards development the utility provided by the specification is more important than reducing technical complexity. The utility of a specification can either be inherent if major elements of the standardised technology are primarily embodied in the specification. This is for example the case for programming languages, where the language itself is specified as a standard and implementing products are measured against their adherence to the standard. If the utility of specifications is not inherent, it depends amongst other criteria on the pace of innovation within the specific market segment. In general, it can be assumed that the faster an implementation changes, the lower the utility of a detailed specification will be. The utility of specifications and efficiency of the process to create them is influenced by major trends in the ICT sector, including improved methods of collaboration and a trend towards openness and transparency (Böhm and Eisape 2019).

The specifications of standards change in their role if parts of the industry or specific market segments differ in the perception of their utility. **Traditional arguments for standardisation, like enabling competition, facilitating interoperability and mitigating cost of change, are still being confirmed by the case study participants.** However, other covered case studies consider a joint implementation as the standard. The code is the standard in this case, as with the Linux kernel. These communities take a neutral stance towards specification, considering it less relevant for their own work, but potentially beneficial for others. The Linux kernel developers for example are interested in participating in revising the POSIX family of standards, where Linux has become a reference implementation as well as a driver of new technical developments. In at least one case (Automotive Grade Linux), a negative stance towards specification was adopted by the community, stating that "specification leads to fragmentation". Here the community actively questions the usefulness of multiple interoperable implementations for standards development. This overall trend causes an important change in the role standards play. At a time when the ICT sector primarily produced physical products that included a small share of the value-added in the form of software, the vast majority of standards implementations where difficult and costly to change. Hardware, however, is increasingly commoditised and the share of the value-added provided by software grew dramatically, as in the example of smartphones. This means that for a smaller share of technologies specifications are conducive to technical development. For the others, open source collaboration provides an alternative, implementation-first development approach. The accelerating industry-wide adoption of OSS technologies may be supported by this changing role of standards, resulting in the characterisation of more recent large-scale OSS communities as primarily industrial research and development cooperation.

Where SDOs used to be the platform for industry consensus building on most ICT technologies, they now retain this role mostly for technologies that benefit from a specification-first development model. This blurs the previously accepted concept of separating technologies into innovative, state of the art solutions on the one hand and widely adopted commodity products on the other hand. **OSS immediately gains the status of a commodity since is it available to everybody in a non-rivalrous and non-excludable fashion.** It is, therefore, also non-differentiating. However, since major, market leading industry actors collaborate in its development, the product is also the result of early-investment intensive research and development and represents the current state of the art. Open source products can be innovative state of the art and commodity at the same time, as well as a public good. This indicates that their development benefits the general public.

With respect to these considerations it is important to keep in mind that standards and OSS almost exclusively interact for software and hardware development or for interfaces between either of them. The findings of this study are formulated specifically against the impact of software on the ICT sector. Other, related phaenomena like open data, open science or open hardware exhibit partially different economic characteristics. OSS inspired collaboration methods, however, have found application in other sectors as well.

5.4. Strengths and weaknesses of SDOs and OSS communities

Before we highlight the strengths and weaknesses of SDOs and OSS communities, we present a comparison of the similarities, but also slight differences.

SDOs	OSS communities
Voluntary input of producers, users and interested groups	Voluntary input of producers and users of software
Initiation by interested stakeholders	Initiation by interested individual or organisation
Continuation based on interest and financial contribution	Continuation based on interest and quality, but also financial donations
Time consuming (more simultaneous) consensus process	Time consuming (sequential) consensus process
No personalised inputs	Identifiable personal inputs (signalling for labour market)
Copyrights of standards belong to SDOs, IPRs (e.g. patents) are restricted by FRAND rule	IPRs are transferred according to OSS licensing schemes
Different output stages (drafts, final standard)	No final output
Regularly updating after some years	Continuous updating
Only specifications of components and interfaces as input for final products	Significant input in software programmes
Followed by high investments in physical capital	Followed by most low investment in physical capital (esp. computer hardware)

TABLE 1: COMPARISON BETWEEN SDOS AND OSS COMMUNITIES (SOURCE: BASED ON BLIND 2004a).

Böhm and Eisape (2019) find in their SWOT analysis of SDOs and OSS communities based on reviewing literature and expert interviews that both complement each other and compete for relevance at the same time, but for different aspects of the functions they provide. Starting from a utilitarian approach to standardisation, they develop a phase model of standardisation that is able to describe both standards and OSS development processes. Based on the assumption that both SDO and OSS communities operate in the same space of technical innovation, they analyse strengths and weaknesses of each group and compare them systematically. Aspects where both sides show strengths are assumed to be areas of potential competition. Aspects where one side shows strengths and the other a weakness invite collaboration. Aspects where both sides show weaknesses indicate a potential need for others, including policy makers, to provide some guidance.

The **strengths of SDO are identified as mature formal standardisation processes, a powerful reputation in a large stakeholder network, widely accepted terms of reference and IPR frameworks, signalling of market opportunities and value-added SDO services**. Weaknesses are **organisational inertia, a dependency on powerful stakeholders, an ecosystem where responsibilities are allocated based on historical developments, under-defined IPR frameworks and reliance on outdated revenue streams** by some SDOs.

The **strengths of OSS communities are rapid prototyping, a global development model based on early and regular releases, voluntary participation in community activities, and the established overall development process of the wider open source**. Weaknesses are a **lack of established supply chain management processes, uncertainty and arbitrariness in licence compatibility and achieving licence compliance, and a meritocracy that focuses primarily on product contributions at the neglect of other potential stakeholders**.

The strengths of SDOs compared to OSS communities found by Böhm and Eisape (2019) support the conclusions from the case studies. **Participants benefit from tested, proven processes of standards development and a long-term roadmap providing stability to industry, research and policy maker participants**. **OSS communities are comparatively strong at developing technical innovations at a fast pace, steering investments effectively through eliminating failing approaches early in the process and practicing evolutionary product development with early and regular releases**,

which is also in line with the case study findings. Böhm and Eisape (2019) establish the argument that **cost of change is a determinant for the efficacy of the specification-first, implementation-first or parallel standardisation approaches**. SDOs and OSS communities are in competition where they offer a choice of alternative collaborations and consensus building processes. They complement each other in the results they produce (specifications versus implementations). Both are still challenged in handling large-scale ground-breaking research that requires significant upfront investments, like the development of pharmaceuticals or mobile communication protocols. Both SDOs and OSS communities are challenged by standards-essential patents (SEP), especially against the general trend towards more openness and transparency. So far, they are challenged to establish a common understanding what the requirements for open standards are, or the exact meaning of FRAND, or the right balance between enforcing standards with mandates and making them freely available, and many other fundamental questions about the future of standardisation.

5.5. Interaction between SDOs and OSS communities

5.5.1. *Preconditions for interaction*

The case study report illustrates how most SDOs and OSS communities historically started as coalitions of interested stakeholders. The formal recognition achieved by some SDOs as either national standards bodies or recognised entities at the European or international level is in some specific cases assumed to be a motivator for OSS communities to collaborate with these formal SDOs. OSS communities, however, value partners only based on the contributions they make in a meritocratic model. Open source communities are interested in collaborating with SDOs that do relevant work in the field they are working in. What unifies SDOs in the eye of the OSS world is that they produce specifications for relevant standards. What unifies OSS communities is that they focus on implementation. Formal recognition was not a relevant differentiator of SDOs in the eyes of interviewees from an open source community background, even though it is important for the relationship between SDOs, industry and possibly policy makers.

The results from the literature review, the case studies and the survey all suggest that **market actors pragmatically choose combinations of OSS with proprietary hardware and software**. Today, such combinations are the norm and seen as the working model of most industrial OSS consortia, like the Linux Foundation or the Eclipse Foundation. There is **no indication that the market pulls towards a situation where only open source solutions are used**. Technology areas with high cost of change as well as competitive, differentiating product features do not favour open source development models. Voluntary participation also means that neither SDO nor OSS contributors are likely to choose such areas for their OSS development work.

The **viability of collaboration between SDOs and OSS communities is influenced by** all three layers of interaction identified in the expert interviews, i.e. **cultural fit, governance models and legal framework** in that collaboration has to be possible and to be preferable over working separately. Since neither side can instruct the other, collaboration probably needs to be envisioned as an integrated cyclic process with feedback loops between specification and implementation, and shared responsibility for both aspects between all participants.

5.5.2. *Interaction in general*

Based on the insights from the case studies, we can derive the following general conclusions about the interaction between SDOs and OSS communities.

Where SDOs and OSS communities' processes are combined, the processes and governance in the working groups and communities often converge. This may lead to parallel OSS development processes that incubate new features combined with standardisation processes to establish consensus, as well as a choice for participants of two alternative platforms for collaboration and consensus-building.

It appears that **a well-working relationship develops if standards developers and OSS implementers largely overlap and many entities potentially contribute to the development process**. Where there is no such overlap, or in situations where few suppliers maintain control over the market, it can be assumed that cooperation is less likely to develop, and the majority of market participants are merely (commercial) consumers of technology with no participation in standards development.

From the perspective of SDOs, study participants consider their interactions with OSS communities mutually beneficial and serving their joint interest in a specific technical area. The OSS contributors help to incubate the developed technology and to test the specification, which helps maintain high quality in standards. The partner OSS community often creates the first or only reference implementation, which might become the de-facto standard implementation later in the process. Interaction with the OSS community also inspires the modernisation of SDO processes, for example through the adoption of new collaboration methods and platforms and increased transparency of decision making. Since experts in the specific market segments are rare, there is a noticeable but partial overlap between the individuals involved in standards development and OSS implementation.

The **OSS communities describe their interaction with SDOs as fruitful and productive**. The collaboration and consensus building processes encourage the stability of specifications, that would otherwise change quickly and cause interoperability issues. OSS implementations sometimes overshoot the functionality specified in the standards based on the faster pace of development. This may cause a shift in the scope of the technical development. In such cases, SDOs may be slower to update working group mandates and charters compared to the rigorous self-selection processes in OSS development.

Some of the larger collaborative projects do not consider the creation of multiple, standards-compliant implementations as useful, since they prefer all potential contributions to be combined into a single product. **While standards help achieve interoperability of proprietary products that do not share an implementation, OSS users tend to choose a joint implementation for that purpose**. In such a scenario, the best interoperability can be achieved by reducing the number of implementations, ideally to one. Based in that, some cases explicitly exclude participating in standards development from their organisations remit.

Freedom to operate is a key precondition for contributors to participate in the development process. Confidence in access to the implemented functionality either through cross-licensing, explicit patent grants in OSS licences or contributor IPR policies are considered necessary for a fast-paced development process. This confidence reduces investment risks and is expected to be achieved at the beginning of collaboration. Multiple case study participants emphasized that they consider the ex-ante acquisition of the required IPR and the absence of negotiation as key advantages of the OSS development process.

Study participants state benefits and costs of a closer integration of standards and OSS development. **The combination of SDO and OSS processes may, however, lead to trade-offs, especially to a slower pace of development and lower innovativeness**. Another benefit is that in areas of high technical complexity, **detailed specification in standards and working OSS implementation may support each other and lead to both higher quality standards and better code**. A further at least possible cost is that the existence of IPR frameworks that include SEPs may impose a barrier to collaboration by reducing the number of potential participants, while royalty-free licensing norms on OSS communities may similarly impede contributions from SEP holders.

Even in an open OSS development collaboration, participants are uncomfortable with the possibility that other actors may use the OSS product, including their contributions, to create competing products. While permissive licences like the MIT licence do not provide any protection against such scenarios, **reciprocal licensing terms have been mentioned repeatedly as a viable IPR regime that protects contributors from future competition** based on their own investments. The risk of competitors creating commercial, proprietary derivative work is a relevant concern to those participants. An IPR regime based on reciprocal licences like the GPL is considered sufficient protection by those participants.

The last section of the stakeholder questionnaire was eventually focused on the interaction between standardisation and OSS. Both in the literature review and in the case studies different types of interactions have already been identified. All three options, i.e. standards

as input into OSS, OSS as input into standardisation and parallel development in addition to the general interconnectedness of standard development and OSS activities are perceived by the respondents to happen on average "sometimes". The distinction between large and small organisations reveals some more differentiated insights. More than 50% of the organisations with less than 250 employees report that their standardisation and OSS development activities are always or often connected, whereas this is only the case for less than a third of the larger organisations. In particular, for more than half of the smaller organisations OSS is used as input for standardisation, whereas this is only claimed by 15% of the larger organisations. In contrast, there is no difference between large and small organisations in using standards as input into OSS development. Finally, more than a third of the small organisations claim parallel developments in standardisation and OSS, whereas this is claimed only by 15% of the larger organisations. Overall, **standards development and OSS activities are much more interconnected for smaller organisations taking their size into account, which much more often transfer OSS as input into standardisation**, whereas this transfer and even the parallel development is not so common for larger organisations taking their size into account. In relative terms, small organisations contribute much more to the integration of OSS and standardisation than large organisations.

5.5.3. *Three scenarios*

At first, we structure the insights about the interaction between SDOs and OSS according to the three scenarios established already in the literature, i.e. the specification first scenario starting with standardisation, the implementation first scenario driven by the implementation of OSS and finally parallel standards and open source development.

5.5.3.1. *Specification first scenario*

In the literature, we find a few examples of standards originally released by consortia, in particular OASIS, or SDOs, like ISO and its process to develop public available specifications, which created the basis for further OSS projects. The most prominent is certainly the PDF specification. Common to most of these examples is that they are either released by SDOs following an explicit RF policy, like W3C or OASIS, or referring to an explicit public patent licence. Both proprietary and OSS licensed projects, e.g. under the GPL licence, have implemented these few standards.

According to Phipps (2019), in particular **formal SDOs are characterised by an implementation-led rather than a requirement-led standardisation approach**. There are also some standards released by SDOs applying the FRAND regime. However, there are very few declarations of SEPs related to these standards with the exception of the mobile and wireless technologies. Nevertheless, there is still the latent fear of conflicts with potential SEP holders, because of the general contradiction between the FRAND regime and some OSS licensing terms. In particular, the popular **GPL is incompatible with FRAND**, but there are several **other OSS licences**, like the MIT or BSD licences, that are likely compatible with FRAND according to Kappos and Harrington (2019). However, there is no general consensus about this conclusion, because others argue that they **are just complementary, but not compatible** (Phipps 2019). In addition, the notion of the incompatibility of the licensing regimes is endorsed by a significant percentage of open source programmers (Bekkers and Updegrove 2013). There are some differences in the interpretation of licences either as contracts or as sui generis legal instruments that make these assessments situational to the applied jurisdiction and difficult to compare. Due to the highlighted relevance of standards implementation for their quality and success, the concerns of the OSS communities related to the ambiguity in the licensing conditions gain further in relevance. Some SDOs have recognised that OSS implementation as an option to promote their standards.

The majority of the projects among the case studies do not consider a specification as the necessary starting point of an implementation. Those that create specifications state well-known benefits like interoperability or enabling independent third-party implementations to improve competition and the general availability of products in the market. This indicates an increasingly utilitarian point of view towards the role of specifications. Specifications are authored, if they provide a tangible benefit. Projects that do not benefit from written specifications often omit them.

Procurement processes, safety or compliance requirements and other conditions, however, continue to reference specifications provided by standards. Fulfilling such external requirements is

one possible utility provided by a specification that may compel projects to provide them first.

5.5.3.2. *Implementation first scenario*

In contrast to the rather few standards which have been the basis for implementations in OSS, **many OSS implementations have significantly contributed to the establishment of standards**, because OSS is available for immediate testing and prototyping of applications. One popular example from the literature is the Open Document Format (ODF), first provided as an OASIS and later even as an ISO standard. Among the case studies, a significant number follows the implementation first paradigm, i.e. the respective OSS communities act as the incubators of newly developed technologies.

However, there are also concerns, since the lack of any specific IPR rules related to OSS still generates uncertainties. The application of the FRAND rules relevant for patents seems to be less appropriate. In some SDOs, there is even implicit resistance to embed software in standard specifications. However, there are also proactive attempts to improve the integration of OSS in patent oriented SDOs, like the open source project Open Source MANO (OSM) launched by ETSI in 2016 under the OSS licence Apache 2.0.

In summary, **the current frameworks of formal SDOs and informal consortia obviously allow the integration of OSS into their standard development process and standards**. Consortia, like W3C and OASIS, which have more a RF culture related to patents and consequently rather limited number or no SEPs at all, are forerunners in starting proactive initiatives to include OSS in their standards. ETSI, a formal SDO with an established FRAND policy and a high number of SEP declarations due to their focus on mobile and wireless technologies, started with OSM a pioneering project. Other SDOs, like CEN and CENELEC, launched recently further pilot projects to respond to the challenges generated by OSS communities in claiming to set de facto standards.

5.5.3.3. *Parallel development scenario*

More recently, **parallel developments both in SDOs and OSS communities are becoming more popular** according to the findings both in the literature review and to the case studies. In particular, the open processes for standardisation with low barriers to entry adopted by W3C or IETF obviously contribute effectively to open source projects implementing specific standards. Furthermore, a few cases of close interaction between OSS and standardisation are mainly focused on consortia, which have strict RF and rather patent intolerant licensing policies, i.e. W3C or OASIS. Finally, larger software companies are meanwhile engaged both in SDOs and OSS, which drives the parallel development, but might also lead to dominant market positions.

The complementarity of SDOs and OSS is also highlighted by the aspect that in contrast to OSS, SDOs prevent forking of their specifications that might result in incompatible implementations.

5.5.3.4. *Comparison of the three scenarios*

Whereas looking at **case studies reveals a trend to the implementation first scenario**, i.e. OSS implementations are the basis for follow-up standards, and the parallel development in SDOs and OSS, the respondents to the **stakeholder survey** assess the **likelihood of choosing any of the three scenarios as quite equal**. However, the perception of the smaller organisations endorses the relative weights of the different scenarios based on the literature review and the performed case studies. In particular, **SDOs implementing a rather strict RF policy related to patents are much more involved in cases about the collaboration between standardisation and OSS communities** both in the past and in the present. Obviously, the compatibility of the IPR regimes applied in these SDOs and OSS is an important precondition for a collaboration to initiate at all. The case studies and survey results support the conclusion that projects are able to establish such suitable IPR regimes without much difficulty, however none of those regimes incorporate royalty-bearing patent licensing or ex-post negotiation. Regarding the technologies being suitable for collaboration between SDOs and OSS communities, opportunities are again being limited by OSS communities almost exclusively producing software or possibly other information goods.

Multiple case studies exhibit a change of approach between the scenarios over time. Especially initiatives that started before the wide-spread adoption of OSS technologies, like the C++ standards committee initially chose a specification-first approach. Later the committee adopted a parallel approach to iterative standards development. There is not enough data to generalise

this as a trend, however, these transitions reflect the development of better methods of collaboration and the general trend towards openness and transparency that influences the ICT sector as a whole.

5.5.4. *Impact of interaction*

Following the analysis of the interaction in general and the direction of knowledge flows, we assess its general impact based on the findings from the case studies and the stakeholder survey. Here, specific insights from the literature are not available.

The case study research revealed different understandings of the nature of possible collaboration between SDOs and the wider open source community. The most widely used thought model experienced within SDOs for "working with the open source community" is the expectation that SDOs develop specifications in standards and the OSS community subsequently implements them. This approach assumes that a specification is created first as part of a standards development process, and that creating a concrete conforming product is left to implementers competing in the market. As discussed before, this specification-first approach to standardisation is only applied in a minority of cases. It does exist, however, for technologies like programming languages where the value of the specification is inherent.

Based on the overall impact that the **reviewed cases** as well as those being discussed in the literature had on the market, two thirds **can be considered highly innovative, large scale collaboration** that have seen wide or sometimes global adoption, especially Java, Linux and PDF. Almost a third have had a significant impact on a specific market segment. For the most recent cases the impact has not been realised even though they are being considered as innovative by participants. About half of the cases achieved market wide relevance across multiple industry sectors as foundational technologies or by driving business-critical infrastructure, even though they originated from the ICT sector.

There is no clear-cut definition of the affected industry sectors and subsectors as the technologies covered by the case studies are multi-purpose. As a general cross-sector trend, computer and telecommunication systems become foundational technologies for various products and business processes.

The choice of an early, parallel or late approach to standardisation does not limit the possibility of success of a project, nor is a specific approach a requirement to a successful standard. However, the incubation of new technologies and features more commonly happens through joint implementations or reference implementations under open source licences. Most innovations covered by the cases are brought to SDOs once proven implementations exist and are generally available. Instead, some case study participants emphasized that they see standards development not as a means to create genuine innovations, but to establish industry consensus on available technologies to enable economies of scale. In general, **the governance and collaboration models need to be considered suitable by the relevant stakeholders to motivate them to participate**, because most widely adopted technologies are also the ones that attract a large number of participants in their development.

In summary, the case studies developed a partial focus on the networking and telecommunications subsector. This is to be expected since the interaction between standards and OSS development naturally centres at software-hardware intersections. The cases show that numerous successful collaborations between standards and OSS development exist and that they have developed a mature, well-established governance as for example showcased by ECMA TC39 or ISO JTC1. Both OSS and SDO processes are suitable for the development of technical solutions at a small and a large scale. Those of the observed collaborations that established explicit patent licensing regimes opted for royalty-free, ex-ante licensing with symmetrical conditions between contributors and between inbound and outbound licences. SDOs are usually not the drivers of technical developments. More commonly, **OSS communities incubate new technical solutions until they become candidates for standardisation and diffusion in the market**. OSS umbrella organisations increasingly provide functions like platforms for collaboration and consensus-building traditionally assumed by SDOs.

The respondents to the stakeholder consultation also have been asked for their assessment of the interaction between OSS and standardisation on their efficiency and

results. The **majority of the respondents perceive a positive impact of this interconnection on standardisation**. In particular, around 70% of the respondents perceive a positive impact on the creation of specifications of technical solutions contributing to interoperability and on the implementation of technical solutions. Standardisation benefits less related to the ideation of new technical solutions, but also to their validation and eventually diffusion, because here only around 60% of the respondents expect positive impacts. Negative impacts from the interaction on standardisation are in general not expected. The differentiation between **small** and large **organisations** reveals that the former **are more likely to expect positive impacts** on the identification of possible technical solutions, i.e. the ideation, and the creation of specifications of technical solutions, i.e. interoperability, whereas the latter see the advantages in particular in the implementation of technical solutions.

If we turn to the **impacts of the interaction on OSS**, we observe even **higher** shares of respondents perceiving **positive impacts**. More than 75% expect positive impacts for the creation of specifications of technical solutions, in particular related to interoperability, and for the implementation of technical solutions. Whereas around 70% perceive positive impacts on OSS both for the identification of possible technical solutions and their diffusion, beneficial impulses for the validation of technical solutions are expected by less than 60% of the respondents. Again, negative impacts are not experienced. The differentiation between small and large organisations reveals in contrast to the expected impacts on standardisation that the former are more likely to expect positive impacts on the validation and diffusion of technical solutions. Larger organisations see the advantages again in the implementation of technical solutions, but also in the identification of possible technical solutions in OSS.

Comparing all the assessments about the interconnection on efficiency and results, it becomes obvious that **smaller organisations perceive knowledge flows from OSS to SDOs as providing the latter with new ideas as inputs for technical solutions**. Larger organisations see advantages for SDOs from OSS in the implementation of technical solutions. In contrast, smaller organisations experience positive impacts of standardisation on OSS on the validation and diffusion of technical solutions. Obviously, there exists a complementarity of effects, which is explained by the size of the organisations.

5.5.5. *Compatibility or complementarity of IPR regimes in SDOs and OSS*

The sparse existing research reviewed in the literature survey that deals concretely with the interaction of SEP licensing and open source software focuses primarily on the legal compatibility of open source licences with FRAND licensing of SEP. This is one important dimension of the interaction, since any directly contradicting terms in a specific combination of open source and FRAND licence would prohibit a combination of the two works in a product. However, it was clearly identified during the case studies and the responses to the survey, but also recently raised by Maracke (2019) and Phipps (2019), that **answering the question of legal compatibility is not a sufficient condition for possible collaborations of SDOs and OSS**.

The case study report established that the question of legal incompatibility can only be evaluated against a specific contractual situation and the individual terms and conditions applied in the concrete open source and FRAND licences. Several experts contributing to the stakeholder survey also endorsed that since many open source licences of very different nature exist and FRAND conditions as well are not harmonised, no general conclusions can be derived. Reviews of legal compatibility only yield useful results for a concrete licensing relationship with a specific open source licence combined with specific FRAND terms. However, even if a case does not incur any incompatibilities, this only means that a collaboration is legally possible, not that participants from SDOs and OSS would be willing to engage in it and contribute towards a common output. **Legal compatibility of licensing terms is a necessary precondition, but not sufficient to establish a successful collaboration between SDOs and the OSS communities.**

IPR regimes serve partially different purposes in SDOs compared to OSS communities. **OSS licences mirror and follow collaboration models** and represent how participants envision the jointly created products to be used, resulting in the strong-copyleft, weak-copyleft and permissive classes of OSS licences. The governance within open source communities develops as a collaboration model first and is then reinforced through a choice of one or more licences.

In contrast, **IPR frameworks at SDOs regulate how participants engage and how conflicts are resolved**. Special attention is given to how participants may later exit the pre-competitive cooperation at SDOs and compete again on products that implement the developed standard. This rationale is foreign to OSS communities, as they do not envision re-engaging in competition once a functional area is covered by an industry-standard OSS implementation. This contradiction may pre-empt the idea of an OSS community creating reference implementations to a standard next to other competing implementations. Such a thought model has not been found implemented in any of the cases. In the same context, OSS communities see no benefit in engaging in standards development simply for the purpose of facilitating alternative or competing implementations.

One original question of this study was whether or not the empirically limited cooperation between standards and open source development is caused by uncertainty about the legal compatibility between SDOs and OSS IPR regimes. The results from the case studies and the literature review do not support this proposition, while the stakeholder survey did not produce a conclusive answer to this question. **Most OSS projects** observed in this study **use licences with reciprocal conditions or explicit patent grants and interact productively with the SDOs relevant for their market segment**. Some SDOs responded to OSS related market changes by establishing flexible or royalty free IPR regimes, like W3C and OASIS and by adopting open source inspired collaboration methods. In the vast majority of the covered cases, FRAND-licensing of SEP is not considered important or there are no explicit IPR policies for it. Generalisations beyond the available data may not be possible considering the situational character of qualitative case study research. However, **in the investigated cases, SEP do not play a significant role in these ecosystems** for a variety of reasons. In some cases, patent holders share their portfolios through cross-licensing or commit to limited patent grants. In other cases, patents covering their technology have already expired or the implementers established a culture of royalty free licensing. In these projects, there is no need to reconcile SDOs and OSS IPR policies. **Except for the telecommunications subsector, the industry does not perceive a conflict between SDOs and open source IPR policies.** Legal issues between OSS licences and SDOs IPR policies have not been found in practice and are not a relevant concern for most cases. In general, stakeholders either do not consider SEP relevant for their specific innovations or implement a royalty-free patent licensing policy. Therefore, they also do not consider this a situation that needs change.

Most commonly, participants adjust to the collaboration methods and IPR policies employed by the communities they engage with, entering into a trade-off between contributing own IPR in return for getting access to the aggregate contributions by the other participants. For activities at the boundary of standards and OSS development, this typically involves adopting a royalty-free patent licensing policy for all cases except ETSI-NFV and OpenAirInterface, which actively anticipate the inclusion of FRAND-licensed SEP into developed standards. This expectation of **royalty-free licensing is considered acceptable and not to be a barrier to collaboration** or to the development of relevant standards. Multiple parties mentioned as a precondition for this model to work well that all participants invest goodwill into making the collaboration work and are open and transparent about their intentions.

The answers to the stakeholder survey confirm the insights from the literature review and the case studies. In general, **participation in standardisation activities under royalty free schemes is more common compared to FRAND**, which is only rarely or at most sometimes applied by the responding stakeholders. In detail, almost half of the respondents never participate in standardisation activities, which follow FRAND. Complementary, more than 50% do always or often participate when royalty free is implemented. In particular, small organisations are almost never involved in activities under a FRAND scheme, whereas the size of organisations does not correlate with the usage of royalty free.

In addition to highlighting that RF might be a subcategory of FRAND but does not necessarily mean no cost for the implementer, Non-FRAND, RAND and RAND-ZERO are mentioned explicitly as other relevant IPR regimes. Furthermore, non-assertion covenant agreements are an option. Obviously, the guaranteed access to technologies, reciprocity and transferability aspects are important for the involved stakeholders.

In contrast to the distinction between royalty free and FRAND applied in standardisation, several licensing models have been developed for OSS. **Looking at the most common regimes, the Apache License 2.0, the MIT License and the GNU General Public License (GPL 2.0) are**

– as among the case studies – are the top three for the respondents to the stakeholder survey followed by GNU General Public License (GNU) 3 and the BSD License 2.0. This ranking corresponds closely with already publicly available data confirming both the validity of the selected cases and the representativeness of the sample. Less common are the GNU Lesser General Public License (LGPL) 2.1, the Simplified BSD License, the GNU Lesser General Public License (LGPL) 3.0 and the Eclipse Public License. No other licence model plays a relevant role.

In addition to the significant differences between the general attractiveness of the various OSS licensing models, we can observe discrepancies between larger and **smaller organisations**. The latter **have much stronger preferences for both the GNU General Public License 3.0 and the GNU Lesser General Public License (LGPL) 3.0**, whereas the former are inclined to the MIT License and the various versions of the BSD Licenses. It can, however, be observed in the case studies that many licence choices are made in the early stage of an OSS project and then never changed. This supports the claim that **licence choices in communities follow the envisioned collaboration model of the contributors**, and that more recent projects more often opt for licences with explicit, as in the Apache-2 or GPL-3 licences, as opposed to implicit or absent patent licensing terms.

The projects analysed in the case studies apply copyright, patent and trademark protection to their products and organisations. Only two projects (White Rabbit and Linux) do not formulate an explicit IP policy, mostly for reasons based on their historical development. Copyright is applied to source code and specifications. The majority of the OSS projects decided for the Apache 2.0 licence, which is a permissive open source licence that includes a licence grant to contributor-owned patents. A smaller group apply the GPL 2.0, a strictly reciprocal licence that requires all modifications to be distributed under similar licensing terms. Java combines the GPL with the Java Specification Participation Agreement (JSPA), a contributor licence agreement that includes a grant of a patent licence. Only two projects apply a broadly permissive open source licence (MIT, BSD) with no explicit patent grant. The ecosystems of some cases invite independent implementations, so that multiple licences may be applied by different organisations representing the same case. Overall, **the cases set up a patent licensing framework either through the use of open source licences that include a grant of contributor-owned patents or by requiring a declaration of SEP or a patent licensing commitment from participants**. Although, the hosting organisations for multiple cases leave an option for FRAND based patent licensing, almost all cases opted for a royalty-free patent licensing policy. This is either because patents where claims cover standardised functionality are expired, as in the case of C++, or because the working group aims at making the standard freely available, where the royalty-free policy is implemented by way of a contributor licence agreement.

Regarding the existence of conflicts between the various copyright licences and the licensing models in standardisation, in particular FRAND, the stakeholder survey revealed the following pattern. Both **the GNU General Public Licenses GPL 2.0 and 3.0 on the one hand and the GNU Lesser General Public License LGPL 2.1 and 3.0 on the other hand create conflicts for the majority of the stakeholders**. For the BSD family of licences only one third report conflicts. Overall, small organisations report fewer conflicts. **The case studies draw a different picture**, however: There, **even if incompatibilities between OSS licences and SDO IPR frameworks may theoretically exist, the participants always resolved these issues or worked around them driven by the common interest in the collaborative development of a standardised technology**. Licensing incompatibilities have not been observed as a practically relevant problem. This inconsistency might be explained by the much broader range of stakeholders being reached by the survey and the option to indicate conflicts anonymously.

In case of conflicts, the strict separation between OSS and FRAND licensing is still the preferred option followed by negotiations to find solutions supported by the experiences reported in the case studies. If no solutions are found, in particular small organisations withdraw from standardisation. Another option is the use of copyright-only licences explicitly excluding patent licence rights, which are negotiated separately. Still more than rarely used are more flexible IPR models in SDOs, which allow case by case IPR schemes, and even the withdrawal from OSS, which is less likely than the withdrawal from standardisation. Almost never are more flexible definitions of OSS, alternative dispute resolutions or eventually litigation at court suggested.

Whereas there are no convincing constructive solutions for conflicts between OSS and licensing models in

standardisation, some approaches of general collaboration between standardisation and OSS are more promising in particular in the perspective of smaller organisations. First, the **stakeholders ask for a higher flexibility of SDOs' patent policy**. Secondly, new processes to integrate OSS in standardisation are suggested. Thirdly, not only more flexible patent policies are asked for, but it is even suggested that SDOs change their patent policies towards royalty free. Below medium, but above low effectiveness we find new governance and conflict solution models, the use of copyright-only OSS licences explicitly excluding patent licence rights and finally a direct combination of SDOs and OSS communities. Finally, the proposals that OSS licences should include FRAND-based patent grants and of more flexible definitions of OSS are perceived as being not very effective. Interestingly, larger organisations perceive these options as much more effective than smaller organisations.

5.6. Conclusion

The evolution of IPR frameworks in the ICT sector is complicated by the ongoing hardware commoditisation that results in the predominant use of commercial-off-the-shelf general-purpose computers that integrate practically all key ICT functions like computing, storage, networking or telecommunication and peripherals. Manufacturers are faced with a market situation where to make competitive products they need access to a large, encompassing set of IPR held by diverse actors. This means that when assessing governance norms and IPR frameworks in the ICT sector, standards and open source development need to be analysed in combination. Market actors are aware of this situation and have partially already adapted to it by generally preferring consensus-driven collaboration. Formal rules act as fall-backs for conflict resolution. **SDO governance focuses more on legal and IPR frameworks and is implemented self-regulatory within policy constraints**, building upon the baseline policies established in interaction with policy makers. **OSS governance is anchored in collaboration models and builds as of yet unregulated upon authority within the autonomous group of contributors**. OSS governance still coalesces, with volunteer-driven communities relying on more implicit governance norms and industry-led OSS communities creating more explicit rules in increasingly normalised project charters. Governance in SDOs and OSS communities still differ in key aspects of philosophy and implementations, which poses a barrier to collaboration.

SDO processes are more inclusive with regard to engaging a broadly defined set of stakeholders. They are also integrated with industry and policy making. OSS communities mostly involve enterprises, other organisations and individual software developers without a systematic multi-stakeholder engagement. There is a strong overlap of participants in standards and open source development especially for large enterprises. Overall, OSS processes are currently less accessible to policy makers and difficult to influence according to industrial and innovation policy goals.

Both SDO and OSS communities are capable of conducting small to large scale collaborations (in terms of number of participants) and small to large scale research and development investments. OSS umbrella organisations increasingly provide collaboration and consensus-building platforms traditionally offered by SDOs. The wider adoption of implementation-first and parallel approaches to standardisation influences the utility of specifications relative to the value of joint implementations. This changes the role of standards themselves as standards and OSS development are becoming alternatives in achieving market diffusion for a technology. OSS poses a new challenge for managing innovation by being innovative state of the art technology offered with the attributes of a commodity, which have traditionally been considered opposites, and as a public good.

A comparative analysis of strengths and weaknesses of SDO and OSS illustrates where they are likely to compete or to complement each other. It emphasizes cost of change as a determinant for the choice of standardisation scenario. Areas where both groups exhibit weaknesses mark opportunities for active innovation policy to address these concerns.

Globalisation and online collaboration shape the landscape of OSS communities and SDO in that interactions build primarily based on relevance in the respective market segment and less on formal recognition. However,

formal recognition still serves a purpose as it signals relevance for example for safety standards and for reliable baseline policies accepted by policy makers. The **converging functions of SDO and OSS umbrella organisations offer actors a choice** of platforms that previously did not exist. In general, participants judge SDO-OSS interaction as fruitful in practice. With the established alternative standardisation scenarios, the model of building competing products compliant to a previously established standard is complemented by the model of single joint implementations. Both approaches are successful at delivering interoperability and competitive, innovative technical solutions. In both cases, access to the wide range of technologies required to build competitive products is key to the freedom to operate of implementers.

Three scenarios, specification-first, implementation-first and parallel standardisation can be observed in the case studies. The specification-first approach declines in relative relevance but is still important in specification-driven technology areas. Some cases transitioned from a traditional specification-first to a parallel approach as the necessary collaboration methods became available. Especially the parallel approach to standardisation represents some of the successful interactions between standards and OSS development and can result in higher quality standards, more innovativeness and better implementations.

Most of the covered projects are judged as innovative or highly innovative by the study participants. As expected, the cases cover key ICT technologies, like computing, networking, cloud computing and telecommunications. Where SMEs perceive a knowledge flow from OSS communities to SDOs, large enterprises experience a flow in the opposite direction. This may indicate preferences for the choice of collaboration and consensus building platform correlated with business size. **Compatibility between OSS and FRAND licensing terms is recognised as a requirement, but not communicated as a practically relevant issue and considered solvable.** However, wherever contributors have a choice, they are more likely to implement IPR policies based on OSS licences and royalty-free patent licensing. Only a small number of OSS licences are relevant in practice, which reduces the problem space for analysing the compatibility of OSS and FRAND licences.

Innovation policy focuses on IPR frameworks and directing research and development funding to increase competitiveness and encourage building technological champions and industry areas of expertise. The results from this study provide new insights especially into the dynamic development of SDO and OSS governance over time that are still lacking in academic literature. SDOs look back to a successful history but are challenged by an accelerating dynamic in science and technology, to which they started to react. OSS processes represent a viable additional approach to the development of technical standards. The success of OSS communities is driven by their dynamic innovativeness. However, they lack in integration with policy making and other stakeholders and may benefit from careful regulation.

6

POLICY RECOMMENDATIONS

6 | Policy recommendations

6.1. Introduction

Based on the insights of the comprehensive analysis that build upon the results of the review of the literature, the insights from the case studies and the assessment of the stakeholder survey, we derive policy recommendations with the aim to improve the interaction between SDOs and OSS in order to exploit further the existing synergies and cross fertilization effects. Since different actors must be involved, we structure the recommendations by target groups. At first, we derive the recommendations addressing SDOs, because here we see the most opportunities to foster and improve collaboration with OSS communities. Second, OSS communities can also contribute to a better interaction with SDOs. Finally, the European Commission or national governments responsible for the framework conditions in general and for SDOs in particular are asked to take both SDOs and OSS and their interaction in various policy areas into account. We conclude with an outlook.

6.2. SDOs

At first, we address SDOs, because they are both benefiting from OSS and disrupted by the increasing importance of OSS in general. In addition, specific OSS organisations aim at setting standards in the future, which would mean immediate additional competitors. In principle, these recommendations address all SDOs, acknowledging however that individual SDOs have already implemented some of them or are currently addressing them.

6.2.1. *Considering software and OSS in IPR policies*

We recommend SDOs to consider addressing software and OSS explicitly within their IPR policies in order to adequately handle the peculiarities of software in general and OSS in particular.

The review of formal SDOs IPR policies reveals that many either not differentiate between specific IPRs, like copyright and patents, or just focus on patents. This challenge might be less relevant for SDOs deciding to still exclusively focus on hardware technologies and eventually patents. By elaborating the IPR policies towards software and OSS, the interface between the guidelines for licensing patent rights, e.g. FRAND, and the different OSS licences also must be addressed. Organisations like W3C and OASIS that follow a rather strict RF policy related to patents are examples for a successful integration of OSS into the work and output of SDOs by creating a legally conducive framework between patent and copyright licensing. It will be useful for SDOs to consider why it is desirable to innovators to participate in such an environment. However, other approaches not based on RF might not follow the principle of legal compatibility, but just of legal complementarity. So far, success cases are missing, which is an indication that a more focused effort should be invested into developing such complementary solutions between FRAND and OSS licences in general or specific OSS licences including non-RF patent grants.

For future approaches we recommend giving special consideration to the point of time at which agreements about the use of IPR are secured by implementers. Within OSS communities the decisions are made ex ante. In SDOs they are partially taken ex-ante, as for example with FRAND commitments, and partially ex-post, as for example with the concrete implementation of the FRAND commitment between the SEP holder and an implementer. Among OSS communities, ex-ante licences call for RF licensing. In SDOs, licences can be negotiated ex-ante as well. W3C and OASIS have decided to go for RF. However, other SDOs might negotiate for a positive price for SEP, like VITA (Baron et al. 2019). The policy of VITA obligates members to declare the maximum royalty rate they will charge for a disclosed SEP before the standard is approved. The licensing offers made to implementers of VITA standards must be on terms and conditions that are both FRAND and not more restrictive than the more specific terms and conditions initially announced. Among OSS communities, ex post RF is applied as well, whereas in SDOs FRAND including RF is the common approach. In such case, conflicts between the licences

might, but not necessarily must arise. We recommend SDOs to elaborate different and alternative approaches for the integration of OSS in their processes either following an ex-ante way of negotiating about IPR regimes, which is likely to be based on RF, or an ex-post decision. The decision of stakeholders will then reveal which approach is going to be more attractive in the long run and whether the coexistence of complementary ways might be a sustainable solution.

Furthermore, we recommend considering in particular the needs of smaller organisations, including SMEs, in drafting the details of the IPR guidelines related to OSS, because they have stronger preferences for copyleft licences including RF patent grants, whereas the larger patent-owning companies favour non-copyleft preferences without patent grants.

In general, we recommend the development of at least incentive compatible solutions, allowing each contributor to achieve the best outcome to themselves by acting according to their true preferences, which are a necessary condition for a sustainable and successful collaboration between SDOs and OSS communities. Therefore, the latter might be involved in drafting the OSS related IPR guidelines at formal SDOs in order to understand and consider the slightly different incentive structure, but also to exploit existing commonalities.

However, if elaborating the IPR policies in SDOs towards OSS fails, the fall-back option is a strict separation between patent and OSS related policies. This separation requires a decision for either ex-ante acquisition of IPR, enabling OSS development, or to leave scope for ex-post royalty negotiations, enabling FRAND regimes. Both the literature, the experts interviewed in the context of the case studies and finally the majority of the respondents to the stakeholder survey recommend this separation as a fall-back.

6.2.2. *Coordination between SDOs*

The elaboration of **more comprehensive IPR policies including software and OSS** requires a better coordination between SDOs and the consideration of the views of public authorities and other stakeholders.

We observe a diversity of IPR regimes in SDOs not only related to copyright and software, but in particular in the area of patents (Baron et al. 2019). This heterogeneity, but also the limited progress in finding effective and efficient solutions in the case of patents has been the starting point for recommending a tandem approach involving both policy makers and SDOs jointly to find common solutions, e.g. proposed by Baron et al. (2019) related to specifying FRAND. Since the authors admit that their proposal has to be elaborated and specified further, we do not recommend such an approach, but the exchange of experiences and ideas among SDOs also considering the view of public authorities and other stakeholders to exploit the variety of possible options. The launched CEN-CENELEC project on Open Source Innovation could be the platform for such an exchange among the national SDOs within the European Union. However, a further exchange with ETSI relying on the experiences with the MANO project at the European level is recommended. Due to the close links between CEN and CENELEC and the international level, a close coordination with ISO and IEC as well as ITU is encouraged.

6.2.3. *Adjusting financing models of SDOs*

Some SDOs depend on selling access to standards. The inclusion of OSS in standards might have an impact on SDOs' financing models. **We recommend these SDOs to consider this trend and to reduce their dependencies on revenues from selling standards.** This has been realised by some SDOs that apply open access solutions already or practice a closer collaboration with OSS communities.

An increasing integration of OSS in standards published by SDOs can be assumed to challenge those SDOs which are selling their standards for a fee, because the software source code is general freely available via the OSS licences. Therefore, we recommend considering the implications of integrating OSS into standards not only related to the compatibility or complementarity between patent and OSS licences, but also for the financing models

of SDOs. As already argued by Baron et al. (2019) the practice and effects of copyright licensing of standards and reference implementations and their impact on public access and re-use would merit a separate study.

6.2.4. *Speed of standardisation processes at SDOs*

Stakeholders and policy makers have complained about the limited speed of standardisation processes at SDOs. **We recommend a closer collaboration with OSS communities, because it might support SDOs in efforts to speed up the processes and to increase the agility of standards development.**

In June 2011, an overall revision of the European standardisation system was called for in Communication 311 setting out a strategic vision for European standards until 2020 (EC 2011). As part of the new package, strategic objectives have been published. Speed and timeliness are of high priority, because European standards need to be quickly available, especially to assure the interoperability in the field of information and communication technology. However, neither software in general nor OSS have been mentioned in this document. Since then, the limited timeliness of processes in SDOs has been expressed in the literature, by experts interviewed during the case studies and the respondents to the stakeholder survey. The potential role of OSS to address this challenge needs to be considered. Since OSS is characterised by its agility, its further integration into the contents of standards released by SDOs is recommended as an option to improve the agility of standardisation processes and eventually the timeliness of standards' content. Since this topic has not been in the core of the current study, we recommend the further investigation of this interaction after SDOs might have decided to open explicitly their processes and standards to OSS communities and contents.

6.2.5. *Inclusion of SMEs at SDOs*

Small organisations, in particular SMEs, face problems in actively contributing to standardisation processes at SDOs. **We recommend SDOs to integrate in particular SMEs active in the software sector more effectively in their standardisation processes by closer collaboration with OSS communities.**

Communication 311 (European Commission 2011) asks not only for speed and timeliness of standardisation processes, but also for inclusiveness. The European Standardisation System should become as inclusive as possible by involving a wide range of participants. In addition to the integration of stakeholders of various interest groups, like NGOs, the involvement of SMEs is called for. Since both the literature, the case studies and the stakeholder survey confirm the higher likelihood of SMEs being involved in OSS communities compared to their participation in SDOs, the closer collaboration between the both of them presents another opportunity to increase indirectly the contribution of SMEs to standardisation and eventually even their participation in SDOs, as already envisaged in the ETSI 3SI Programme on Societal Stakeholders, SMEs and Inclusiveness. The programme is designed to increase the visibility of the societal stakeholders' and SMEs' interests in ETSI.

6.3. OSS communities

Whereas we have derived several recommendations addressing SDOs, we have only a few suggestions targeting OSS communities. Since OSS communities are mostly autonomous and driven by the aggregate of their contributor's interests, they will primarily respond to changing incentives based on market forces and regulatory influences more than to recommendations of outsiders. Attempts to influence OSS communities will have to focus on adjusting the supply-side environment of the European market and incentivising the communities to adjust, also considering that the legal entities representing the communities may not be based in the EU area.

6.3.1. *OSS definition*

Despite existing attempts to define open source independently, **we recommend keeping and strengthening the existing Open Source Definition.** The definition is broadly supported by the OSS community as well as the overwhelming majority of industry actors and therefore the basis for possible collaboration between them and SDOs.

Since there has been a high level of acceptance among the OSS communities, any efforts to challenge the definition by stakeholders outside the OSS communities is not increasing their willingness to collaborate with SDOs. The Open Source Definition provides a baseline of minimum requirements that normalises expectations towards OSS licensing relationships. This common baseline is an advantage of the wider Open Source community that facilitates large-scale collaboration by practically eliminating transaction of cost of participation.

6.3.2. *OSS foundations*

Larger OSS communities should consider in engaging in the development of future strategies according to WTO standardisation principles, which includes openness, consensus and transparency, because SDOs that develop standards must meet these governance requirements. In addition, standards that include software specifications may be referenced in legislation. Consequently, OSS communities have a choice to produce the specifications themselves or to collaborate with SDOs. We encourage OSS communities to collaborate with SDOs to benefit from their reach, brand, and network for that purpose.

The wider OSS community benefits from applying a principled definition to what makes a contribution and from treating all contributors as equals, no matter if they are individual volunteers, businesses, research organisations or governmental agencies. Historical prejudices sometimes shared in the "hacker community" that free software is the prerogative of civil society and hackers are not justified considering that today's community composition includes a majority of corporate contributors. Global OSS collaboration offers a unique opportunity to build bridges between the interests of individual, civil society, enterprises and the state, provided they are willing to contribute to the free software commons. The wider community can work towards realising this potential by actively influencing the quality of the collaboration process as perceived by the different types of participants through community management and setting governance norms, while maintaining and reinforcing the principles of free software like meritocracy, transparency, non-discrimination, shared stewardship and open collaboration. By identifying and lobbying for software freedom as the unifying overarching goal, the OSS community can build the foundations for a successful integration with governments or regulators and SDOs.

Only standards and technical specifications as defined by Regulation 1025/2012 are likely to be referenced in legislation, so OSS communities have a choice to produce the specifications themselves, like the Linux Foundation (Biddle 2019), or to collaborate with SDOs and benefit from their reach, brand, and network for that purpose. OSS communities should expect to be held to higher standards regarding social responsibility in the future and should consider this a sign of their success in contributing to the common good.

6.3.3. *OSS-FRAND compatible licences*

Attempts to combine elements of OSS licences with conditions for FRAND licensing of SEP are in general of limited success. **We recommend both OSS communities and stakeholders active in SDOs to continue developing new models of collaboration and to test them in the market**. Innovative approaches may either be successful or provide new impulses to improve existing SDO and OSS processes. Market actors will indicate the usefulness of these new approaches by way of their decisions to participate.

Although there have been attempts to combine elements of OSS licences with conditions for FRAND licensing of SEP, like the OpenAirInterface project, they have not shown a

significant adoption in the market outside research and development or academia. However, as already argued in the literature and based on our findings, legal compatibility is just a necessary, but not a sufficient condition for the success of such solutions among OSS communities. The viability of collaboration between SDOs and OSS communities is influenced by the cultural fit, governance models and legal framework in that collaboration must be possible and to be preferable over working separately.

6.4. European Commission and national governments

In general, the involvement of governments in markets can only be justified by market or system failures. Nagle (2018, 2019a) shows that OSS is creating positive externalities. Blind and Jungmittag (2008) reveal the positive macroeconomic effects of standards. This provides a general justification for public authorities to support both standards and OSS development and therefore also to improve the interface between SDOs and OSS. In addition, Swann (2010) derives several incidences of market and system failures related to stakeholder participation in standardisation, but also to the integration of research and innovation in standardisation.

6.4.1. *R&D&I policies*

Standardisation is utilised as a channel of knowledge and technology transfer for publicly funded research, development and innovation projects. **We recommend policy makers in the Member States and the European Commission in particular to promote OSS in addition to standardisation as a further channel of knowledge and technology transfer**. In this context, **the interface between OSS and standardisation must be defined and elaborated further as a parallel and complementary transfer channel** to exploit possible synergies and minimize redundancies and conflicts.

Governments and the European Commission have realised the benefits of a better integration of research, development and innovation policies on the one hand and standardisation on the other hand by using the latter as an additional channel of knowledge and technology transfer. This novelty in the current European framework programme Horizon 2020 can be seen in the context of the shift from proprietary research and innovation towards fostering open access in science or open innovation (Moedas 2015, European Commission 2016).

Since more and more research projects involve aspects of software development, both the transfer of results into OSS communities and the interface between them and standardisation activities at SDOs need to be considered. Therefore, we first recommend considering the accumulated body of OSS as an important part of the technology stock available to innovators in the EU. Policies should be updated to reflect that public R&D investments shall contribute to this technology stock by encouraging the integration of R&D results into OSS as the default and directing public R&D funding into private proprietary products only as an exception. Commercialisation of R&D results should focus on building marketable products and services *on top* of this common, non-differentiating technology stock. Commercial products that gradually improve on existing OSS without adding new functionality higher in the stack compete with a potentially all-encompassing collaboration of other stakeholders and are unlikely to succeed commercially. Selection criteria for EU framework programs for research and innovation should be reviewed and updated against this recommendation.

The option of using OSS as a technology transfer channel should be further implemented in R&D&I policies to foster the integration and minimise redundancies between academia, industry and public policy making. In addition, the relation to intellectual property rights, in particular patents generated in the context of publicly funded research, also needs to be clarified. First examples exist of universities that have expanded their transfer strategies to explicitly include OSS and standardisation as further channels in addition to patents, entrepreneurship and collaborative research projects.

6.4.2. *IPR policy*

The current regulatory frameworks both related to copyright and patents neither reflect the relevance of standards nor software as such and OSS in particular. **Policy should consider OSS and standards in future revisions of European copyright and patent legislation.**

The interface between SDOs and OSS related to their different licensing regimes cannot be influenced directly by European or national Intellectual Property law. However, possible negative implications can be avoided or mitigated by undertaking pro-active consultation with both SDO and OSS stakeholders. There continues to be a need for EU policy makers to understand better the various tenets of open source software from established business models or licensing frameworks. For example, conflicts in relation to standards, of the recently approved Directive on copyright in the Digital Single Market on OSS communities should be considered in future revisions. Another example, the European Patent Convention does not include a reference to standards and standardisation either, although standard documents are used increasingly as a source of prior art.

6.4.3. *Public procurement policies*

Public procurement as an important demand-side innovation policy is already recurring on standards, but in official policy documents rarely on OSS despite the already existing option to reference OSS in public procurement. **We recommend the explicit inclusion of OSS in public procurement policies, e.g. in updating the public procurement directives or the public procurement strategy. Equally, we recommend investigating the interrelation between standards and OSS in public procurement.**

In improving the effectiveness and efficiency of public procurement, governments have looked at standards as a way of reducing the cost-of-ownership of certain products and the risk of lock-ins covered by proprietary or de facto standards. In Europe in particular, this has led to specific measures in the area of public procurement (see also Baron et al. 2019). Therefore, public procurement must comply with Directive 2014/24/EC, which differentiates between formal standards and other technical specifications developed by private organisations. For the latter, a description of functional requirements and use of technology-neutral specifications is additionally encouraged. Art 23(1) of the Directive requires that "[t] echnical specifications shall afford equal access for tenderers and not have the effect of creating unjustified obstacles to the opening up of public procurement to competition". Therefore, standards should not be used in a discriminatory fashion that is unjustified by the subject matter of the contract. The key element in EU public procurement law is a requirement that public authorities procure software or other technology systems by reference to standards (as opposed to proprietary technologies). In addition to cost savings in purchasing these standard-based products, standards might reduce costs of document format incompatibility and conversion.

Whereas standards are mentioned both in the procurement directive and in the more recent communication on making better use of standards in public procurement for building open ICT systems (European Commission 2013a), neither software in general nor OSS in particular are mentioned. However, Nagle (2019a) proves the positive impact on demand for OSS by a change in France's technology procurement policy that required government agencies to favour OSS over proprietary software in an attempt to reduce cost. This increase in contributions to OSS by French developers led to benefits for France that increased its national productivity and competitiveness by increasing the number of firms using OSS, the number of IT start-ups, and the amount of IT labour, and decreasing the number of software related patents.

6.4.4. *SME policies*

The involvement of SMEs in SDOs is still limited. **Policy makers, in particular in member states, should further promote SMEs' involvement both in SDOs and OSS communities within EU and national SME policies.**

We have already addressed the better inclusion of SMEs in standardisation via a stronger collaboration with OSS communities in the recommendation targeting SDOs. Despite initiatives like StandICT.eu to support the participation in international standardisation, the still limited support of SMEs related to their involvement in SDOs (OECD 2019) should not only be expanded in general, but also include their support related to their involvement in OSS communities, although the barriers to entry are much lower. Nagle (2018) reveals the positive productivity effects for companies contributing to OSS, which are biased strongly to larger companies.

6.4.5. *General competition policy*

SDOs and OSS engage in a healthy competition from the process perspective. **We recommend the European Commission to create a level playing field between SDOs and OSS communities** to foster innovation. This requires creating exchanges between the evolutionary selection process in OSS communities and the formalization within SDOs, but also may add additional obligations, like working with multi-stakeholder platforms or adherence to minimal standards for governance norms.

For OSS and standardisation to be considered as instruments to support public policy, regulators should create a level playing field via an expansion of Regulation No 1025/2012 on European standardisation towards OSS. This requires creating exchanges between the evolutionary selection process in OSS communities and the formalization within SDOs, but also may add additional obligations, like working with multi-stakeholder platforms, or adherence to minimal standards for governance norms, e.g. following WTO principles, that support the long-term viability of the OSS development model. If OSS foundations become dominant platforms, they have the responsibility to ensure that their rules do not impede free, undistorted, and vigorous competition according to the recommendations proposed by Crémer et al. (2019).

Policy makers have provided substantive guidance on the legal boundaries and requirements applicable to the substance of IPR policy choices of SDOs with the safe harbour approach defined in the guidelines to horizontal co-operation agreements. No such guidance exists with regard to OSS communities. **We recommend developing specific requirements for horizontal co-operation that apply to both SDOs and OSS communities and their collaboration.**

In the specific area of IPR policy, policy makers have provided substantive guidance on the legal boundaries and requirements applicable to the substance of IPR policy choices with the safe harbour approach defined in the guidelines to horizontal co-operation agreements (European Commission 2011). Under this approach, the policy maker defines and states legal requirements and identifies general practices of SDOs, which are responsible both for devising specific policies in line with the identified general practices and their compliance. For this purpose, the role of OSS umbrella organisations should be considered closer to that of SDOs than the role of individual OSS communities, which is also apparent in their membership structure as well as in the variety of projects hosted by these foundations.

6.4.6. *Open source software as public infrastructure*

SDOs are already well-integrated into the European research and policy frameworks, while for OSS communities such integration is still at the beginning. **We recommend integrating OSS communities into the European research and policy frameworks where justified by their generation of positive externalities in the European Union.**

The public support of OSS foundations could be raised to a level comparable to the support provided to SDOs, especially if they commit to a charitable cause and comply both to the relevant WTO regulations and the European guidelines to horizontal co-operation agreements.

Today, OSS runs a large part of the technical infrastructure of an information and knowledge driven society. OSS should be considered as an infrastructure of the information age of similar importance to highways and bridges. It is worth investigating the benefit of public medium-to-long term investments into OSS infrastructure that supports European Union policy goals. **We recommend further evaluating policy options for the European Union**

to contribute directly to OSS. This may require changing the regulatory framework or establishing European OSS development organisations either next to or integrated with existing European SDOs.

The acceptance of the public interest in the contributions OSS makes to the common good could justify the establishment of a European OSS development umbrella organisation either next to or integrated with existing European SDOs. Careful consideration needs to be applied to avoid disrupting the upstream/downstream model peer production process that is based on self-identification. This can be avoided by selectively awarding competitive, time-limited grants similar to current research funding by the EU. Governmental and regulatory representatives should expect to be received as welcome contributors, but also to have to earn their merit in the communities like any other contributor. When developing policy measures aimed at fostering OSS development, sector specific experiences may not be generally applicable. In particular, the highly concentrated, regulated and politically influenced mobile communication sector may not be a useful yardstick for the development of general public OSS policy. Experiences from a plurality of highly innovative technology areas like cloud-native computing, automotive platforms or programming languages that involve standards setting and implementation should be taken into account. Practices need to be developed that reflect the trend towards openness and transparency in general and the WTO requirements in particular. Exclusive third-party rights to formal standards that are mandated or where conforming with the standard might despite FRAND commitments be a barrier to market entry will find less acceptance and may be considered by the public as inappropriate rent-seeking or invitation to morally hazardous behaviour. Next to welfare losses from the lack of adoption of formal standards, public policy that facilitates SEP may undermine the competitiveness of local industry sectors by inviting outsiders to compete by participating in global collaboration on developing OSS solutions. The availability of formal standards where compliance is mandatory or practically required as open standards would eliminate this possibility.

6.5. Outlook

We have derived several specific recommendations in particular addressing SDOs and OSS communities in the short run as well as some suggestions for the European Commission or national governments in adapting the current regulatory framework to the increasing relevance of OSS and the related OSS communities. The traditional IPR frameworks have served society well in the industrial age and continue to do so in most industry sectors. In the ICT sector, new rules have developed since the emergence of the internet that change the efficacy of these traditional IPR frameworks. Both the development of the concept of SEP in combination with formal standards as well as open collaboration and code licensing methods applied in the wider OSS community represent adaptations to this changed ICT environment. The trend towards more collaborative and cooperative approaches in society that is represented by both SDOs and OSS communities is a welcome opportunity to develop more efficient methods to manage innovation. The impact of the changes in the ICT environment is all-encompassing. It affects policy areas like research and development, public procurement, SME support or competition policy. Adapting to these sea changes will require coordinated actions by the European Commission and the national governments to support specific long-term policy goals like achieving the Digital Single Market. Both standards and open source development are welcome tools to help mitigate the challenges of globalisation and digitalisation. By developing a deep understanding of the underlying processes, setting aside differences and collaborating towards economic development and sustainability goals, Europe has a chance to lay the ground for modern institutions that shape and facilitate technical innovation.

GLOSSARY

Glossary

code of conduct A code of conduct describes the behavioural norms and rules that community contributors are expected to adhere to. Once adopted, a code of conduct is part of the explicit governance norms of a community.

commodity A commodity is a good with normalised attributes, giving instances of its fungibility. Commodities commonly are produced under price competition. Free and open source software (FOSS) that implements common, non-differentiating features of a computer system is considered a commodity.

community A FOSS community produces information goods, predominantly computer programs, in a collaborative process based on voluntary participation.

Eclipse Foundation The Eclipse Foundation is a not-for-profit industry association (US 501(c)(6)) that provides a global community of individuals and organisations with a mature, scalable, and commercially focused environment for collaboration and innovation.

fair, reasonable and non-discriminatory Licensing under fair, reasonable and non-discriminatory terms is a voluntary commitment some SDO request from a patent owner that participates in standards development.

free and open source software The term free and open source software refers to software that is distributed under a licence which complies with the Open Source Definition. The Open Source Initiative is the steward that approves licences for being compliant with this definition.

governance In the context of FOSS, governance describes the totality of implicit and explicit behavioural norms, codes and processes that regulate the relation- ship between contributors and the community as a whole.

implementation In the context of standardisation, the term implementation refers to a product that is compliant with the specification of a standard.

information goods Information goods are expensive to create, but only incur negligible cost of reproduction. Assuming marginal cost pricing, the price of an information good converges to zero under perfect competition.

intellectual property rights Intellectual property rights (IPR) include copyright, designs, patents, trademarks and other rights that are associated with intellectual property (IP) and are utilised to grant permission to use the work through licensing and other relationships.

intellectual property Intellectual property (IP) is a term that describes intangible creations of the human intellect that can be controlled by an owning entity, like artistic works, inventions and designs. IP is made a tradeable good through the application of intellectual property rights (IPR).

Linux Foundation The Linux Foundation is a not-for-profit industry association (US 501(c)(6)) dedicated to building sustainable ecosystems around open source projects to accelerate technology development and commercial adoption.

meritocracy In the context of FOSS, the term meritocracy is used to describe a system where contributors gain reputation in a community solely based on the value of the contributions they make.

Open Source Definition The Open Source Definition formulates the terms soft- ware must comply with to be considered FOSS. It is maintained by the Open Source Initiative. By way of the Open Source Definition, especially it's unanimous

acceptance, the term “open source” gained a precise meaning across the wider FOSS community, and is therefore a term of art and part of open source culture.

open source The term “open source” is used in this paper as a synonym to FOSS or free software. It originally describes a campaign to promote free software to business.

physical goods Physical goods require at least a combination of labour and materials to build. Assuming marginal cost pricing, the price of a physical good is affected by the factors required for its production, and therefore larger than zero.

software stack Computer systems consist of multiple layers of subsystems that together provide a platform that applications run on. Lower parts of the stack are usually less differentiating and typically FOSS. Some stacks are so common that they have names, like the LAMP (Linux, Apache, MySQL, PHP) stack.

source code Source code is the fundamental component of a computer program that is created by a programmer and is referred to as the “before” versions of a compiled computer program.

specification Specification means a document that prescribes technical requirements to be fulfilled by a product, process, service or system. .

standard A standard is a document established by consensus and approved by a recognised body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context (EN 45020:2006).

standard-essential patent A standard-essential patent contains claims that must be used to implement a standard.

standardisation Standardisation describes an activity of establishing, with regard to actual or potential problems, provision for common and repeated use, aimed at the achievement of the optimum degree of order in a given context (EN 45020:2006).

standards development organisation A standards development organisation is an entity whose primary activities are developing, coordinating, promulgating, revising, amending, reissuing, interpreting or otherwise maintaining standards that address the interests of a wide base of users.

upstream/downstream model The analogy of the upstream/downstream model uses the mental image of a large river that collects the water from many smaller and smaller tributaries (the communities) and delivers it to the ocean (the users). Key tenets of the upstream/downstream model are the non- negotiability of the free software licensing terms and community governance norms.

wider open source community The phrase wider open source community is commonly used to describe the totality of individuals, smaller and larger communities, umbrella organisations and entities collaborating on developing the commons of FOSS in the global upstream/downstream model.

ACRONYMS

Acronyms

3GPP – 3rd Generation Partnership Project

AGL – Automotive Grade Linux

AGPL – Affero General Public License

ANSI – American National Standards Institute

ARPA – Advanced Research Projects Agency

BSD – Berkeley Software Distribution

CEN – European Committee for Standardisation

CENELEC – European Committee for Electrotechnical Standardisation

CLA – Contributor License Agreement

CNCF – Cloud Native Computing Foundation

CPU – Central Processing Unit

DG Enterprise – Directorate-General Enterprise

DIN – Deutsches Institut für Normung

DSM – Digital Single Market

EC – European Commission

ECMA – European Computer Manufacturers Association

ECSIP - European Competitiveness and Sustainable Industrial Policy Consortium

ETSI – European Telecommunications Standards Institute

EU – European Union

EURAS – European Academy for Standardisation

FLOSS – Free/Libre Open-Source Software

FOSS – Free Open-Source Software

FRAND – Fair, Reasonable and Non-Discriminatory

FRAND Z - FRAND with zero royalties

FSFE – Free Software Foundation Europe

GCC – GNU Compiler Collection

GPL – General Public License

GSM – Global System for Mobile Communications

GTLL – Global Technologies Limited

ICT – Information and Communications Technology

IDC – International Data Corporation

IEC – International Electrotechnical Commission

IEEE - Institute of Electrical and Electronics Engineers

IEEE-SA – IEEE Standards Association

IETF – Internet Engineering Task Force

IIC – Institute of Electronics and Communication, Inter-Integrated Circuit, Industrial Internet Consortium

IoT – Internet of Things

IP – Intellectual Property

IPR – Intellectual Property Rights

ISC – Internet Software Consortium

ISO – International Organization for Standardization

IT – Information Technology

ITU – International Telecommunications Union

ITU-R – ITU Radiocommunication Sector

ITU-T – ITU Telecommunication Standardization Sector

JIS – Joint Initiative on Standardization

JRC – Joint Research Centre

JTC1 – ISO/IEC Joint Technical Committee for Information Technology

LFN – Linux Foundation Networking

LGPL – Lesser General Public License

LO – Large Organisations

LOT – License on Transfer

MANO – Management and Orchestration

MIT – Massachusetts Institute of Technology

MQTT – Message Queuing Telemetry Transport

MSP – Multi-Stakeholder Platform

NFV – Network Function Virtualization

NGO – Non- Governmental Organisation

NIST – National Institute of Standards and Technology

OAI – Open Archives Initiative

OASIS - Organization for the Advancement of Structured Information Standards

OCED – Organisation for Economic Co-operation and Development

OCF – Open Connectivity Foundation

OCI – Open Container Institute

ODF – Open Document Format

OFE – OpenForum Europe

OGC – Open Geospatial Consortium

OIN – Open Invention Network

ONAP – Open Networking Automation Platform

OOCRAN – Open Orchestration Cloud Radio Access Network

OpenJDK – Open Java Development Kit

OPNFV – Open Platform for NFV

OSI – Open Source Initiative

OSL – Open Software License

OSM – Open Source MANO

OSS – Open Source Software

OWF – Open Web Foundation

PDF – Portable Document Format

PNG – Portable Network Graphics

PPI – Public Procurement of Innovative solutions

R&D – Research and Development

R&D&I – Research and Development and Innovation

R&I – Research and Innovation

RAND – Reasonable and Non-Discriminatory

RAND-ZERO – RAND with zero royalties

RDFa – Resource Description Framework in Attributes

RF – Royalty Free

RFC – Request for Comments

RISES - Research on Innovation, Start-up Europe and Standardisation

RTDI – Research, Technology, Development and Innovation

SDO – Standard Development Organisation

SEP – Standard-Essential Patent

SME- Small to Medium Enterprise

SMO – Small- and Medium-Sized Organizations

SOIT - Spoločnosť pre otvorené informačné technológie (Open Information Technology Society)

SVG – Scalable Vector Graphics

SWOT – Strengths, Weaknesses, Opportunities and Threats

TC – Technical Committee

TCK – Test Compatibility Kit

TIFF – Tagged Image File Format

ToR – Terms of Reference

TRIPS – Trade-Related Aspects of Intellectual Property Rights

W3C – World Wide Web Consortium

WG – Working Group

WTO – World Trade Organization

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LIST OF FIGURES

List of figures

LIST OF TABLES

List of tables

ANNEXES

- ANNEX 1. LITERATURE REVIEW
- ANNEX 2. CASE STUDIES
- ANNEX 3. STAKEHOLDER SURVEY

Annex 1 | Literature Review

1.1. Methodology of the literature review

The literature review used two types of sources. On the one hand, we searched for all academic literature on Intellectual Property Rights (IPRs) and standardisation in information and communication technologies following the definition by Comino and Manenti (2015), with a specific focus on patents and copyright issues, open source software in particular. On the other hand, we screened the publication of the standardisation organisations and other associations for recent publications related to open source software.

Before we screened the academic literature, we investigated the existing studies on the relation between IPRs in general and patents in particular on the one hand and standardisation on the other hand. In contrast to the numerous studies on SEPs in general and FRAND in particular, the analysis of important previous studies, such as the EC studies conducted by Blind et al. (2002), Blind et al. (2011), the ECSIP (European Competitiveness and Sustainable Industrial Policy Consortium) consortium (2014), the report presented by the US National Academy of Sciences edited by Maskus and Merrill (2013), the Independent Review of the European Standardisation System performed by Ernst & Young (2015), and even the recent studies about licensing terms of Standard Essential Patents by Pentheroudakis and Baron (2017) and CRA (2016), but also the governance of SDOs (Baron et al. 2019) reveal that the issue of OSS is in general not addressed at all or only marginally. Exceptions are the report of the conference organised by the European Commission on the option to implement standards following the FRAND regime in OSS (European Commission 2012) and the EU-funded report by Open Forum Europe (2017b) that is analysing the collaboration models between SDOs and cloud open source software development initiatives.

Consequently, we have consulted the databases Web of Science (provided by Thomson Reuters), Scopus (provided by Elsevier) and Google Scholar. The very narrow search including "open source", "standardisation", "patent*" and "FRAND" did not reveal any in a scientific journal published paper in Scopus and only Lopez-Berzosa and Gawer (2014) in the Web of Science. Therefore, we deleted "FRAND" from our search, but generated still less than ten publications by the two search tools. Deleting "patent*" from the search revealed more than 500 publications in Scopus and almost 400 publications in Web of Science. However, the screening of titles and abstracts reduced the number of relevant papers to just a few above 20 in Web of Science and in Scopus with a large overlap. Finally, the most relevant sources according to the search results of Google Scholar have been screened to complement the most relevant papers identified by the Web of Science and Scopes searches. However, the quality of the search results based on Google Scholar was rather limited, because most of the papers ranked as very relevant did not address the topic of our literature review. Consequently, we relied on the around 30 papers from the Web of Science and Scopus search. This low number is not surprising, since Contreras (2017) comes in his recent literature review about IPR and standardisation to the conclusion that "Given the increasing importance of open source software to the global technology infrastructure, further research in this area is needed." supported by screening the reference lists in Baron et al. (2019) and Maracke (2019).

1.2. Results of the literature review

Legal studies, like Li (2018) or Maracke (2019), organise their overviews according to the permissiveness of the licensing regimes combined with the questions, whether the licences contain patent grants. However, in order to structure our review of academic papers, we divide the studies into three categories following Lundell and Gamalielsson (2017), but also Clark (2016), without immediately considering the tension between OSS licences and the FRAND regime related to patents. First, we consider cases, which start as standardisation projects within formal or informal standardisation bodies but are eventually implemented as OSS projects. The second option is the initial implementation of software via OSS projects followed by a standardisation process. The third and final option is the parallel development of standards and their implementation as OSS.

1.2.1. *Scenario 1: Standards implemented as OSS ("standard first")*

On the generic level of the telecommunication industry, Wright and Druta (2014) analyse the increasing implementation of standards by open source projects despite the telecommunication technology infrastructure mainly licensed according to the FRAND model. They assume that the patent-based FRAND model is not going to change radically but complemented by open source components. In order to benefit from these interactions, companies that have not yet been engaged with open source communities need to develop appropriate strategies and policies to delineate the functionalities between proprietary and open source and the different IPR regimes to avoid contamination and conflicts between each other. However, they ask also both the formal standardisation bodies and informal consortia and alliances to adjust their governance, IPR rules and even their staff.

Whereas Clark (2016) presents Universal Business Language UBL v1 originally released by OASIS and meanwhile developed further to ISO/IEC 19845:2015 released in 2016 as an example of a standard, which created the basis for further OSSs project in many local and regional projects, he does not address the role of the possible tension between patents and open source. In contrast, one very prominent example of the first scenario analysed related to IPR in depth by Gamalielsson and Lundell (2013) is the release of the PDF specification as ISO standard ISO 32000, which is then implemented in various OSS. In the context of our study, it is important to note that Adobe issued a Public Patent License granting every individual and organisation "the royalty-free right, under all Essential Claims that Adobe owns, to make, have made, use, sell, import and distribute Compliant Implementations". This licensing regime allows OSS implementations under the GPL. However, some OSS contributors expressed some concern for potential risks for patent infringements related to the PDF format including the risk that redistributors obtain patent licences making the program eventually proprietary. However, not only patent protected content, but also copyrighted fonts creates worries among the OSS developers. Finally, the initial licences were changed in both open source projects to stronger copyleft licences due to business reasons and to resolve licence incompatibility issues with other OSS projects.

Following these case studies, Lundell et al. (2015) expand their analysis both to the licences required for standards issued by formal and informal standardisation bodies. In addition to three ISO standards (PNG, JPEG 2000, and TIFF/EP) implemented in open source software, they analyse the SVG (Scalable Vector Graphics) standard released by W3C and the PNG (Portable Network Graphics) standard (ISO/IEC 15948:2004) initially published in by the Internet Engineering Task Force (IETF) as RFC 2083 and soon after as a W3C standard. The information they received from W3C and ISO let them conclude that these organisations are not aware of any royalty-bearing patents that are essential for the implementation of the Portable Network Graphics specification. Several widely deployed (proprietary and open source licensed) software projects have implemented solutions for SVG and PNG under the GPL licences. For the investigated standards, Lundell et al. (2015) come to the conclusion that the owners of patents impacting on the standards have no interest in providing licences for those patents which would allow the implementation in software to be provided under the GPLv3 licence. Consequently, they conclude that any organisation interested in implementing these standards under any open source software licence would face significant risks. However, for many companies it is important to be able to implement the standard in OSS provided under common open source licences, including licences from the GPL-family (Lundell et al., 2011). In addition, Mitchell and Mason (2010) note that there may be a fundamental mismatch between the requirements of some open source software licences (notably those of the GPL family), and parallel patent licences, unless the terms of those licences are extremely liberal.

In summary, Lundell et al. (2015) conclude that there is no problem of implementing standards as OSS so long as the implementer of a standard using software licensed under a GPL family licence can distribute that software in such a way that the recipient has no fewer rights that the implementer has. In other words, if the implementer has the benefit of a specific patent licence, any recipient of the implementer's code will also need to have the benefit of a patent licence on the same terms, either directly from the licensor, or as a sub-licence from the implementer. However, they identify a problem if the implementer of a standard containing third party GPL code has to cause any recipient of that code to receive a licence (including a patent licence), which would enable the recipient to exercise all rights permitted under the GPL, including the right to modify the code, so that it no longer implements the standard, but nonetheless still has the benefit of a

relevant patent licence. Such a broadly drafted patent licence would render the economic value of the patent close to zero, so it would be unlikely to be acceptable for the patent owner. Consequently, they come also to the conclusion that FRAND licences are incompatible with open source licensing owing to the inability of the licensee to sub-license to downstream recipients (Dardailler et al. 2012, Phipps 2019) confirming the European Commission (EC 2013a) that such licensing conditions for standards "create barriers for open source projects to implement the technical specification".

In order to solve this tension, Lundell et al. (2015) propose a compromise between these two options guided by the scope of the patent licence in GPLv3, which does not expect a distributor of GPL software to provide a blanket patent licence to recipients covering all possible modifications of the code transferred. They expect support of stakeholders from both proprietary and open source software, and, in particular, from organisations like the Free Software Foundation supporting the GPL family of licences, that an approach like this would be compatible with both the spirit and the legal terms of the relevant licence. On the one hand, they assume that many companies are not only involved in standardisation processes, but also in the contribution to open source code. Consequently, they argue that these mainly larger companies should be also familiar with licensing their patents royalty free to those being interested in implementing the standards. This royalty free based licensing should be compatible with open source licences, like GPLv3, LGPLv3, Mozilla 2.0 and Apache 2.0 containing patent licensing clauses. These clauses limit the licence granted to the scope of the claims implemented by the version of the software as distributed by the patent licensor. For example, a recipient receiving a word-processing software from the licensor cannot assume that the patent licence is covering significant changes of the original word processing software allowing very different applications. They admit that whereas any open source licence grants the recipient under its copyright provisions the freedom to make the above-mentioned changes, the patent sections of the same licence may not allow it. However according to Lundell at al. (2015), it is still an acceptable open source practice to limit the scope of an included patent licence granted to the implementations of the standard. The recipient is still free to change the functionality of software under the open source licence in a way that its functionality does no longer meet the requirements of the standard. However, she or he is not benefiting any more from the original patent licence.

In contrast to the specific case-based approach by Lundell et al. (2015) and their related work, Kesan (2011) applies a systemic theoretical legal review, irritatingly called "empirical analysis", of the interplay between open source software licensing and FRAND licensing. In his examination of all OSS licences available in 2011 and approved by the Open Source Initiative (OSI), he comes to the conclusion that there is no inherent conflict between OSS and FRAND (see also Kappos and Harrington 2019). In particular, only the GPL and the Lesser GPL licence among the eight most popular OSS licences conflict with FRAND. Furthermore, he concludes that "only a small fraction of the remaining 59 OSI-approved licences have any conflict with FRAND". Consequently, he makes the concluding statement that "the vast majority of OSS licences are fully compatible with FRAND, with regard to both monetary and non-monetary terms."

Comparing Kesan (2011) with the studies by Lundell et al. (2015) reveals that there are indeed conflicts between FRAND based standards and their GPL based implementations. Since GPL-licensed open source software is one of the most common type of open source software according to Lundell et al. (2011), EC (2012b) and Li (2017), the notion that the majority of obviously less used OSI licences by Kesan (2011) does not solve the tension.

Mitchell and Mason (2011) also come to the conclusion that GPL 2, GPL3 and related licences are likely to be incompatible with FRAND licences in contrast to e.g. to the European Union Public License as argued by Li (2017). However, they go even one step further and contradict Li (2017) that even royalty free FRAND licences are not compatible with the GPL family, because although each licensee will be able to obtain his own individual licence from the patent owner for free, this is not automatically the case for downstream users of the GPL. The problem is the fundamentally different architecture of the "cascade" licensing of OSS under GPL and the parallel licensing of computer-implemented inventions under the FRAND licensing scheme (see also EC 2012b). In particular, if the granter of the GPL licence cannot provide the same automatic downstream cascade of patent rights as he can in respect of copyright, he cannot grant a GPL copyright licence. Mitchell and Mason (2011) leave it as an open question whether these contradictions could be solved if the patent holder were prepared to agree to the downstream transmission of the licence.

Finally, the above-mentioned issues concerning implementation of standards in software has recently received attention amongst several SDOs, but it should be noted that implementation issues have not received always appropriate attention (Egyedi 2007). Egyedi (2007) argues that developing standards neglects often standard implementation, but SDOs need to consider implementation issues, since standards development and implementation are closely intertwined related to their impact. She recommends SDOs to shift their emphasis from standard development to a more systematic inclusion of implementation concerns both at the technical level of standard committees and the policy level of SDOs.

In summary, there are examples of the implementation of standards via OSS discussed in the literature. However, these standards are mainly developed in SDOs following a RF licensing scheme, like OASIS and W3C. According to Phipps (2019), these SDOs are characterised by an implementation-led rather than a requirement-led standardisation approach. There are also some standards released by SDOs applying the FRAND regime. However, there are no declarations of SEPs related to these standards. Nevertheless, there is still the latent fear of conflicts with potential SEP holders, because of the general contradiction between the FRAND regime and OSS licences. In particular, the popular GPL is incompatible with FRAND, but there are several other OSS licences, like the MIT or BSD licences, being compatible with FRAND according to Kappos and Harrington (2019). However, there is no general consensus about this conclusion (see also EC 2012b), because others argue that they are just complementary, but not compatible (Phipps 2019). In addition, the notion of the incompatibility of the licensing regimes is endorsed by a significant percentage of open source programmers (Bekkers and Updegrove 2013). Due to the highlighted relevance of standards implementation for their quality and success, the concerns of the OSS communities related to the ambiguity in the licensing conditions gain further in relevance.

1.2.2. *Scenario 2 OSS code as input into a standard ("software implementation first")*

The second scenario according to Lundell and Gamalielson (2017) is characterised by the initial implementation of software, which eventually leads into technical specifications of standards also called implementation-led standardisation by Phipps (2019). Under this scenario, a software implementation precedes the development and endorsement of the technical specifications of a standard released either by a formal and or informal SDO. Already more than ten years ago, Schöchle (2003) has perceived open source software as a form of standardisation outside both of formal SDOs and informal consortia. Despite being a form of distributed development process, he perceives it also as a form of standardisation, because it leads to standards, which, like open source, serve as platforms upon which new market can built on. Furthermore, he mentions IETF as an early example of a standardisation consortia, which has relied on open source software. According to Schöchle (2003), the advantage of standardisation is the open documentation of the results in standards avoiding the fragmentation in distributed development projects, such as in open source software. In addition, Behlendorf (2009) claims that many OSS implementations of ICT standards have significantly contributed to the establishment of standards, because OSS is available for immediate testing and prototyping of applications. Furthermore, extensions open source code are easier to adopt, but its utility is easier to be compared to a specification of a standard.

One specific example is the development of software, which eventually evolved into the development of the OpenDocumentFormat ODF later established as ODF standard and nowadays recognised and provided as an OASIS standard. This standard was even transferred to ISO and published as ISO/IEC 26300:2006. However, due to the competition within ISO (Blind 2011) with ISO/IEC 29500:2008, ISO/IEC 26300:2006 was not maintained within ISO. The very initial work on the implementation was the proprietary software StarOffice, which was later released as open source software by OpenOffice.org. StarOffice lead eventually to the OASIS OpenDocumentFormat ODF, which enabled FOSS suites of royalty-free office document, spreadsheet and presentation software. The FLOSS release of OpenOffice.org further evolved into Apache OpenOffice and LibreOffice (Gamalielsson and Lundell 2014).

According to Li (2017), it is in general more complex for SDOs to utilise open source working practice to develop standards. She differentiates between two sub-scenarios. On the one hand SDOs can use source code directly in specifications. On the other hand, specifications refer to

the same functions they derive from open source projects. The direct use of running code requires at first the check of the copyright issue over this specification, because SDOs own the copyright of specifications, while in the open source project developers remain the right holder. The major problem is that it is uncertain whether SDOs still can claim the copyright if code is included as part of the specifications. This problem is confirmed by Lundell and Gamalielsson (2017), who conclude their paper not only with the open question of which open source licence should be used, but more important which organisation has or should have the copyright for the developed software in which the technical specification of the standard is implemented.

In case of some SDOs (e.g. ITU and ETSI), guidelines have been released, which may apply to direct code utilisation, if contributors to open source code agree to them. These may solve the ownership issue, since these guidelines give the option to contributors to either transfer the ownership or grant a software licence. Nevertheless, the problem then lies on distribution. The right granted by such guidelines to copy, modify and distribute are only limited to specific situations listed in those guidelines. Such restrictions obviously contradict the free distribution guaranteed by OSS licences.

Despite of general rules related to the inclusion of copyright protected content, the lack of any IPR rules specifically related to open source software, e.g. by IEEE[2], may generate some uncertainty. In addition, SDOs accredited by the American National Standard Institute (ANSI) may lack a particular clause for code ownership and distribution in specifications, since the ANSI appears to discourage software from being embedded in standard specifications (Bekkers and Updegrove 2013). If such specific clauses are missing, the general copyright rules for specifications of standards apply, which restrict significantly the distribution of code embedded in the specification. This is in contrast to the sharing and collaborating practice and licences implemented by the OSS communities. However, IEEE recently perceives the benefits of incorporating OSS in their standards without addressing the (copy)right problem.[3]

In the second sub-scenario presented by Li (2017), the code included in the specifications of the standards becomes essential, like patent-protected knowledge in the case of essential patents. Here, addressing the copyright issue becomes even more crucial. According to her analysis of ETSI, ITU and IEEE none of them have a particular clause regarding essential copyright. The ETSI IPR policy even emphasizes that software embedded in specifications shall not be used as mandatory for compliance (ETSI 2017). As argued before, SDOs accredited by ANSI have been discouraged in general from including software in standards, let alone letting them be essential.

Since there are no specific guidelines related to software code, one may refer to the clause for patents. In case of ETSI, the essential claims subject to FRAND licence terms use the general term "intellectual property rights", which is broad enough to encompass not only patent rights, but also copyright. Therefore, like in the case of SEPs, implementers of standards containing code could try to get a FRAND copyright licence in order to be able to copy and implement the standard (code). In parallel, such software code will be licensed under the various OSS licences. However, Li (2017) leaves it open whether FRAND licence terms or OSS licences will prevail also referring to Bekkers and Updegrove (2013), who recommend treating licensing of patents and copyrights differently, because both types of IPRs quite distinct.

In addition to including software code in the technical specifications of standards, the functions from OSS code can also be adopted in a standard. Here, Li (2017) distinguishes between the licences applicable to the OSS code. If the OSS licence does not contain any patent clauses, like the MIT or BSD, the patent issue could only be left to the policies of the relevant SDO, which might eventually subject to the FRAND commitment (according to Li 2017). However, if an OSS licence includes a patent clause, e.g. the Apache v.2, the patent right is granted on a RF base. The open question is whether SDOs can require the patent owners who contribute patents to the standard to licence it under FRAND licence even if there is already an OSS licence with RF patent licensing. However, Li (2017) cannot find any entitlements for SDOs to do so in their current IPR regimes.

Since most SDOs have no specific rules regarding the licensing of OSS code integrated in the specifications of standards, Li (2017) concludes that the OSS licensing terms are the "only clear applicable rule". Consequently,

[2] https://standards.ieee.org/develop/policies/bylaws/sect6-7.html#7 retrieved March 27th 2018.
[3] https://beyondstandards.ieee.org/general-news/open-source-ieee-involved/ retrieved March 27th 2018.

granting RF licences should be applied to use the code in standard embedded technologies. However, such rules might be a strong disincentive for at least some patent owning innovators, because the option to collect royalties on SEPs might be one of the main incentives for many innovators to contribute standardisation (e.g. Lerner and Tirole 2015). However, in the survey by Blind et al. (2011) patent owning companies technologies rate the relevance of the freedom to operate achieved by a standard as much higher.

In addition to the conflict regarding the licensing terms for OSS and patents, there is a systemic difference in licensing software according to the OSS licensing terms and patents according to FRAND. OSS licences follow a cascade effect, which restrict the implementers of OSS in other areas not applicable to FRAND (Li 2017). Although using patents for free, OSS licences contain in general a "patent retaliation" clause, which discourages recipients from litigating against the work that incorporates the patented contribution by terminating the patent right. The idea is to prevent implementers from filing lawful litigation, if the find their patents included in the same work have been infringed. However, the current IPR regimes of SDOs guarantee patent owners this opportunity.

Despite the general tension of the licensing conditions for OSS on the one hand and patents on the other hand, there are first efforts of SDOs to promote the utilisation of OSS in their work. Li (2017) and Maracke (2019) present and analyse the open source project Open Source MANO (OSM) launched by ETSI in 2016 under the OSS licence Apache v.2, which is aligned with ETSI Network Function Virtualization (NFV) Information Models (ETSI 2017 https://osm.etsi.org/). Meanwhile, almost 100 organisations produced one million lines of code. Li (2017) analyses the potentially applicable IPR rules by relying on ETSI's IPR policy and the relevant Apache v.2 licence clause complemented by the Terms of Reference of OSM[4] and the Contributor License Agreement (CLA), which has the same copyright and patent licence rules as the Apache v.2.

Apache v.2 is among the most popular Open Source Licences (OSLs) identified by the OSI, accounting for over 15% of the open source projects in the records.[5] It is not a copyleft licence, but it includes the so-called "patent retaliation" clause, i.e. the receivers of the granted RF licence on patents are not allowed to initiate patent litigation against any entity alleging that the work in general or a contribution in particular justifies a patent infringement, otherwise the RF granting licence will be terminated.[6]

In summary, the application of the ETSI IPR policy in particular related to SEPs and the Apache v.2 licences are essential. So far, these two regimes do not contradict each other, because no organisation has declared SEPs on OSM. However, this might change in the future and conflicts between ETSI's IPR policy and Apache v.2 will be likely.

According to the ToR the deliverables from OSM are not ETSI technical specifications and that code will not be directly included in specifications. However, Li (2017) find some hints in the projects that might not be able to exempt all the possibilities for overlapping easily. One of the functions of OSM stated in the ToR is to "provide practical and essential feedback to the finalization of the ETSI MANO stage two and three specifications." Such feedback helps formulate the ETSI MANO Standards and the future 5G standards. Moreover, Li (2017) predicts that standards that are based on existing OSM implementations are possible, because many multi-party de facto standards (implementations) existed before selective process and multi-protocol activities carried out by SDOs, such as the IETF or W3C. In particular, the technical sharing between the RDFa standard and the Drupal project showed high possibility for overlapping functions between standards and an open source project. Although a direct inclusion of code has been avoided by the ToR, there is still a high possibility that some functions derived from OSM code can be adopted into ETSI NFV standards. Since OSM is a hosting open source project in ETSI, possible patents based on such code are likely from ETSI members who have signed the CLA. If patents turn out to be essential, FRAND must be applied. Patent licences must be made available royalty free to any recipient that agrees to Apache v.2 in OSM. This necessity will raise concerns among SEP holders. In addition, Li (2017) expects more concerns related to the "patent retaliation", because currently no mechanism are established to monitor the continuing contributions to the project. This creates some uncertainty, for example for SME's who might rely on patented innovative technologies

[4] https://portal.etsi.org/Portals/0/TBpages/OSM/Docs/ETSI_OSG_OSM_ToR_2016-02-09.pdf.
[5] https://www.blackducksoftware.com/top-open-source-licenses.
[6] https://www.apache.org/licenses/LICENSE-2.0.

to compete against big market actors, which may explain the decrease of around 100 participants in OSM in 2018 to 70 participants from 50 ETSI members in June 2019.[7]

In summary, the current frameworks of formal SDOs and informal consortia obviously allow the integration of OSS into their standard development process and standards. SDOs, like W3C and OASIS, which have meanwhile more a RF culture related to patents and consequently rather limited number or no SEPs at all, are forerunners in starting proactive initiatives to include OSS in their standards. ETSI, a formal SDO with an established FRAND policy with a strong focus on the patent intensive mobile and wireless connectivity technology and therefore a high number of SEP declarations started with OSM a pioneering project. Despite taking the tensions between the traditional licensing regimes of patents on the one hand and OSS on the other hand in the framework of the project into account, the decreasing number of companies contributing to OSM might be an indication for the still existing legal uncertainty. The situation becomes even more complex, because the open source project Open Orchestration Cloud Radio Access Network (OOCRAN) contributes also to the ETSI MANO standards. However, OOCRAN is managed under the AGPL and not Apache v.2 (Floriach-Pigem et al. 2017). Obviously, not only the bilateral relationship between patent licensing and OSS licensing is challenging the integration of OSS in standards, but also the multilateral interfaces in case of different OSS projects following not the same OSS licensing regime.

Despite these challenges, the strict exclusion of OSS code in standards' specifications is certainly no sustainable strategy, because the available OSS code is already large and further growing. Furthermore, some OSS communities already claim to set de facto standards, which is challenging both formal SDOs and informal consortia (Updegrove 2015). Finally, both the increasing competition between SDOs and consortia and the additional competitors from the OSS communities as additional standard setters are likely to increase the pressure to cooperate with the latter. Industry standards may also be developed by competition between OSS communities, forgoing formal specification altogether.

1.2.3. *Scenario 3: OSS and standardisation in parallel ("standard and implementation of standard in parallel")*

Whereas in the previous two scenarios a more or less clear distinction between the starting point of the process and the transfer in the other area has been drawn, Scenario 3 represents the reciprocal action between the development of technical specifications of a standard together in parallel with the development of one (or several) implementations(s) of technical specifications of a standard in OSS software.

Lundell and Gamalielsson (2017) further developing Gamalielsson et al. (2015) analyse the bi-directional influences between the OSS project Drupal provided under the GPL licence version 2 being a copyleft type and the development of the RDFa (Resource Description Framework in Attributes) standard for the interchange of data on the web at W3C. Support for RDFa 1.0 was achieved in the OSS project Drupal by its first implemented in the core of Drupal 7 (RDFa is implemented in a separate module in Drupal). Gamalielsson et al. (2015) conduct a case study based on quantitative analyses of issue tracker data for different issue trackers for W3C RDFa and the Drupal implementation of RDFa. Their analysis provides details on how and to what extent organisational influences occur in W3C RDFa and the Drupal implementation of RDFa, by specifically providing a characterisation of issues and results concerning contribution to issue raising and commenting, organisational involvement over time, and individual and organisational collaboration on issues. In particular, they found that contributors from five different organisations were active in both W3C RDFa standardisation and Drupal RDFa implementation. In particular, two organisations are substantially influencing the two communities. This close cooperation is driven by the fact that the work practices adopted in the Drupal project are similar to those implemented in W3C RDFa standardisation. They conclude, that meanwhile many companies are used to engage with strategically important OSS projects, among which several implement standards. Since many standards are currently being implemented in OSS projects, the possible lock-in effects caused by standards are inhibited. In particular,

[7] https://portal.etsi.org/TBSiteMap/OSM/ListofOSMMembers.aspx.

transparent implementations provided as OSS projects are able to foster clarity concerning how to interpret a technical specification of a standard, which promotes high quality technical specifications of standards. In turn, technical specifications of standards which are (and can be) implemented in transparent OSS projects promote interoperability and longevity of whole systems. Gamalielsson et al. (2015) conclude that widely deployed standards can benefit from contributions provided by a range of different individuals, organisations, and types of organisations not only directly to a standardisation project or indirectly via an open source project implementing the standard. In particular, the RF culture established by W3C obviously contributes effectively to open source projects implementing specific standards.

A second example under Scenario 3 presented by Lundell and Gamalielsson (2017) is focused on IETF, which uses an open process for participation. Consequently, it implies that anyone can join the IETF merely by showing up at a meeting or participating on the relevant list server. In detail, the IETF standards RFC 821 (Simple Mail transfer protocol) and RFC 822 for the format of ARPA Internet messages are two Internet standards published in 1982, which describe the syntax of an email message (Allmann 2011). These two standards have evolved over several versions in parallel with the development of the sendmail software. As a consequence, the ambiguities in the standards were exposed quickly, like well-meaning features that were unnecessarily difficult to implement. However, it is also mentioned that meanwhile such quick updates in standards are not so easy anymore. In addition, the implementation of the IETF standard in sendmail often led to an extension of the standards, because some implementers enhance the protocol to add new functionalities. When the implementation of a standard goes beyond the technical specification defined by the standard, Lundell and Gamalielsson (2017) are afraid of the unintended effect that there are limited incentives to correct errors in the initial specifications. Sendmail has been criticized for being too liberal in what it accepts, e.g. accepted addresses that did not include the domain name, this liberality puts very little pressure on authors of mail submitters to fix the problem. In addition, illustrative diagrams and examples in standards aid to their understandability but create inconsistencies to the text. Consequently, it is proposed that examples in standards should be deleted.

Another approach for developing standards is to use reference implementations, which implies that a single implementation that is defined to be correct, all other implementations are correct if and only if they work against the reference implementation. However, using reference implementations for the development of technical specifications of standards are not unproblematic, since no implementation is completely bug-free. Consequently, finding and fixing a bug in the reference implementation essentially changes the standard. Then, the above-mentioned relevance of standards' implementation is challenged by a possible lack of interoperability (Egyedi 2007). Overall, the classic waterfall model in software engineering does not work well for building standards. The problem is that the specification of standards mandates things that are only marginally useful but are difficult or impossible to implement and the cost of going back and modifying then specification goes up exponentially with time.

As a third example, Clark (2016) mentions that the OASIS MQTT (Message Queuing Telemetry Transport) technical committee standardised an industry protocol for lightweight sensor and device coordination, which has been complemented and informed by Eclipse's open source code projects. In this case, the two teams also feed each other improvements.

In addition to these specific cases of parallel developments, some further general aspects of the third scenario have to be addressed. Rosen (2010) highlights a complementarity between SDOs and OSS. In contrast to OSS, SDOs prevent forking of their specifications that might result in incompatible implementations (also argued by Atlass et al. 2017), e.g. W3C does not want a forking of HTML5, but wants the implementation of OSS. One proposed compromise was to allow software derivative works, but no specification derivative works. However, it was argued that such a licence was incompatible with GPL. Another approach by IETF was requiring specification writers to distinguish between code and text. The IETF copyright licence allows derivative works for code, but not for text.

In practice, large software companies working together in developing standards, SDOs, like W3C and IETF, have little incentives to ask for royalties or to impose burdens on implementations. Moreover, open source projects have refused to implement proprietary standards at all. Also, contributors to OSS sign contributor licence agreements (CLAs) to provide written confirmation of their copyright and patent promises. For example, the Open Web Foundation (OWF) writes agreements for industry standards, incl.

identification of patent claims licensed for free, to mitigate the risks of litigation. Therefore, almost no litigation cases can be observed. However, the Oracle vs. Google case is an exception. It relates to the Java standard, where open and proprietary implementations exist. Oracle asserted its patents against Google's implementation of the Android open source operating system. In addition, Apache Software Foundation complained about Java Community Process requirement that implementers pass a compatibility kit test before receiving Java patent licences from Oracle when those test compatibility kit (TCK) licences expressly prohibit certain kinds of implementation and derivative works, because it is incompatible with OSS.

This is in line with the perception by Lundell et al. (2015), who see significant risks in implementing standards in software under any software licence, when the legal conditions for use of specific standards cannot be clarified and all necessary patent licensed cannot be obtained. This point is supported by the importance of the absence of negotiation and the acquisition of licences to all necessary IPR at the beginning of OSS collaboration that was identified as part of the study results.

In addition to the rights problem, contributions to an open source project as well as to standards development might be driven by specific interests (see Blind and Mangelsdorf 2016), which may cause tensions among different stakeholders. In case of close interactions between OSS and standardisation, the influence of large companies contributing to both processes might become dominant and even anti-competitive. Therefore, one effective strategy for countering such potential threats for influencing specific standards in a specific direction of single contributors is a transparent and open process for participation in standardisation. Bekkers and Updegrove (2013) mention W3C as such an example for low barriers for entry and participation shaped by a culture of free licence rights not accepting fees for patents referenced in their standards. This example shows the interrelationship between IPR regimes and openness, which might be a strategy to prevent anti-competitive behaviour by making use of the interaction between OSS and standardisation.

Summarizing the insights related to the third scenario of parallel developments in OSS and standardisation confirm on the one hand the observations related to the first and second scenario. In the early days of the Internet, IETF as a consortium driven by individual members, like OSS projects, has been involved in the development of an email format in parallel to OSS projects. However, the few cases of close interaction between OSS and standardisation are mainly focused on consortia, which have strict RF and rather patent intolerant licensing policies, i.e. W3C or OASIS. They have been already been identified as being in a good position to integrate input from OSS projects in contrast to formal SDOs applying the FRAND scheme. The recursive integration of inputs from standardisation respective OSS may lead to a virtuous circle of standards of higher quality and broader distribution. In contrast, the challenges for the FRAND based SDOs and consortia already elaborated for the unidirectional relations also will create difficulties for the parallel developments. In the long run, higher quality standards due to inputs from OSS and their broader diffusion via OSS will put further pressure on formal SDOs and informal consortia following the FRAND regime.

1.2.4. *Future developments*

Complementing the case studies and legal analyses following the three scenarios, Updegrove (2017a) postulates in 2017 the advent of "open hybridization" defined as the "well-considered marriage of open source software and open standards" despite playing down the role of code for standardisation two years before (Updegrove 2015). However, not only Updegrove (2017a), but also Clark (2016) expect the convergence of open source and standards methodologies. OpenForum Europe (2017a) also proposes collaboration of SDOs with open source foundations instead of hosting OSS projects themselves. In summary, it is likely that a fourth scenario of a hybrid of standardisation and OSS will emerge in the near future in addition to the three scenarios introduced by Lundell and Gamalielsson (2017). If SDOs miss the opportunity to collaborate with OSS communities, OpenForum Europe (2017a) expects OSS foundations to become serious competitors for the former. However, Updegrove (2017b) perceives that the OSS communities underestimate the need for standards and the opportunities of standardisation. Therefore, there are good reasons to prioritize the hybrid solution still without knowing its necessary specifications in detail and its likelihood of success.

1.3. Review of the SDOs publications

Bekkers and Updegrove (2013) in the survey about the IPR policies of 12 SDOs reveal that the majority did until 2012 not consider copyright or software. In the common ISO, IEC and ITU jointly adopted and in 2015 revised Guidelines for the Implementation of the Common Patent Policy (ITU/ISO/IEC 2015), software is yet not mentioned at all. Still in 2017, software copyright issues are not high on the agenda of SDOs (Li 2017, 2018).

Since IPR-related rulings can also be made outside the Common Policy and Guidelines, the ITU has issued in 2011 Software Copyright Guidelines (ITU 2012) including licensing approaches ranging from waiving the copyright to Royalty Free (RF) licence and to licence with reasonable monetary compensation. It is linked to a software copyrights database, like for standard-essential patents, but with very disclosed few declarations, i.e. less than five in 2018. ISO and IEC do not even have such a database. This observation is also confirmed by the fact that ISO does not mention open source in their 2020 strategy at all, whereas IEC announced it in its current masterplan, that it will consider OSS as one fundamental change that will impact its core operations in the future. In contrast, ISO provides public access to the references listed in every ISO standards, recently defined by Blind et al. (2019) as standard-essential publications.

CEN and CENELEC mention the objective to identify the opportunities of OSS for standardisation in order to exploit their complementarities in their work programme 2018 (CEN CENELEC 2017). The project, launched under the chairmanship of the German standardisation institute DIN, which acknowledges the relevance of open source software in its updated strategy released in 2016 (DIN 2017), did not yet produce any results.

ANSI published already in 2008 a guideline on software in standards without addressing open source. However, ANSI organised with stakeholders of industry and the OSS communities an event in 2016 to explore OSS and its impact on standardisation but did not publish yet any conclusions or even consequences on its website.

ETSI has – also since 2011 – an explicit paragraph in its IPR policy version of April 2017 addressing software in general, without mentioning explicitly OSS. If software is included in any element of a standard, there is no obligation to use that software to conform to the standard (or technical specification). Furthermore, the owner has to agree to a worldwide, royalty-free, sub-licensable copyright licence to prepare derivative works of the contributed software. The copyright licence granted shall also extend to any implementer of that standard for the purpose of using the software in any compliant implementation, unless the contributing member grants an irrevocable copyright licence on fair, reasonable and non-discriminatory terms and conditions for the purpose of using the software in any compliant implementation. In a special report released in 2012 (ETSI 2012), ETSI published some recommendations about the usage of elements of OSS in the development of ETSI standards, but also about their adoption within OSS communities. One scenario describes the consideration of code from OSS-producing organisations in the development of technical specifications and standards. Here, the main challenges are perceived in the collaborative work with the OSS communities. The second scenario characterises the adoption of interfaces to become prescribed within ETSI standards. Here, the main challenge is to ensure that the OSS licence applying to the interfaces or languages is not preventing the licensing of essential patents according to FRAND terms, otherwise an incompatibility with ETSI IPR policy may arise. In the third scenario, OSS code is included in a Technical Specification. Again, the challenge is to ensure that the OSS licence applying to the input, i.e. interfaces or codes, and to any derivative work does not prevent the licensing of essential patents on FRAND terms because of the incompatibility with ETSI's IPR policy. Consequently, ETSI members are encouraged to be careful in introducing external materials. Furthermore, ETSI standards should not adopt or reference OSS code with OSS licensing regimes that limit their implementation with the exception that owners of related standard-essential patents are adequately compensated. Consequently, ETSI standards should be not approved if the OSS licence applicable to the integrated OSS content restrict their implementation because owners of standard-essential patents are prevented to seek FRAND-based licences or any implementers of ETSI standards – adequately compensating the SEP owners – from developing or acquiring software or hardware necessary for producing or commercialising their products or services. Whereas the ETSI report released in 2012 included only generic recommendations with focusing on a specific technology or a set of standards, ETSI identified and provided an overview about standardisation activities and standards related to cloud computing including relevant OSS projects, but without addressing licensing issues (ETSI 2013). However, a report released in 2016 (ETSI 2016) investigates the relationship and the interactions between

standardisation and OSS in cloud computing addressing explicitly the challenges of the tensions between patent licensing and OSS licences. The report acknowledges that a clarification of the licences applied to OSS has to be included in a standard or in an implementation of a standard. On the one hand, it is highlighted, again as in the 2012 report (ETSI 2012), that it has to be ensured that OSS included in standards does not restrict their usage, but also does not conflict with ETSI's IPR policy. On the other hand, it is admitted that there is no consensus that this IPR policy is compatible with the implementation of ETSI standards by OSS communities, i.e. the implementation of standards available under a FRAND licence in OSS is obviously difficult. In summary, the workshops about OSS and standardisation organised by ETSI in 2015 and 2016 did obviously not contribute to further progress in solving the tension between the FRAND and the OSS licensing model, which is indirectly confirmed by the missing references in the most recent ETSI work programme (ETSI 2017). However, ETSI is still working on finding solutions to solve this tension.

In contrast, OASIS and W3C include in their policies the requirement to make software available under the commonly used open source licences to facilitate and to protect the implementation of their standards. Specifically, the OASIS policy now includes a track, which is crafted to particularly facilitate the implementation of standards in software made available under all of the commonly used open source licences. The intention was a shift from the focus of disclosure rules related to essential content, i.e. patents or copyrights, towards a more 'licence-centric' approach in order to provide greater protection for users of OASIS standards (Bekkers and Updegrove 2013).

In the development and deployment of the Internet, a culture of free licence rights for Internet infrastructure was developed and maintained. In parallel, OSS was increasingly commonly used to provide the software 'stack' supporting the servers that enables the functioning and success of the Internet. Consequently, W3C already in 2003 adopted the option of RF in their standardisation processes.

IETF follows a slightly different strategy by requiring that any source code included in a standard must be made available under the BSD open source licence in addition to including copyrights in its disclosure requirements. This requirement applies both to essential and non-essential copyrights in software code, as no differentiation between the two is made. Surprisingly, the IEEE SA does not address software in its recently updated IPR policy or in its updated bylaws (also stressed by Li 2017).[8] However, The IEEE Standards Association Corporate Advisory Group (CAG) initiated an ad hoc for OSS a couple of years ago.

The limited focus on copyright in general, and software or open source software in particular, has certainly economic implications in various dimensions. First, the few SDOs or consortia explicitly addressing software are able to develop a stronger profile in standardising topics based on software alone or on the combination of software and hardware. Here, the actors with standardisation needs obviously decide according to the perceived competencies of the SDOs, including the governance related to software. Second, the FRAND regime relevant to the licensing of standard-essential patents established in traditional SDOs, i.e. members of ISO and therefore guided by the ISO/IEC/ITU IPR policy, is not necessarily attracting contributors to OSS, which are used to rather royalty free dominated licensing schemes. Therefore, a separation or division of work can be expected also in the future despite the significant efforts in particular by ETSI to find solutions for the coexistence of FRAND licensing and OSS licences responding to the expressed needs of some of their members organised within the Fair Standards Alliance (2017). Secondly, the rather strict royalty free based policies of OASIS and W3C following the OSS licensing schemes facilitate the implementation of their standards. Third, the IPR policies of SDOs related to software are linked to their business models, in particular those that do not make their deliverables freely available. It seems more difficult to sell standards under a royalty free regime integrating OSS in standards. However, this tension has not yet been addressed in the publications of SDOs and consortia.

1.4. Summary

The background as presented in the literature review leads, first, to very general conclusions as regards the growing importance of standard setting processes and their use of IPR, not only patents, but also copyrights on software. The general assessment is, secondly, that standardisation has a multidimensional role. It intermediates between

[8] http://standards.ieee.org/develop/policies/bylaws/sb_bylaws.pdf.

science and technology driven research and innovation and demand-sided innovation policies (OECD 2011) framed by various regulatory framework conditions. Patents and copyright-protected software including open source software are the major IPRs used as inputs for ICT-standardisation and also relevant for the accessibility of the output of ICT standardisation. Therefore, IPR utilisation in standardisation processes adds a further dimension.

In general, standards are developed by a number of different actors within a voluntary consensus-oriented process. Considering the accompanied increasing variety of interests of actors involved in standard setting, standard setting governance determines the success of SDOs in the sense of integrating the different interests at stake also asked for the European Commission. Effective rule setting and governance of SDOs are crucial for the successful development and eventually the implementation of standards. The IPR policy approaches developed by SDOs will have to consider not only specific rules and procedures for FRAND licensing relevant for patents, but even more for the treatment of open source software.

Annex 2 | Case studies on the interaction of OSS and FRAND licensing in standardisation

The project "Interaction between Open Source Software and FRAND licensing in Standardisation" aims at gaining a deeper understanding of the motivators and inhibitors of a closer collaboration between standards development organisations (SDOs) and open source software (OSS) communities. It focuses on the interaction and compatibility of the different licensing schemes and their effect on the success of collaboration. Our study assumes that it is necessary, but not sufficient to identify under what legal framework such a collaboration is possible. Beyond the legal options, the stakeholders involved must be positively motivated to participate in this collaboration by providing adequate and incentivising framework conditions. To illustrate this motivation, the study investigates cultural and governance aspects of the involved organisations as well as the relevant IPR frameworks.

The Digital Single Market (DSM) "is a strategy by the European Commission (EC) to ensure access to online activities for individuals and businesses under conditions of fair competition, consumer and data protection, removing geo-blocking and copyright issues." The pillars of the DSM strategy are improved access for consumers and businesses to digital goods and services, creating beneficial conditions and a level playing field for digital networks and innovative services, and to increase the standard of living across Europe by realising the growth potential of the digital economy.

A key ingredient to achieving the growth goals intended in DSM is standardisation. Standardisation promises efficiency gains through economies of scale, fosters competition between producers of standard-conformant products and benefits consumers through increased compatibility and interoperability, but also improved trust and reduced risks. Besides economic gains, implementing well-functioning frameworks that assure consumer and data protection and fair competition require specific standards to guide market actors and the judiciary towards goals set by policy makers.

Standards development and OSS development are two parallel processes that influence the information and communication technology (ICT) sector to standardise on successful products or processes. Standards development is facilitated by established SDOs and well-integrated into the European policy framework via the New Legislative Framework (Decision No 768/2008/EC). Its benefits are clearly understood. Open source is software that is commonly developed in a decentralised production process characterised by auto-organisation and collaborative development. While its benefits are also well-understood by now, there is still uncertainty about the interaction between SDOs and open source communities and about how to position open source development in the EU regulatory framework. In the 2015 edition of the Rolling Plan, the "use of open source elements by better integrating open source communities into SDOs' standard setting processes" was encouraged.[9] The recent communication on standard-essential patents concludes with the objective that "the Commission will work with stakeholders, open source communities and SDOs for successful interaction between open source and standardisation, by means of studies and analyses".[10]

Since both standardisation (Blind and Jungmittag 2008) and OSS (Nagle 2019a) contribute significantly to economic growth and the positive welfare effects of the ICT sector, it is assumed that a closer cooperation between SDOs and OSS would benefit both and support achieving the growth goals of the DSM.

A central question in the debate about this relationship are the choices of intellectual property rights (IPR) regimes implemented by SDOs and open source communities, and how these choices influence both sides ability and motivation to cooperate. Since innovators may contribute patented technologies to the development of standards, some SDOs, like the European Telecommunications Standards Institute (ETSI), favour IPR regimes that allow for the combination of standards with patented technologies. Others, like W3C, prefer IPR frameworks based on royalty-free licensing or apply a mix of IPR policies that matches the specific subject matter to be standardised. Multiple initiatives within SDOs are currently investigating suitable

[9] European Commission (2016): Rolling Plan for ICT Standardisation 2016.

[10] European Commission (2017): COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL AND THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE Setting out the EU approach to Standard Essential Patents, COM(2017) 712 final.

IPR regimes for combining or experimenting with including open source facilitation into their portfolio of services.

Consequently, some of the resulting standards are covered by standards-essential patents (SEPs) that need to be licensed to implement the standards. The EC considers fair, reasonable and non-discriminatory (FRAND) licensing conditions essential for SEP-encumbered standards. The literature review has shown the tension, but also authors close to the wider open source community, like Phipps (2019) have expressed concerns that FRAND conditions are potentially incompatible with open source licensing models, or otherwise inhibit a possible cooperation. The case study report gathers experience from a wide range of successful and unsuccessful attempts of cooperation between SDO and open source communities, presents it in the form of multiple case studies, and develops an initial understanding of the factors that support and suppress such cooperation. The findings from this investigation have been used as input to the ongoing stakeholder survey and are further studies in the analysis section of the report.

2.1. Case study concept and methodology

The research project that this case study report is part of was kicked off in February 2018 and performed in three partly overlapping phases. The delivery of the first phase was a comprehensive literature survey submitted in April 2018 that aimed at grounding the later field work on the academic state of the art. In parallel, a set of case studies was produced in the second phase that also started in February 2018. The results of the performed case studies are presented in this chapter. The third phase built upon the results from the first two and consists of a wider survey of relevant stakeholders. The transition between phases two and three was marked by an expert workshop held on 18 September in Brussels.

The case studies report was developed following these steps:

— First, insight into the specific area of interest was gathered through multiple open-ended, qualitative, in-depth interviews with representatives of key stakeholders, especially organisations that participate in standards development, open source activities or both, SEP rights holders, European and international SDO, and major open source communities, standardisation consortia and umbrella organisations. The interviews followed an interview guide approved by the European Commission and the steering committee established

CERN, IEEE AND THE WHITE RABBIT PROJECT
CLOUD FOUNDRY AND MULTI-PLATFORM CLOUD COMPUTING
OPENSTACK AND DATACENTER VIRTUALIZATION
KUBERNETES AND THE CLOUD NATIVE COMPUTING FOUNDATION
GENIVI, W3C AND AUTOMOTIVE IN-VEHICLE INFOTAINMENT
AUTOMOTIVE GRADE LINUX AND THE LINUX FOUNDATION
ECMA TC39 AND THE JAVASCRIPT PROGRAMMING LANGUAGE
ISO JTC1 AND THE C++ STANDARDS COMMITTEE
THE DEVELOPMENT OF THE JAVA PROGRAMMING LANGUAGE SPECIFICATION
DOCKER, CONTAINER RUNTIMES AND THE OPEN CONTAINER INITIATIVE
BLOCKCHAIN AND DISTRIBUTED LEDGERS
THE OPEN CONNECTIVITY FOUNDATION AND THE IOTIVITY PROJECT
ETSI NVF AND OPEN SOURCE MANO
OPNFV AS A COMPLEMENTARY NFV IMPLEMENTATION
SOFTWARE DEFINED NETWORKING AND OPENDAYLIGHT
ONAP AND THE CONVERGENCE OF PHYSICAL AND VIRTUAL NETWORK FUNCTIONS
THE LINUX FOUNDATION NETWORKING FUND
OPEN AIR INTERFACE AND OFF-THE-SHELF 4G AND 5G
THE LINUX OPERATING SYSTEM
The OPEN INVENTION NETWORK

TABLE 2. LIST OF CASE STUDIES.

to accompany the study. They are tailored to gain a deep understanding of the experience of the participants regarding the interaction between FRAND licensing and open source from a cultural, governance and legal perspective. The individual interviews are not targeted towards a specific case study. However, the exchange with the participants revealed interesting cases.

— The interviews resulted in a set of findings and an initial understanding of the subject. Based on these findings, data about the case studies has been gathered in a second step, through field work, directed research and direct interaction with the case study subject entities. The interviewees had been informed about the selected cases and encouraged to provide more specific input if they can.

— In the final step, the findings from the interviews and the case studies have been aggregated into informed insights about the motivators and inhibitors of SDO and OSS collaboration.

2.2. Stakeholder participation

The case studies developed as part of this project aimed at getting first-hand, in-depth experience from expert practitioners at the intersection between standardisation and open source. Since there is only a small body of literature to draw from regarding this specific subject, as confirmed by the literature survey, the case study research was performed based on a fieldwork approach. Evidence is gathered through direct interaction with participants in the concrete cases and evaluated against the insights derived from the qualitative expert interviews. The in-depth insights from the interviews provided the foundation for the more concrete field work investigation of the individual case studies.

The interviews have been held with practitioners from an industry, SDO and open source community background. They do not map directly to concrete case studies, since it is assumed that the interviewees draw on experience from both ecosystems and from participation in multiple open source communities and SDOs. Interview questions where standardised, but allowed for open-ended answers, enabling participants to express a variety of perspectives and the aggregation of cross-sections of interview results. The outline for the interviews consists of 29 individual questions with various sub-questions. It was developed within the study group and reviewed with the steering committee before the beginning of the interview process. Interviewees have been selected to represent key SDOs and open source stakeholders. However, the invitation process was organised openly and shared across multiple forums to reduce a possible selection bias. Once invited participants agreed to being interviewed, the interviews where for the most part organised as teleconferences. Provided the interviewees agreed, the audio of the discussion was recorded and will be archived with the study group for scientific reproducibility. The interviews are evaluated by aggregating the details for each individual question horizontally across all interviews. The results from this process are used to interpret the case study findings.

Candidates for case studies have been identified based on suggestions from stakeholders attending the kick-off and steering committee meetings, individual initiative by interested third parties, and by way of recommendation from the wider open source and SDO related network of the study group. From these candidates, cases where selected that represent concrete standards or open source software development activities (as opposed to program development or task forces that develop concepts), represent large enough numbers of participating entities, show relevant market adoption of their products and distinctive specification and implementation activities. While it was not a requirement that the cases originate in the ICT sector, it turns out that most of them are. The cases are described based on assessments of 40 different parameters structured the same for each case study.

Conclusions from the case studies are again drawn by horizontally aggregating the findings based on the standardised case study structure. They are used in the second phase of the study to develop and conduct a wider stakeholder survey and become part of the final study report.

2.3. Case selection criteria

The case studies have been selected based on a set of concrete criteria:

- Each case needs to exhibit a relevant connection between standards and open source development based on an existing collaboration or interaction. Exploratory activities, intentions to establish collaboration and other preparations for a future interaction have not been considered as they may turn out to not be viable and never lead to an actual collaboration.
- From the remaining cases, those have been preferred that excel in essential community metrics, especially the number of participating entities and the amount of contributions raised. These metrics can be applied separately to both standards and open source development activities.
- The developed standards or open source technologies must have found adoption in the market. Adoption was assessed through knowledge transfer to other entities than those involved in the collaboration as well as from successful attempts at commercialization of the results.

Not all cases fulfil all three of the criteria. Two exceptions have been made based on the importance of the specific instances in shaping the boundary between standards development and open source:

- The OpenAirInterface project was included in the report even though it has not yet seen significant adoption in the market outside research and development or academia. It was included because it fulfils the other two criteria and applies a unique licensing model that combines elements of the Apache-2 open source licence with conditions for FRAND licensing of SEP (Maracke 2019).
- The Open Invention Network was included in the report even though it does not produce concrete specifications or open source technologies. It was included because it creates a patent cross-licensing environment for open source collaboration and has successfully built an influential community that shapes the IPR frameworks of multiple collaborative projects included in the case studies.

The report covers more initiatives that originate within the wider open source community than from within SDOs. The authors actively sought out additional more standards development related activities for inclusion in the study by reaching out to the participants in the study, the standardisation community and the project advisory board. This outreach did not discover additional activities not yet covered by the report. The authors are confident that the selected cases cover a large share of the spectrum of initiatives at the boundary of standards and open source development. However, some risk remains that other activities relevant for the analysed interaction are not covered by this report.

2.4. Interview evaluation and case studies preparations

The interviews serve as a first qualitative step towards gaining a good understanding of the boundary between standards and open source development before beginning the research work for the individual case studies. 13 roughly 90 minutes interviews have been performed to prepare the case study research. Interviewees have been invited openly based on their prior experience with the study subject and engaged in in-depth discussions based on a predefined set of relatively open questions. The interview design allowed for the interviewees to extend on aspects important to them, resulting in a broad spectrum of experience being made available for analysis. This enabled the authors to gather a realistic impression of the industry sentiment regarding standards and open source development in a qualitative approach. The following paragraphs in this section describe issues identified during the interviews that where then further researched in the case studies.

2.4.1. *The question of legal compatibility and reasons to participate in collaboration*

The sparse existing research reviewed in the literature survey that deals concretely with the interaction of SEP licensing and open source software focuses primarily on the legal compatibility of open source licences with

FRAND licensing of SEP. This is one important aspect of the picture, since any directly contradicting terms in a specific combination of open source and FRAND licence would prohibit a combination of the two works. However, it was clearly identified during the interviews that answering the question of legal compatibility is not sufficient to provide answers of genericity or to serve as a foundation for shaping a possible collaboration. First, a question of legal incompatibility can only be evaluated against a specific contractual situation combined with the individual terms and conditions applied in the concrete open source and FRAND licences. Since many open source licences of very different nature exist and FRAND conditions as well are not normalised, no general conclusions can be supported simply because there was a combination of the two. The statement that some combinations of specific open source licences with specific FRAND terms are incompatible and others are not is only useful when applied to a specific licensing relationship. Second, if a case can be cleared not to pose any incompatibilities, this only means that a collaboration is legally possible, not that participants from both sides would be willing to engage in it and contribute towards tangible results. Legal compatibility of licensing terms is a necessary precondition, but not enough to establish a successful collaboration between SDOs and the wider open source community. This guided the case study research to investigate the reasons why actors engage in standards and open source development, and how these are related to the applied IPR framework.

2.4.2. *Different expectations towards the possible benefits of collaboration*

The interviews revealed that there are different understandings about what the nature of a possible collaboration between SDOs and the wider open source community should be. The most widely used thought model experienced within SDOs for "working with the open source community" is the expectation that SDOs develop specifications in standards and the open source community subsequently implements them. This approach assumes that an as of yet unimplemented innovation is invented first and specified as part of a standards development process, and that creating a concrete conforming product is left to implementers competing in the market.

The vision behind this understanding is that an inventor conceives an innovation and formulates it in a specification, which may become a formal standard. The creative, inventive work is expected to be embodied in the specification, and the later implementation follows the blueprints of it. The open source development community exhibit a different process. It usually assumes that the inventive work of finding creative solutions to problems is performed as part of the software implementation process, and that specifications are authored after the creative problem is solved. It is highly unlikely from this perspective that specifications can be developed in ex-ante working group processes and will then be picked up by the open source community to be implemented. For a potential collaboration to be successful, the interviewees indicated that a common understanding of the role and utility of specifications that then become formal standards needs to be developed.

2.4.3. *Open source software and open source community*

The terms open source software and open source community have been used with different meanings during the interviews. The term open source software refers to software that is distributed under a licence which complies with the open source definition. The Open Source Initiative is the steward that approves licences for being compliant with this definition.[11] To convey a more precise meaning to the terms in this study, open source community and wider open source community will be differentiated. We use the term *wider open source community* to describe the global network of individual projects, developers, research institutions, business and any other entities that participate in the creation of open source software. The wider open source community is connected in

[11] https://opensource.org/osd. Another widely used reference is the Free Software Definition by the Free Software Foundation (https://www.gnu.org/philosophy/free-sw.en.html). For the purpose of this study, both definitions are roughly equivalent.

an overarching upstream/downstream network that integrates individual open source packages into complete software stacks. Software stacks solve a higher-level problem, like a Linux distribution that provides a complete operating environment for example for end-users, a device platform like Yocto that can be used to build embedded systems, or an enterprise platform like OpenStack that runs datacentres. A specific *open source community* focuses on a more concrete set of software packages – the operating system kernel, the C library, or a compiler. Here it is comparatively easy to identify who contributes what to the product, on which the idea of meritocracy builds. Meritocracy in open source communities is understood as the concept that each contributor is valued in the community solely based on the contributions they make. Specific communities can be big or small, ranging from one to hundreds or sometimes thousands of developers. It is helpful to consider organisations that are aggregates of specific communities, like the Eclipse Foundation or the KDE Community, as *umbrella organisations*, because they serve a different purpose of providing representation and administration to the communities they support. Decisions are made at the level of the individual open source community and coordinated within the wider open source community, for example through voluntary collaboration and conferences. No central decision-making process exists to steer the whole wider open source community. The work of the wider open source community is coordinated by way of competition between alternative solutions for downstream integration and adoption. In the case studies, this insight has been used to identify where collaboration decisions are made and what organisations act more as umbrellas with an overarching facilitating role. We consider the *entity that invests* work time or funding into the development of OSS as the contributor. In case of corporate employees, while the individual developer works on the code, the employer is the contributor that makes the decision to participate and also in most cases gains copyright on the contributions made by the employee. The principle of voluntary participation in OSS communities means that the entity that ultimately makes the investment decision is also the one that decides on participation. Even if employees are given a certain leeway to decide what exactly to focus on, the decision to employ them and assign them to OSS development work is still the employers. Independent individual developers and corporations are contributors that voluntarily participate in OSS development, which is similar to how the same entities decide to participate in standards development.

Reducing the problem of collaboration between standards and open source development to implementing standards in open source software as opposed to engaging with the open source ecosystem to create implementations of new technologies frames the research question to one of product licensing. The requirement that a software is open source if it is distributed under a licence that follows the Open Source Definition does not prescribe how the software is being developed. Some open source products, like Android, are being industrially developed by a single vendor with very little to no outside contributions. However, most OSS are developed by a network of voluntary individual or organisational contributors. Open source communities successfully produce software if contributors (both individuals and organisations) are motivated out of their self-interest to voluntarily do so. A collaboration between SDOs and open source communities will be beneficial to all sides if it combines the innovativeness and agility of open source communities with the diligence and multi-stakeholder review of SDOs. Asking how this can be achieved is a matter of governance in the specific and the wider open source communities, not a question of the licensing conditions of open source software.

2.4.4. *The roles of governance and legal frameworks*

Explicit, written governance norms and IPR frameworks regulate the behavioural expectations towards participants in SDOs (see Baron et al. 2019 on the governance of SDOs). For conflict resolution, most interviewees referred to these SDO frameworks as well-established guidelines that for the most part prevent conflicts by making the expected behaviour explicit and providing a platform for implementing those expectations. Participants orient themselves based on these SDO frameworks that usually existed before they joined. They do not consider other conflict resolution methods necessary. Conflicts that cannot be solved by enforcing the widely accepted SDO IPR framework almost never occur in practice of the investigated case studies in contrast to the increasing number of litigations related to SEPs (Pohlmann and Blind 2016).

Similarly, open source licences are often expected to be what regulates how open source communities collaborate. This was put in question during the interviews, as it reverses the order of events. Communities initially came together to jointly produce a solution in the form of a concrete implementation that they had a common interest in. Then they established a model of collaboration that suited their purpose. And then finally they set out to formulate or adopt a licence that embodies their collaboration method and allowed others to work with the community in the intended way. Later, communities have for the most part adopted already existing licences. However, they do so based on what licence supports the collaboration model they chose. It is not common that a community is set up by choosing a licence and implementing a conflict resolution process based on the details of the licence. The detailed terms of the licence do not express how the community operates. The governance norms of open source communities have been described during the interviews as almost completely separate from open source licensing terms. From this perspective, the collaboration models as well as the IPR frameworks of SDOs and open source communities must match to establish a successful interaction. A community might even adopt a different, more suitable licence if the collaboration model changes.

In addition, concerns have been raised during the interviews that open source licence agreements cannot be interpreted in an abstract fashion. Open source licences are essentially templates that contain suggested terms and conditions. The recipient and the authors engage in a concrete agreement based on conclusive acts of offer and acceptance. What the parties agreed to in this agreement depends on what the offering and the accepting party should have reasonably understood. What the original authors of the licence text intended to express or limit in the meaning of the contained clauses may diverge from what contributors and recipients understand today. In case of uncertainty, a legal agreement needs to be interpreted against the intent based on which the parties made it. This aspect is complicated in the context of SEP licensing depending on whether or not the offering party holds a patent with claims that are implemented in the code. The statement "permission is hereby granted, free of charge, to any person obtaining a copy of this software and associated documentation files (the "Software"), to deal in the Software without restriction…" contained in the MIT licence may in such a scenario easily be understood to include even an explicit licence to the patent in question.[12] During the interviews, it was identified that such uncertainty is considered not helpful, which was mentioned as one important reason that the open source community steers towards licences that include an explicit, not implicit, grant to the contributor's own patents. This is, however, a question of clarity of or uncertainty about the licensing conditions, not a question of the compatibility between open source and FRAND licensing terms. The question of what licences are preferred today and how those interact with SEP licensing terms was researched in detail in this study. The question whether or not some specific licences may include an implicit patent grant was not considered relevant (see the legal discussions in Li (2018) and Maracke (2019)).

2.4.5. *The impact of formal recognition of SDO on the collaboration with open source communities*

Most SDOs and open source communities historically started as coalitions of interested stakeholders to work together on either standardisation or collaborative software development. Some SDOs over time gained formal recognition as either national standards bodies or recognised entities at the EU or international level. Based on this a differentiation is made between formal and informal standardisation. In the eyes of many SDO participants, the prestige of an SDO is closely related to it being formally recognised. It is also commonly assumed that such recognition should be a motivator for open source communities to collaborate with these SDOs. Open source communities, however, value partners based on the contributions they make in a meritocratic model. Open

[12] The authors refrain from further investigating the nature of the patent grant embodied in the text of MIT family of licences, acknowledging that arguments have been brought forward making the case for no patent license, an implicit patent license or an explicit patent license. Even though multiple study participants considered it important to resolve this decades-old debate, the outcome should only have a very limited impact on the results of this study.

source communities are interested in collaborating with SDOs that do relevant work in the field they are working in, for example the W3C or IETF. What unifies SDOs in the eye of the open source world is that they produce specifications for relevant standards. What unifies open source communities is that they focus in implementation. Formal recognition was not a relevant differentiator of SDOs in the eyes of interviewees from an open source community background. However, formal recognition is recognised as important for the relationship between SDOs, industry and possibly policy makers. During the case study research, these aspects were further investigated.

2.4.6. *Market pull and external push for OSS adoption*

Interviewees where asked why enterprises, regulators and others are interested in a collaboration between SDOs and open source. The answers indicated that there seem to be two different motivations at play, which should be treated separately during the analysis. One can be described as an external push, the other one as a market pull.

Market pull is caused by the attractiveness of the open source model to market participants that causes them to adopt OSS and processes out of their own self-interest. Automatic licensing and the absence of negotiation reduce transaction cost to a minimum. They enable complex contributor networks that in the face of negotiations over IPR would be prone to anti-commons situations. In an anti-commons situation (Heller 1998), the cost of negotiation over the right to a good reach a point where it is prohibitive to the intended transaction. The market pulls towards open source approaches because they provide a way to pool funding to produce non-differentiating software and focus research and development investments towards differentiating commercial features. Market actors pragmatically choose combinations of OSS with proprietary hardware and software. Today, such combinations are the norm and seen as the working model of most industrial open source consortia, like the Linux Foundation or the Eclipse Foundation. The market does not pull towards a situation where only open source solutions are used, because collaboration is not a viable strategy for the development of competitive, differentiating product features. Market pull is characterised foremost by voluntary participation of all participants.

External push is created, among others, by societal expectations towards openness and transparency, politicians that use open source as an argument in debates, or by regulators that perceive open source either as a threat to be stemmed or as an opportunity. Unlike market pull, such demands do not represent voluntary participation of contributors in Open source development.

2.4.7. *Software versus hardware*

Commoditization is a long-standing trend in the ICT sector. It describes the replacement of expensive, custom or otherwise specific hardware solutions with off-the-shelf hardware components and functionality implemented in software. Through economies of scale, this process benefits consumers by drastically driving down prices, and in turn threatens the business models of companies that sell hardware products that now can be implemented in software. Economically, this trend also represents a shift from inventions being implemented as physical goods to the same inventions being implemented as information goods. This is often used as an argument that this means these information goods needs to be covered by the same IPR that previously covered hardware. This issue was raised as an open question during the interviews. Historically, different IPR frameworks developed for technical inventions and creative goods that are, among other things, based on the cost of creating additional units of these goods.

In the case studies, it was further investigated what IPR frameworks the participants consider suitable for source code and technical inventions, especially when engaging in collaborative development.

2.5. Results and analysis of the case studies

The case studies cover standardised structured set of criteria that will be evaluated in the following section. The criteria are of a qualitative nature and cannot be normalised for a quantitative evaluation. For example, the assessment of the match between the SDO and open source community IPR regimes cannot easily be summarised in numbers. What the cases and the evaluation describe is a comprehensive profile of the market, the stakeholders and the governance framework at the boundary between open source and standardisation. The results are indications of underlying principles and norms that shape this intersection. Some of these expectations have been further verified in the study's stakeholder survey. The following subsections provide a cross-sectional assessment of the answers to the same questions for the 18 different cases that produce specifications or implementations (exceptions are the Linux Foundation Networking Fund and the Open Invention Network).

The scope of the study reduces the technologies represented by this evaluation to functionality embedded in software and hardware. The results cannot directly be transferred or applied to standards development activities that do not involve a similar combination of physical and information goods or a global collaboration of implementers. For example, the discovery of prevalent implementation-first or parallel approaches to standardisation is important but may only be applicable to intangible products that are created during research and development and are not later manufactured in mass production (instead, they are copied at negligible costs per unit).

The results of the case studies are presented in an aggregated fashion. They can, however, not be used to derive averages or quantitative assessments. Among other factors, the self-selection bias of interview and case study research participants creates a noticeable clustering of cases that represent the telecommunications industry and industry-driven open source projects.

2.5.1. *The need for standardisation*

The reviewed projects differ in their view on the role of the specification that a standards development process creates. The majority of the projects do not consider a specification as the starting point of an implementation. Instead, many develop specifications based on proven functionality in existing implementations, and some even require a working implementation for a feature to be added to the specification. Those that create specifications state well-known benefits like interoperability or enabling independent third-party implementations to improve competition and the general availability of products in the market. This indicates an increasingly utilitarian point of view towards the role of specifications. Specifications are authored if they provide a tangible benefit. Projects that do not benefit from written specifications often omit them.

Procurement processes, safety or compliance requirements and other conditions, however, continue to reference specifications provided by standards. Fulfilling such external requirements is one possible utility provided by a specification that may compel projects to provide them.

2.5.2. *The approach to standardisation*

The traditional view on the process of standards development is that specifications are created based on voluntary stakeholder participation, e.g. by industry, research or other societal organisation, are promulgated to communicate stakeholder consensus and are then embedded in standards-compliant products by implementers. Case study participants explained how historically the incubation of newly standardised technologies was discussed as a common problem in SDOs. These standards were developed specification first before any implementations existed (see section 5.5.3). This paradigm is not prevalent anymore in the researched cases. 16 of 18 cases apply an implementation-first or a parallel approach to standardisation. For the initiatives that apply implementation-first or parallel approaches, the respective open source communities act as the incubators of the specifications. Only two cases focus on creating specifications first, which means the traditional model described above is becoming less prevalent in the ICT sector.

2.5.3. *Relevant stakeholders*

The stakeholders mentioned by the representatives of the different cases are rather similar between standards development and open source implementation focused projects. The key relationships are between telecommunications operators and data network operators as the commercial consumers of software and equipment, original equipment manufacturers, equipment suppliers of different tiers, software vendors and service providers. Other important stakeholders are commercial and individual software developers that influence the adoption of technologies and academia and research organisations as a source of innovations. The wider open source community sometimes takes on the role of a software vendor, replacing commercial software providers especially for foundational technologies like operating systems or cloud infrastructure software.

The absence of variance in the set of stakeholders between cases underlines that standards and open source development serve the needs of the same community with different processes and methods. Actors choose to participate in specific projects based on a presumed match between their business goals and the organisations aims and governance.

Other stakeholders, like environmental groups, civil society or government representatives have not been mentioned by the study participants. This can be interpreted in a way that the interests represented by them are relevant in general, but do not have a specific relevance for the subject of the study.

2.5.4. *IPR and governance frameworks in standards and open source development*

The projects apply copyright, patent and trademark protection to their products and organisations. Only two projects (White Rabbit and Linux) do not formulate an explicit IP policy, mostly for reasons based on their historical development. Copyright is applied to source code and specifications. The cases set up a patent licensing framework either through the use of open source licences that include a grant of contributor-owned patents or by requiring a declaration of SEP or a patent licensing commitment from participants. Although the hosting organisations for multiple cases leave an option for FRAND based patent licensing (examples are ISO/IEC JTC1, ECMA for TC-39, ETSI-MANO and OpenAirInterface), almost all cases opted for a royalty-free patent licensing policy. This is either because patents where claims cover standardised functionality are assumed to have expired, as in the case of C++, or because the working group aims at making the standard making the standard available at royalty free terms, as in the case of TC-39 where the royalty-free policy is implemented by way of a contributor licence agreement.

SDO hold copyright on balloted standards documents or specifications and make them available through their usual channels, either as free downloads as in TC-39, or for purchase as for IEEE and ISO. Working documents are increasingly kept on collaboration platforms like GitHub. Most organisations (all cases except ETSI-NFV and OpenAirInterface) do not set up provisions for including features covered by SEP in standards documents. The vast majority of interviewees and case study participants stated doubts that royalty-bearing SEP licensing and open source development can be successfully combined.

The majority of the open source projects covered in the cases (Cloud Foundry, OpenStack, Kubernetes, AGPL, Docker, OCF, OPNFV, OpenDaylight, ONAP, OpenAirInterface, Hyperledger) decided for the Apache-2 licence, which is a permissive open source licence that includes a licence grant to contributor-owned patents. A smaller group (White Rabbit, C++ with the implementation that is part of the GCC compiler family, Java and Linux) apply the GPL-2, a strictly reciprocal licence that requires all modifications to be distributed under similar licensing terms. Java combines the GPL with the Java Specification Participation Agreement (JSPA), a contributor licence agreement that includes a grant of a patent licence. Only two projects, ECMAscript and the Bitcoin based implementations of blockchain, apply a broadly permissive open source licence (MIT, BSD) with no explicit patent grant. The ecosystems of some cases invite independent implementations, so that multiple licences may be applied by different organisations representing the same case. For example, C++ implementations are released under the GPL-2 (GCC), the permissive NCSA licence (Clang) and proprietary licences (Microsoft Visual C++). OpenAirInterface also

applies the OAI Public License which is based on the Apache-2 licence but replaces the Apache-2 patent grant with provisions for FRAND licensing. The OAI Public License is not approved as an open source licence by the Open Source Initiative.

2.5.5. *Innovativeness and contributions to the state of the art in the affected industry subsectors*

Based on the overall impact that the reviewed cases had on the market, two thirds can be considered highly innovative, large scale collaboration that have seen wide or sometimes global adoption, especially Java and Linux. Almost a third have had a significant impact on a specific market segment. Only two (Genivi and OpenAirInterface) need to be considered as less impactful, however, this is mostly because at the time of writing the case study report they did not achieve larger adoption in the market, even though both projects are considered as innovative by participants.

About half of the cases achieved market wide relevance across multiple industry sectors as foundational technologies or by driving business-critical infrastructure, even though they originated from the ICT sector. This includes cloud technologies like OpenStack that operate essential services in the financial and automotive sector, among others. Other affected sectors mentioned during the interviews are energy, health care, manufacturing, logistics and government services. There is no clear-cut definition of the affected industry sectors and subsectors as the technologies covered by the case studies are multi-purpose. As a general cross-sector trend, computer and telecommunication systems become foundational technologies for various products and business processes. This means that changes to IPR and regulatory frameworks potentially cause market wide effects, affecting all industry sectors where open source technology has become business critical.

2.5.6. *SDO landscape*

The SDO involved in the case studies are ETSI (5 cases), ISO (4), W3C (3), IEEE (2), IETF (2), ECMA (1) and OASIS (1). Six projects opted not to participate in standards development and focus on implementation driven strategies. The reasons for actors to participate in standards development in these cases vary widely. One cluster of drivers is the goal to enable adoption in the market through technology transfer, fostering competition and improving interoperability (4 cases). In the 3 cases that cover programming languages the specifications as such are the reference for developers and implementers. Another reason to standardise mentioned for multiple cases are to support the availability of open standards. In the blockchain ecosystem, development activities are not yet very structured, so that no coherent standards development regime has emerged. The Hyperledger project focuses on implementation.

Only two cases (ETSI-NFV and OpenAirInterface) actively anticipate the inclusion of FRAND-licensed SEP into developed standards. All others either do not consider SEP relevant for their specific innovations or implement a royalty-free patent licensing policy. The participants in these projects that engaged with the interviews or the case study field work also do not consider this a situation that needs change. The most common participation strategy adopted by actors is to adjust to the collaboration methods and IPR policies employed by the communities they engage with. For activities at the boundary of standards and open source development this typically involves adopting a royalty-free patent licensing policy. For all cases except ETSI-NFV and OpenAirInterface, this expectation of royalty-free licensing is considered acceptable and not to be a barrier to collaboration or to the development of relevant standards. Multiple parties mentioned as a precondition for this model to work well that all participants invest goodwill into making the collaboration work and are open and transparent about their intentions.

2.5.7. *Contribution to standards development*

Except two cases that have yet to achieve significant adoption in the market (GENIVI and OpenAirInterface), all others have had decisive impact in their technology areas. 7 cases build foundational technologies and 3 facilitated interoperability based on an early implementation. 4 cases (the programming languages and ETSI-NFV) achieved wide adoption in the market based on available specifications that existed first. This indicates that the choice of an early, parallel or late approach to standardisation does not limit the possibility of success of a project, nor is a specific approach a requirement to a successful standard. More importantly, the governance and collaboration models need to be considered suitable by the relevant stakeholders to motivate them to participate. The most widely adopted technologies are also the ones that attract a large number of participants in their development.

The incubation of new technologies and features more commonly happens through joint implementations or reference implementations under open source licences. Most innovations covered by the cases are brought to standardisation once proven implementations exist and are generally available. The assumption that royalty-bearing SEP licensing is a necessity for innovators to participate in standards development is not supported by the cases in contrast to the findings by Baron et al. (2019) based on survey results. Instead, some case study participants emphasized that they see standards development not as a means to create genuine innovations but to establish industry consensus on available technologies to enable economies of scale. Innovation in their view is better coordinated through market competition.

2.5.8. *Value system of contributing to open source development*

The cases representing collaborative open source efforts illustrate the usual combination of the pragmatic view that considers open source a proven, well-working method of producing high quality software and the principled view that emphasizes the imperative of free access to software technologies as a societal necessity.

The pragmatic reasons to contribute to open source development mentioned in the cases are to establish effective reuse and minimise duplication of effort between projects, to reduce risks, to pool research and development investments for non-differentiating technologies and to reduce the number of parallel implementations of the same functionality. Avoiding contributor fragmentation towards different communities competing over adoption is a central concern. An understanding of a rule of thumb has evolved in the industry that states that at least 80% of the software code shipped with modern devices should be collaboratively developed common platform functionality and the remaining 20% represent the differentiating features vendors compete over. Especially the industry-driven collaborative open source projects represent an important focal point for collaboration that facilitates the allocation of the remaining research and development spending towards differentiating functionality.

The principled perspective that emphasizes ethical aspects of software freedom is represented by arguments that publicly funded research should be made freely available to the general public (like in the current promotion of Open Access to scientific publications) and that the chosen licensing model should ensure that they remain free, or by the goal to ensure the means of production of digital goods like compilers or device platform are freely available to innovators. Some participants state that they strongly prefer collaborative approaches for the development of business-critical software infrastructure and that they would rather use jointly implemented solutions than those dominated by single or a small group of entities that maintain control over the specific market segment. This mirrors reasons stated as motivators to participate in standards development.

Most participants in the study agree that the prevalent open source methods provide a well-established balance between the pragmatic and the principled concerns. Some caution that by interfering with the established open source norms through changes to the accepted interpretations of open source licences or patent licensing policies, the delicate governance balance may be disturbed, leading to declines in participation.

The majority of implementations represented by the cases serve as upstream and downstream projects at the same time. This means that these projects make extensive use of software modules developed by other parts of the

wider community, while they themselves become building blocks for further downstream projects. For example, the Linux operating systems provides the container features necessary for container runtimes like Docker, which then become key elements of the Cloud Foundry or Kubernetes platforms. Projects that solve specific problems without engaging with the wider open source community (like in the case of White Rabbit) are rare.

2.5.9. *Knowledge transfer and commercialization*

Some of the cases represent platforms or software systems characterised by complex, long-term technical developments that require larger investments and strong commitment from participating companies. OpenStack, Cloud Foundry or the Linux operating system are examples for such developments that then become foundational technologies other products are built upon. There is strong interdependence and reuse between the different software projects described by the cases. This reduces the duplication of development effort and cost which represents an increase in the efficiency of the innovation process compared to patent races and other competing innovation processes. A key function of the wider open source community is the early filtering of relevant projects and communities and to enforce the "fail early" approach to less convincing attempts.

2.5.10. *Decisions to participate in standards and open source development*

The reasons for participating in standards development stated by the study participants match those identified in the literature review. Standards development provides stability to the technical innovation process by enforcing a disciplined approach and the creation of complete specifications. The schedules and planning horizon of SDO and open source communities are similar and support each other, while businesses are often forced to plan from one release to the next. For some cases, standards are useful in their own right or as prerequisites for adoption, as in the cases of programming languages or mobile communication protocols. Standards support interoperability and are used as references for regulatory compliance. They also help overcome fragmentation in the market caused by diverging, incompatible or only partially standards-compliant implementations, as was the case for early C++ compilers or JavaScript interpreters. Standards force vendors with strong market positions to open up for competition (Docker). The processes at SDOs facilitate consensus building embedded in a governance and IPR framework that allows for compromises between competitors.

The reasons stated by organisations for participating in open source development only partially overlap with the reasons for participating in SDOs. Some organisations impose general internal policies or recommendations to use OSS and open hardware licences where possible. Participants aim at creating new technologies to overcome a dominant market presence of a single or a small group of vendors in a specific market segment. Examples are OpenStack, cloud infrastructure in general or OpenAirInterface. Collaborating on a joint implementation competing with incumbent businesses can help to re-establish competition, reduce prices, increase the variety of solutions offered in the market and rekindle innovation. In other cases, joint open source implementation helped increase interoperability between existing or new solutions (e.g. Cloud Foundry, OpenStack, ONAP). Some study participants consider contributing to open source development a more suitable approach to develop industry standards if an implementation-first approach can be implemented.

Regarding the desirability of a close cooperation between standards and open source development, study participants state benefits and costs. One benefit is the combination of diligent, stable, elaborate SDO processes with the fast pace of development in OSS, as for example mentioned by ECMAscript, Java or AGL. A possible cost is that cooperation between SDO and OSS does not realise benefits in itself, so that there is no solution that fits all setups and case by case decisions are necessary. The combination of SDO and open source processes may lead to trade-offs, especially to a slower pace of development and lower innovativeness. Another benefit is that in

areas of high technical complexity, detailed specification in standards and working open source implementation may support each other and lead to both higher quality standards and better code. This aspect is mentioned for C++ and Docker. A further potential cost is that SEP encumbered IPR frameworks in SDO may impose a barrier to innovation by limiting the potential participants.

2.5.11. *Match and compatibility of SDO and open source IPR regimes*

This study originated from the observation of only limited cooperation between standards and open source development and uncertainty about whether questions of legal compatibility between SDO and open source IPR regimes may be a reason for that. The cases do not support this assumption. Most modern open source projects use licences with reciprocal conditions or explicit patent grants and interact productively with the SDOs relevant for their market segment. Those SDOs responded to open source related market changes by establishing royalty free or a choice of different IPR regimes. The IPR policies and processes, including procedures for the vesting of patent grants, are well-established and mature in both standards and open source development. In such environments FRAND-licensing of SEP is not considered important or there are no explicit IPR policies for it. Throughout the case studies, SEP do not play a significant role in these ecosystems for a variety of reasons, even though patent portfolios with essential claims may exist. In some cases, patent holders share their portfolios up-front through cross-licensing or commit to limited patent grants. In other cases, patents covering their technology have expired, as for C++, or the implementers established a culture of royalty free licensing, as for example in AGL. In these projects, there is no need to reconcile SDO and OSS IPR policies. Except for the telecommunications subsector, the industry does not perceive a conflict between SDO and open source IPR policies. Legal incompatibilities between open source licences and SDO IPR policies have not been found in practice and are not a relevant concern for most cases.

Where SDO and OSS processes are combined, the processes and governance in the working groups and communities often converge, leading to parallel open source development processes that incubate new features combined with standardisation processes to establish consensus.

It appears that a well-working relationship develops if standards developers and open source implementers largely overlap and many entities potentially contribute to the development process. Where there is no such overlap or in situations where there is a strong concentration of few suppliers in the market, no cooperation develops, and the majority of market participants are merely (commercial) consumers of technology with no participation in standards development.

For non-differentiating technology (created by SDO or by OSS communities) reciprocal licensing terms or explicit patent grants contained in the OSS licence mean that neither collaborators nor users (i.e. non-participating organisations) can directly compete with collaborators based on the jointly created technology by creating patent-protected derivatives of the original work. Such IPR regimes protect contributors from future competition based on their investments. This was considered a relevant concern voiced by case study participants that contribute to collaborative development. An IPR regime with provisions to ensure that collaboratively developed technology stays freely available was found to encourage motivation to participate in these development processes.

2.5.12. *Cultural aspects related to innovation, standards and open source*

It is apparent that IPR regimes serve partially different purposes in SDO compared to open source communities. For the latter, licences mirror and follow collaboration models and represent how participants envision the jointly created products to be used. In situations where a single product should serve all purposes and attract as much research and development investment as possible, as for example with the Linux kernel, a strictly reciprocal licence, in this case the GPL-2, is applied. Variants that diverge from the main product are not welcome or encouraged in such environments. In situations where one implementation is designed to be adopted as widely as

possible but still developed by one collaborative project or community, a limited reciprocal (or "weak copyleft") or a permissive licence with an explicit patent grant is applied. Most of the cases fall into this group, with the majority opting for the Apache-2 licence. If there is little cohesion within the community or there are no assumptions about how and where the joint implementation is going to be used, a permissive licence like MIT or BSD is chosen. Governance in open source communities develops as a collaboration model first and is then reinforced through a choice of licence. In contrast, IPR frameworks at SDO regulate how participants engage and how conflicts are resolved. Special attention is given to how participants may later exit the pre-competitive cooperation at SDO and compete again on products that implement the developed standard. This rationale is foreign to open source communities, as they do not envision re-engaging in competition once a functional area is covered by an industry-standard open source implementation. This contradiction may pre-empt the idea of an open source community creating reference implementations to a standard next to other competing implementations. Such a thought model has not been found implemented in any of the cases. In the same context, open source communities see no benefit in engaging in standards development simply for the purpose of facilitating alternative or competing implementations.

Both SDO and OSS communities are strongly driven by innovation. Both consider themselves standard setters, however not necessarily through the creation of specifications. Instead, open source communities see joint implementation as a viable way to create industry standards, and open source collaboration as a means to facilitate innovation in a market segment. In some cases, for example in the case of Kubernetes, they consider SDO processes as unsuitable for fast-paced innovation.

A dynamic perspective may be attained by comparing the development of cases over time and the progression of different technical collaborations in the same market segment, as for example in the cases of GENIVI and AGL as automotive software platforms. Attitudes and priorities towards specification change over time. In earlier stages, industry actors emphasize the creation of specifications. In a later stage, they may move towards incubating new technologies using open source approaches and apply parallel specification and implementation or an implementation-first approach. Such transitions can be observed in the development of C++ and Java, as well as in the automotive sector.

Whether balloted and draft standards are made available for a fee or for free seems to have limited to no impact on adoption. One reason for that may be that the fees applied are comparatively low compared to the necessary investments in products and engineering expertise. Access to standard documents is also mostly required by implementers of the standard, not necessarily by users. While making standards available for a nominal fee may not be preferred, it appears to be culturally compatible with open source norms.

Many highly motivated, idealistic individuals are involved both in standards as well as in open source development. Individual study participants stated they enjoy the collaboration between standards and open source development as one of like-minded people driven by a joint interest in the technology they create. In the JavaScript community, the common motivation is to advance the programming language so that it supports the developer community as well as possible. In the case of the White Rabbit project, working group members are enthusiastic to establish a new state of the art. All participants seem to take pride in their visible individual contributions. From a perspective of personal motives and motivation, participants in standards and open source development share many values and convictions.

2.5.13. *Interactions between SDO and open source communities*

From the perspective of SDO, study participants consider their interactions with open source communities mutually beneficial and serving their joint interest in a specific technical area. The open source contributors help to incubate the developed technology and to test the specification, which helps maintain high quality in standards. The partner open source community often creates the first or only reference implementation, or as in the case of Java and OpenJDK becomes the de-facto standard implementation later in the process. Interaction with the open source community also inspires the modernisation of SDO processes, for example through the adoption of new collaboration methods and platforms and increased transparency of decision making, as in

the cases of JavaScript and ECMA. Since experts in the specific market segments are rare, there is a noticeable overlap between the individuals involved in standards development and open source implementation. The same people may be involved on both sides.

The open source communities also describe their interaction with SDOs as fruitful and productive. The collaboration and consensus building processes encourage the stability of specifications, for example in the White Rabbit case, that would otherwise change quickly and cause interoperability issues. Open source implementations sometimes overshoot the functionality specified in the standards based on the faster pace of development, as for example with language extensions in C++ compilers or ECMAscript interpreters that are not covered by the specifications. This may cause a shift in the scope of technical development, as for example in the case of network automation that grew functionality beyond the original scope of NFV. In such cases, SDOs may be slower to update working group mandates and charters compared to the rigorous self-selection processes in open source development.

Larger collaborative projects with a well-defined purpose, as for example the Linux kernel developer community, see little usefulness in multiple, standards-compliant implementations. Freedom to operate is a key precondition for contributors to participate in the development process. Confidence in access to the implemented functionality either through cross-licensing, explicit patent grants in open source licences or contributor IPR policies is considered necessary for a fast-paced development process. The usefulness of formal standardisation is not accepted per se. Specifications and the necessary standards development processes to create them need to provide tangible benefits to the community to justify investing effort into participation and slowing the development process to accommodate the required consensus building. To avoid that, some cases explicitly exclude participating in standards development from their organisations remit. The projects recognise that users of their technology have a choice and compete for adoption, as in the case of alternative programming languages. Regular, relatively fast revisions of standards (for example, roughly annual standard updates for JavaScript) are considered necessary to maintain market shares in a competitive environment. In some cases, open source inspired collaboration methods are adopted by SDOs, for example by hosting draft documents in publicly accessible Git repositories.

2.5.14. *Other stakeholders*

SDO as well as open source umbrella organisations facilitate the participation of industry, individual contributors and academia in the standardisation process. By providing widely accepted IPR policies or project charters, they help to normalise governance norms.

The Open Invention Network (OIN) creates an influential cross-licensing environment for some of the larger collaborative projects represented by the cases, for example AGL, Linux, Kubernetes, OpenStack, JavaScript, C++, Docker and Java. Participants voluntarily enter into the OIN cross-licensing agreement to complement the rights and obligations from the open source licences applied to the project code. This combination creates an innovation environment where patent litigation practically does not occur.

Other stakeholders that do not participate in the standardisation process but may be affected by the produced results, as for example environment protection or civil rights groups, are not reported by the study participants to be involved in the cases. Some SDO provide multi-stakeholder platforms. Communities and SDOs are usually open for comments from outsiders. Beyond that, there seems to be few forums, like the ETSI with its ITS events, where outside stakeholders may formulate their interests. It is not clear from the cases whether or not participants see this as a situation that should be improved.

The cases covered mostly represent industrial standards development and open source collaborations. Both also accommodate the participation of volunteer contributors and academic institutions where it is applicable, which supports knowledge transfer.

2.5.15. *Market and societal aspects*

Fostering a healthy environment for competition in the market is a key EU policy goal. Companies are to compete based on the quality and price of their products with no unfair advantages. Both SDO and open source collaboration are pro-competitive, provided they follow basic principles of open governance and access to their processes and products, like defined in the guidelines on horizontal co-operation agreements.

SDO created carefully balanced governance and IPR policies that model a transition from pre-competitive cooperation to competition in the market based on standards-compliant products. Commitments to FRAND licensing of SEP are part of that balance, as are requirements for transparency of decision-making processes.[13]

The welfare contributions of goods like standards and OSS are an important guideline for the public interest in their production. In this study, we understand the term common good as the benefit or interest of society as a whole (Tirole 2017). The goals and values of the EU as well as the sustainable development goals of the UN are examples for perceptions of the abstract common good concept. A public good is a specific good that is non-rivalrous and non-excludable. It is non-excludable if individuals cannot be excluded from making use of it. It is non-rivalrous if the use of the good by one individual does not degrade the use of the same good by others. A statue displayed in a public square is a public good. The free-rider problem postulates that public goods are generally under-provisioned by private entities (Weber 2004). Ways to resolve this issue include the provision of public goods by the state, as for example with internal and external security, or voluntary collaborative methods, as for example in the work of privately funded charitable organisations.

A public good may contribute positively or negatively to the common good. Polluted air in a city, for example, is a public good that negatively affects the common good. Generally, public policy attempts to reduce or eliminate negative and encourage and foster positive contributions to the common good. Standards that are open to implementation and publicly available (even if access to them requires a nominal fee) are public goods that positively contribute to the common good by encouraging economic growth (Blind 2004b). According to the Open Source Definition, every piece of software distributed under an open source licence guarantees a) free redistribution of the source code including the right to create derivative works, making the software non-rivalrous, and b) no discrimination against persons, groups or fields of endeavour, making the software non-excludable. A key attribute of OSS therefore is that is it always a public good. Since it serves as a foundation for the creation of concrete ICT products and the mere existence of OSS cannot cause public harm, OSS also contributes positively to the common good (Nagle 2019a). No scientific consensus has been reached as to the public good character of standards with SEP claims. Proponents argue that the FRAND commitment in principle makes the standard available to all interested parties and therefore a public good. Opponents argue that already the requirement to negotiate with a private entity or the possible failure to achieve agreement with the SEP rights holder means that parties may be excluded from implementing the standard, making the standard a private good. It can be assumed that different opinions about this possibly mixed private and public good character of SEP covered standards is one argument that underlies the open standards and the FRAND/SEP debate in the ICT sector.[14]

Open source development is considered pro-competitive if participation is open to all and the results are released under accepted open source licences. The basic requirements for open source licences make products distributed under such a licence public goods. This ensures that neither participating nor non-participating entities will be able to gain an unfair advantage from contributing to those goods. The governance models for large-scale, industrial open source collaboration are still evolving. However, the communities covered by the cases apply well-documented, accessible and transparent decision-making processes that are open for participation to all parties.

In the fast-paced innovation environment of the ICT sector vendors usually compete for price with otherwise

[13] An analysis of SDO governance processes has been performed by Baron et al. (2019).

[14] By causing externalities, private goods may also positively or negatively contribute to the common good. Assessing the public versus private good character of SEP covered standards is beyond the remit of this study. It may, however, be crucial to the efficacy of future SDO regulation and worth investigating further.

commoditised products like storage space, CPU count, memory capacity, network throughput or latency. The sector is characterised by a fast deterioration of prices for such commodities. The technical progress that causes the necessary efficiency gains depends on interoperability and low market barriers to entry. This argument assumes a (widely accepted) relationship between competition in the market, productivity increases and product and process innovations.

2.5.16. *Metrics and assessment of success*

The goal of the case study report is not to provide an assessment of the success of the described cases. To deliver a complete picture of the interaction between standards and open source development, each case study contains a verbal summary of how successful the case is in the market. These qualitative summaries cannot be directly compared to each other.

When assessing the success of an individual case, common metrics for collaborative endeavours have been applied. The success of community building has been evaluated based on the number of participating entities, the number of individual contributors and the number of contributions raised. Market penetration and commercialization was assessed based on the observable ecosystem of market actors offering products or services and on industry adoption where foundational technologies may have become important or even business-critical for commercial users. The pace of innovation is assessed for example based on the cadence of software releases or revisions to specifications. These assessments are not directly comparable, as there is no accepted way to account for external variables like the existing state of the art or overall technical complexity in a market segment.

Proxy metrics of innovativeness like the number of patent applications filed in the respective market segment have been avoided. Open source communities not only do not file patents, they also actively work to reduce the attractiveness of patenting in the collaborative zone. Instruments applied towards that aim are choices of licences with explicit patent grant like the Apache-2 licence, the constant creation of prior art or encouraging cross-licensing through the Open Invention Network.

2.6. Observations

2.6.1. *Motivators and barriers to collaboration*

The cases indicate that all three layers of interaction identified in the expert interviews – cultural fit, governance models and legal framework – are relevant influences on the viability of collaboration between SDO and open source communities. Collaboration has to be possible and to be preferable over working separately. One key aspect to understanding this interaction is the principle of voluntary participation. Neither side can instruct the other to perform certain tasks or to focus for example on implementation versus specification. Collaboration probably needs to be envisioned as an integrated cyclic process with feedback loops between specification and implementation, and shared responsibility for both aspects between all participants. A positive influence may be the match of the timelines for producing results between SDOs and open source communities, while businesses may be driven by shorter development cycles under time-to-market pressure.

2.6.2. *Business and collaboration models*

It is obvious that the availability of the product of the wider open source community partially disrupts existing business models, especially if they are built on the exclusivity of implementation details, trade secrets and patent protection of functionality that gradually grows to be implemented as a public open source good. Usually, this is the result of a well-functioning market with competition between different collaboration models, as long as this gradual shift is caused by market pull. Care should be taken if business models are made viable or invalidated by external push.

Most of the presented cases developed without noticeable regulatory encouragement or investment, indicating that it can be assumed that the coordination of standardisation processes is achieved through competition in the market. Regulatory interventions into the market need to be assessed carefully for the balance of the possible positive effects and welfare losses. In the case of the interaction between SDO and open source communities, regulatory intervention affects voluntary participation and changes the allocation of research and development investments. It needs to be further investigated how regulatory intervention affects the viability of business models and competition, and how regulators can positively influence the market to foster innovation and economic growth.

2.6.3. *Collaboration models for developing complex platforms*

The assumption that was raised during some of the expert interviews that committee work at SDOs is necessary to produce complex standards that cover a wide range of functionality across different technology areas cannot be confirmed. Communities like Cloud Foundry or OpenStack produce comprehensive software platforms that require research and development investment, long-term commitment and effective governance norms and IPR regimes of similar or larger efforts compared to some standards development efforts. All these aspects have been found implemented in open source communities as well as SDOs. The success of the development effort seems to depend more on momentum, the intention to overcome obstacles and work towards a common goal, and the personal motivation of the participants involved. The diligent review of specifications performed in SDOs has shown a positively stabilising effect that enables implementers to produce conforming products.

2.6.4. *Creating a level playing field between standards and open source development*

The expectation that "open source is welcome to join but must accept our established SDO governance framework" illustrates that especially long-term participants in SDO activities assume a mixed perspective of peers in the standardisation process and authority. As peers in the standardisation process, they interact with others, including open source communities, as equal market participants that compete at eye level. When they assume a position of authority, they project the gravitas of the institution (usually the formally recognised SDO) they are embedded in and demand that potential collaborators accept its relevance and follow its IPR regime. This stance mixes two perspectives, the macro-economic reasoning of the policy maker, and the micro-economic reasoning of a competitor in the market. The cases indicate that formal recognition (which with regard to this study currently only exists for SDOs) is helpful but not enough to entice parties to mutual collaboration. Other drivers for example are technical relevance, effective processes and a cultural fit.

Interfering with market forces to enable specific business models carries the risks of perpetuating historical developments or missing promising new approaches. Regulators usually attempt to create a legal framework for innovators that enables competition between alternative approaches and lets different business models compete in the market for viability. For further analysis, the questions of macro-economic competitiveness and micro-economic competition need to be clearly separated. From the perspective of the standardisation process, SDOs and open source communities should be considered peers and equal actors in a "standardisation market", especially because of their partially differing characteristics that cater to different market needs.

2.6.5. *Suitable IPR regimes for physical and information goods*

Hardware and software exhibit different economics based on unit marginal cost being the equilibrium price in markets with efficient competition. The commoditisation and virtualisation of hardware functions in software does not just drive down prizes, they also transition functionality from physical to information goods. The growth of open source communities is one piece of evidence for this more general shift towards commoditisation and hardware function virtualisation. The case studies show that even in the same market segment, the IPR frameworks

applied cannot easily be transferred from hardware to software implementations, as they will not necessarily be accepted by participants. Instead, a new set of separate and disjunct behavioural norms for collaborative and competitive environments emerged. Where collaboration is the dominant model, the common expectation is that all contributing entities that form the community jointly act as a steward over the created technology and make it available to everybody. Where collaboration is not suitable, actors compete as before and focus on differentiating product features. Institutions have emerged that facilitate participation in the collaboration process, like the major open source umbrella organisations as well as SDOs like IETF or W3C, and that create IPR frameworks representing the concept of joint stewardship in the collaborative environment, like the Open Invention Network.

2.7. Assessment of the interaction between standards and open source development

The cases organically developed a partial focus on the networking and telecommunications subsector. Amongst other factors, this is encouraged through the self-selection bias caused by which parties made themselves available as interview and study participants. Since networking and telecommunications technology is especially affected by the tensions between SDO and open source IPR regimes, stakeholders in these specific technologies have been particularly motivated to provide input to the case studies. However, the interaction between standards and open source development most noticeably affects software/software and software/hardware interfaces, so that the cases still describe a representative subset of the relevant subject matter for the study. The following paragraphs try to summarise a number of take-aways from the case studies.

First, fruitful collaborations between standards and open source development exist, as for example in the case of the White Rabbit project, the different programming languages or the Linux operating system. The processes applied by these collaborations evolved over time, and continue to do so, resulting in well-established governance models as for example showcased by ECMA TC39 or ISO/IEC JTC1.

Open source approaches are suitable for the development of research and development heavy innovations that require significant up-front investments in large, diverse stakeholder networks, as can be observed for OpenStack, AGL, LFN or Linux. Open source communities are commonly driven by their own set of motivations mostly based on technical needs. Non-contributing entities have little impact on setting their technical roadmaps. Based on that, a collaboration between standards and open source development is difficult to enforce especially considering the generally voluntary nature of participation on both sides. Some projects even adopt implementation-only policies, which potentially leaves a gap where no specifications will be produced that can be referenced by regulators or other stakeholders.

While individual open source projects may serve a specific technical need and may remain relatively small in terms of contributor and contribution counts, with the adoption of their products they become part of a complex upstream/downstream network of continuously integrated open source technologies that develop in lockstep based on decentralized coordination and a normalised, negotiation-free IPR regime. The cases of the CNCF, AGL, LFN or Linux provide examples for this effect.

Different widely adopted open source projects have developed IPR regimes that combine source code licensing and patent licensing. They all however effectively implement royalty-free patent licensing schemes.

In cases where larger organisations decide to participate in open source development, the benefit from gaining access to the totality of contributions made by other collaborators commonly outweighs the potential gains from royalty-bearing patent licensing. Participants in the cases like GENIVI, AGL, LFN or Linux regularly forgo potential patent royalties in favour of joint implementation.

Once actors in a market segment congregate to establish open source collaboration for the provision of foundational software technologies for that segment, the focus of the collaboration sometimes shifts away from specification to joint implementation. The jointly developed solution effectively solves the interoperability and software quality problems.

Technology areas where specifications communicate the basic uses of the technology independent of the use of specific implementations, as in the case of the

programming languages covered by the cases, remain standards-development driven, but adopt collaborative open source methods to develop new standard features. They may for example make draft specification or discussions of new features openly available, even if the balloted standards still need to be purchased for a fee.

In some cases, the wider open source community actively invests to prevent business-critical technology from being dominated by single or small numbers of companies, as in the case of Docker and the OCI. The number of independent contributing entities to a specific software product is an important metric of community health in practice. Larger collaborative projects like AGL, Hyperledger, CNCF, OCI or OpenStack have hundreds of participating entities that contribute under licences that usually include a patent grant.

Software-focused standards development projects rarely take the technical lead with specifications that are then implemented by the wider open source community as reference implementations. SDOs are usually not the entities developing new and innovative technologies. It is more common that vibrant open source communities incubate new technologies that then become candidates for standardisation.

One of the most successful software innovations in general, Java, provides an example where specification, reference implementation and test suite are jointly developed in presence of royalty-free licensed SEP, but outside an SDO.

Voluntary open source contributions and contributions generated through direct research and development investments of companies are complementary and can lead to similar results in terms of technical development, as shown by ETSI-NFV, Open Source MANO and OPNFV, underlining the argument that both are alternative approaches to the development of technical standards. Open source methods result in freely available implementations but depend on the willingness of contributors to create them. Proprietary research and development results in potentially patented inventions but can be funded through commercial investments. The approach selected for a specific scenario needs to take the composition and business models of the potential contributors to a new technology into account. Both approaches can be combined in a way that they compete for market share in the same market segment, as in the cases of ETSI-NFV and the LFN sub-projects.

Innovative new technologies over time become commodity and tend to be collaboratively implemented as open source technologies. This open source implementation then demonstrates the state of the art and rarely leaves an opportunity for competitive inventiveness, since this would require a single inventor to compete with a consortium representing many of the relevant stakeholders in a market segment. OpenDaylight, OpenStack, Linux or Kubernetes illustrate this effect.

The traditionally separate assessment of SDOs and open source umbrella organisations becomes more difficult to maintain. Different aspects of standards development, like consensus building and ensuring interoperability and quality levels, are increasingly provided by open source umbrellas as well. Membership models of industry-driven open source organisations also show similarities to models applied by some SDOs. For a better understanding it may be necessary to assess the individual functions of standards development separately with a utilitarian approach and less focused on the established institutional framework.

In summary, fruitful collaboration between standards and open source development can be observed in the cases. Successful royalty-bearing licensing of SEP in combination with open source development cannot be observed, even though attempts like OpenAirInterface exist. Most SDOs represented in the cases as for example W3C or OASIS have adopted royalty-free or FRAND-Z SEP licensing schemes over time. Through the evolution of open source governance towards standardised behavioural norms, the wider open source community continues to build a commons of freely available foundational software technologies and grows and extends it also through patent cross-licensing and the increasing adoption of open source licences that include patent grants.

Annex 3 | Stakeholder Survey

3.1. Methodology

The aim of the stakeholder survey was to gather and analyse the views of a broad set of stakeholders on the topic of the interplay between patents and OSS within standardisation processes in general and FRAND and OSS licences in particular, hereby creating a robust empirical representation of the opinions and issues at stake.

The approach of designing the survey follows the state-of-the art. It reflects our experiences with similar surveys about IPRs in ICT (Blind et al. 2011; Blind et al. 2017). We took account of the structure of surveys and questionnaires in the study area performed by other researchers, e.g. the questionnaire of policy options in the ECSIP study of 2014 and on the governance of standardisation bodies (Baron et al. 2019) with a focus on IPR regimes.

Based on the insights from the literature review, the case studies, which already followed a rather detailed interview guideline, the above-mentioned surveys and the interim workshop performed in September 2018, we started to design of a questionnaire. A first draft of the questionnaire was sent to the EC by the middle of October 2018. The survey format is a mix of closed and open-ended questions, with an emphasis on the former. This draft was distributed asking for feedback among the steering committee of the project composed of both patent owning companies and representatives of the OSS community, as well as legal experts of European standardisation bodies. There have been several rounds of feedback until the questionnaire was finalized and put online using the lime survey tool at the beginning of November 2018 and finally tested.

The final structure of the survey includes the following topics:

- Section A: Position of the person answering the questionnaire
- Section B: Basic economic information about your organisation
- Section C: Use of Intellectual Property Rights
- Section D: Involvement in standardisation and open source software communities
- Section E: Interaction between OSS and standardisation

In parallel, a database of experts being active in the field, who have for example the workshop performed in the context of the other projects related to patents and standards, has been built up. By the middle of November, these experts, but also the following mailing lists have been informed about the survey:

- ETSI IPR Mailing List
- ETSI OSS Mailing List
- Members of the EU ICT Standardisation Multi-Stakeholder-Platform (MSP)
- List of experts attending previous workshops and being involved in the governance project
- Linux Foundation
- Eclipse Foundation
- Free Software Foundation Europe
- Open Source Initiative
- OpenForum Europe
- Distribution of the link via Twitter.

These mailing lists and contacts assure in addition to the notes published at the websites of DG CONNECT and JRC that the consultation achieves a broad coverage of different types of stakeholders including a sufficient number of eventually filled-out questionnaires. We decided to go for an open stakeholder consultation in contrast to a closed survey approach, which allows controlling for the responses, because we have to open the survey for the OSS communities. In contrast to patenting companies, which can be defined according to specific criteria based on patent databases, individuals, companies or other organisations active in OSS cannot exactly be defined and approached, but only via the mailing lists of open source foundations (see already Blind et al. 2005).

3.2. Results

In the following sections, we are presenting the results of the stakeholder survey. Overall, 315 respondents started to complete the survey. However, the majority of the respondents did not continue to answer the then following questions to the very end.

In the following chapter, we are presenting the results starting with the profiles of the respondents and their organisations covering companies and different types of private and public institutions, their use of Intellectual Property Rights, their involvement in standardisation and open source software (OSS) communities and finally their interaction between OSS and standardisation.

3.2.1. *Respondents*

More than 200 participants revealed their position in their organisation. On the one hand, around 20% are the Chief Executive Officers or in the top management. In general, responses from small organisations having below 250 employees or younger organisations are provided by their CEOs, which has to be taken into account interpreting the differences in the answers between small and large organisations. Overall and in particular in larger companies, members of the R&D department, members of the R&D departments, but also of the legal and standardisation department have responded to the survey. Due to the high correlation between responses of CEOs from small- or medium-sized organisations, we do not further differentiate the answers according to the position of the respondents, because only those from CEOs would allow a differentiation based on a significant number of responses.

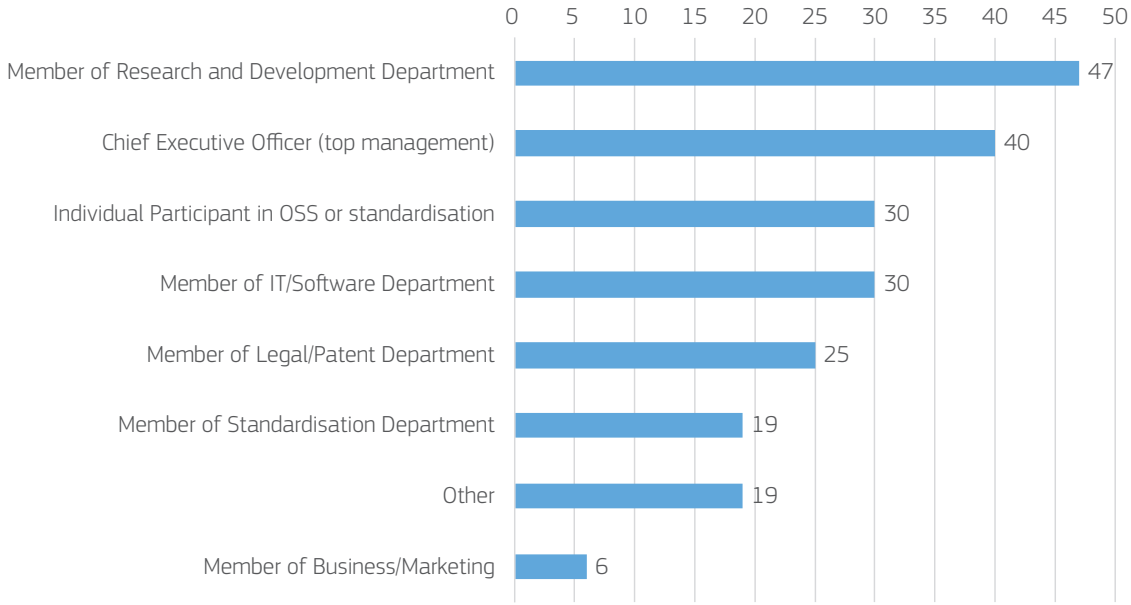

FIGURE 7*: POSITION OF PARTICIPANTS.

The location of the participants' countries is – despite the limited number of answers to this question – broadly distributed among 20 countries with around one third of answers from France and Germany, but also 20% from the United States and Canada.

The information provided about the basic economic characteristics of the organisation is rather limited. Whereas the information about the annual turnover is rather incomplete and skewed with a median value of just above EUR 3 million, the average number of employees is above 20.000, but the median at 80 employees. Therefore, we have a significant share of small- and medium-sized organisations, which enables us to split the sample in 31 organisations with more and 45 organisations with less than 250 employees, the official upper limit in the SME definition of the European Commission. This distinction will be used for a differentiated analysis of the responses.

In addition, only around 20 organisations provided information about the share of their licensing revenues and licensing payments as share of total turnover. In

* Labels next to the bars in the figures indicate number of valid responses received in the survey.

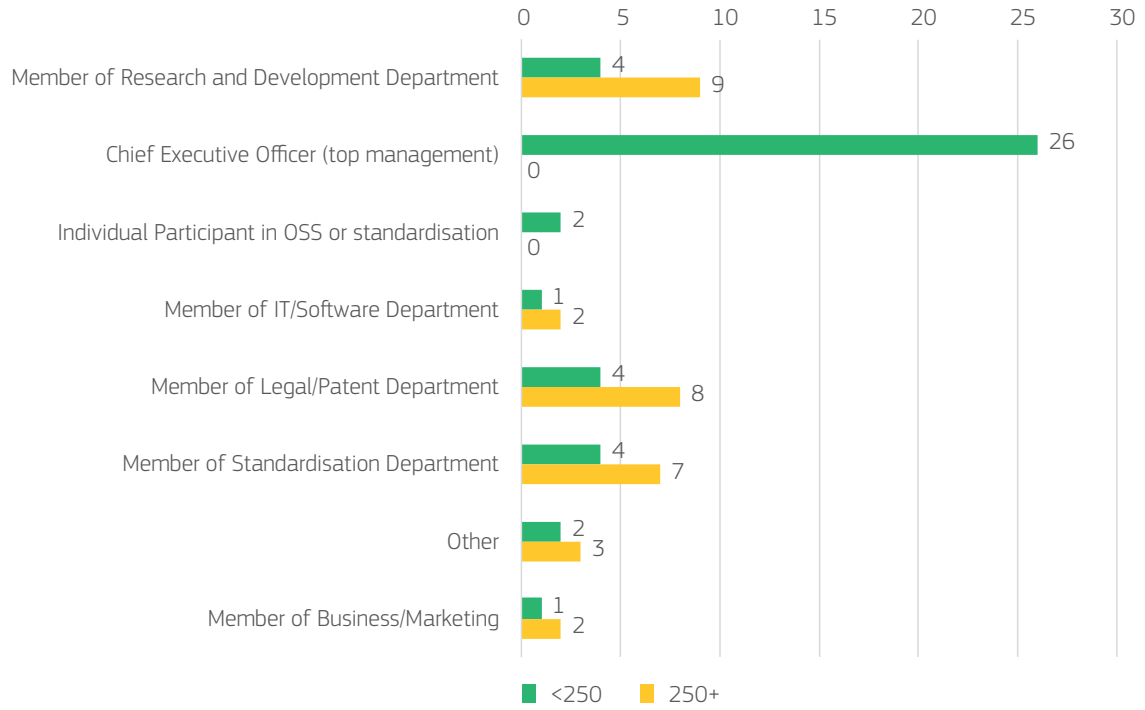

FIGURE 8: POSITION OF PARTICIPANTS – SMO VS LO.

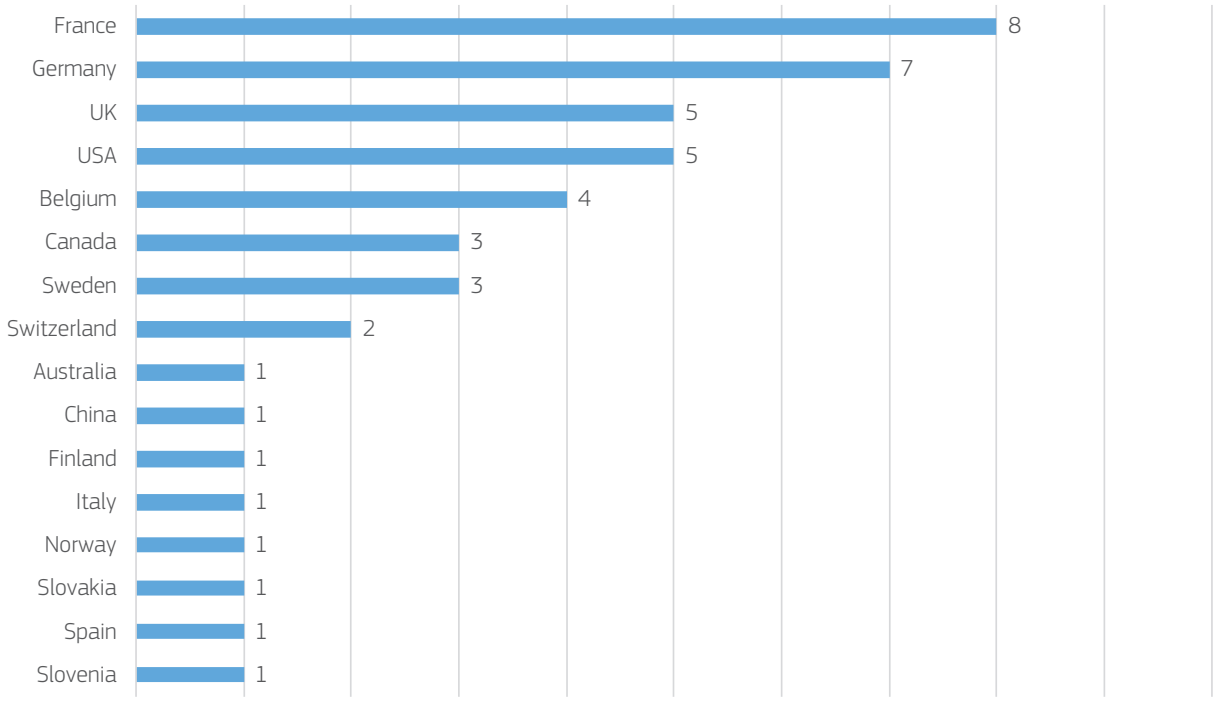

FIGURE 9: COUNTRY OF PARTICIPANTS.

contrast, around 80 respondents provided information about the year of their organisations' foundation. Here, the median is the year 2000, which is an option to split the sample in younger and older organisations. Almost all organisations founded after 2000 have less than 250 employees. Therefore, we stick to the organisation size as an option to differentiate the sample.

In general, the business models of the respondents' organisations are rather diverse as displayed in Figure 3. In general, organisations have between one and two business models, sometimes even three (see also Blind et al. 2017). Around 20% of the organisations are providing software, another 10% are independent software developers, i.e. 30% of the respondents have a strong software

background and are in more than 60% of the cases also small- and medium-sized organisations. Another third of the respondents are representing organisations producing final goods, supplying components, being systems integrators or network operators. This third are in two third of the cases also organisations with more than 250 employees. In addition, almost 20% are employed by private or public research institutes or universities. Finally, respondents also represent organisations providing private or public services, i.e. the latter by governmental institutions.

The qualitative analysis of the answers about organisations' core businesses reveals a quite diverse picture with more

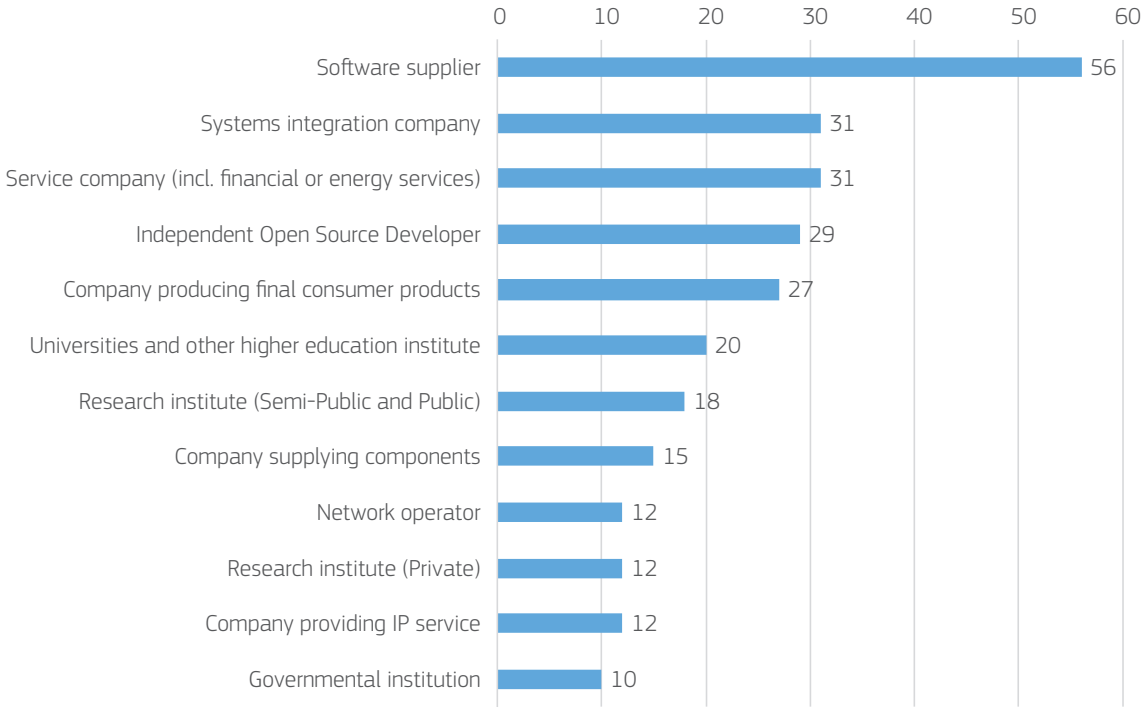

FIGURE 10: ORGANISATIONS' CORE BUSINESS MODEL.

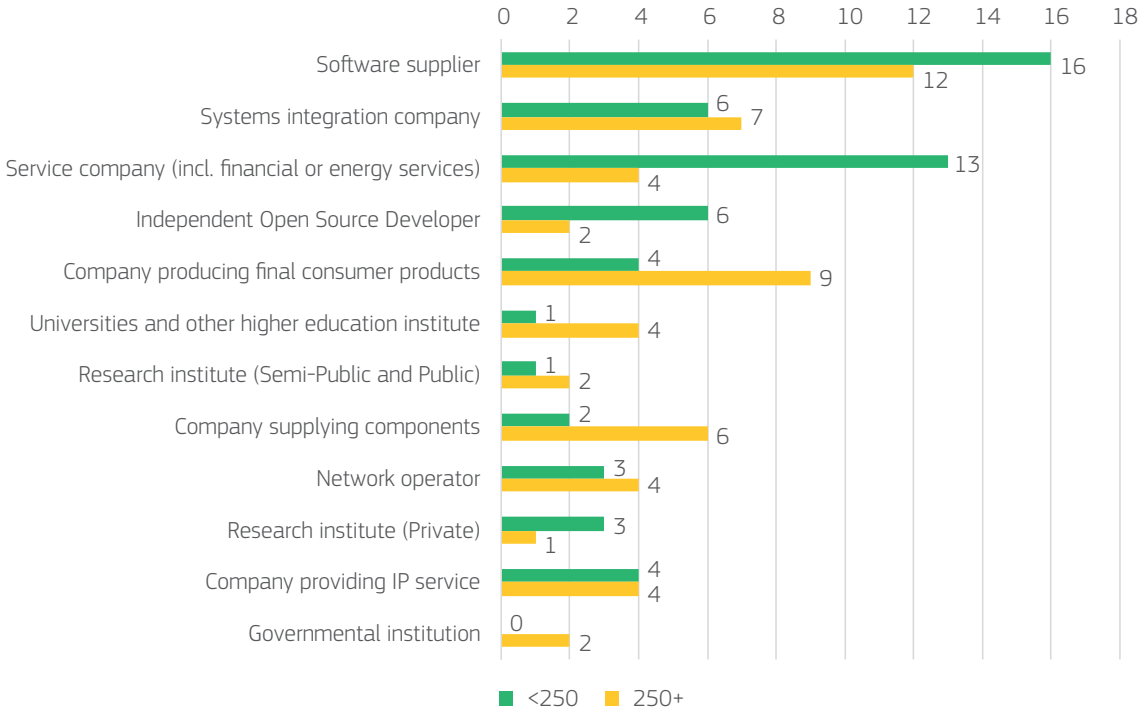

FIGURE 11: ORGANISATIONS' CORE BUSINESS MODEL – SMO VS LO.

than a quarter of the organisations being active in the software sector. More than 10% are organisations in the information technology. In addition, the sample includes more than 10% research organisations, universities and other organisations providing education. Furthermore, consulting and law companies as well as private non-profit and public organisations complete the large spectrum of organisations. Overall, the answers are consistent with the distribution of organisations' business models.

3.2.2. *Use of Intellectual Property Rights*

In a first major section of the questionnaire the respondents have been asked for the application, registration or claiming different Intellectual Property Rights (IPRs) between 2015 and 2017. Almost one hundred respondents answered this question.

Not even half of the organisations has applied for global patent families with a median value of almost one thousand. This share is higher than the ratio reported in the German Community Innovation Survey, which is around 20% in Germany (Rammer et al. 2016). In contrast, almost 60% have registered trademarks with a median of two, two thirds even claim copyrights with a median value of ten and even three quarter have globally registered domain names with a median of five. Industrial designs have only been registered by a third of the organisations, but with a median of fifteen. A similar distribution has been found by Blind et al. (2017) in the context of a European survey focused on ICT patents. Finally, almost one quarter of the respondents use other forms of IPRs. Here, trade secrets are explicitly named.

If we differentiate the answers into organisations with more and less than 250 employees, then it becomes obvious that almost 90% of the larger organisations applied for patents, but less than 10% of the smaller organisations. This structural difference can be also observed in the data collected in the German version of the Community Innovation Survey (Rammer et al. 2016). The discrepancy between large and small organisations is even higher for the registration of industrial designs, which are used by two thirds of the larger organisations, but almost by none of the smaller. For the use of the other IPRs, the size bias is not so drastic, e.g. three quarter of the larger organisations use trademarks, but also more than 50% of the smaller organisations. Furthermore, almost every larger organisations is claiming copyrights, but also almost half of the smaller organisations. The registration of domain names

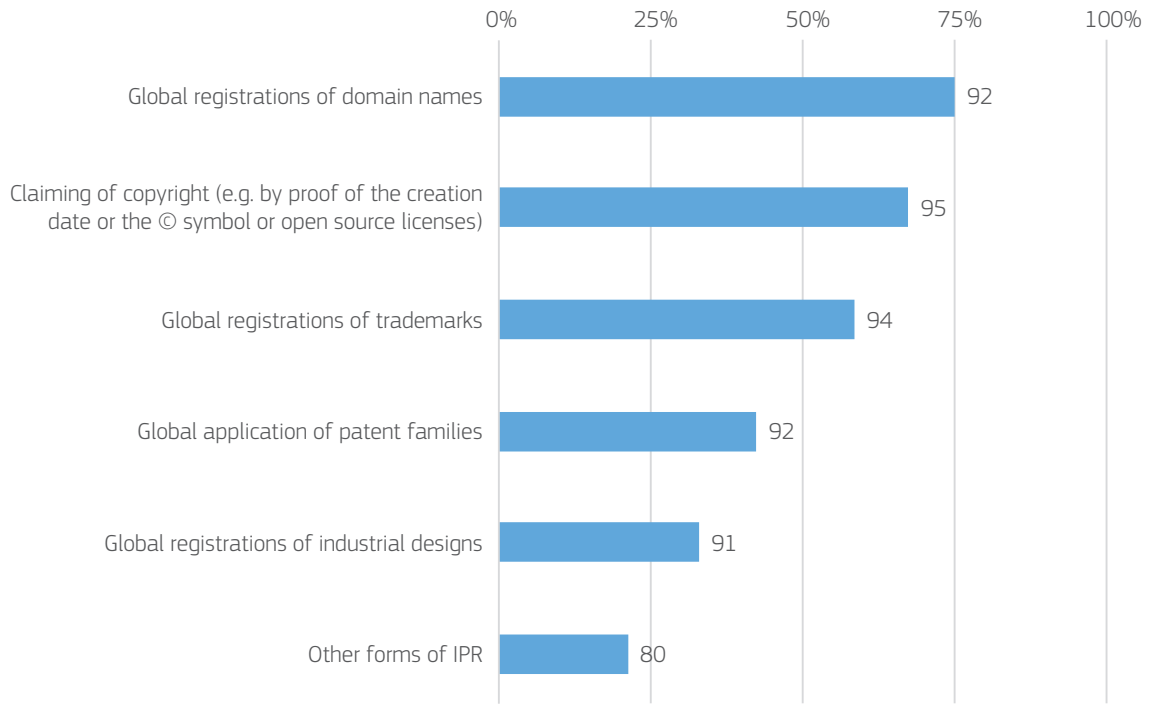

FIGURE 12: USE OF INTELLECTUAL PROPERTY RIGHTS BETWEEN 2015-2017.

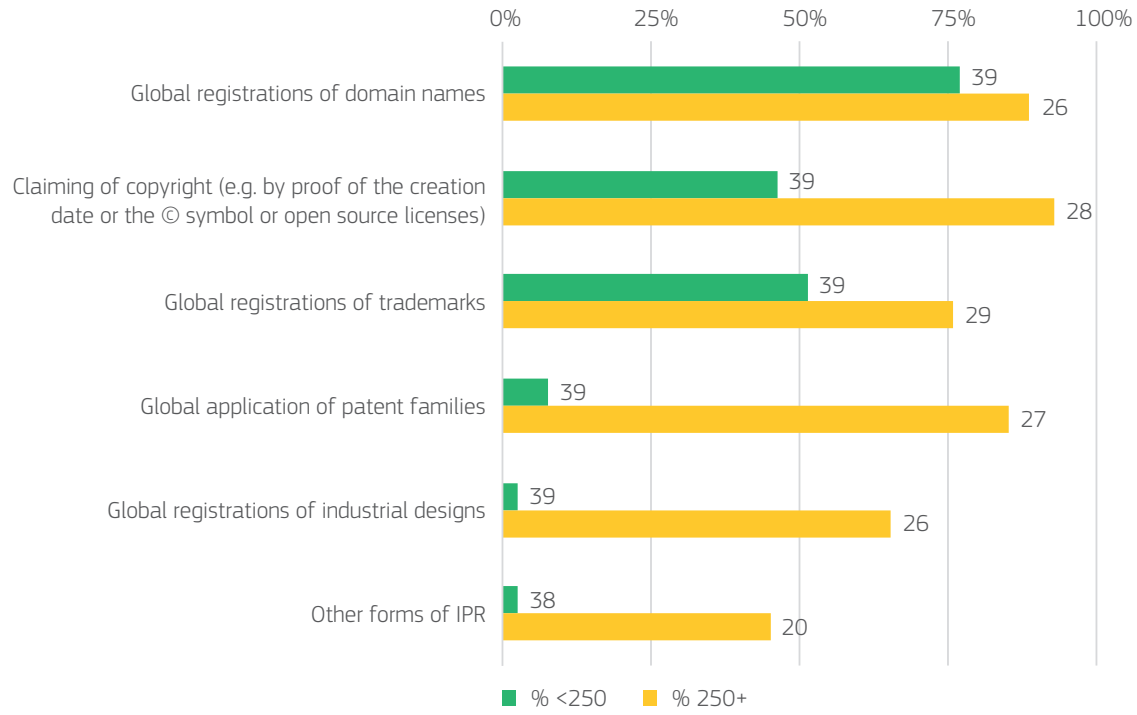

FIGURE 13: USE OF INTELLECTUAL PROPERTY RIGHTS BETWEEN 2015-2017 – SMO VS LO.

is almost as common for smaller organisations with 77% compared to the 88% of the larger organisations. These differences are confirmed by splitting the organisations by turnover in more or less than EUR 2 million or by founding before or after the year 2000.

Since less than half of the organisations have applied for patents, consequently even a lower share of one third is licensing out or even selling patent families to third parties (see figure 1 in the chapter 4), which is slightly more than the 20% reported by Blind et al. (2017) in the context of ICT patents. If we just focus on those organisations applying for patents, 70% of them licence out their patents with a median value of almost 250 patent families. This value is rather high compared to figures below 5%, e.g. revealed in the German version of the Community Innovation Survey (Rammer et al. 2016). Regarding licensing in or buying patents, the share of organisations is almost identical at around one third and again more than the quarter reported by Blind et al. (2017). Obviously, there is a significant exchange of patent rights between the organisations owning patents, but the expected higher share of organisations licensing in patents cannot be observed. In addition, only five patent families are licensed in by the median organisation.

One third of the organisations own patents with a median value above 50, which refer to standards and open source. A slightly lower share of organisations has declared patent families, with a median value of around 20, to SDOs as potentially essential. Only one quarter of the organisations, i.e. almost half of the patent owning organisations, generate revenues out of these standard-essential patent families based on only three patents as median. Slightly less than one quarter of the organisations have patents which are implemented with a median value of three in OSS projects and products. Finally, one quarter of the organisations are involved in other forms of licensing, in particular cross-licensing is mentioned. If we focus on the small organisations, then all the mentioned options are not used by more than 90% of the respondents. Only almost 15% of the small organisations mentioned that they licence in or buy patents and just above 10% own patent families which refer to standards or OSS.

In summary, the patent related activities of the responding organisations are concentrated at larger organisations, whereas the smaller organisations are almost completely excluded. However, the high licensing activities both inward and outward, which are much more than the number found in the German Community Innovation Survey (Rammer et al. 2016), are in line with both the high patent intensity of the sample and the need of the complex ICT industry to integrate technologies from producers of complementary products.

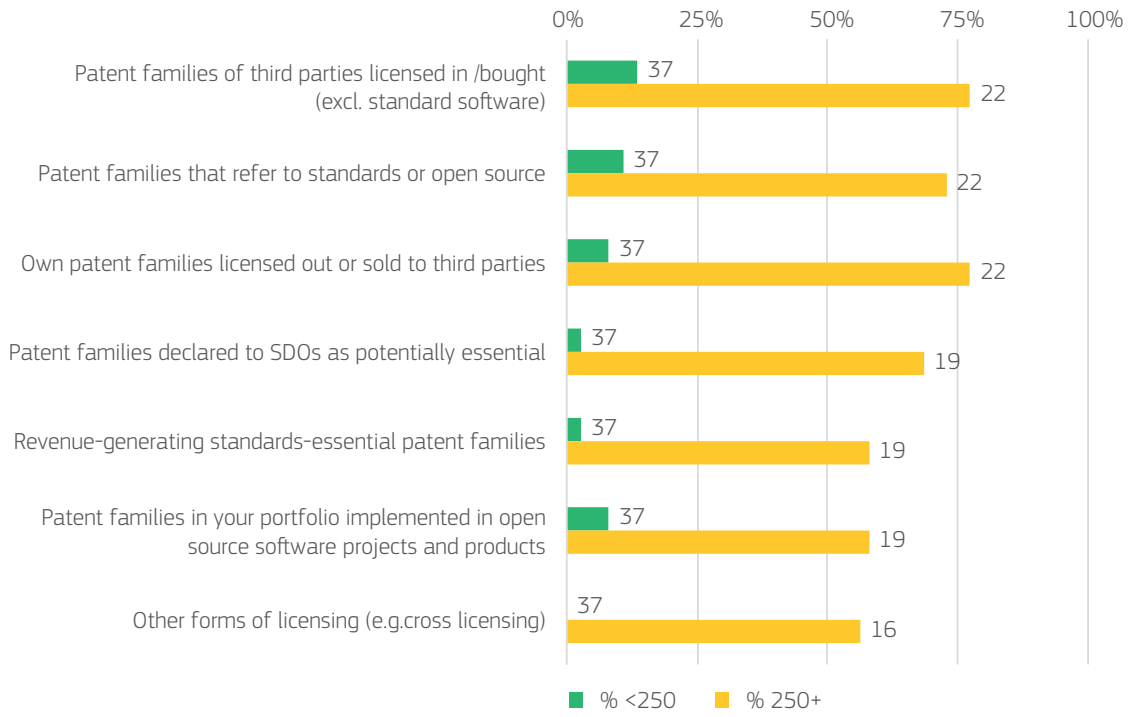

FIGURE 14: LICENSING AND TRADING OF INTELLECTUAL PROPERTY RIGHTS BETWEEN 2015-2017 – SMO VS LO.

3.2.3. *Involvement in standardisation and open source software*

The second major part of the questionnaire focuses on organisations' involvement in standardisation and OSS communities. From the originally more than 300 respondents, more than 200 did not answer the basic question about an involvement in standardisation, which might be an indication that two thirds are not active in standardisation. However, this share is rather 50%, because around one half of those organisations, which responded positively to the following question about their involvement in OSS, are active in at least one of the different types of standardisation organisations.

On average, an organisation is active in almost three different types of standardisation organisation. Most popular are international consortia. This dominance is further supported by the standardisation organisations mentioned under "Others". Here, we find further international consortia, like OASIS, OGC and W3C. However, taking all types of consortia plus the category "Others" sums up to slightly more than 42%, whereas the naming of the formal standardisation bodies accumulates to more than 57%. This ratio is certainly specific to the focus on information and communication technology in general and software in particular, because across all sectors German companies are five times more active in formal standardisation bodies compared to consortia (Rammer et al. 2016). Due to this specific focus, most organisations are active at ETSI followed by the international standardisation bodies ISO and ITU in addition to the involvement at the national standardisation bodies, being a requirement for the participation at the European or international level. The limited number of answers about the number of seats in technical committees (TCs) and working groups (WGs) reveal median values between two to over ten, in particular at 3GPP.

Looking at the differences between small and large organisations, it is obvious that the latter are much more active in standardisation than the former. This phenomenon confirms previous studies, e.g. by Blind (2006) or Wakke et al. (2015). Furthermore, the differences are higher related to participation in formal standardisation bodies compared to consortia.

Whereas only around half of the respondents are active in standardisation, almost 90% of the responding organisations are currently involved in open source development activities, which is significantly more than the share of the respondents of the survey conducted by Baron et al.

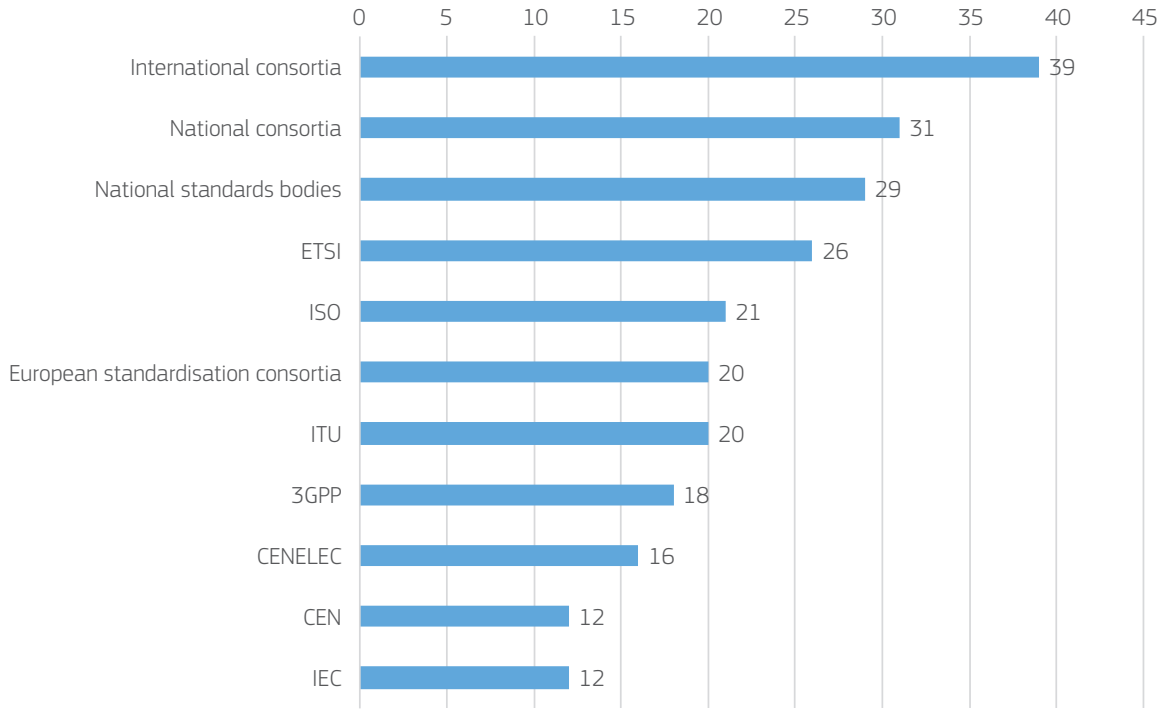

FIGURE 15: INVOLVEMENT IN STANDARDISATION ORGANISATIONS AND CONSORTIA.

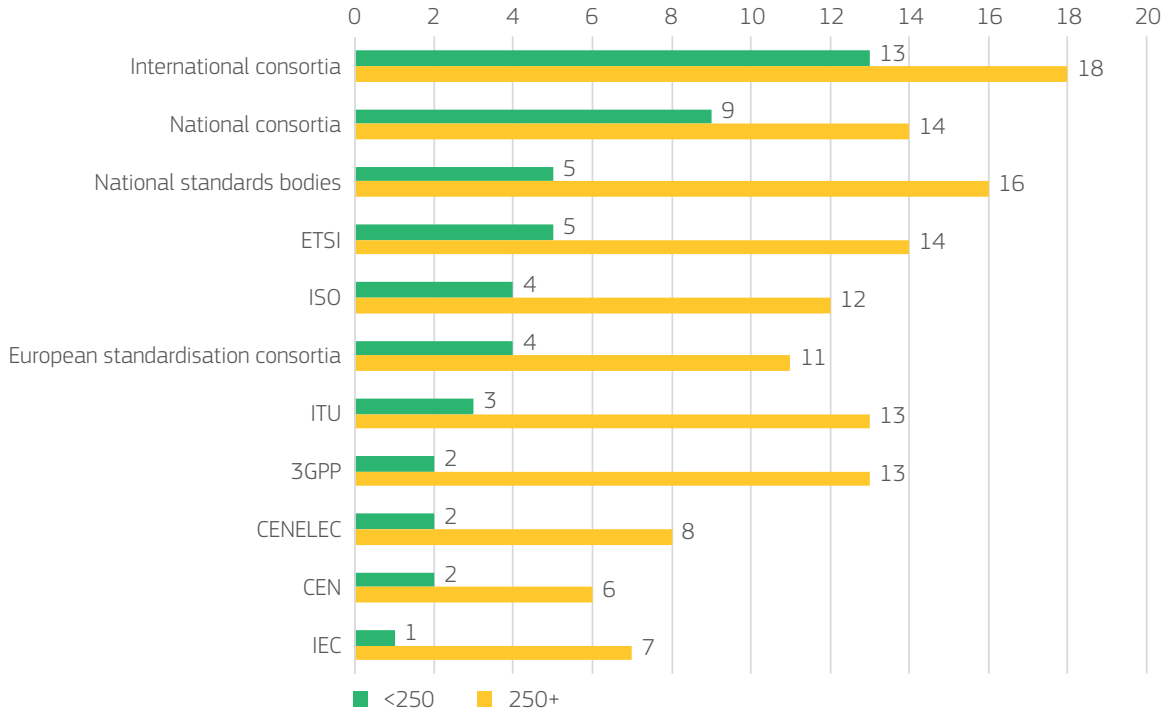

FIGURE 16: INVOLVEMENT IN STANDARDISATION ORGANISATIONS AND CONSORTIA – SMO VS LO.

(2019). The involvement takes different forms. In general, the organisations of all respondents are using OSS with a median value of 100 OSS projects. In particular, OSS is used by over 90% as input into the application level, slightly more than three quarter as input into the intermediate level, i.e. middleware, and around two thirds as input into base layer, i.e. into the operating system or the platform level. Here, the median number of OSS projects is 10. Around 80% of the responding organisations are occasionally contributors to five and regularly to ten OSS projects. In detail, the respondents named under the category of other forms of involvement the Linux, Apache and Eclipse Foundation, FSFE, the Open Source Initiative, OpenForum Europe and OW2 as those community organisations they are engaged

Organisation/Consortia	Median Number of Seats
National standards bodies	5
National consortia	3
International consortia	5
CEN (European Committee for Standardisation)	7.5
CENELEC (European Committee for Electrotechnical Standardisation)	5
ETSI (European Telecommunication Standards Institute)	5
3GPP	11.5
European standardisation consortia	2.5
ISO (International Organisation for Standardisation)	3
IEC (International Electrotechnical Commission)	10
ITU (International Telecommunication Union)	2.5

TABLE 3: MEDIAN NUMBER OF SEATS.

in. With regard to IP management, LOT Network was mentioned. The remaining organisations named by the respondents focus on specific technologies, like networking (ONAP, OPNFV, OpenDaylight, OpenAirInterface Software Alliance, O-RAN and TMForum), programming languages (Python Software Foundation, JavaScript Foundation), cloud computing (Cloud Foundry, Cloud Native Computing Foundation), geospatial technologies (Open Source Geospatial Foundation, Open Geospatial Consortium), web technologies (W3C, OASIS, OMG, IIC, Drupal and Joomla), smart platforms (Fiware Consortium), open hardware (Open Source Hardware Association) as well as regional organisations (GTLL for the Paris region, SOIT.SK for Slovakia and others).

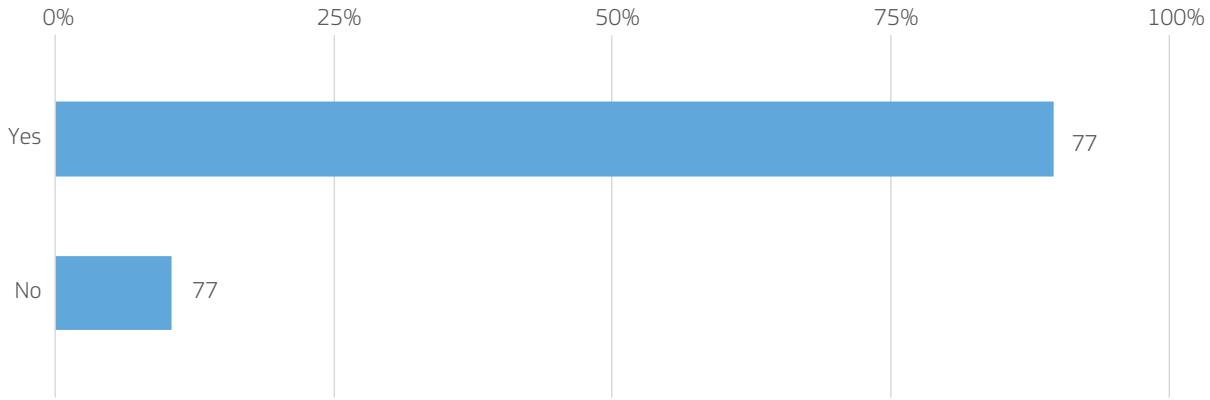

FIGURE 17: INVOLVEMENT IN OSS.

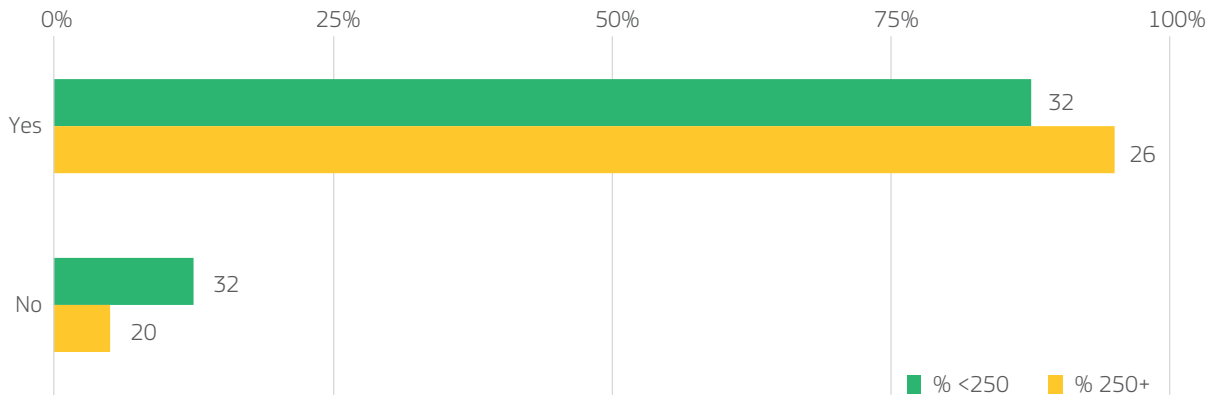

FIGURE 18: INVOLVEMENT IN OSS – SMO VS LO.

The differentiation in larger and smaller organisations reveals that larger organisations are, in general, more involved in all activities with one important exception. Small organisations claim slightly more often to be a regular contributor to OSS despite their size disadvantage.

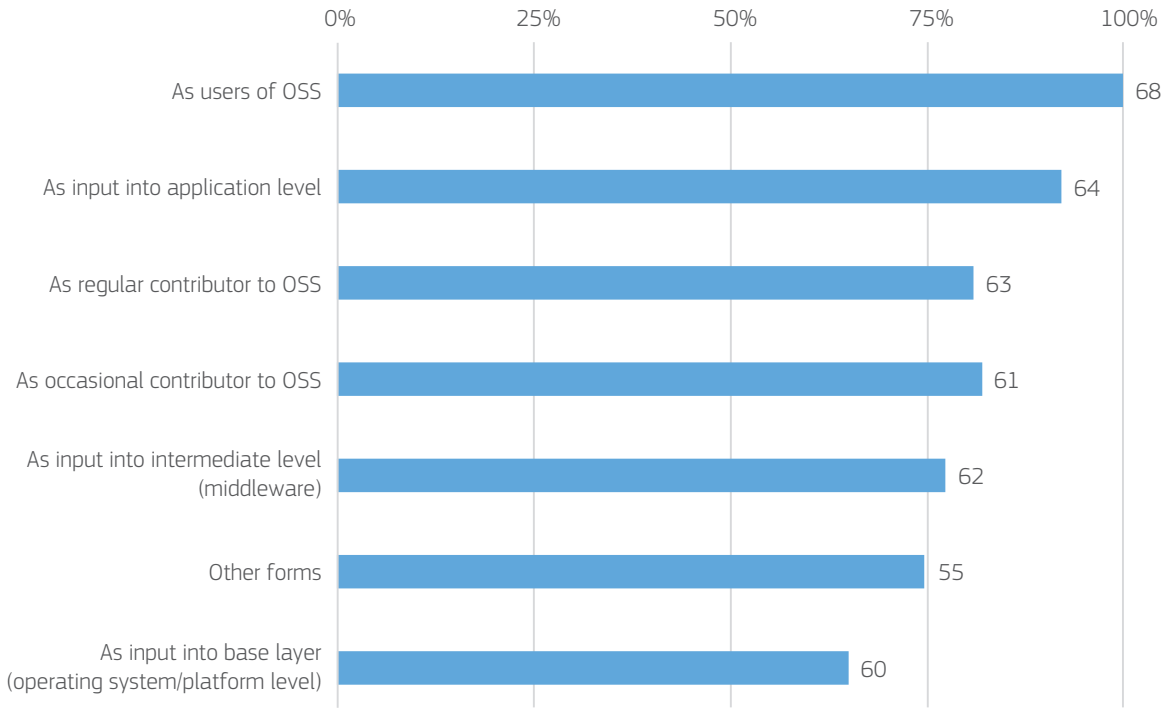

FIGURE 19: USAGE/CONTRIBUTION TO OPEN SOURCE SOFTWARE.

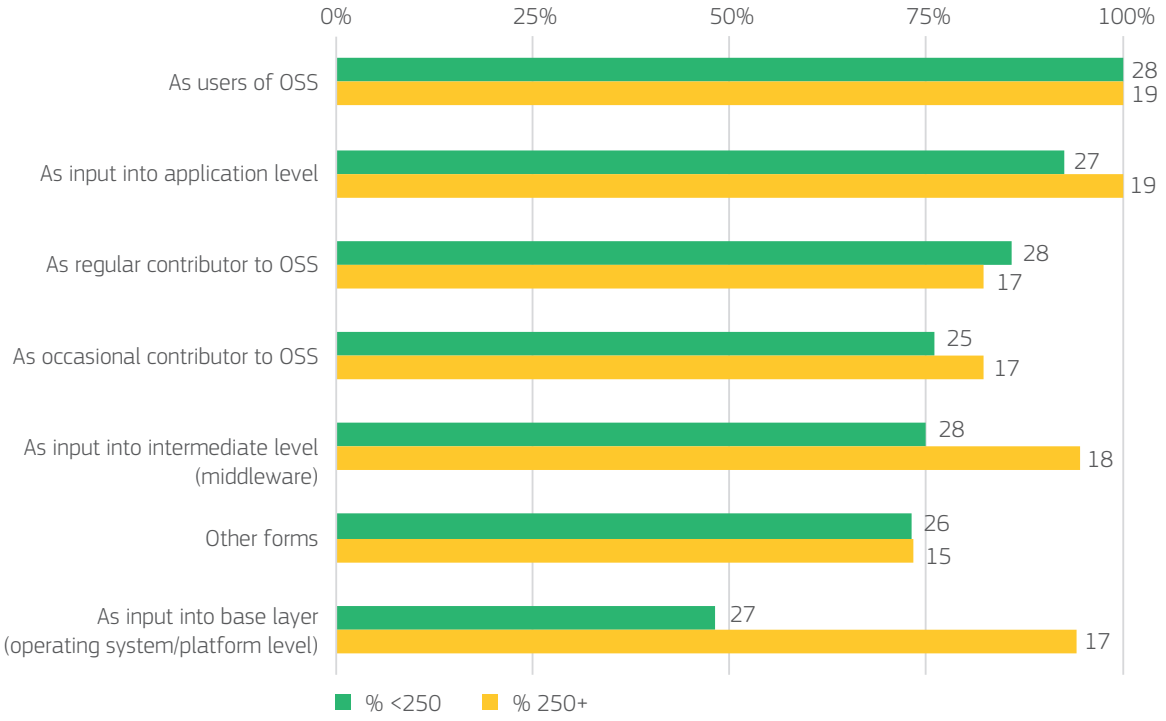

FIGURE 20: USAGE/CONTRIBUTION TO OPEN SOURCE SOFTWARE – SMO VS LO.

In order to identify the motivations of organisations to join both standardisation activities and OSS development, the respondents were asked to assess the relevance of a set of incentives, which are going back to previous studies related to standardisation (e.g. Blind and Mangelsdorf 2016) and OSS (Hertel et al. 2003; von Krogh et al. 2012).

Starting with the incentives to standardise (see figure 2 in chapter 4), we find that developing standards of high quality, carrying forward the state of the art of technology and finding technical solutions are most relevant for the respondents. The following motives, like company interest, knowledge creation, establishing networks, increasing reputation, specifying regulations, knowledge seeking and market access are slight above medium relevance. Slightly below medium relevance are shorter development times, personal interest, the royalty free use of standards, the development of non-differentiating solutions, lower cost for R&D and return on investment for R&D. Only of low relevance is the inclusion of own IPRs in standards. Here, we find a significant difference between the patent owning respondents, who assess the relevance between medium and low and those not owning patents, for whom the incentive is only between low and very low relevance. The incentives to join standardisation in the mechanical or electrotechnical engineering industries are quite different putting an even higher emphasis on specifying regulations and enforcing own content (Blind and Mangelsdorf 2016). Finally, the differentiation between small and large organisations reveals that for the former the royalty free use of standards is more relevant.

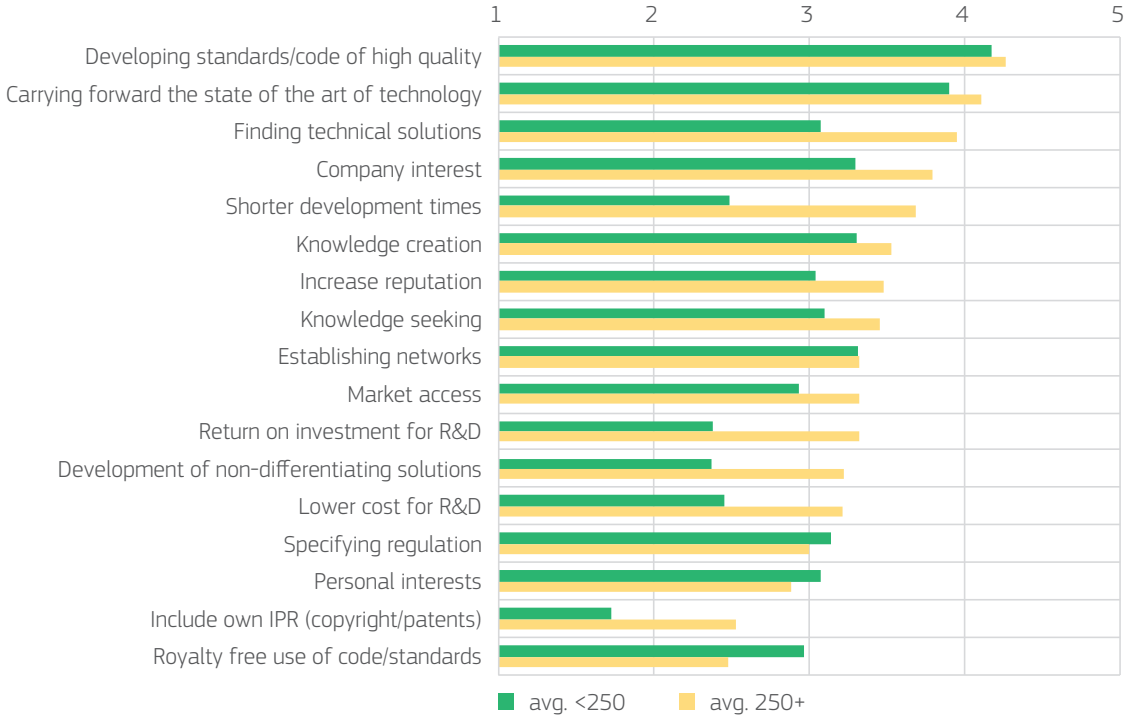

FIGURE 21: INCENTIVES TO JOIN STANDARDISATION ACTIVITIES (SCALE: 1 = "VERY LOW"; 2 = "LOW"; 3 = "MEDIUM"; 4 = "HIGH"; 5 = "VERY HIGH") – SMO VS LO.

Looking at the motives to join OSS development (see figure 3 in chapter 4), we find the two incentives of developing code of high quality, which is confirming the top relevance found by Blind et al. (2005) and carrying forward the state of art of technology on the two top position reaching an overall assessment above high relevance. Slightly below high relevance ranks finding technical solutions, company interest, shorter development times, knowledge creation, personal interest, increasing reputation, lower cost for R&D and establishing network. Closer to medium relevance are rated knowledge seeking, royalty free use of code, market access, return on investment and development of non-differentiating solutions. Even below medium relevance is the specification of regulation, because open source code is not appropriate as input for regulations. Again, the inclusion of own IPR in OSS is rated below low relevance. However, there is no difference between patent owners and those organisations without patents. Looking at other incentives reveals that smaller organisations rate several of them as much more relevant starting with the reputation increasing effect, but also the establishment of networks, the finding of technical solutions and knowledge creation accompanied with a much stronger personal interest.

In addition to the listed incentives, some respondents underline the relevance of interoperability to be achieved both by standardisation and OSS. Furthermore, the contribution to OSS is perceived as a strategy to prevent

proprietary software solutions, which might create a vendor lock-in and consequently closes markets instead of opening them. Therefore, contributing own code or technology of high quality to OSS allows to control the roadmap of software development and independency of software, but is also perceived as a contribution to a common good, including humanitarian goals, and the alignment of a whole eco-system. Similar arguments are mentioned related to standardisation. This strategy also allows to deter other market entrants by establishing dominance in a market with open source products. Regarding the process, the speed of software development and testing via OSS by multiple parties are mentioned. OSS and standards not only allow access to global markets but also enable a rapid and inexpensive market development via an inexpensive or even royalty-free implementation of code and technologies among respondents' organisations and their customers. In particular, SMEs benefit from open standards, also if they are referenced in public procurement processes. OSS is also the platform to identify highly qualified experts interesting to hire (e.g. already mentioned by Lerner and Tirole 2002). Finally, it is highlighted that open standards and OSS can help deliver good governance, societal freedoms, economic health, business growth, global competition, and technological innovation.

If we compare the assessment of the incentives to join standardisation activities vs OSS development, we observe the following patterns. First, the relevance of almost all incentives are rated higher for OSS with two exceptions. The inclusion of own IPR is slightly more relevant for the participation in standardisation than for joining OSS. Secondly, standards are obviously a more effective approach to specify regulations, in particular in the European Union in the context of the New Approach. Secondly, the largest differences can be found for the incentive of lower cost for R&D and shorter development times, important drivers for joining OSS. In addition, the personal interest is assessed to be more relevant for the involvement in OSS. However, in addition to finding technical solutions the royalty free use of code, which is also connected to a positive return of investment in R&D, is obviously much more important for an involvement than the royalty free use of standards.

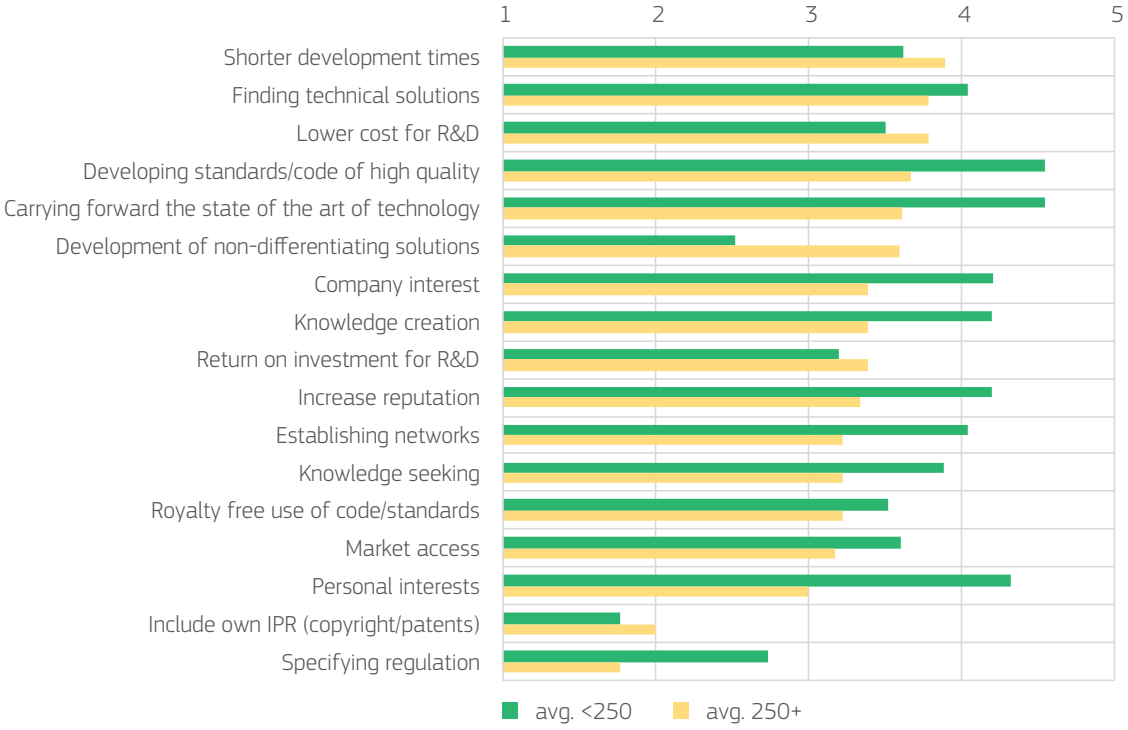

FIGURE 22: INCENTIVES TO JOIN OSS ACTIVITIES (SCALE: 1 = "VERY LOW"; 2 = "LOW"; 3 = "MEDIUM"; 4 = "HIGH"; 5 = "VERY HIGH") – SMO VS LO.

A further explanation for the higher assessment of the incentives to get involved in OSS compared to standardisation is the general higher importance of being involved in OSS development compared to standardisation development. This bias towards OSS is reinforced by the assessment that two thirds of the respondents expect an increase of importance of OSS compared to less than half related to standardisation. In the assessment of the current relevance, we observe a significant difference between large and

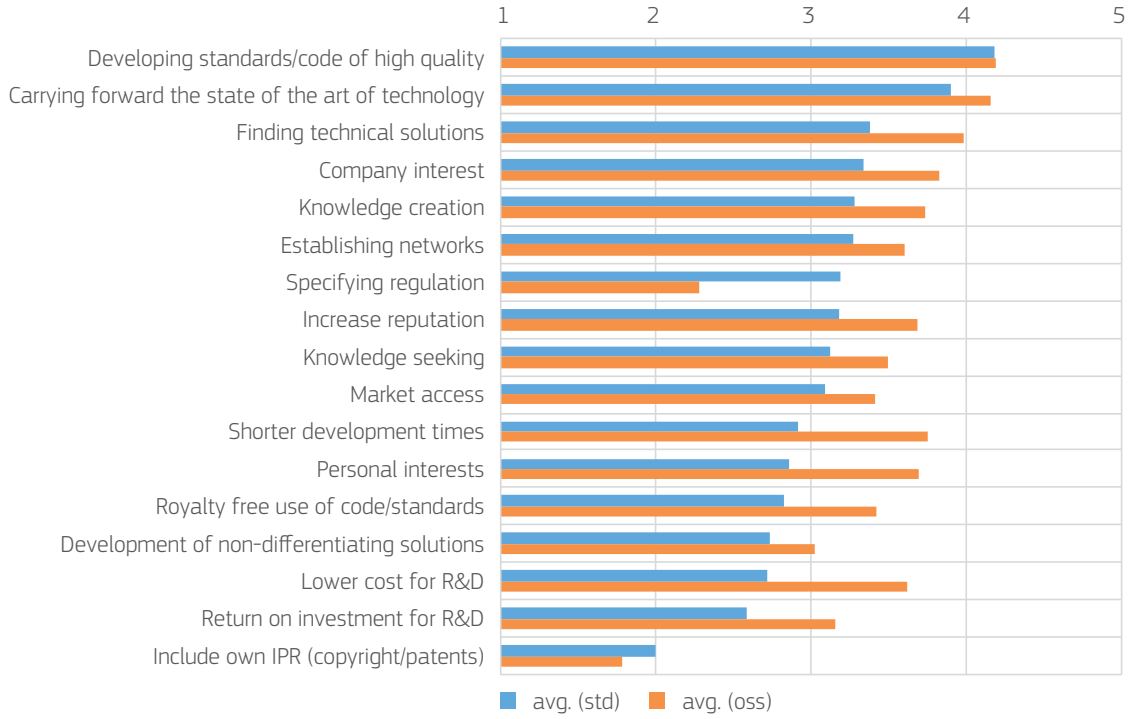

FIGURE 23: INCENTIVES TO JOIN STANDARDISATION VS OPEN SOURCE SOFTWARE DEVELOPMENT (SCALE: 1 = "VERY LOW"; 2 = "LOW"; 3 = "MEDIUM"; 4 = "HIGH"; 5 = "VERY HIGH").

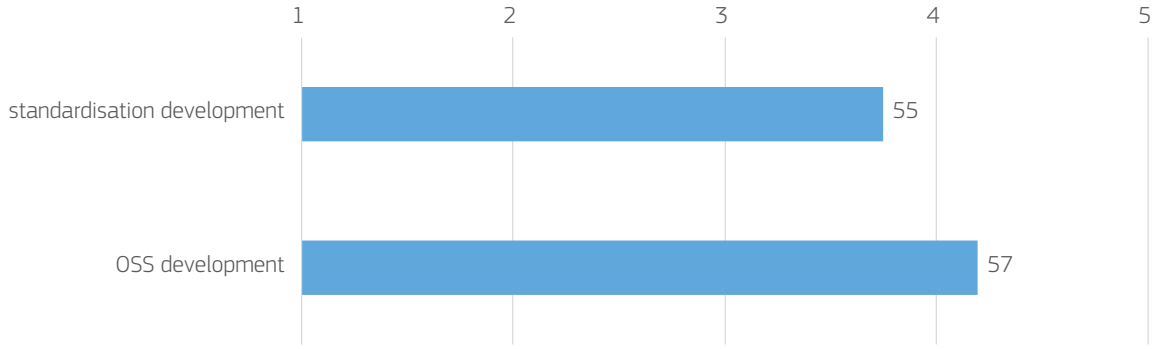

FIGURE 24: IMPORTANCE OF INVOLVEMENT IN STANDARDISATION AND OSS DEVELOPMENT (SCALE: 1 = "NOT AT ALL IMPORTANT"; 2 = "SLIGHTLY IMPORTANT"; 3 = "IMPORTANT"; 4 = "FAIRLY IMPORTANT"; 5 = "VERY IMPORTANT").

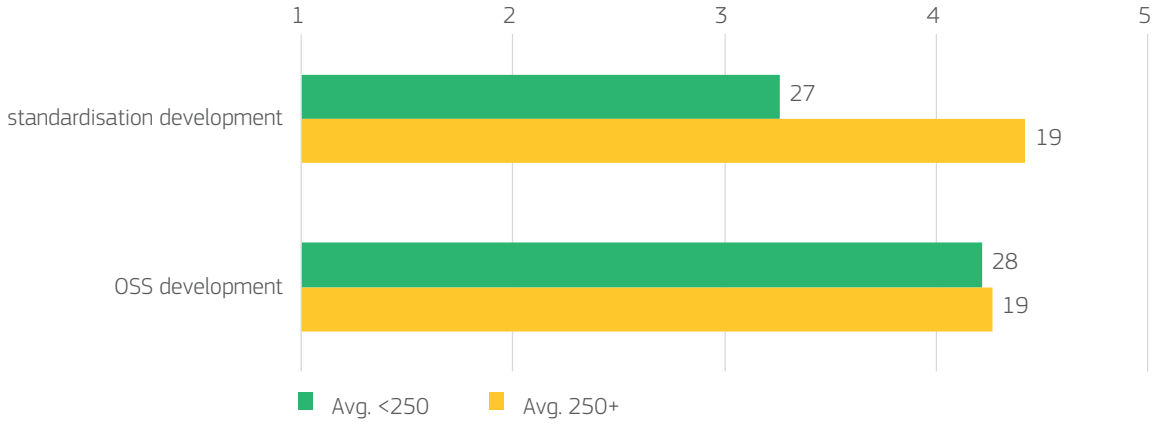

FIGURE 25: IMPORTANCE OF INVOLVEMENT IN STANDARDISATION AND OSS DEVELOPMENT – SMO VS LO (SCALE: 1 = "NOT AT ALL IMPORTANT"; 2 = "SLIGHTLY IMPORTANT"; 3 = "IMPORTANT"; 4 = "FAIRLY IMPORTANT"; 5 = "VERY IMPORTANT").

small organisations related to the importance of standardisation. Whereas the two thirds of the former assess it as very important, this is the case for less than one third of the latter. This assessment is consistent with the lower participation of smaller organisations in standardisation bodies. Related to OSS, we observe not such a significant difference. Obviously, standardisation plays for small compared to large organisations a less relevant, whereas we cannot observe such a difference related to OSS. Related to the future, the expectations related to standardisation are overall balanced between an increased and constant relevance and quite similar between large and small organisations, whereas the majority of all organisations, in particular larger organisations, expects a further increase in the relevance of OSS.

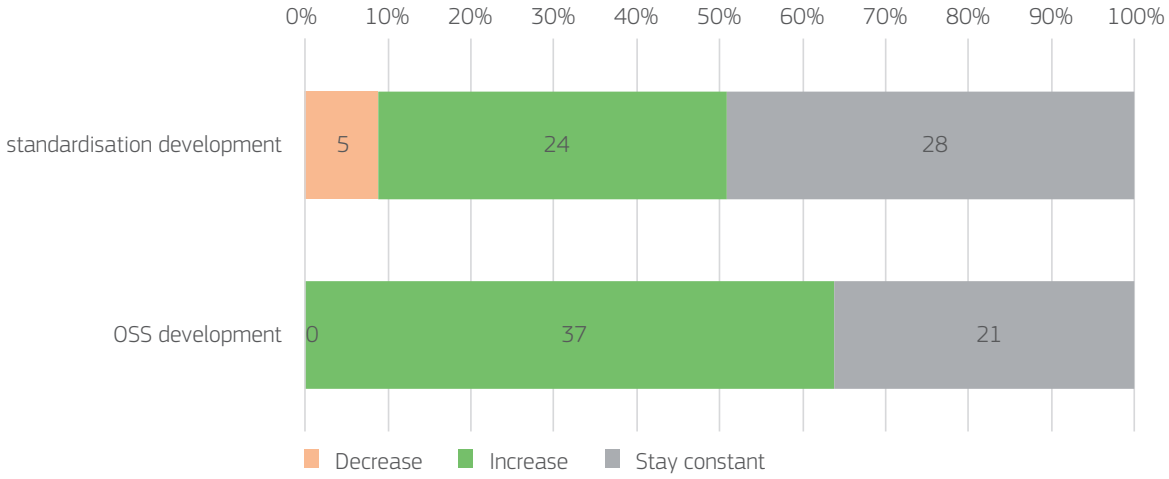

FIGURE 26: IMPORTANCE OF INVOLVEMENT IN STANDARDISATION AND OSS DEVELOPMENT IN 5 YEARS.

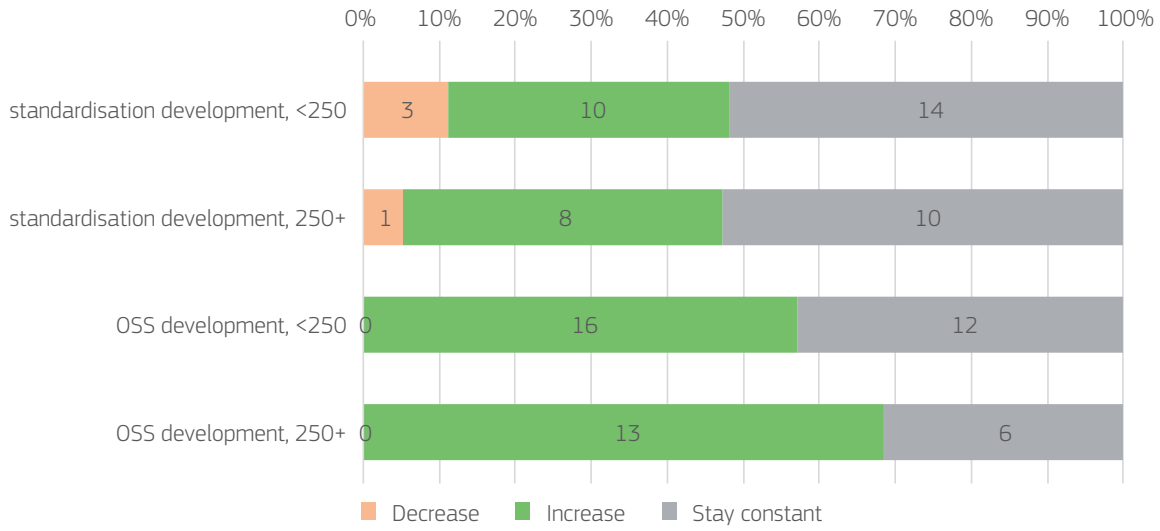

FIGURE 27: IMPORTANCE OF INVOLVEMENT IN STANDARDISATION AND OSS DEVELOPMENT IN 5 YEARS – SMO VS LO.

3.2.4. *Interaction between OSS and standardisation*

The last section of the questionnaire was eventually focused on the interaction between standardisation and OSS. Both in the literature review and in the case studies different types of interactions have already been identified. Surprisingly, all three options, i.e. standards as input into OSS, OSS as input into standardisation and parallel development in addition to the general interconnectedness of standard development and OSS activities are perceived by the respondents to happen on average "sometimes". However, the distinction between large and small

organisations reveals some more differentiated insights. Surprisingly, more than 50% of the organisations with less than 250 employees report that their standardisation and OSS development activities are always or often connected, whereas this is only the case for less than a third of the larger organisations. In particular, for more than half of the smaller organisations OSS is used as input for standardisation, whereas this is only claimed by 15% of the larger organisations. In contrast, there is no difference between large and small organisations in using standards as input into OSS development. Finally, more than a third of the small organisations claim parallel developments in standardisation and OSS, whereas this is claimed only by 15% of the larger organisations. Overall, standards development and OSS activities are much more interconnected for smaller organisations, which much more often transfer OSS as input into standardisation, whereas this transfer and even the parallel development is not so common for larger organisations. Obviously, small organisations contribute much more to the integration of OSS and standardisation than large organisations.

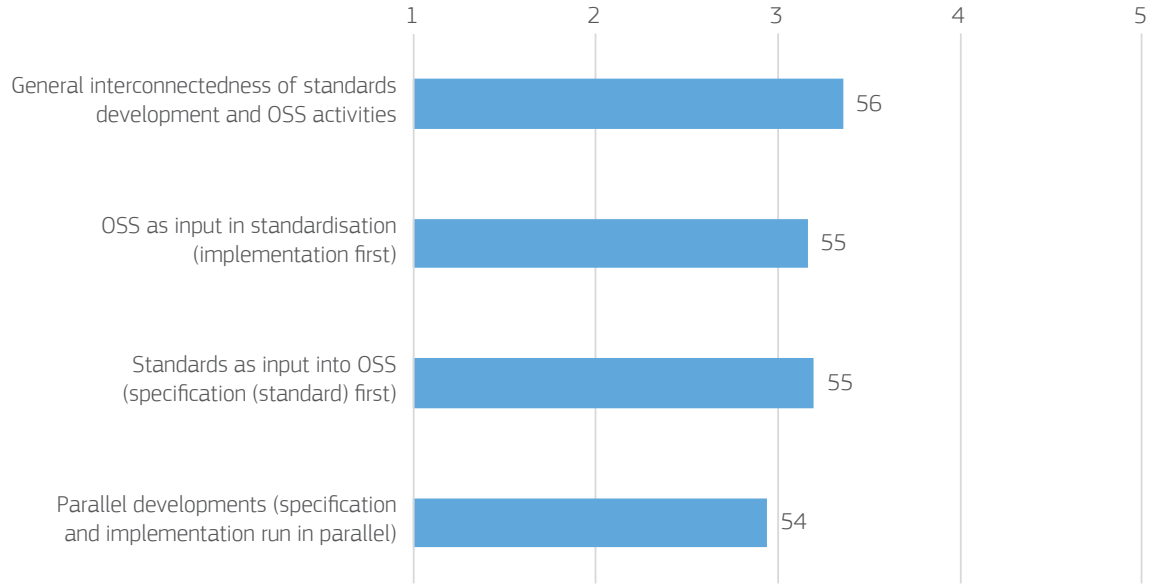

FIGURE 28: FREQUENCY OF INTERCONNECTION BETWEEN STANDARDS DEVELOPMENT AND OPEN SOURCE ACTIVITIES (SCALE: 1 = "NEVER"; 2 = "RARELY"; 3 = "SOMETIMES"; 4 = "OFTEN"; 5 = "ALWAYS").

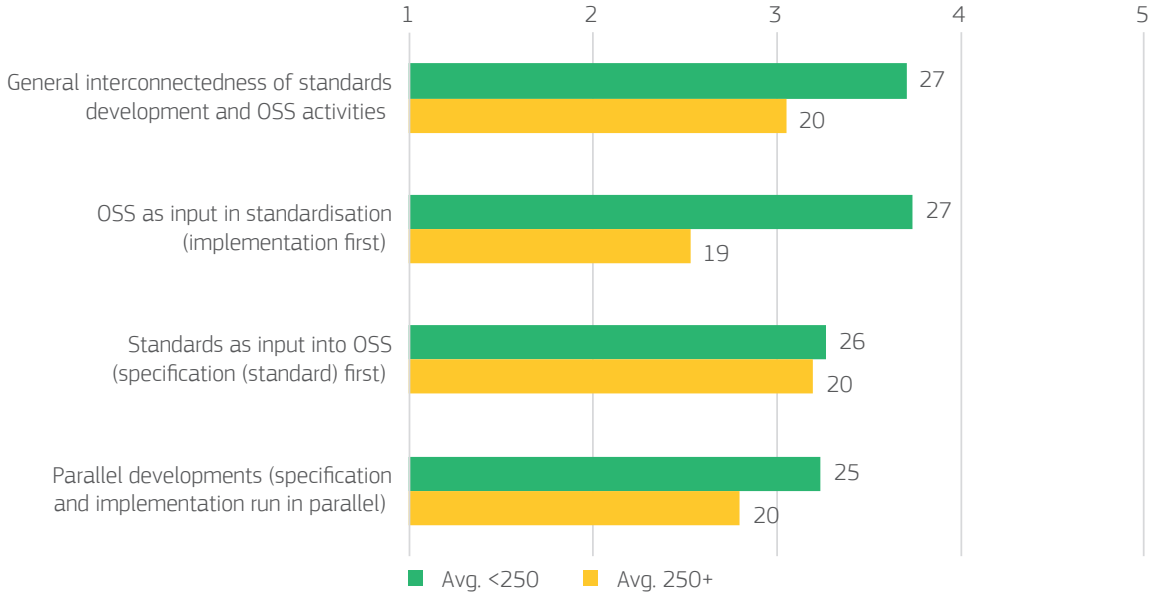

FIGURE 29: INTERCONNECTION BETWEEN STANDARDS DEVELOPMENT AND OPEN SOURCE ACTIVITIES – SMO VS LO (SCALE: 1 = "NEVER"; 2 = "RARELY"; 3 = "SOMETIMES"; 4 = "OFTEN"; 5 = "ALWAYS").

In the answers to the open question about other forms of interaction, we find different and partially contrary positions. Some argue that the way modern standards for the Internet and the Web are defined today does not leave much room for the interpretation for coding, so the standardisation and open source development goes hand-in-hand at all level. There are specific organisations, in particular OpenForum Europe (OFE), which promote both open source and open standardisation, representing their member's opinion that both are important elements for an open, competitive market place and for driving and facilitating innovation and digital transformation. The OpenForum Academy also functions as a leading think tank in this respect also issuing publications and papers on the two topics.

Other experts postulate that open source and standards address complementary, but different topics and purposes. Consequently, there are – in their view – a few specific cases where technical specifications and software/code are co-developed, such as in audio, speech and video codecs.

Respondents involved in standardisation claim that a strong industry commitment towards the development of a specific standard is sufficient for its successful deployment irrespective of OSS for a reference implementation. In contrast, often OSS communities would take notice and start developing alternative independent OSS implementations according to their perception. Consequently, they also expect that if standards do not address market needs, open source implementations will also not be successful.

First standardisation committees develop already reference implementations using the tools, but also some processes of open source projects and under licences compatible with the SDO's IPR framework. The produced code is freely accessible to all, because providing "open source" test cases and material is also important for testing interoperability of standard implementations.

In general, some standardisation organisations realise that their membership covers a multitude of wants and perspectives, when it comes to the interaction of OSS and standardisation. Some of their members are interested only in open source projects that are non-related to standards. Others pursue standards with no tie back to open source. Still, others may want a symbiotic or complementary form of open source and standardisation projects. Standardisation organisations offer that all of these options and perhaps others to be explored and appropriately utilised through their collaboration platform as stakeholders identify their desired end goals and associated results.

Following the identification of the different types of interaction, the respondents have been asked for their assessment of the interaction between OSS and standardisation on their efficiency and results. Starting with looking at the impacts on standardisation (see figure 4 in chapter 4), we observe that the majority of the respondents expects a positive impact of this interconnection on standardisation. In particular, more than 70% of the respondents perceive a positive impact on the creation of specifications of technical solutions contributing to interoperability and only slightly less than 70% on the implementation of technical solutions. However, standardisation benefits less related to the ideation of new technical solutions, but also to their validation and eventually diffusion, because here only around 60% of the respondents expect positive impacts. Overall, less than 10% of the respondents expect negative impacts from the interaction on standardisation.

The differentiation between small and large organisations reveals that the former are more likely to expect positive impacts on the identification of possible technical solutions, i.e. the ideation, and the creation of specifications of technical solutions, i.e. interoperability, whereas the latter see the advantages in particular in the implementation of technical solutions.

If we turn to the impacts of the interaction on OSS, we observe even higher shares of respondents perceiving positive impacts. Almost 80% expect positive impacts for the creation of specifications of technical solutions, in particular related to interoperability, and around 75% for the implementation of technical solutions. Whereas around 70% perceive positive impacts on OSS both for the identification of possible technical solutions and their diffusion, beneficial impulses for the validation of technical solutions are expected by less than 60% of the respondents. However, only around 5% perceive negative impacts.

The differentiation between small and large organisations reveals in contrast to the expected impacts on standardisation that the former are more likely to expect positive impacts on the validation and diffusion of technical

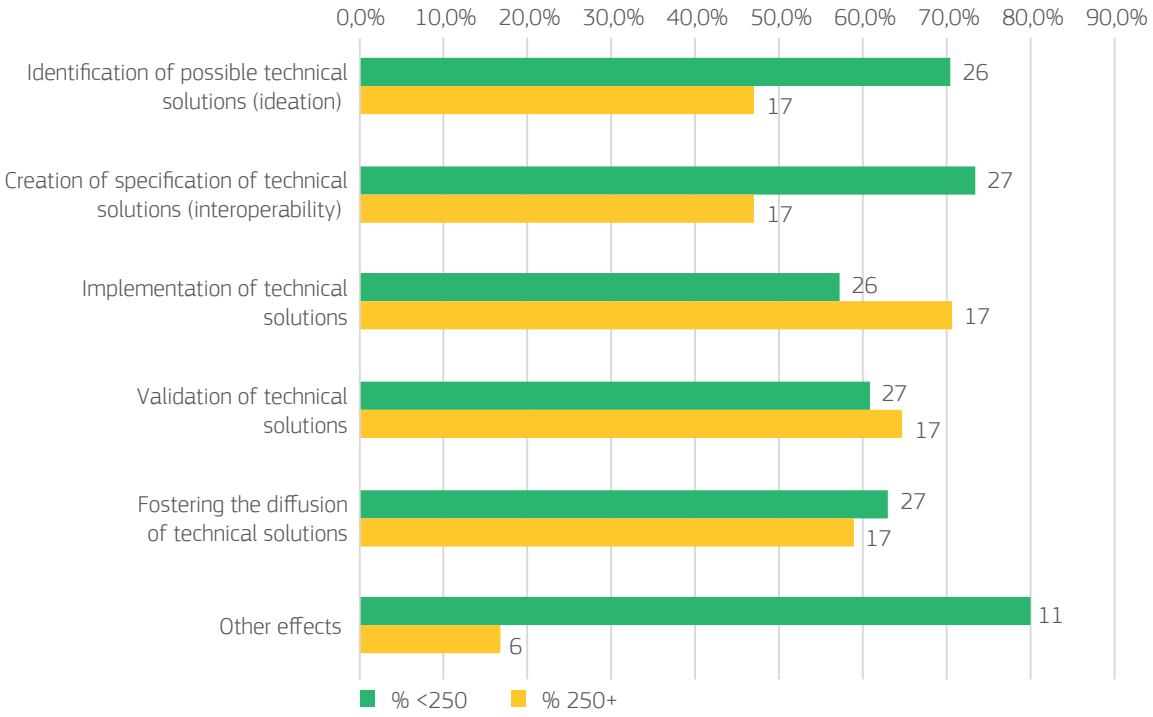

FIGURE 30: POSITIVE IMPACT OF INTERCONNECTION OF OSS AND STANDARDISATION ON EFFICIENCY AND RESULTS OF STANDARDISATION – SMO VS LO.

solutions. Larger organisations see the advantages again in the implementation of technical solutions, but also in the identification of possible technical solutions in OSS.

Taking the latter insights of the interconnection on efficiency and results of OSS together with those on standardisation, it becomes obvious that smaller organisation perceive knowledge flows from OSS to standardisation as providing the latter with new ideas as inputs for technical solutions. Larger organisations see advantages for standardisation from OSS in the implementation of technical solutions. In contrast, smaller organisations experience positive

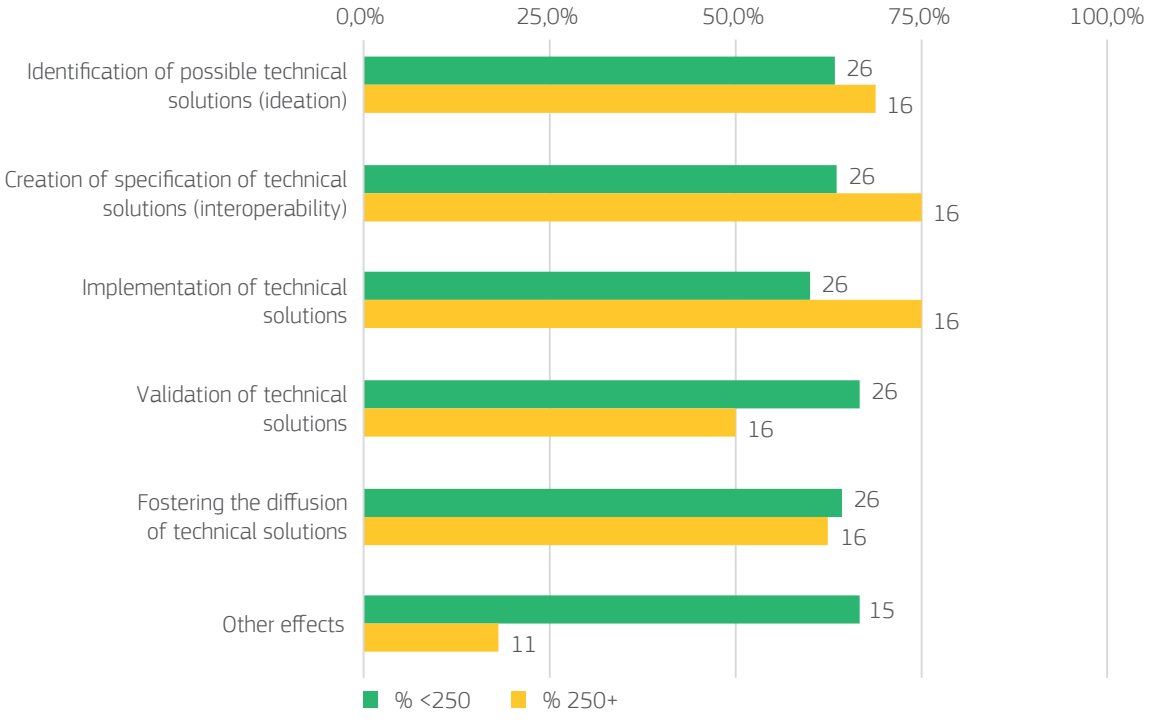

FIGURE 31: POSITIVE IMPACT OF INTERCONNECTION OF OSS AND STANDARDISATION ON EFFICIENCY AND RESULTS OF OSS – SMO VS LO.

impacts of standardisation on OSS on the validation and diffusion of technical solutions. Obviously, there exists a complementarity of effects, which is explained by the size of the organisations. However, it has to be mentioned that smaller organisations are also less involved in standardisation confirming previous studies (Blind 2006, Wakke et al. 2015).

In the answers to the open questions about the impacts of the interconnection of OSS and standardisation, several additional effects have been mentioned. In general, it is agreed that standardisation and open source are today two well working ecosystems, between which well working interrelations have already been established. Further interrelations will be established case by case and organisation by organisation driven by the respective memberships' and business' needs. However, significant top-down changes are perceived to be critical, because they could have unintended and probably negative consequences. Nevertheless, there also needs to be room for creative new models of interactions. In general, it has been highlighted by the respondents that the impacts are always very case specific depending on the project, community management, the stakeholders involved, the available resources and the final goals.

Several additional positive impacts of OSS on standardisation are named. First, OSS identifies the actual areas of non-differentiation, because no one contributes to the differentiating areas. Second, OSS defines the lower bounds for technology use, like price and access. Other effects of interactions between standardisation and OSS can include optimization of solutions for standardisation, the extensions of standards and their improved robustness. For some standardisation projects, open source projects provide some complementary technology. In such cases a closer interrelation is certainly important and has a positive impact. There are, however, also standardisation projects where open source does not generate an impact.

From a procedural perspective, OSS can provide a methodology for fast paced feasibility testing and also enable the development of collaborative networks, which could be positively influencing software development in standardisation bodies and consequently standardisation. In particular, the use of OSS licensing might assist in certain cases where either the use of existing OSS code is needed or useful for an SDO's software development purposes or there is a limited need for code to be developed under an OSS licence for external use, e.g. in case of APIs.

Overall, the respondents do see that there is likely to be a positive impact for identifying, implementing, validating and fostering technical solutions through the development and use of OSS outside of an SDO, and that its limited use and development for particular purposes in an SDO might be helpful in certain situations.

In general, the positive impacts of OSS on standardisation outweigh the negative impacts being mentioned. In order to avoid negative impacts, the OSS licence both should not conflict with either an SDO's IPR policy or the SDO's members' legitimate expectations, but should encourages contributions from all stakeholders, i.e. it does not have the effect of excluding certain stakeholders.

Looking at the mentioned impacts of standardisation on OSS (see figure in chapter 4), it has been claimed that there may be many different relations between standardisation and OSS and each SDO has to find its own way regarding the best ways for making use of OSS and for establishing cooperation. The spectrum ranges from exchange of information and mutual support to standards bodies getting actively involved in open source work.

In particular, analysing the impacts on open source projects, which build on standards developments, should require a differentiation according to the following three situations. First, when standards exist before open source initiatives, they can help to guide open source initiatives to create their technical specifications, which might be a positive impact. Secondly, standards created at same time as the OSS negotiations around the new standards might slow down the open source community to create its technical specifications. In addition, there is a risk that technical specifications in OSS advance more quickly than standards specifications and as standard catches up, it 'forces' re-engineering of OSS. Both impacts could be negative. Thirdly, standards are created after OSS. Then, the standards might impact the existing ecosystem in reducing the variety in OSS. On the one hand, this might be negative, if this reduces the dynamic and 'creative' nature of many OSS teams competing in the parallel exploration of the search space to develop a winning or elegant solution. On the other hand, it might be positive in stabilising the subject area (hence, foster investment) and ensuring a level playing field (hence promoting competition by allowing smaller players to have a chance). This positive impact is more likely, where interoperability is important. Especially during the consolidation after an initial phase of rapid exploration of OSS solutions, the aspect of standards needs to be considered.

Negative impacts on OSS are expected when poorly designed standards – notably those which would force redefinition of the term "open source" to include alien components such as patents – cause substantial confusion and reduce the pace of adoption of OSS in general. Indeed, it is conceivable that some proponents of adding patents into an open source standardisation effort have exactly such an objective.

Other stakeholders are concerned about a possible reduction of return on R&D investment in standardisation, because of unfounded OSS community-generated fears and uncertainty related to imposition of licensing costs of adhering to standardisation policies, and potential for licence conflicts with those policies. This in turn leads to reduced willingness of patent holders to contribute to open source projects.

Some respondents observe that OSS tends to be solution orientated and will revert to adopt newly developed standards or to participation in standardisation, once it reaches adoption in the market. Another observation is that interoperability is inherent to OSS projects as a precondition to efficient collaboration, scaling and to mitigate vendor lock-in.

In several answers to this open question related to the effects of the interaction, the role of IPR regimes is already addressed, to which the next block of questions is devoted.

3.2.5. *IPR Regimes in Standardisation and OSS*

Moving on to the IPR regimes in standardisation and OSS, the answers reveal the following practices. If we review the IPR policies applied in standardisation activities that the respondents are accepting, we observe the following pattern. In general, participation in standardisation activities applying royalty free schemes is much more common with an average value above "sometimes" compared to FRAND, which is likely to be between "rarely" and "sometimes". In particular, less than 20% of the respondents never participate in standardisation activities which apply royalty free schemes, this share is more than double in case FRAND is implemented. Complementary, more than 50% do always or often participate when royalty free is implemented, but less than 40% when FRAND is realised. In particular, small organisations are almost never involved in activities under a FRAND scheme, whereas the size of organisations does not correlate with the popularity of royalty free.

In addition to highlighting that royalty free might be a subcategory of FRAND but does not necessarily mean no cost for the implementer, Non-FRAND, RAND and RAND-ZERO are explicitly mentioned in the open category of other IPR regimes. The other IPR policies that are relevant to respondents' participation in standardisation activities are non-assertion covenant agreements. Obviously, the guaranteed access to technologies, reciprocity and transferability aspects are important.

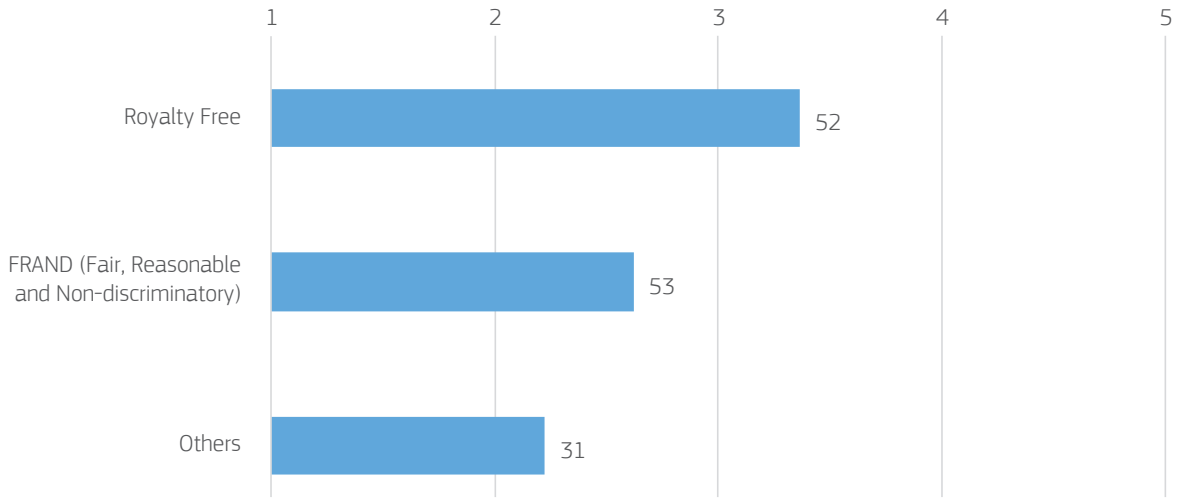

FIGURE 32: PARTICIPATION IN STANDARDISATION ACTIVITIES WITH ROYALTY FREE OR FRAND POLICIES (SCALE: 1 = "NEVER"; 2 = "RARELY"; 3 = "SOMETIMES"; 4 = "OFTEN"; 5 = "ALWAYS").

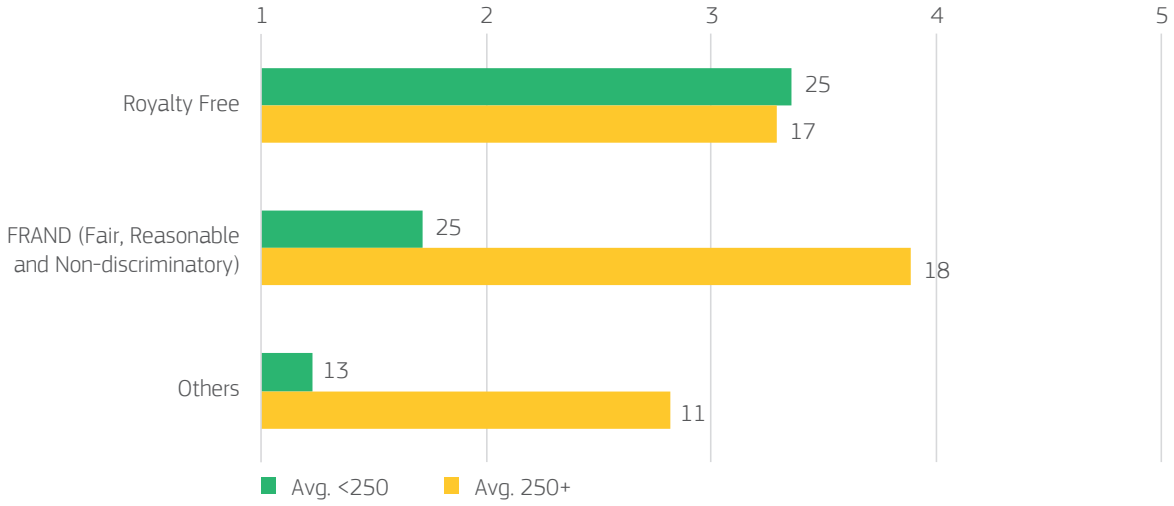

FIGURE 33: PARTICIPATION IN STANDARDISATION ACTIVITIES WITH ROYALTY FREE OR FRAND POLICIES – SMO VS LO (SCALE: 1 = "NEVER"; 2 = "RARELY"; 3 = "SOMETIMES"; 4 = "OFTEN"; 5 = "ALWAYS").

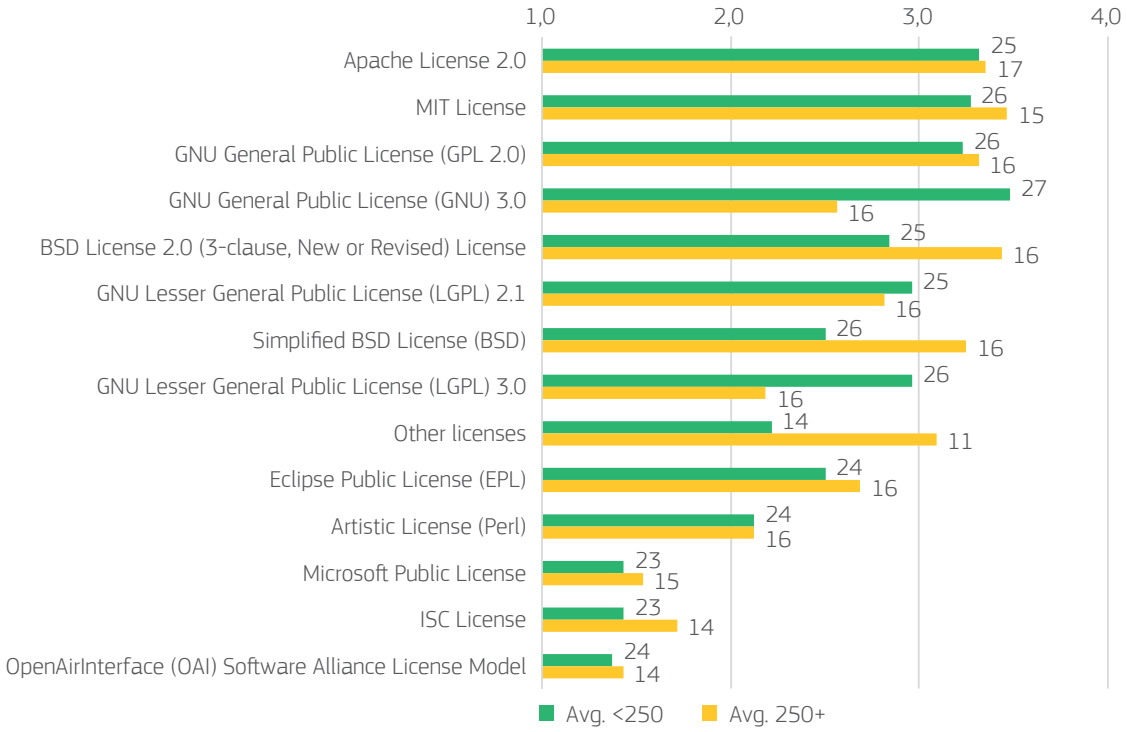

FIGURE 34: PARTICIPATION IN OSS ACTIVITIES WITH VARIOUS COPYRIGHT LICENCES – SMO VS LO (SCALE: 1 = "NEVER"; 2 = "RARELY"; 3 = "SOMETIMES"; 4 = "OFTEN"; 5 = "ALWAYS").

In contrast to the very few IPR regimes applied in standardisation, several licensing models have been developed for OSS. Looking at the most common regimes among (see figure 6 in chapter 4), the respondents the Apache License 2.0, the MIT License and the GNU General Public License (GPL 2.0) are the top three followed by GNU General Public License (GNU) 3 and the BSD License 2.0, all above being rated sometimes. This ranking corresponds closely with the one published by WhiteSource in early 2017.[15] Between sometimes and rarely we find the GNU Lesser General Public License (LGPL) 2.1, the Simplified BSD License, the GNU Lesser General Public License (LGPL) 3.0 and the Eclipse Public License. Just rarely used is the Artistic License (Perl). Between rarely and never

[15] https://resources.whitesourcesoftware.com/blog-whitesource/top-10-open-source-software-licenses-of-2016-and-key-trends.

the Microsoft Public License, the ISC License and the OpenAirInterface (AI) Software Alliance License Model are common among the respondents.

In addition to the significant differences between the general attractiveness of the various OSS licensing models, we can observe discrepancies between larger and smaller organisations. The latter have much stronger preferences for both the GNU General Public License 3.0 and the GNU Lesser General Public License (LGPL) 3.0, whereas the former are inclined to the MIT License and the various versions of the BSD Licenses.

In the answer to the open question about other licensing schemes, it is again highlighted that licence choices are case-specific decisions. Others point out that actors choosing to participate in an OSS project rarely get to choose the licence they contribute under, as existing projects or the umbrella organisations that host them already chose a licence for the project. The question whether or not OSS licences only cover copyright or also other rights to use the code is discussed controversially, with some respondents assuming that even the simple MIT licence contains a patent grant, others insisting that OSS licences only cover copyright, and others pragmatically pointing out that the Apache 2 License, which includes an explicit patent grant as well as the BSD licences, is a suitable choices for using OSS in businesses. The OpenAirInterface licence is disputed, because several respondents question that it meets the OSI definition of an open source licence.

Finally, the respondents were asked for the existence of conflicts between the various copyright licences and the licensing models in standardisation, in particular FRAND. Here, it becomes obvious that both the GNU General Public Licenses GPL 2.0 and 3.0 on the one hand and the GNU Lesser General Public License LGPL 2.1 and 3.0 create conflicts for around two thirds of the respondents. For the BSD Licenses only one third report conflicts. Overall, small organisations report less conflicts.

The detailed descriptions of the experienced conflicts between the chosen OSS and the licensing models in standardisation summarised under "Other licences" in the figures reveal the following positions. Some argue that OSS licensing and FRAND are in general incompatible and that only fully open licensing is acceptable, because FRAND excludes out small businesses and increases burdens on open source builders. The conflicts will increase, as more advanced technologies are being implemented, like software on top of general-purpose computers, because the distinction between a patent on a device and a patent purely on software is becoming more nebulous. Others

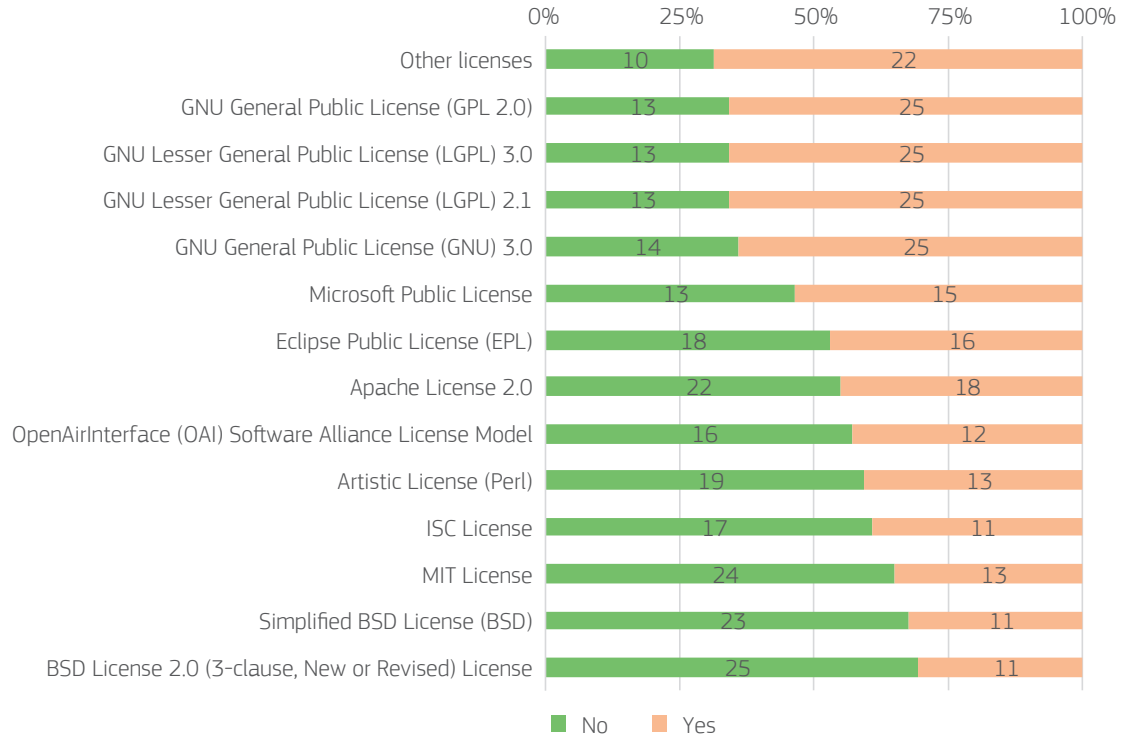

FIGURE 35: CONFLICTS BETWEEN THE FOLLOWING COPYRIGHT LICENCES AND LICENSING MODELS IN STANDARDISATION.

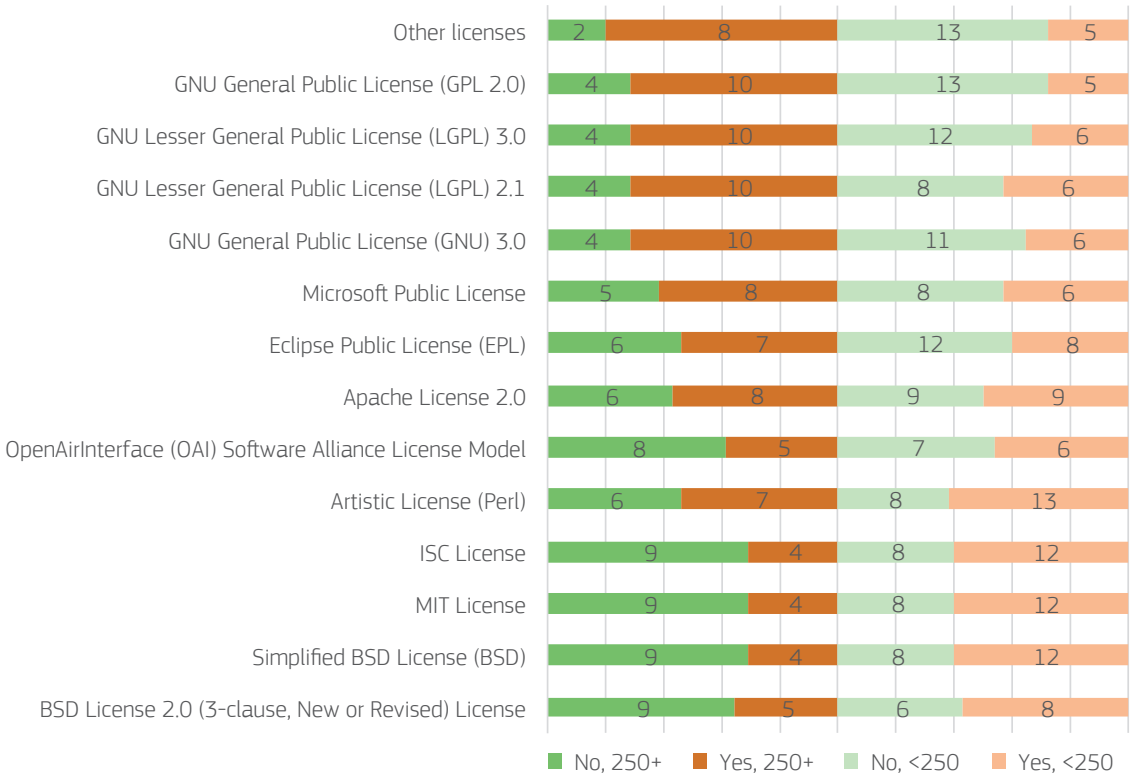

FIGURE 36: CONFLICTS BETWEEN THE FOLLOWING COPYRIGHT LICENCES AND LICENSING MODELS IN STANDARDISATION – SMO VS LO.

explain the conflict as of commercial as opposed to legal nature, as reciprocal OSS licences like the GPL-3 require a royalty-free patent licence, while FRAND does not imply royalty free licensing. This may prevent the patent owner from monetizing their patent portfolio. Since the patent owner is free to choose a different business model, the issue is for some respondents not a question of legal compatibility.

In general, it is emphasized that questions of the compatibility of OSS and standards licences need to be evaluated on a case-by-case basis based on the concrete licences and IPR frameworks. For example, one respondent argues that in particular complementary dual or even multiple licensing schemes sometimes govern the exact same software and companies may make software available under different conditions and licences. For example, software can be released under a GPLv3 licence for those members of the open source community, who prefer that licence, and at the same time the same software might be released in parallel under a BSD 3-clause licence, for those who prefer this option. Therefore, it is argued that software code or other material can be contributed to SDOs making the promise that the relevant patents are available to implementers under a licence containing an express royalty-free patent licence. Furthermore, those proponents support the perspective that FRAND licence commitment applies to all implementations of the specification, while the OSS licence commitment applies to one specific open source implementation. Therefore, both should be to co-exist without conflict. This argument, however, does not take into account that multi-licensing is only applicable in the case of a single-vendor OSS development model and in presence of strong contributor licence agreements. In such cases, the copyright and patents rights holders are identical, which is not a case that applies to SDO collaboration (Riehle 2010). It is also mentioned that conflicts arise when not all relevant patents are disclosed before the publication of the standards, which is obviously the case (e.g. Baron et al. 2014).

Some respondents only consider licences acceptable that clearly indicate that patent rights are not granted, like the BSD 3-Clause Clear License or the Fraunhofer licence. Other emphasize uncertainty from the potential implicit patent grant in licences that may result in courts at determining that patent rights have been granted with the OSS licence.

Another argument brought forward is that SDO FRAND promises and OSS licences should simply be considered as two different and separate promises, where no party is obligated to make one such promise simply because they have made the other. This would mean that having

an SDO undertake software development using an open source licence does not conflict with FRAND and does not obligate any SDO participant to agree to an OSS licence except on a voluntary basis.

In case of conflicts, there are – at least in theory – various options to solve them. Overall, the respondents have not very often experienced effective solutions. Most solutions are rated only between rarely and sometimes successful.

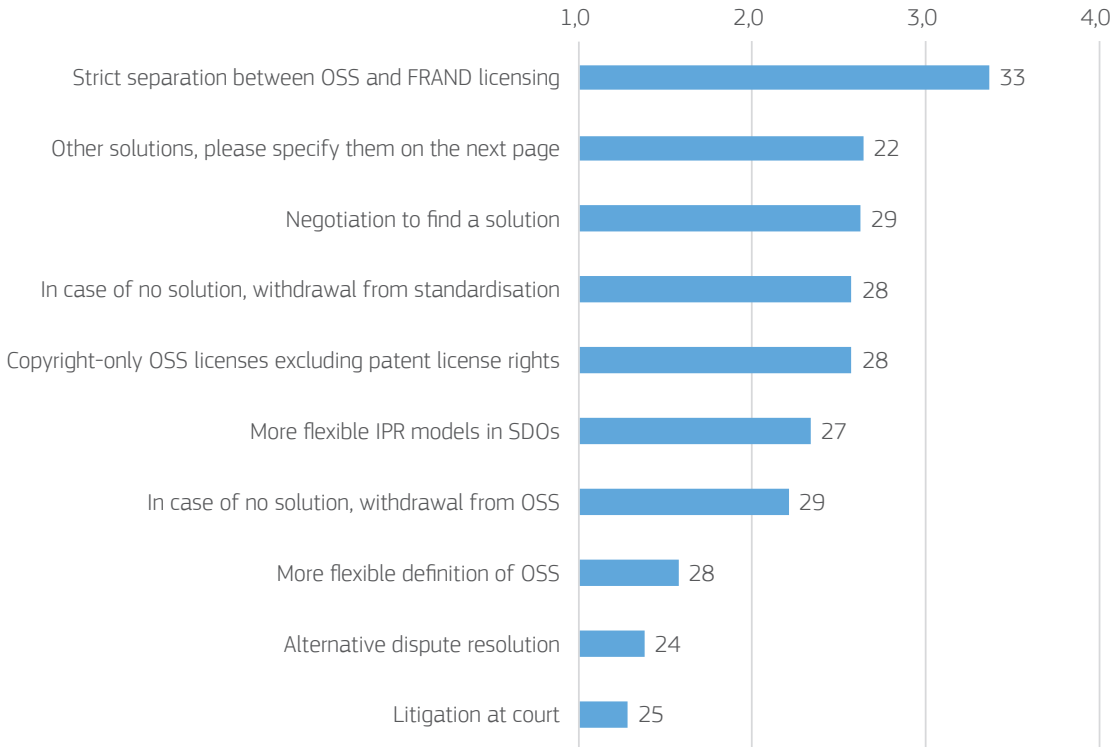

FIGURE 37: SOLUTIONS FOR CONFLICTS BETWEEN OSS AND LICENSING MODELS IN STANDARDISATION (SCALE: 1 = "NEVER"; 2 = "RARELY"; 3 = "SOMETIMES"; 4 = "OFTEN"; 5 = "ALWAYS").

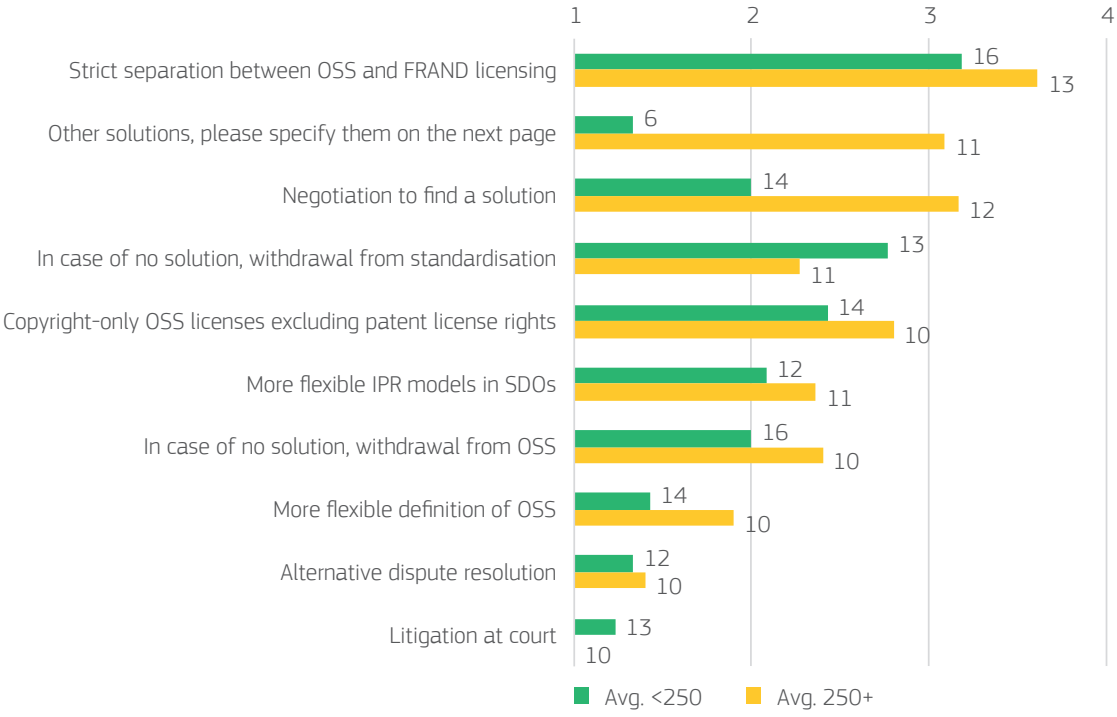

FIGURE 38: SOLUTIONS FOR CONFLICTS BETWEEN OSS AND LICENSING MODELS IN STANDARDISATION – SMO VS LO (SCALE: 1 = "NEVER"; 2 = "RARELY"; 3 = "SOMETIMES"; 4 = "OFTEN"; 5 = "ALWAYS").

Most appropriate is the strict separation between OSS and FRAND licensing followed by negotiations to find solutions. If no solutions are found, sometimes organisations withdraw from standardisation. Another option is the use of copyright-only licences explicitly excluding patent licence rights, which are negotiated separately. Still more than rarely used are more flexible IPR models in SDOs, which allow case by case IPR schemes, and even the withdrawal from OSS, which is less likely than the withdrawal from standardisation. Almost never are more flexible definitions of OSS, alternative dispute resolutions or eventually litigation at court suggested. Focusing on small organisations' most preferred solution, it turns out that they are withdrawing from standardisation in addition to the strict separation. All other options are rarely used by them.

With regard to the question of what other solutions respondents would recommend reconciling SDO IPR frameworks and OSS licence conditions, it was pointed out that both IEEE-SA and OASIS have developed models based on voluntary commitments or patent non-assert clauses that successfully facilitate existing SDO/OSS collaboration.

Some explained that they considered it to be unrealistic to expect that OSS licences or the OSD should be changed, since they are fundamental to OSS. In the wider open source community, the right to distribute OSS, that is developed and maintained on an open collaborative platform, is fundamental to the success of OSS. A small minority argues that any assertion that one definition of open source should be adopted and that this should be the OSD is unhelpful towards the aim of integrating elements of standards and OSS and consider it important to note that there is no one definition of open source. This opinion is, however, not shared by the vast majority of respondents. Almost all participants consider the OSD as the valid definition of open source.

Multiple participants point out that tensions between SDO and OSS IPR frameworks are not a practical concern for them. Some state that they have not encountered and do not expect to encounter conflicts between the OSS and standardisation licensing models that require them to withdraw from either the OSS or standardisation development work and that they have not experienced a need for litigation or other dispute resolution in this area. Others mention that the use of copyright-only OSS licences that explicitly exclude patent grants is very rare. It should not be considered OSS development in the sense that that the wider open source community normally expects and considered more like a "FRAND-based collaborative source code development" model. Some believe that the primary purpose of SDOs should be standards development and that they should not be implementing standards.

In a final question, we asked for an assessment of the effectiveness of various general approaches of collaboration between standardisation and OSS. In contrast to the rather rarely used solutions for conflicts between OSS and licensing models in standardisation, the assessment of at least some approaches of general collaboration between standardisation and OSS is between medium and even high. First, it is asked for a higher flexibility of SDOs' patent policy. Secondly, new processes to integrate OSS in standardisation are suggested. Thirdly, not only more flexible patent policies are asked for but it is even suggested that SDOs change their patent policies towards royalty free. If we look at the ranking of the effectiveness of the solutions differentiated by the size of organisations, we find a strong preference of smaller compared to larger organisations for SDOs changing their patent policy to royalty free and being more flexible in their patent policies, but also for new processes to integrate OSS in standardisation. Obviously, they see in particular the requirement of changes in the policies of SDOs. Below medium, but above low effectiveness new governance and conflict solutions we find new governance and conflict solution models, the use of copyright-only OSS licences explicitly excluding patent licence rights and finally a direct combination of SDOs and OSS communities. Finally, the proposals that OSS licences should include FRAND-based patent grants and of more flexible definitions of OSS receive the assessment of being of only low effectiveness and even lower. Interestingly, larger organisations perceive these options as much more effective as smaller organisations.

General proposals of other approaches of collaborations can be grouped according to the following categories. Some just focus on the licensing regimes and claim to abolish FRAND and to establish (F)RAND-ZERO to OSS implementations.

Others argue more in general that co-development or parallel development of open source software and standards should be organised in a way that informs each other but operates under independent licensing regimes. The Open Connectivity Foundation's development of specifications in parallel to IoTivity's OSS project is mentioned as a good example.

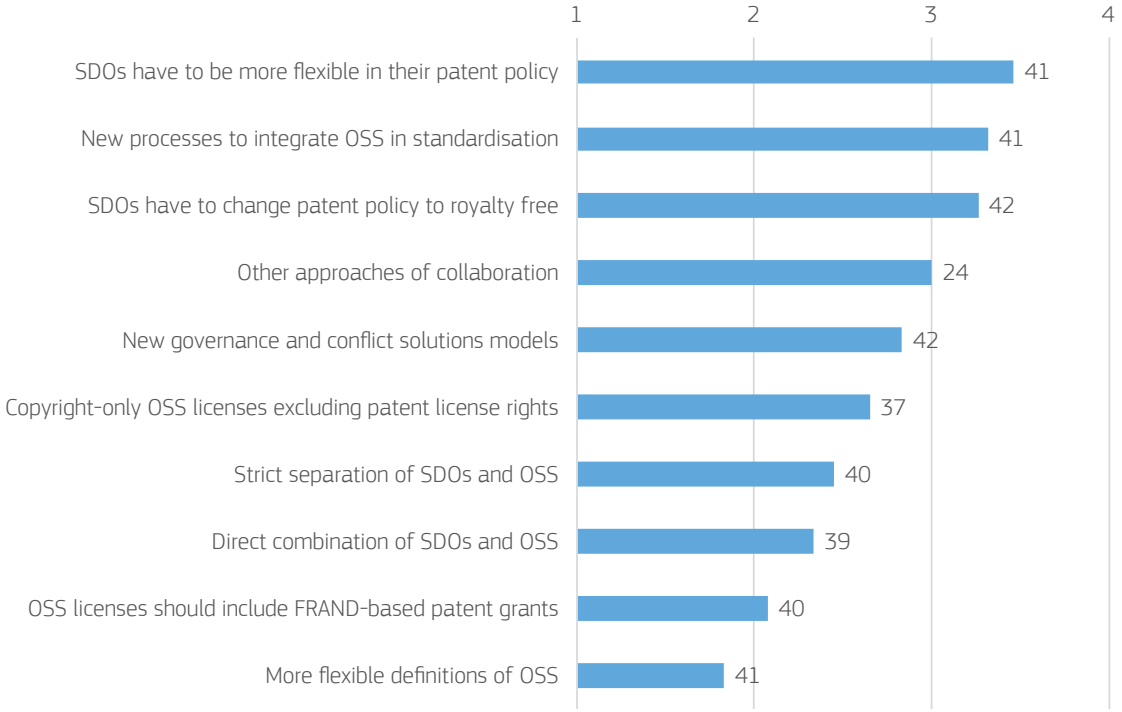

FIGURE 39: EFFECTIVENESS OF APPROACHES OF COLLABORATION BETWEEN STANDARDISATION AND OSS (SCALE: 1 = "VERY LOW"; 2 = "LOW"; 3 = "MEDIUM"; 4 = "HIGH"; 5 = "VERY HIGH").

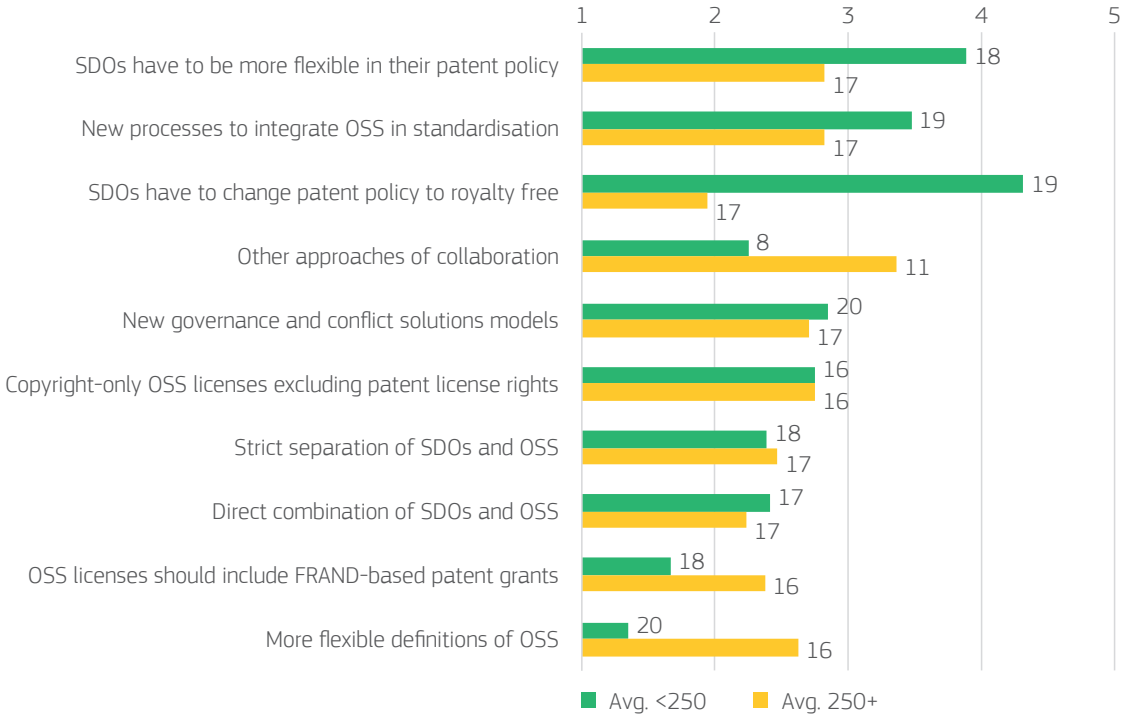

FIGURE 40: EFFECTIVENESS OF APPROACHES OF COLLABORATION BETWEEN STANDARDISATION AND OSS – SMO VS LO (SCALE: 1 = "VERY LOW"; 2 = "LOW"; 3 = "MEDIUM"; 4 = "HIGH"; 5 = "VERY HIGH").

However, SDO can develop more source code (reference implementation) and later decide to work jointly with an OSS community to also have an "open source" implementation. The scope can be slightly different. Open source developers that are currently not SDO members can be integrated in a standard process, but this will only be successful if the open source community is willing to accept some of the slower structural aspects of the development process (e. g. contributions, use cases, potentially membership commitment and fees

etc). It is also argued that SDO governance is strong and seems adequate for a fair participation for all interested stakeholders. They also offer a declaration mechanism that OSS communities, which are not always transparent and often controlled by a few entities, do not provide. According to these voices, in the eventuality that a joint SDO/OSS is found, the SDO governance and its declaration mechanism shall prime. This would provide certainty on the licensing status of the standard/code as anyone could make an IP declaration (see "at the outset" in the ISO policy).

However, open source software and specification-development organisations, such as OASIS, implement already processes to try to understand the origin of each OSS contribution. If the OSS contributor is not also part of the specification-development effort, special processes are used for handling and considering whether and how to use or integrate the OSS contribution. If the OSS project merely intends to implement an existing standard, then this question is not relevant. If the OSS project is able to provide feedback or tools for a standard during the standardisation process, then the importance of the above will depend on nature of the crossover between the two.

IEEE supports the ability for FRAND conditions in standardisation, and further, its bylaws (including those terms covering the Letters of Assurance) apply to open source projects that are also part of our standardisation activities. Its intellectual property review process takes into account any Letters of Assurance when considering the question as to whether or not a particular work can be released as open source. The IEEE offers the Apache 2.0 licence for situations where a contributor has a patent claim on the covered work and they wish to make an explicit worldwide, non-exclusive, no-charge, royalty-free patent grant. According to IEEE, these is no situation, in which its FRAND policies have conflicted with its open source activities. However, it may or may not be the case that its participants chose to not pursue open source as a form of collaboration out of concerns related to patent licensing.

In addition to a closer coordination between OSS and standardisation, others believe that generally the development of OSS is best done outside of an SDO, because it enables both communities to do what they do best and limits conflicts. However, under this constellation, it is important that a collaboration agreement is set up between the SDO and OSS project which governs the degree and nature of information exchange between the two, and possibly also for each community to have observers or access to meetings and/or documents relating to the other's work. However, processes need to be in place in both communities to enable this and to ensure technical contributions are not made by one or the other, as such, to the other's work (i.e. the code or the standard itself). Contributions should only be made by their respective members or contributors. One issue though may be a lack of a legal entity that can bind the parties as regards the contributors to OSS.

In instances, when an SDO wishes to develop OSS, for example, where there may be no external interest to do so, then it is claimed that clear processes are in place to ensure that there is a separation between contributions to an OSS project and the development of a related standard, as both will be governed by different licensing commitment regimes. Equally, appropriate approval processes should be in place to determine on a case-by-case basis whether the benefits of developing code under a particular licence would outweigh the risks, and of course whether the development is likely to be successful in light of those risks and the possible costs. It is stressed, that the scope of any OSS project within an SDO should be clearly delineated. The rules and procedures of the SDO should be adhered to - though they may need to be necessarily changed to enable code development - and members' interests who contribute to the SDO's standards should be taken into account. SDOs should avoid developing implementations of the code for commercial purposes (not least due to competition law concerns) and they should manage IPR expectations associated with the code, especially for potential users of it. Therefore, it is recommended, that SDOs would be best served by limiting their code development to tools or specific reference implementations needed to guide associated ongoing standard developments. Providing the appropriate governance rules and processes are in place, then there should generally be no need to change the SDO's IPR policy.

However, the proponents of this proposal stress that the risks and concerns above are likely to be reduced if SDOs avoided traditional OSS licences and used an unambiguous copyright-only licence that is subject to their IPR policies or FRAND based licences such as the OAI licence. According to them, these types of licences are also likely to lead to more contributions and therefore more successful code development. As regards the OAI licence, it is also likely to

be useful for openly developing code in areas where the best likely contributors to the code may hold valuable IPR.

Others argue that for SDOs developing OSS the choice of licensing – whether non-open source or open source – can be made on a case by case basis depending on the needs of the project and the preferences of the participants. Suggestions that some sort of special model is necessary to address software development, including open source, at SDOs would improperly limit standards' participants ability to design and implement effective, innovative technologies.

Most of the respondents agree that there a not very many combinations of standardisation and open source development. Where OSS and standardisation collaborate, the result is successful. However, there are numerous answers to the open question of concrete examples of direct combinations of standardisation and open source development listed in the Annex. It is obvious that the successful examples are mainly hosted at standardisation organisations following a royalty free regime.

The answers to the final open question regarding the subject of OSS and standardisation in general, and standard-essential patents or FRAND in particular confirm the previously revealed and discussed different positions of the respondents similar to the observations by Baron et al. (2019).

In general, some respondents confirm that the combination of OSS and open standards would lead to best possible combination of rapid innovation and broad adoption eventually benefitting the end users. However, there is obviously also room for improvement in organising the interaction and the exchange of information. In particular, it is questioned whether SDOs are really very open for input from other organisations, like OSS communities. Furthermore, two dimensions of tension are mentioned. First, an open source implementation often becomes the main or only codebase used in most products, whereas in standards, there are quite a lot of corner cases and optional features that needs thorough testing for interoperability purposes. An SDO developed reference implementation ensures that all features are tested. The testing of corner cases in open source projects is not needed, when everyone uses the same open source code and when the open source code is a subset of the standard. This can be detrimental to product interoperability and market differentiation. A role could be found for open source implementations in standard interoperability testing to ensure that different code base are interoperable with a reference implementation. Second, standardisation and OSS projects often have different timeframes. When a long timeframe is envisaged for an SDO project, there could be a role for an intermediate open source implementation to help stabilise core concepts for intermediate market needs. Though, the long-term purpose should not be shaped by an immediate and temporary market demand. In order to respond to the increasing time pressure, another trend is mentioned to produce standards in a lesser descriptive way but in the form of software code – at least in some contexts, e.g. regarding standards for software interoperability but also other technical standards that may in the future be able to implement by activating a runtime engine and thus shortening implementation time and effort tremendously. In this context, the requirement of the European Commission to ensure that ICT-related standards are set in a way that is more responsive to policy needs, agile, open, more strongly linked to research and innovation, better joined-up, and thus that they ultimately have more impact for the wider European economy has also to be mentioned. It is admitted that such challenges will require a lot of new thinking around new forms of standardisation including the option of integrating OSS. In addition, room for rather generic instead of prescriptive and incremental institutional and procedural innovations of SDOs is needed, which might be hindered by their internal, more restrictive governance (Baron et al. 2019).

From a technical and business view, OSS and standardisation are not competing from the perspective of other respondents, because they do not address the same issue, i.e. standardisation is more a functional model, whereas OSS focuses on implementation. Others see open-source and proprietary just as two extremes of a continuum of business models and ask for ensuring technology access and business model neutrality for all participants on both open source and open standardisation. In this context, new business models based on OSS and patents, but not necessarily on SEPs are mentioned. Furthermore, the definition of open source according to OSI should not be questioned or changed. However, the role of patents related to software is perceived to be rather critical, in particular patents on software-implemented innovations should be not granted confirming the results of the stakeholder survey by Blind et al. (2017) focusing on ICT patents.

There is on the one hand a significant group of stakeholders which confirm their position of perceiving a fundamental

incompatibility between OSS and FRAND questioning the later regime and the concept of standard-essential patents in general (see also Blind et al. 2017). In contrast, other respondents claim that FRAND licensing promises and open source licensing can readily co-exist in the marketplace and mention the ETSI OSS Mano project is a particularly successful example of such collaboration.

Finally, the closer integration of standardisation and OSS will also challenge the existing business models of SDOs.

3.3. Summary

Despite of the limited response to the stakeholder survey, the analysis of the responses reveals sound and internally consistent results. In addition, the results are also in line with the insights from methodologically similar analyses. The differentiation of the sample into large and small or medium-sized organisations, which is almost identical to a separation into patent owning and not patent owning companies, reveals interesting insights, which also guide the derivation of policy recommendations.

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