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Industry consortia in mobile telecommunications: Firm behaviour, taxonomy, and implications for practitioners and policymakers

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2G	Second Generation of Mobile Telecommunication Standards
3G	Third Generation of Mobile Telecommunication Standards
3GPP	3rd Generation Partnership Project
4G	Fourth Generation of Mobile Telecommunication Standards
5G	Fifth Generation of Mobile Telecommunication Standards
5GAA	5G Automotive Association
5GPPP	5G Infrastructure Public Private Partnership
AIOTI	Alliance of the Internet of Things Innovation
ARIB	Association of Radio Industries and Businesses
CA	Cluster Analysis
CEPT	European Conference of Postal and Telecommunications Administrations
DBSCAN	Density-Based Spatial Clustering of Applications with Noise
DV	Dependent Variable
EC	European Commission
ETSI	European Telecommunications Standards Institute
GSM	Global System for Mobile Communications
GSMA	GSM Association
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IOR	Interorganisational Relationship
IoT	Internet of Things
IP	Intellectual Property
IPR	Intellectual Property Right
ISG	Industry Specification Group
ITU	International Telecommunication Union
IV	Independent Variable
LTE	Long-Term Evolution
MEC	Multi-access Edge Computing
NGMN	Next Generation Mobile Networks Alliance
NPE	Non-Practising Entity
OLS	Ordinary Least Squares
OPNFV	Open Platform for NFV
PCA	Principal Component Analysis
PCG	Project Coordination Group
QCA	Qualitative Content Analysis

SEP	Standard Essential Patent
SIG	Special Interest Group
SIP	Session Initiation Protocol
SSO	Standard Setting Organisation
TCP/IP	Transmission Control Protocol/Internet Protocol
TSG	Technical Specification Group
UMTS	Universal Mobile Telecommunications System
V2X	Vehicle-to-everything
(W)-CDMA	(Wideband) Code Division Multiple Access
W3C	World Wide Web Consortium
WG	Working Group
(W)LAN	(Wireless) Local Area Network
WTO	World Trade Organization

Acknowledgments

An African proverb states that it takes a village to raise a child. Similarly, it also takes a village to work on a dissertation project that is in some ways similar to a child—it does not always do what you would like it to, and you think about and worry about it most of the time. Yet, you are extremely protective of it and would not have it any other way. Since it took such a village to finish this dissertation, I would like to take this opportunity to thank some of the people who have made this possible.

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Since it seems to be somewhat customary to include a wise quote somewhere in a dissertation, I would like to close with the (slightly adapted) words of Shawn C. Carter, also known as Jay-Z:

"If you're having [diss] problems, I feel bad for you, son.
I got ninety-nine problems but [the diss] ain't one."

Abstract

In spite of the existence of numerous formal and quasi-formal Standard Setting Organisations (SSOs) dedicated to technology standardisation in mobile telecommunications, numerous industry consortia have been established that are related to standardisation in some way.

Industry practitioners tend to recognise the importance of industry consortia with respect to standardisation as well as technological development in the industry. Yet, knowledge about their focus areas, activities, organisational set-up, and links to formal standardisation is quite limited.

This dissertation aims to provide detailed insights into industry consortia and their workings. The first study of this dissertation is concerned with the raison d'être of industry consortia, which is explored based on semi-structured interviews with 13 industry experts. Building upon these insights, the second study aims to provide a comprehensive picture of the diversity of industry consortia. This is done by means of cluster analysis based on a dataset encompassing manually collected information on a sample of 100 consortia active in the industry. The results of this analysis feed into a detailed taxonomy of industry consortia consisting of six categories. Finally, the third study of this dissertation aims to shed light on implications of firms' memberships in industry consortia. By connecting data of consortia memberships from the second study to data on declared Standard Essential Patents (SEPs), this study examines relationships between firms' memberships in consortia and strategic patenting behaviour in standardisation.

Zusammenfassung

Trotz der Existenz von zahlreichen formalen und quasi-formalen Standardsetzungsorganisationen (SSOs), die sich der Technologiestandardisierung im Mobilfunk widmen, werden zahlreiche Industriekonsortien begründet. Diese beschäftigen sich zu Teilen auch mit standard-relevanten Themen.

Industrieexperten erkennen die Bedeutung von Industriekonsortien an, sowohl in Hinblick auf Standardisierung als auch auf die allgemeine Technologieentwicklung in der Industrie. Jedoch ist das Wissen in Bezug auf Fokus, Aktivitäten, Organisation und Beziehung zur formalen Standardisierung von Konsortien begrenzt.

Diese Dissertation zielt darauf ab, einen detaillierten Einblick in Industriekonsortien und ihre Tätigkeiten zu geben. In der ersten Studie dieser Dissertation wird der Sinn und Zweck von Konsortien beleuchtet, basierend auf semistrukturierten Interviews mit Industrieexperten. Aufbauend auf diesen Erkenntnissen, wird in der zweiten Studie ein umfassendes Bild von der Vielfalt von Industriekonsortien erstellt. Dies wird mithilfe einer Clusteranalyse, basierend auf einem Datensatz mit Informationen zu 100 Konsortien, die in der Industrie aktiv sind, erreicht. Aus diesen Resultaten wird schließlich eine Taxonomie, bestehend aus sechs Kategorien von Industriekonsortien, aufgebaut. Anschließend soll die dritte Studie dieser Dissertation einen Einblick in Implikationen von Konsortien-Mitgliedschaften von Firmen geben. Mithilfe von Daten zu Konsortien-Mitgliedschaften aus der zweiten Studie, sowie Daten zu deklarierten standardessenziellen Patenten (SEPs), wird die Beziehung zwischen Firmen-Mitgliedschaften in Konsortien und strategischem Patentieren in der Standardisierung untersucht.

1 Introduction

1.1 Motivation

Mobile telecommunication standards tend to have a large impact on various industries. Starting with the third generation of mobile telecommunication standards (3G), these standards were no longer just about communication, via voice or text, between mobile phones. Instead, a convergence between traditional telecommunications and the IT industry kicked off more far-reaching convergence between industries. The fourth generation of mobile telecommunication standards (4G), and the much anticipated fifth generation (5G), brought along various use cases of mobile technologies. Developments such as the Internet of Things (IoT) and Industry 4.0, and the associated use cases and opportunities, impact a wide variety of industries. This means that current and future mobile telecommunication standards have a wide range of stakeholders.

Firms directly involved in the creation of standards are not the only stakeholders of mobile technologies, but the exact technical specifications of standards are obviously especially relevant to them. These are usually ICT firms, and especially traditional players in the realm of telecommunications, such as vendors (e.g. Ericsson, Huawei, and Nokia), and (network) operators (e.g. Orange, Telefonica, and Vodafone). For them, the relevance of mobile telecommunication standard stems from technical reasons, which are intertwined with business reasons. For one, it is important for them to align their own products and developments with standards. But also, they need to make sure that when they invest resources in R&D, they invest in promising developments that are in line with standards to come. These developments can then result into patents, which are a lucrative source of income for many ICT firms. Leiponen (2008, p. 1904) even argues that the outcomes of standardisation "can […] determine a firm's fate in the marketplace".

When it comes to the creation and setting of standards, formal Standard Setting Organisations (SSOs) take centre stage. These are organisations that are formally recognised by national or international authorities (International Telecommunication Union 2014), such as the European Telecommunications Standards Institute (ETSI)[1]. In mobile telecommunications, standards are usually created within the Working and Technical Specification Groups of the 3rd Generation Partnership Project (3GPP). Within these groups, technology experts from firms and other interested organisations (e.g. research institutes) work on the exact technical

[1] ETSI is a recognised regional standards body under Regulation 1025/2012 (see European Parliament and Council 2012).

specifications of standards. However, even though standards are created within 3GPP, 3GPP does not *set* the standards, and is hence not an actual SSO. Rather, it is a partnership of regional formal SSOs, including ETSI. These SSOs convert the 3GPP specifications into actual regional standards.

Even though 3GPP has been the central organisation with regards to mobile telecommunication standards since the emergence of 3G, it is by far not the only organisation that matters. When asked about key developments in telecommunication standardisation, industry experts repeatedly mention the phenomenon of industry consortia, and many of them agree that they are extremely relevant for overall industry and technology development.[2] When enquiring about distinguishing characteristics of industry consortia in the literature, one comes across several aspects. These include that they are alliances of like-minded companies (Cargill 2002; Pohlmann 2014), they tend to have narrower interests than formal SSOs (Chiao et al. 2007), and are perceived to be "less formal" (Simcoe 2014) when it comes to their organisational set-up.

Many industry experts say that industry consortia are an interesting and important development to follow, but they also tend to admit that they lack a comprehensive overview of the landscape of consortia. Also, some of them are unsure about the exact modalities of consortia, since the formation of consortia often happens in a rather informal process—the process is often initiated by very few managers from different firms that observe a certain need or opportunity in the industry. In many cases, these managers are in regular and close contact anyway, and the idea of consortia formation arises naturally. Interestingly, in spite of their seemingly rather informal character, consortia can substantially impact formal standardisation (Baron et al. 2014; Delcamp and Leiponen 2014). This impact on standardisation is often coined "pre-standardisation" (Delcamp and Leiponen 2014), which entails that consortia can contribute their work to formal SSOs via individual (firm) members, or maintain formalised relationships on the organisational level.

Thus, consortia are widely considered to be an important development in the industry, but many of them are perceived to be rather opaque. This makes them an interesting phenomenon to study. However, the literature on industry consortia is surprisingly sparse. Only few studies discuss industry consortia in-depth (e.g. Baron et al. 2014; Delcamp and Leiponen 2014; Hawkins 1999; Pohlmann 2014). Thus, the questions that lead to this dissertation were: What exactly are industry consortia? What are they doing? What kind of consortia are there and what is their impact?

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[2] This information stems from semi-structured interviews conducted in the context of this thesis, a more extensive analysis of these interviews will follow in Chapter 2.

This dissertation aims to shed light on four key aspects regarding industry consortia: 1) A definition of industry consortia, 2) an elaboration on their raison d'être, 3) a comprehensive classification, and 4) an examination of the implications of industry consortia. I will work on these four aspects using an empirical and phenomenon-driven approach. Since, as previously mentioned, the intricate structures, rules, and processes of industry consortia are rather difficult to observe, I aim to dig deep into consortia's organisational set-up in order to provide a comprehensive definition and taxonomy. Then, I would like to take a glimpse at potential implications of industry consortia memberships. These implications can be manifold and in many cases difficult to measure, which is why I focus on the relationship between firm memberships and behaviour in standardisation. More precisely, I look at whether consortia memberships of firms can be associated with advantageously placing own intellectual property (IP) in standards.

1.2 Research objectives

This dissertation comprises three studies exploring different aspects of industry consortia in mobile telecommunications. They are outlined in the following.

The first study, titled "Boundaries of standard setting organisations: An exploration into the raison d'être of industry consortia in mobile telecommunications", is concerned with an elaboration on why industry consortia exist in the first place. More precisely, based on semi-structured interviews with industry experts, I discuss why firms may feel the need to initiate, form and join consortia.

In the second study, titled "Industry consortia in mobile telecommunications standards setting: Purpose, organisation and diversity" I aim to provide an overview over the landscape of industry consortia. In this study, I develop a definition of industry consortia, and provide a comprehensive classification or taxonomy of consortia. The taxonomy is based on manually collected qualitative and quantitative data on 100 consortia active in the industry, which builds the base for a cluster analysis. The interview data utilised for the first study is used to support the analysis and interpretation of the taxonomy results.

The third study, titled "Implications of industry consortia memberships: Information, control, and strategic patenting", is concerned with providing a snapshot of potential implications of industry consortia. I examine the relationship between consortia memberships and IP-related firm behaviour in standardisation, which entails strategically placing own IP in standards in order to obtain valuable patents. This is done by means of connecting data on consortia memberships with data on declared standard essential patents (SEPs), and conducting regression analysis based on this data.

1.3 Structure of this thesis

The remainder of this dissertation is organised as follows. This thesis comprises three papers, each covering the content of one of the previously mentioned studies and constituting one chapter.

Chapter 2 consists of the first study. It starts with a literature review including studies on standardisation in telecommunications, the phenomenon of industry consortia, and an introduction to the theoretical framework used for the remainder of the Chapter (2.2 and 2.3). After presenting the methodology (2.4), I describe and organise the results of semi-structured expert interviews (2.5). The results then build the basis for an analysis of the interview results based on the theoretical framework introduced earlier (2.6).

Chapter 3 consists of the second study. I first review existing studies in the area of industry consortia, especially classification of industry consortia (3.2). Then, after an outline of the methodology and the data used for this study (3.3), some relevant results from the analyses of the semi-structured interviews (3.4, see also Chapter 2) are summarised. This leads into the investigation of a sample of 100 consortia (3.5), and a taxonomy based on cluster analysis (3.6). Finally, the resulting taxonomy and its implications are discussed (3.7).

Chapter 4 consists of the third study. After a review of the most relevant literature in the areas of standardisation, IP and IP-related firm behaviour in standardisation, and firm networks (4.2), I present my hypotheses (4.3) as well as the data and the methodology (4.4 and 4.5) to be used for the following analyses. Next, I describe the steps of the regression analysis as well as the results, closing with an interpretation (4.6) and discussion (4.7) of the results.

I conclude this thesis with an overall conclusion and outlook, summarising the results and providing an elaboration on their potential implications.

It is important to note that each of these chapters is designed to be a stand-alone paper, which means that some repetitions, especially with regards to definitions, are unavoidable.

2 Boundaries of standard setting organisations: An exploration into the raison d'être of industry consortia in mobile telecommunications

2.1 Introduction

When talking to telecommunication industry experts about current relevant topics in the industry, one topic keeps coming up repeatedly: industry consortia (henceforth also referred to as "consortia"). In the literature, they are described as alliances of like-minded companies (Cargill 2002; Pohlmann 2014) or "special-interest groups" with narrower interests than formal SSOs (Chiao et al. 2007). The emergence of industry consortia has been taking place since the late 1980s (Hawkins 1999), in spite of the existence of numerous established organisations where industry players have for a long time been coming together to collaborate. Such established organisations include standard setting organisations (SSOs) where firms jointly work on and define technical standards. From the literature, we also know that at least some of the work done within consortia is related to standardisation (Leiponen 2008; Pohlmann 2014), so they can in some way be similar to SSOs. Hence, when looking at the increased emergence of consortia, the question arises why and when firms choose to undertake some activities in industry consortia rather than within already established SSOs. Moreover, one could question the sheer existence of industry consortia, since there are already various ways and institutionalised options for collaboration available to firms in telecommunications. In order to understand this question, one may go one step further and pose the question why *SSOs* are even needed—that is, why standards-related work cannot just happen within the firms themselves.

Searching responses to the latter question, the idea of the boundaries of the firm come into play. In his fundamental work on this topic, Coase (1937) says that firms decide to step outside if certain work cannot (comfortably) be done inside a firm: As a firm gets larger, there are decreasing returns to any additional transactions happening within the firm. Williamson (1981, p. 550) (along with Ouchi and Barney 1981) talks about "efficient boundaries" established by the questions "which activities should be performed within the firm, which outside it, and why". Williamson (1981) puts transaction cost in the centre of attention—implying that if certain transactions do not work well for some reason (e.g. due to the difficulty of a task or misunderstandings), leading to transaction cost, the question is whether alternative governance structures can be identified in which transactions can be organised.

In the specific case of the telecommunication industry, it seems that collaborating within SSOs does not solely happen because having the standardisation work within a firm makes firms too large, or because standardisation-related transactions would be too cumbersome or difficult for a firm to handle. In fact, it is also the characteristics of telecommunication standards themselves which make collaboration and coordination within SSOs useful and necessary. One key characteristic or goal of many technologies in the area of telecommunications is compatibility. This means that different components or (sub-)systems are compatible (David and Steinmueller 1994), also between different firms. One mobile phone consists of multiple pieces of hardware and software from a variety of firms, and these need to function with each other and make the mobile phone work. In addition, different devices need to be compatible in a way that for instance end users of Samsung mobile phones are able to telephone end users of Apple mobile phones. In effect, these aspects imply that firms in the industry have to make sure that they coordinate in order to achieve compatibility.

Since the creation of the third generation of mobile telecommunication standards (3G or UMTS), the primary organisation for the creation of mobile telecommunication standards has been the 3rd Generation Partnership Project (3GPP). 3GPP is a partnership[3] of regional SSOs such as the European Telecommunications Standards Institute (ETSI). The actual technical work on standards is done within the working groups and technical specification groups of 3GPP, and the regional SSOs then convert the developed set of technologies into actual (regional) standards. As previously pointed out, next to 3GPP, numerous other organisations, or industry consortia, related to mobile telecommunication standards have been emerging. Not only is there a large number of these organisations, but also a large variety. Hence, in the standardisation literature, there is some discourse on whether and to what extent industry consortia (or similar organisations) substitute or complement[4] established organisations such as 3GPP (Baron et al. 2014; Blind and Gauch 2005; Chiao et al. 2007; Lerner and Tirole 2006). Industry consortia can create their own standards, while some act in a pre-standardisation way (Leiponen 2008), meaning that they prepare technological work that is then brought into established SSOs. In contrast, others are relatively independent from 3GPP because they create "add-ons" to the 3GPP standards (see also Chapter 3), such as specific applications.

While one can easily find out about the explicit purposes, focus, and general idea of specific industry consortia via their websites and press releases, the exact motivations for the establishment of these organisations remain in the dark. In this paper, I would like to understand the

[3] See https://www.3gpp.org/about-3gpp (retrieved on 02/04/2020).

[4] In economics, one usually refers to a complementary good if it enhances the value of another good because the two goods are usually consumed together. This means that the consumption of additional units of one good imply more consumption of the other. In this context, a complement is rather understood as "something that fills up, completes, or makes better or perfect", which is an alternative definition provided by the Merriam-Webster dictionary.

firm perspective on their rationale of establishing and joining industry consortia, while focussing on the reasons why existing SSOs may not suffice in some cases—thus, I focus on the boundaries of SSOs.

This paper first provides an overview of the literature on the boundaries of the firm and interorganisational relationships (IORs), which provides the theoretical backdrop for my work (see Oliver 1990). Then, I will introduce some literature on the history of SSOs as well as industry consortia. After a description of the methodology used to collect the data for this project, I will provide a descriptive overview of the results of my data collection exercise, namely semi-structured interviews. Finally, I will bring together the literature in the field as well as my data analysis, and elaborate on some additions to the existing theory.

I build upon the scheme developed by Oliver (1990), and find that the raison d'être of industry consortia can be subsumed by seven key aspects. I call these aspects the "reasons for consortia formation", which then determine the boundaries of SSOs: asymmetry, common goals, efficiency, information / hedging, novelty, uncertainty, and recognition. These reasons for consortia formation are moderated by conditions affecting the way these reasons translate into actions.

2.2 Literature review: Theoretical background

This first part of the literature review aims to lay down the theoretical background for this paper. As pointed out in the introduction, the main question that I aim to answer is why industry consortia emerge in an environment where there are already numerous established organisations and opportunities for collaboration. Thus, in the following, I will examine literature on firm boundaries, interorganisational relationships, and strategic alliances.

2.2.1 Boundaries of the firm and interorganisational relationships

According to Coase (1937, p. 395), a firm "will tend to expand until the costs of organising an extra transaction within the firm become equal to the costs of carrying out the same transaction by means of an exchange on the open market or the costs of organising in another firm". This is in line with the traditional idea of the coordination of economic activity—it either happens within firms or "hierarchies" (where entrepreneurs do the coordination), or via the price mechanism on the market (Coase 1937; Richardson 1972). Thus, the literature usually speaks of a division between "markets and hierarchies" (Williamson 1973).

However, this clear "division of labour between the firm and the market" leaves out "dense networks of co-operation and affiliation by which firms are inter-related" (Richardson 1972,

p. 883). Thus, Richardson (1972) implies that there is an intermediate form of organising economic activity which is neither taking place within a single firm nor left to the market and its price mechanism. Hagedoorn (1993) examines firm boundaries in the context of technology cooperation in particular. He finds that the boundaries are usually "defined in terms of vertical relationships of economic exchange from one company to another" (Hagedoorn 1993, p. 371). However, he argues that technology cooperation is usually different because it goes beyond economic exchange, and rather encompasses "relatively long-term strategic considerations regarding lateral relationships between companies" (Hagedoorn 1993, p. 371).

There are different ways of understanding and naming cooperative relationships or activities between firms, emphasising different aspects of these relationships and activities. For instance, Schermerhorn (1975, p. 847) speaks of interorganisational cooperation as "the presence of deliberate relations between otherwise autonomous organisations for the joint accomplishment of individual operating goals". While this understanding emphasises the goals that individual organisations want to pursue by means of cooperations, other perspectives provide a broader view on this. A more general perspective is provided by Oliver (1990) who looks at interorganisational relationships or relations (IORs) (Galaskiewicz 1985; Oliver 1990): Oliver (1990, p. 241) defines IORs as "relatively enduring transactions, flows, and linkages that occur among or between an organisation and one or more organisations in its environment".

When it comes to the reasons for the formation of IORs, different studies mention various reasons for IOR formation. Also, they present different ways or systematics of naming and classifying these reasons. Schermerhorn (1975, p. 848) argues that "there would be agreement: (a) That there exists a set of important factors which may individually motivate organisations to involve themselves in interorganisational cooperative activities; and (b) that interorganisational cooperation is potentially associated with a set of 'costs' which may be incurred by participating organisations". Even though there is broad agreement that this general statement holds true for cooperative relationships, there is variation in the extent, nature, and classification of reasons presented for IOR formation.

Oliver (1990) provides a useful synthesis of literature on IOR formation, summarising reasons for IOR formation found in the literature. Further, she aims at predicting the formation of certain types of IORs. In line with the tenor of most studies in the relevant areas (e.g. Schermerhorn 1975, van de Ven 1976, Whetten 1981), she includes actual reasons for IOR formation, and conditions affecting IOR formation. Thus, she understands these conditions to act as a kind of moderator for the reasons for IOR formation. However, again, the exact understanding, terminology, and classification systems used for these two aspects differ between studies.

Schermerhorn (1975, p. 853) provides a more granular approach and differentiates between situations where (a) needs drive organisational decision makers to consider “interorganisational cooperation a possible action strategy”, (b) demand drives decision makers “to consider interorganisational cooperation a preferred action strategy”, and (c) there is support capacity that refers to “organisational, comparative and environmental conditions [that] are such that the implementation of interorganisational cooperation is possible once the decision to cooperate manifests itself among organisational decision makers”. Hence, (a) and (b) seem to consist of rather internal (to the firm) reasons for the formation of IORs, while (c) resemble the previously mentioned conditions moderating (a) and (b). Oliver (1990) summarises (a) and (b) under reasons for the formation of IORs or “critical contingencies for forming IORs”.

Oliver (1990) distinguishes between critical contingencies for forming IORs, and elaborates on the conditions under which these contingencies are particularly relevant for the type of IOR to be formed. Hence, the conditions act as a kind of moderator for the mechanism of action of the critical contingencies—the conditions can either increase or decrease the probability of relationship formation. According to Oliver (1990), there are six critical contingencies of relationship formation:

- **Necessity**: Relates to the fulfilment of legal or regulatory requirements that necessitate the establishment of IORs.
- **Asymmetry**: Relates to a “power approach” to IORs which implies that IORs are motivated by the option to have a certain power, influence, or control over another firm or its resources.
- **Reciprocity**: Pertains to the formation of IORs with the aim of following “common or mutually beneficial goals or interests” (Oliver 1990, p. 244). This can also imply that firms “base alliances on concrete strategic complementarities that they have to offer each other” (Gulati 1998, p. 301).
- **Efficiency**: Means that firms aim at an optimisation of their “internal input/ output ratio” of a firm (Oliver 1990, p. 245) when they form IORs. This idea is closely related with the transaction cost perspective (Coase 1937; Williamson 1981).
- **Stability**: Is also called “predictability”, which implies that firms form IORs when they face environmental uncertainty. Eisenhardt and Schoonhoven (1996, p. 137) go into a similar direction and find that “a high payoff for cooperation is particularly likely when firms are in vulnerable strategic positions”, for instance because they enter new markets or offer pioneering technology.
- **Legitimacy**: Refers to aspects such as reputation, image, and prestige that firms target when forming an IOR, which can then lead to enhanced legitimacy.

Now that I have provided an overview of the reasons for forming IORs, I would like to provide more detail on strategic alliances. Most strategic alliances, as defined in the next section, seem to be included in Oliver's definition[5] of IORs. Furthermore, strategic alliances are particularly interesting for studying industry consortia in the realm of telecommunications since technology partnering is usually understood as a form of strategic alliance (Hagedoorn 1993).

2.2.2 Strategic alliances

Strategic alliances are formed based on "strategic needs and social opportunities" (Eisenhardt and Schoonhoven 1996, p. 136). They are "voluntary arrangements between firms involving exchange, sharing, or co-development of products, technologies, or services" (Gulati 1998, p. 293). Usually, they consist of formally independent firms that are legally autonomous (Gulati et al. 2012). According to Gulati (1998), entering a strategic alliance is in itself a strategic action, and the formation of alliances is often related to strategic complementarities between firms. In line with the idea of the boundaries of the firm, as presented earlier, Dyer and Singh (1998, p. 662) argue that entering alliances may be beneficial because they "generate competitive advantages only as they move the relationship away from the attributes of market relationships".

A number of strategic alliances together can constitute a (social) network (Gulati 1998) because there is a set of actors (firms or other organisations), and one or more relations between the actors (Contractor et al. 2006). These emerging strategic networks[6] provide firms with relationships to numerous relevant peers, and can thus potentially provide a firm with "access to information, resources, markets, and technologies; with advantages from learning, scale, and scope economies" (Gulati et al. 2000, p. 203). This implies that a firm's advantages or disadvantages are oftentimes connected to the "network of relationships in which the firm is embedded" (Dyer and Singh 1998, p. 660).

Hagedoorn (1993) closely analyses one kind of strategic alliances, namely technology partnering. Technology partnering encompasses "interfirm cooperation for which a combined innovative activity or an exchange of technology is at least part of their agreement" (Hagedoorn 1993, p. 372). Further, he examines motives for entering into interfirm technology cooperation,

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5 To my knowledge, the available definitions of strategic alliances do usually not include a temporal definition (note that according to Oliver, IORs are "relatively enduring transactions"). Thus, very short-term alliances (e.g. for a specific event) could not qualify as IORs.

6 See Chapter 4 for a thorough analysis of firm networks resulting from consortia memberships.

and classifies these motives into three categories: 1) motives related to basic and applied research and some general characteristics of technological development, 2) motives related to concrete innovation processes, and 3) motives related to market access and search for opportunities. As we will see in the next sections, some consortia can be understood to pursue technology partnering. The idea that “companies cooperate in their efforts to innovate” (Hagedoorn 1993, p. 371) is a prevalent idea in some consortia, however, it is in many cases not the dominant reason for the initiation, establishment, and joining of industry consortia.

2.3 Literature review: Industry background

This second part of the literature review is concerned with the industry background that constitutes the backdrop for the establishment of industry consortia. After a general introduction to the standardisation procedures in mobile telecommunication, I will briefly outline the history of standard setting in this particular area. Afterwards, I will get to the phenomenon this paper is focussed on: the emergence of industry consortia.

2.3.1 Mobile telecommunication standardisation

In the context of mobile telecommunication standards, firms mainly coordinate with other firms via 3GPP. Even though most firms working on standards within 3GPP conduct their own R&D prior to (and during) the creation of standards, at some point firms are required to coordinate and hence cooperate to achieve compatibility. Standards or parts[7] thereof, laid down in technical specifications, can also be developed by a single firms, they are then also called “proprietary specifications”, and “the firm retains full control over the specifications and their future evolution” (International Telecommunication Union 2014, p. 17).

However, proprietary specifications can hamper compatibility when there are multiple ones existing in the market. Compatibility is the most relevant aspect when it comes to mobile telecommunication standards: “Compatibility standards assure the user that a component or subsystem can successfully be incorporated, and be ‘inter-operable’ with other constituents of a larger system of closely specified inputs and outputs” (David and Steinmueller 1994, p. 218).

[7] For example, 3GPP standards are usually divided into releases, which are again divided into stages. The work results are laid down in technical specifications (Third Generation Partnership Project (3GPP) 2020b.

Hence, much of the groundwork on standards (i.e. extensive R&D) is done within firms[8], but the work on the definition of standards is done within the working and technical specification groups of 3GPP, together with other firms. Thus, the work happening in 3GPP is decisive regarding the exact parameters of mobile telecommunication standards. Bar and Leiponen (2014, p. 1) also stress that "in many network industries, there is a strong cooperative element to standardisation".

As stated in the introduction, 3GPP is basically a partnership of regional SSOs called Organisational Partners. It is them who "convert the Technical Specifications and Technical Reports approved by the Partnership Project into national/regional deliverables" (see Article 47 of the Working Procedures of the Third Generation Partnership Project (3GPP) 2020a). This means that even though telecommunication standards are *made* within 3GPP, 3GPP itself is technically not an SSO itself since the regional SSOs *set* the standards. SSOs "establish rules governing rights to participate in the standards-development process, consensus-based procedures for decision-making, the open availability of standards' specifications, and often also policies on patents' interaction with standards" (International Telecommunication Union 2014, p. 19).

2.3.2 History of standard setting organisations in telecommunications

Setting standards in telecommunication is mostly in the responsibility of SSOs that are defined as "those that are recognised as such by public authorities (for example, in Europe, Directive 98/34/EC designates CEN, CENELEC, and ETSI to be recognised regional standards bodies)" (Bekkers et al. 2011, p. 1002).

In Europe, telecommunication standardisation efforts began with the European Conference of Postal and Telecommunications Administrations (CEPT)[9], founded in 1959. In the beginning, CEPT was mostly steered by postal and telecommunications administrations that were often monopolies in their respective countries. CEPT played a major part in the initiation of the Global System for Mobile Communications (GSM) (Funk and Methe 2001), the second generation of mobile telecommunication standards (2G). But the final standard was then created in ETSI, which started its operations in March 1988 (Besen 1990).

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[8] In some cases, the groundwork may also be done cooperatively. Examples include 5G trials where firms with different core competencies collaborate to test certain solutions (See https://www.computerweekly.com/news/252482697/Singapore-to-test-5G-in-industry-40-trial for an example, retrieved on 20/05/2020).

[9] See https://www.cept.org/cept/background (retrieved on 1/04/2020).

The European Commission (EC) initiated the establishment of ETSI in order to achieve European harmonisation: “EC saw the need for a new organisation, both to accelerate the standardisation process and to promote a greater degree of harmonisation among the various European telecommunications systems” (Besen 1990, p. 521). The differences between ETSI and CEPT are also related to the composition of members, and the openness of membership. While CEPT was dominated by telecommunications administrations and public network operators, ETSI also included manufacturers of telecommunications equipment as well as private service providers and users. Naturally, this also brought in new interests and goals into standardisation (Besen 1990).

After GSM, the firms dominating the European telecommunication industry sought to retain their position by creating a third generation of mobile telecommunication standards (3G) based on GSM. But since 3G was set out to be a global standard, competition between different technological solutions from different countries and regions arose. NTT Docomo from Japan had a promising technology in place to base 3G upon, namely Wideband Code Division Multiple Access (W-CDMA) (Funk and Methe 2001), also known as the Universal Mobile Telecommunications System (UMTS). CDMA2000 was a serious competitor[10], and was the dominant solution (in terms of subscribers) until July/August 2004 (Saugstrup and Henten 2006). But Nokia and Ericsson from Europe managed to persuade NTT Docomo of basing W-CDMA upon GSM (Funk and Methe 2001), which then lead to the European industry supporting the W-CDMA solution. In addition to Ericsson and Nokia, European (public) telecom service providers and telecom regulators were supportive of the European effort to make 3G a standard dominated by the European telecommunication industry: “European performance in the field of mobile communications has been relatively favourable. [...] one important reason for this favourable position lies in the decisive role of the development of technical standards, which was a joint effort between (public) telecoms service providers, telecoms regulators and private firms.” (Dalum et al. 1999, p. 123).

3G also lead to a fundamental change in the standardisation landscape: UMTS was “no longer a European project” (Leiponen 2008, p. 1905), but a global one. Hence, 3GPP was initiated as a partnership between the regional SSOs, called Organisational Partners, including ETSI. These regional SSOs are formal SSOs since they “are recognised as such by public authorities (for example, in Europe, Directive 98/34/EC designates CEN, CENELEC, and ETSI to be recognised regional standards bodies)” (Bekkers et al. 2011, p. 1002). As previously

[10] Patent rights and licenses were an important factor as to why some firms favoured one 3G solution over the other. Ericsson promoted W-CDMA, and Qualcomm CDMA2000. (Saugstrup and Henten 2006)

mentioned, 3GPP (or more precisely its members) is still in charge of creating mobile telecommunication standards nowadays. The fourth generation, also called Long Term Evolution (LTE), came out of 3GPP, and members of 3GPP are currently working on the fifth generation (5G). At this point, 3GPP consists of seven[11] regional SSOs.

2.3.3 Emergence of industry consortia in telecommunications

As stressed in the introduction of this paper, firms have been forming yet new organisations next to 3GPP and the established SSOs in the industry. At this point, there is not much common ground on the understanding and definition of industry consortia, and how they differ from other standards-related organisations. Hence, in the following, I will lay out the definitions developed within Chapter 3 that I will use for the remainder of this paper.

Apart from formal SSOs, quasi-formal SSOs are of high relevance in the industry. As previously defined, formal standard setting organisations (SSOs) are "those that are recognised as such by public authorities (for example, in Europe, Directive 98/34/EC designates CEN, CENELEC, and ETSI to be recognised regional standards bodies)" (Bekkers et al. 2011, p. 1002). Quasi-formal SSOs are similar to formal SSOs "in most respects other than not being formally recognized by national authorities" (International Telecommunication Union 2014, p. 21). They have usually established themselves in the industry based on the success and widespread use of their standards (Simcoe 2014). Examples of quasi-formal SSOs include the Institute of Electrical and Electronics Engineers (IEEE), the Internet Engineering Task Force (IETF), and the World Wide Web Consortium (W3C).

Next to formal and quasi-formal SSOs, firms have been forming industry consortia and other non-technical interest groups (that can sometimes be relevant to standards). I follow the definition of industry consortia developed in Chapter 3: *"In the context of standardisation in the telecommunications industry, consortia are collaborative alliances of organisations which offer a forum for the discussion, development, coordination of development, testing, certification, and/or promotion of technologies or technology systems."*

Within this definition, consortia can do several things. They can develop technologies, they can contribute these to standardisation by formal SSOs, or publish standards themselves, in which case they act as (non-formal[12]) SSOs. They can contribute to standards or not work on

[11] See https://www.etsi.org/committee/1418-3gpp for most recent information (retrieved on 25/05/2020).

[12] They are different from formal SSOs because, as per our definition, they are not formally recognised by any national or supra-national authority; nor can they be acknowledged as quasi-formal SSOs (similar to formal SSOs but without the recognition).

standards at all, yet still be very relevant for technical evolution in the industry. This definition of consortia only includes organisations (to some extent) involved with technical aspects, so it excludes organisations only occupied with non-technical[13] issues. Consortia are not formally recognised by any national or supra-national authority. (see Chapter 3)

Even though there is already an extensive network of existing (quasi-)formal SSOs, industry consortia have been emerging. Hawkins (1999, p. 159) notes that “beginning in the late 1980s, a substantial number of firms in the telecommunication, computer, consumer electronics and media industries began to become involved in an intriguing form of inter-firm collaboration”. The question is why firms even feel the need to form these industry consortia. Scholarly contributions do not necessarily agree on the nature of the relationship between consortia and the making of standards. Many contributions emphasise the phenomenon of pre-standardisation, which usually gives consortia a rather complementary[14] character. Pre-standardisation can refer to the preparation of work within consortia with the purpose of bringing it into formal standardisation, or also to the alignment of firm positions with the purpose of jointly pushing certain aspects within (quasi-)formal SSOs. This preparatory work does not substitute work being done in formal standardisation. So some consortia “sponsor and develop technologies for standardisation” (Pohlmann 2014, p. 0). Delcamp and Leiponen (2014, p. 36) claim that consortia help “accelerate the [standardisation] process”. In a similar vein, Hawkins (1999) finds that consortia can support the efficiency of formal standardisation processes. Hence, since consortia can be an instrument of coordinating firm efforts prior to standardisation (Delcamp and Leiponen 2014; Leiponen 2008), they are assumed to enhance the influence of consortia member firms in formal standardisation. Blind and Gauch (2005, p. 38) also remark that they “know from several formal standards that they have a predecessor in the consortia world”, which implies that (almost) complete standards have been prepared within consortia and then handed over to formal SSOs. However, more recent contributions tend to recognise that consortia activities can go beyond pre-standardisation (Baron et al. 2014; Lerner and Tirole 2006; Pohlmann 2014). For instance, Pohlmann (2014, p. 1) identifies consortia that “produce widely adopted and important standard solutions“. Thus, consortia could in theory

[13] Non-technical interest groups focus on the non-technical rules of the industry (for instance relating to intellectual property). Thus our definition of consortia does not include them.

[14] In economics, one usually refers to a complementary good if it enhances the value of another good because the two goods are usually consumed together. This means that the consumption of additional units of one good imply more consumption of the other. In this context, a complement is rather understood as “something that fills up, completes, or makes better or perfect”, which is an alternative definition provided by the Merriam-Webster dictionary.

also substitute (quasi-)formal SSOs because standards could just as well be made within consortia. With their idea of forum shopping, Lerner and Tirole (2006) go in a very similar direction. Their forum shopping model works on the assumption that firms can choose between different organisations to validate/certify their technology, ranging from formal SSOs to what they call “special interest groups” (which seem to bare resemblance to industry consortia). On the other hand, Hawkins (1999, p. 160) claims that “most consortia explicitly disassociate themselves with 'standards-making' as such”.

Figure 2-1 illustrates, in a simplified way, how 3GPP, its Organisational Partners (regional SSOs), and industry consortia can be inter-related. Obviously, there are more standards-related organisations that could be depicted here. But, as previously mentioned, 3GPP is the organisation where technical specifications for mobile telecommunication standards are made. Thus, 3GPP is of particular interest when examining industry consortia and their role in the industry. In the figure, there are three exemplary firms that are involved in 3GPP, its Organisational Partners, and/or some of the three exemplary consortia. I addition, there can be institutionalised relationships between consortia and 3GPP and its Organisational Partners. Even though the figure shows a rather simplistic image of the standardisation landscape including industry consortia, it is apparent that firms, (quasi-)formal SSOs, and industry consortia are intertwined in a close-knit and complex standardisation network. Again, this poses the question why firms feel the need to initiate and establish yet additional standards-related organisations such as consortia, and which role these consortia play in the standardisation environment.

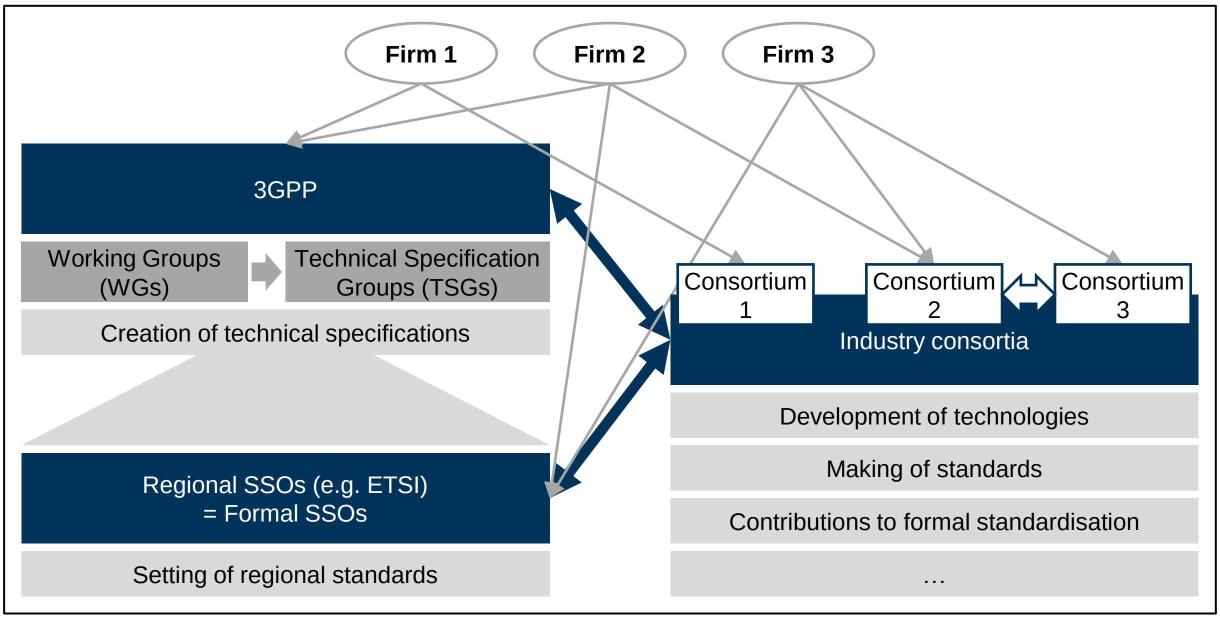

Figure 2-1: Schematic presentation of relationships between 3GPP, industry consortia, and firms

In this paper, I aim to empirically examine and analyse firms’ reasons for joining, initiating, and establishing industry consortia, and include conditions under which they are likely to be formed. As previously laid out, this topic has already been discussed in the literature to a certain extent: We have some knowledge about why firms form IORs and strategic alliances, and why they may adapt their network under certain circumstances. On the consortia level, there is literature looking at the scope of consortia and their position in the standardisation sphere. However, I am not aware of contributions specifically looking at why and when firms feel the need to add new consortia to the mix, especially when they are already connected to many relevant players through existing (quasi-)formal SSOs. This exactly what I aim to do: My empirical analysis as well as existing contributions will build the basis for an elaboration on the boundaries of SSOs—that is, when and why firms feel the need for industry consortia even though there is already and extensive landscape of (quasi-)formal SSOs.

2.4 Methodology

This research project is set out to be an exploratory project, which means that there is no ex-ante construction of hypotheses based on theoretical considerations. Hence, I use a case study approach where I inductively develop theory based on the cases. (Eisenhardt and Graebner 2007, p. 27). I used semi-structured interviews to collect qualitative data, and each organisational affiliation of the interviewees serves as one case. Thus, I conducted a multiple case study, following a replication logic (Yin 2003). This means that I select each case so that “it either a) predicts similar results (a literal replication) or b) predicts contrasting results but for predictable reasons (a theoretical replication)” (Yin 2003, p. 47).

In line with the established guidelines on case study research where the goal is to develop theory rather than testing it, I use theoretical rather than random sampling (see Eisenhardt 1989). This means that I have selected and approached interviewees based on their experience and role in the industry, so that they are “selected because they are particularly suitable for illuminating and extending relationships and logic among constructs“ (Eisenhardt and Graebner 2007, p. 25). As a starting point to identify interviewees, I looked into 3GPP meeting participation lists, and lists of 3GPP chairpersons, and approached personal contacts in the telecommunications industry. In particular, my goal was to get in touch with interviewees with substantial experience in the telecommunications industry, ideally in standardisation. In total, I talked to 13 interviewees within twelve interviews, amounting to a total interview time of approximately twelve hours. Interviewees include chairpersons of major formal SSOs, representatives of industry consortia, managers at major vendors and network operators, the founders of a telecommunication consultancy, as well as representatives from small firms and start-ups in the industry (see Table 2-1 for overview). All of the organisations interviewees are affiliated with have headquarters in Europe. Interviews took place between 2016 and 2017, five of them personally, and seven via telephone.

The semi-structured interviews were conducted based on interview guidelines, including a standard set of questions for all interviewees, but adapted to the individual expertise of the interviewee(s). I based the initial set of questions upon literature on the topics of standards and industry consortia in telecommunications, as well as information from reports and white papers. The interview guidelines were iteratively adapted during the course of the interviews in order to take into account past best practices as well as emerging dominant topics.

All interviews were recorded and transcribed, and I conducted the data analysis using the interview transcripts. For data analysis, I roughly followed the Qualitative Content Analysis (QCA) and inductive category development approach as described by Mayring (2000, 2014). This means that categories are "coming from the material itself, not from theoretical considerations" (Mayring 2014, p. 80). The coding scheme was adapted iteratively during the process. Initially, in order to develop a first draft, I did the coding of five interviews in 2017. The analysis of these interviews provided me with a rough idea of predominant concepts mentioned. Then, I did a review of the coding scheme after working on additional transcripts, and considering preliminary results from other projects (see Chapter 3) in early 2018. This step allowed for the construction of a final coding scheme in 2019 (see Appendix A, Figure 6-1). Obviously, as the telecommunication industry is subject to continuous development and change, especially when it comes to technological advances and new standards. However, the general role of industry consortia in telecommunication standardisation does not seem to have changed much, since the institutional set-up has remained more or less the same. Naturally, due to technological change, single consortia gain or lose in importance as technologies gain or lose in importance. But 3GPP is still the central organisation in the making of mobile telecommunication standards.

Following Eisenhardt (1989), for the analysis of the interview content, I started with a within-case analysis, that is, I carefully identified and examined relevant quotes within each interview. Thus, "each case serves as a distinct experiment that stands on its own as an analytic unit" (Eisenhardt and Graebner 2007, p. 25). Then, I followed up with a cross-case analysis, looking for aspects that kept coming up in multiple interviews, or were particularly emphasised by interviewees. Finally, building upon the results from the analysis of interview data, in connection with academic literature, I built theoretical constructs based on analysis of interview data.

2.5 Results

This section will describe the results obtained from the semi-structured interviews. The aim of the interviews was to gain insights into the phenomenon of industry consortia, by means of understanding and exploring its determinants. That is, interviewees were openly asked to name and elaborate on aspects they deemed particularly relevant. In addition, in some cases, I specifically inquired about aspects that appeared to be relevant based on previous interviews, information from the field (e.g. white papers, reports, short conversations with experts during industry events), as well as the academic literature.

Because interviewees have been assured they will remain anonymous, I allocate a code name to each of them (see Table 2-1). This code name will be used in the text whenever a quote from the relevant interview is mentioned or paraphrased. The table also provides information on the interviewees' positions, which allows for understanding quotes in the context of the expertise of the interviewee in question.

Table 2-1: List[15] of interviewees with their allocated code names

Interviewee position (at the time of interview)	Firm category	Case / Code name	Interview date and duration
Vice President Business Development	Vendor	*Xi*	*11-03-2016; 1:14 h* *21-09-2016; 00:49 h*
Standardisation Manager, engineer (retired)	Vendor	*Omicron*	*19-04-2016; 1:19 h (jointly with Pi)*
Secretary General	Quasi-formal SSO	*Pi*	*19-04-2016; 1:19 h (jointly with Omicron)*
Technology Management	Enterprise communication systems	*Koppa*	*20-04-2016; 1:12 h*
CTO and Founder	IoT Start-up	*Rho*	*14-07-2016; 00:59 h*
Standardisation Manager / Chairman	Vendor / Formal SSO	*Sigma*	*28-09-2016; 1:41 h*
Standardisation Manager / Chairman	Vendor / Formal SSO	*Tau*	*04-10-2016; 1:46 h*
Member of Secretariat	Formal SSO	*Upsilon*	*22-11-2016; 1:06 h*
Vice President Research/Innovation	Operator	*Phi*	*14-03-2017; 00:42 h*
Programme Management	Industry consortium	*Chi*	*17-03-2017; 00:24 h*
Managing Director	SME providing test/ measurement systems	*Psi*	*27-03-2017; 00:55 h*
Founder, Board Member	Telecommunications consultancy	*Omega*	*19-09-2017; 1:00 h (jointly with Sampii)*
Founder, Board Member	Telecommunications consultancy	*Sampi*	*19-09-2017; 1:00 h (jointly with Omega)*

Based on the interview transcripts, I was able to identify five overarching themes (see Table 2-2 for an overview), all of which related to the determinants of the phenomenon of industry consortia. Since many of the five themes were mentioned repeatedly by most interviewees, I will provide a narrative on each of these themes instead of describing each interview in detail.

[15] They are ordered by organisational affiliations: 1) Vendors, 2) Operators, 3) (Quasi-)formal SSOs and consortia, 4) Others

All of these themes generate a backdrop for analysing the boundaries of SSOs and the emergence of consortia.

Table 2-2: Overview over themes related to the determinants of the phenomenon of industry, as obtained from interviews

Theme	Key aspects
(1) Evolution of the telecommunication industry and demands on standardisation	• Technological developments regarding 5G and the IoT • Relevance of non-ICT firms in standardisation • Novel and versatile use cases of telecommunication standards • Increasing role of software
(2) Motivations and limitations for engaging in formal SSOs	• Long life cycles of telecommunication standards • Revenue stemming from IP brought into standards • High investments in R&D related to standards • Strict rules of formal SSOs • Political and strategic aspects of involvement in formal standardisation
(3) Motivations and limitations for joining existing and establishing new industry consortia	• Pace and efficiency of work in consortia relative to formal SSOs • Political resistance in formal SSOs • Rigidity of SSO rules and flexibility regarding rules and processes of consortia • Facilitation of formal standardisation by preparatory work done in consortia • Supplementary role of consortia
(4) Set-up of new consortia and their structures and rules	• Complex and lengthy process of setting up new consortia and deciding on modus operandi • Flexibility with structures and rules • Opportunities arising from beneficial design of consortia structures and rules • Potentially cumbersome and lengthy process of setting up consortia
(5) Relationship between consortia and (quasi-) formal SSOs	• Various possible ways for consortia to collaborate with or influence the work of formal SSPs • Possibility of formalised relationships between formal SSOs and consortia • Formal SSOs adopting or referring to consortia work • Consortia preparing solutions for inclusion in formal standards • Single firms bringing technologies from consortia into formal SSOs

2.5.1 Evolution of the telecommunication industry and demands on standardisation

One topic frequently discussed by the interviewees is current technological developments in the industry, especially in the context of 5G and the IoT. The key developments, as discussed by the interviewees, will be laid out in the following. Furthermore, as stressed earlier, these developments are of particular relevance to the standardisation landscape and its evolution. Hence, I will also put emphasis on this relationship.

The first challenge stems from the growing involvement of several firms outside of ICT, the so-called verticals. 5G, being an enabler of extensive IoT use cases, affects various industries—for instance, by being used in industrial campus networks[16] or providing the infrastructure for vehicle-to-everything (V2X)[17] autonomous driving. Many IoT use cases can already be realised or supported by LTE technologies, but 5G is especially geared and marketed towards such applications. Xi emphasised that 5G does “not sort of really introduce a new interface technology. It is more about meeting all those diverse requirements from different industries”. This highlights that 5G is designed to affect a multitude of industries and therefore attracts attention and involvement from a diverse set of actors.

Now that firms from various industries have a heightened interest in the performance parameters of 5G, standardisation is faced with novel challenges. With many firms from these industries “playing a much bigger role” (Pi[18]), established structures and ways of working/collaborating/innovating in the telecommunication industry are increasingly questioned. One challenge is related to established conventions and implicit knowledge within industries. Phi (from established operator) made clear that in telecommunications, there has been extensive collaboration between industry players during the last 20 years, for instance due to standardisation and roaming. He stressed that, in contrast to telecommunication firms, “players in automotive never saw this necessity [to collaborate] in the past […] this is changing, due to autonomous driving et cetera, but this is rather new to them”. Sigma summed up the challenge: “This is the thing with 5G and IoT… there are these different industry branches with different systems… and yet somehow, we have to get together”.

The second challenge related to the involvement of various industries is the emergence of new (technical) demands regarding telecommunication networks. Even though some of the

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[16] See https://www.telekom.com/en/company/details/5g-technology-in-campus-networks-556692 (retrieved on 07/04/2020) for an example.

[17] See https://www.ericsson.com/en/news/2019/9/5g-and-v2x (retrieved on 07/04/2020).

[18] Some interviews have been conducted in German, and relevant quotes have been translated.

demands coincide with the “traditional” ones (such as data rates, latency, and reliability), some of them are more pronounced (e.g. extremely short latencies, up to one millisecond), or even entirely different. In terms of more pronounced demands, the amount of data traffic is one concern, since “a lot of vehicles will be talking to each other, talking to roads, to traffic lights… and suddenly, you have millions of additional participants that produce data traffic” (Omega). When it comes to new and diverse demands, many interviewees feel that telecommunication standards need to be fit for many purposes: “We need a solution for automotive, maybe one for manufacturing, we also need something for the health industry. Also, we still need something for Mobile Broadband, and these things could definitely be different. This means that we have to be more flexible in the way we produce mobile networks.” (Phi)

A third challenge mentioned within the realm of technological developments is the increasingly influential role of software, which relates to an enhanced role of Open Source Software (OSS) and associated organisations. This phenomenon challenges the way mobile networks are composed, and also more drastically the business model of many established players in the industry. Tau emphasised that there has been a pronounced movement from hardware to software within the last two decades that is becoming “more pressing, which means one does not really sell boxes anymore”. Phi also explained that the traditional switching technology is increasingly realised as virtual software, so that there is a “de-coupling of hardware and software”. This de-coupling implies that software can be implemented on independent, possibly generic, hardware.

Unsurprisingly, the previously described technological developments have an effect on the way standards are made and SSOs, especially 3GPP, operate. More, and also more diverse, firms are somehow affected by telecommunication standards. Many interviewees are under the impression that 3GPP is too large and working too slowly, Upsilon even described 3GPP as a “machine that is overloaded”. Xi remembers that “maybe when 3GPP was formed, it was in 1999, I think 150 companies were sort of engaged”, but currently (2016) “it is more than 700[19] I think”.

However, in spite of these issues, 3GPP is still perceived to be fit for the development of standards to come. Chi recognised some positive changes within 3GPP, he thinks it “has become significantly more efficient and faster than a few years ago”. Xi also mentioned the importance of the unique ecosystem around 3GPP: “If you look at the commitment that you have, the ecosystem that we have built around 3GPP… it doesn’t really make sense to modify that.”

[19] As of May 2020, 3GPP has 698 members (firms and other organisations such as research institutes); see https://webapp.etsi.org/3gppmembership/QueryForm.asp for full list (retrieved on 20/05/2020).

2.5.2 Motivations and limitations for engaging in formal SSOs

When discussing and evaluating the rules and processes of standardisation, some interviewees take into account life cycle considerations, heavily impacting future revenue, to be relevant. Rho said that "it takes ten years to define a technology, standardise it and then it is ten years running". The creation of standards follows a clearly defined "waterfall" process which implies "we have the requirements [first], then comes architecture, and then comes the protocol" (Tau). These relatively long time spans affect firms' behaviour in standardisation because getting their technologies in the standard may lead to long-term benefits: "A company has vested interests in a solution, it's going to push as hard as they can to get it adopted because that's where their revenue is going to come from" (Upsilon). For some firms, one integral part of their revenue is licensing fees from intellectual property brought into standards.

But it is not just revenue considerations that are relevant for the behaviour of firms in standardisation. For some firms, it is also crucial to anticipate relatively early which technological direction a standard will take because they "know when the standard is fixed, it's gonna be five years later before we have mass volume products […] so you have to sort of […] know what is happening in five years" (Rho). This is of particular relevance if firms play an integral part in providing the basic infrastructure (vendors) of components thereof (e.g. chips, modules). Since these products build the backbone of standards, they need to be more or less ready to be deployed once a standard is fixed: "As an infrastructure provider, I think they [Nokia, Ericsson etc.] have to be on the leading edge of the standards because first, the base station are built for the phones" (Rho). Sigma also stressed that firms have to conduct substantial R&D prior to entering standardisation with a certain technology because "when one is ready to really begin with a standard, in the sense of adopting a work item, then you usually have a really clear view on what is feasible […] you do not know all the details, but you know about general technical feasibility".

Even though many interviewees recognised that firms have some freedom to manoeuvre when it comes to standards making, they generally find that rules within formal SSOs are relatively strict. Upsilon explained: "Outside of the room, lots of negotiations may take place. Once you come into the committee room, very strict rules apply as to […] how the Chairman conducts the meeting, how the members must behave. Otherwise you are just going to end up in court, that's for sure." This means that firms tend to come together and discuss standards-related aspects outside of formal SSOs. But still, Xi generally considers the existing (formal) standard setting mechanisms to be "a very good system", and he appreciates that "it is not sort of trying to give an advantage for certain companies like you find other times in organisations that are set up".

In spite of the fact most interviewees still find 3GPP and the existing standard setting mechanisms to be suitable and working well, some of them mention concerns. Most of them relate to political and strategic considerations and behaviour in standardisation. Interestingly, these concerns do not seem to substantially affect the interviewees' attitude towards 3GPP and the way standardisation currently works. Rather, the problems mentioned are perceived to be an inevitable by-product of standardisation.

Upsilon claimed that "it is sort of naive to think that we always take the best solution, of course we don't", and that whenever "a company has vested interests in a solution, it's going to push as hard as they can to get it adopted because that's where their revenue is going to come from". In a similar vein, Psi said that many things also boil down to political aspects, for instance that firms "cannot expect to get everything into standards one-to-one" because other firms may oppose certain technologies or parts thereof for non-technical reasons. However, even though firms may initially not want to endorse a certain solution, they need to think about whether "it is is better off having that work in the club [SSO]; so at least I have some control and access to it" (Upsilon).

2.5.3 Motivations and limitations for joining existing and establishing new industry consortia

The two previous sections already point out that if suggested work is not accepted within formal SSOs, firms may take it somewhere else. In many cases, this "somewhere else" is an industry consortium. Chapter 3 provides an overview over objectives that firms may pursue within consortia. Table 2-3 provides a summary of these objectives. In contrast[20], this section focusses on why firms feel the need to move standards-related work outside of (formal) SSOs. This means that it is more about motivations and circumstances that may make firms consider doing work in consortia. I will divide them into two groups, one that includes aspects strongly related to perceived shortcomings of existing (formal) SSOs, and one that includes other aspects.

[20] Still, there may be some overlaps between this chapter and Chapter 3.

Table 2-3: Overview over objectives of firms within industry consortia

Objective	Summary
Add-on technology development	Development of technologies, which act as an add-on to 3GPP technology (e.g. applications), within consortia.
Early technology development and circumventing political interest	Driving of novel ideas and technologies within consortia, for instance by preparing proof of concepts and trials. Then, these technologies can be brought into 3GPP.
Promote group interests	Promotion of the (often commercial) interests of a certain group of firms, usually not directly related to technology development, within consortia.
Speed up the standards development process	Using consortia to help accelerate standards development, both full standards and parts of them.
Anticipate key technological developments	Monitoring the industry landscape and anticipating major technological developments with the help of connections to major players in the market through consortia.

The first motivation for joining or establishing industry consortia is related to the speediness and efficiency of standardisation. Many interviewees explained that the making of standards in formal SSOs, for instance 3GPP, can be relatively slow, which is due to the formal processes and the sheer size of the organisations: In some cases, “given the full membership in 3GPP, it would be quite cumbersome and take a long time to get the work items and the specifications developed there” (Xi). Omicron said that moving outside of established SSOs makes sense if “the old structures are too slow” and if the organisations “cannot provide the right infrastructure”. Pi also agrees that smaller SSOs and industry consortia make sense when “standardisation should be done by a very small group and very fast”.

Besides, a frequently mentioned issue of established (formal) SSOs is political resistance coming from firms involved. This means that firms may oppose or block certain ideas, solutions, and technologies due to considerations rather unrelated to their actual technical performance, but rather because “they don’t like it” (Upsilon) for other reasons. For instance, firms could find new ideas too “radical” (Upsilon) or too “disruptive” (Tau). Usually, this kind of behaviour happens because novel solutions may question the business model or technological direction that a firm has been focussing on. Hence, if firms “foresee that it will be cumbersome to drive the work in 3GPP due to political resistance” or if they “realise that [they are not] getting any success out of driving [it] in 3GPP”, they will rather drive it elsewhere. This lack of success does not only stem from single firms blocking work, but also from the structure and rules of formal SSOs: New work “would have to be approved by the board because it’s new and novel work”, and it may not “fit within an existing technical body”. Hence, “you would be creating a new technical committee [and] that would have to go through the board which takes time, it’s risky, people might try to block it if they don't like it" (Upsilon). One example that was mentioned by two interviewees is MulteFire[21]. MulteFire is perceived to be a "hot political potato" (Xi) because it competes with Wi-Fi that constitutes key business for many industry players. Sigma explained that firms involved in MulteFire knew that if they try to bring this technology into 3GPP, "operators will for sure try to block it or thwart it". Hence, they decided to form a consortium.

As previously pointed out, rules and processes of formal SSOs are perceived to be relatively restrictive (one reason being that they are significantly constrained by competition law). These rules and processes are usually rigid, and member firms usually have very little room when it comes to adapting them. Most interviewees highly rate this restrictiveness because they think it makes the process fair and transparent. On the other hand, some firms seem to want "to have some ability to change the rules so that they suited the way they want to work", which leads to the creation of industry consortia (Upsilon). Upsilon also added that for creating industry consortia "the motive is always that the creators have the control; they set the rules of engagement".

In contrast to the three previously mentioned aspects, firms may join and establish industry consortia due to considerations (relatively) independent of the characteristics of established SSOs. Rather, these considerations relate to current technological developments or to opportunities they would not get otherwise.

Firstly, as emphasised many times before, one important characteristic of 5G and the IoT is the involvement of various industries (verticals). Since the players involved in telecommunication standardisation may not be aware of or fully understand the verticals' demands, Sigma pointed out that "it is essential to include the demands coming from these verticals in the early stages; that we at least manage to get them to articulate their demands clearly, and get them to participate". On the other hand, "if you were sort of requiring all those other industries to take part in 3GPP, to represent and drive their specific requirements, then 3GPP would explode" because "it would be too many members of companies and [...] there would be too many differing and competing interests" (Xi). Also, Phi reasoned that historically, firms from other industries, for example the automotive industry, "are not used to this kind of collaboration". Phi added that "getting to an agreement between four to five telco operators is relatively fast, but try to reach an agreement between Toyota, BMW, and Renault or something". Furthermore, interviewees think that communication between telecommunication and automotive firms can

[21] LTE and 5G operating in unlicensed or shared radio spectrum (see https://www.multefire.org/about/; retrieved on 8/04/2020).

be tricky because people come from different professional background and with different technological expertise: “It can of course be frustrating for people […] If I think of cars and then suddenly I have to talk to somebody who deploys VPNs or sets up private networks somewhere. Then, two people talk about the same technology, but with entirely different perspectives.” (Tau). Hence, initial discussions about expectations and demands are often conducted within industry consortia, “new organisations that are sort of neutral set-up between telecom companies and new industries, like the automotive industry for example” (Xi). These organisations then fulfil “the role to handshake the requirements between automotive industry and the telecom industry”, and the “telecom industry [takes] the responsibility to feed those [requirements] back into 3GPP” (Xi). These practices tend to be welcomed by practitioners because standardisation may be facilitated.

Another aspect closely related to technological developments in the industry, particularly the increasing role of software in standards, is the supplementary role of consortia. That is, firms may work on applications that are “on top of the 3GPP access network architecture” (Xi). An example includes Network Function Virtualization (NFV). Phi also mentions the Telecom Infra Project that has been initiated by Facebook, but he does not believe that it directly affects formal standardisation. Rather, he thinks that “it is a complement to standardisation because it is for example about standardising hardware for data centres”.

Firms may also want to form consortia in order to prepare for standardisation. However, it differs insofar as preparation is not meant in a technical sense—that is, firms mostly do not work on technologies to bring into standardisation, but rather try to agree on other issues, for example needs and requirements related to standards. These may then be fed back into standardisation. Tau explained that “sometimes, operators may want to be on their own because they need to do some self-discovery, for example Deutsche Telekom, Vodafone, and O2”. He further clarified that it is clear that “they have some common interests” so in some cases, when they feel the need to discuss a certain issue, “first, they get together and agree that ‘in standardisation in 3GPP, […] we will not fight each other when it comes to this topic”. Tau also perceived this practice to be helpful for accelerating work in 3GPP. In this context, Chi brought up the example of the Next Generation Mobile Networks Alliance (NGMN) that was founded because “the network operators, meaning Deutsche Telekom, Orange, E-Plus, and others said that ‘what happened in UMTS standardisation, that the needs of network operators were basically not considered, should not happen again’”. Hence, industry consortia can provide fora for like-minded firms to prepare for standardisation. However, some interviewees are also critical of this practice. Consortia representing a certain group of firms may invite and specifically ask other firms to contribute with their knowledge, but then, their votes may not be taken into account when it comes to actual decisions. Tau mentioned GSMA as one such example.

2.5.4 Set-up of new consortia and their structures and rules

The first aspects to be considered when looking at the process of setting up new consortia is the initiation of this process. Consortia result from firms coming together with a shared interest or agenda. If firms aim to start a piece of technical work, they usually ask themselves whether there “are […] any existing forums where you can try the work?” (Xi). Xi added that existing fora “can be used as a vehicle to drive a certain topic, and if there is not, then you need to set up a new forum”. In some cases, opportunities to establish a new consortium “come along the way” when firms with the “same type of interests” come together (Xi). Other interviewees have experienced the initiation of a consortium to mostly come from firms with a proprietary interest in a certain technology that they wish to promote. Sampi thinks that “there are consortia that maybe have a good approach or good technologies, and they try to market these technologies on a larger scale”, and Omega stressed that “mostly, one firm, which has developed a chip or realised a certain technology, is in the lead”, and “around this firm, other firms accumulate that market this technology”. This implies that consortia could be (mis)used to promote a certain proprietary technology, which makes the industry resemble a “shark tank” at times (Sampi). In a similar vein, Koppa explained that “interest groups are forming, maybe around a small pool of firms; and initially, they may not understand themselves as a standards group”. And according to Koppa, these interest groups may at some point lead to an industry consortium.

Once a consortium is initiated, the general set-up (basic rules and processes) and the membership needs to be planned. Deciding on the set-up can take quite a bit of time. Upsilon said if you form a consortium, “you’ll spend the first three to six months discussing the rules and what those rules should be”. In the case of Bluetooth, Upsilon remembered that in “the first year, they [members] did no technical work, they just spent a whole year trying to agree what the rules would be”. However, consortia do not necessarily need to be established independently, they can also be established as ETSI Industry Specification Groups (ISGs).This means that they are hosted and supported by ETSI. Regarding these ISGs, Xi commented: “I mean, one advantage of using ETSI is of course, you have a ready-made-standard-type of membership agreement. You have to follow the ETSI IPR rules, you can get secretarial support, you have working procedures, you have the web platform. So, it is much easier to start a new initiative.” Upsilon further elaborated on the framework of ETSI ISGs: “You can define your own rules within certain limits. So you can decide on the voting rules for example, you don’t have to follow the traditional ETSI rules. You can propose another way of voting. You can set up your own internal structure. The only rules that you really can’t change are those of intellectual property control where you really use the ETSI IPR policy” (Upsilon). In terms of planning of the membership, most interviewees agreed that it is most important to have the relevant groups of players represented in the consortium. Sigma talked about how the membership in ETSI MEC (Multi-access Edge Computing) came to be: “We said that we should have at least two of the three significant groups. Then, we said that actually, we need the IT players, that’s why we talked to Intel and IBM. And of course, we need the operators. And then, we started. Currently, we are around 70 member firms, after just about two years.” Membership composition also seems to be relevant when it comes to the outside impression of consortia. Tau explained that “when you see that there are two big players in there and the third one is missing, that looks weird to outsiders”. He added that when there is a big player in there and “two other no-names”, it is clear to outsiders that the big player is trying to push its own ideas.

Even though agreeing on the rules of a consortium can be a cumbersome process, it is also an opportunity for firms to adapt the rules to their objectives: “That’s the whole reason when you create a forum, you have the founding companies who create the forum and they normally tip the table in their favour. So the founders preserve rights for themselves, you know, maybe, I mean, the founders can be on the board.” (Upsilon) This aspect also received some criticism, for instance Eta said that “nowadays, this privileged membership is not really modern anymore”. He further explained: “Nowadays, you want to see a membership where everybody is involved and everybody has the same rights and duties.”

2.5.5 Relationship between consortia and (quasi-) formal SSOs

The relationship between consortia and (quasi-)formal SSOs can pan out in a few different ways. Consortia can either collaborate with SSOs via formalised relationships, and they can bring in their work via individual member firms. Besides, in their standards documents, SSOs can reference work done by external organisations, including consortia. Then, consortia work going into SSOs can take two different forms, it can either be technical work or more business-related requirements being considered.

When it comes to formalised relationships between consortia and SSOs, consortia usually communicate with SSOs “via liaisons” (Tau), this happens for instance in 3GPP and ETSI. For example “if we are talking ETSI, I mean ETSI has more than 80 relationships with external bodies” (Upsilon). Upsilon also elaborated on the forms these relationships can take, varying in the intensity of collaboration: “We have three different levels that we can cooperate at. So, we have a letter of intent which is the lowest model. We have memorandum of understanding, which is the next level and then we have a cooperation agreement which is the highest level.” In many cases, these relationships emerge because technical committees (e.g. in ETSI) come across interesting work taking place outside the organisation. Then, “they would then request ETSI institutionally to create a relationship with that body so that they can work with each other”

(Upsilon). On the consortia side, Chi explained that consortia can put their results into a document that can then, in the context of a liaison, be sent to a standards organisation for consideration. On the other hand, Xi said that what SSOs are “trying to avoid is having an organisation send in a document into 3GPP saying ‘here is the [consortium’s] input’”. Thus, consortia input seems to be welcome and desirable to SSOs as long as there is some kind of institutionalised relationship between a consortium and an SSO. As pointed out previously, external work can also be brought into SSOs via individual firms if there is “no formal way” (Xi).

It is not always necessary to set up some form of connection in order to include a consortium’s work in an SSO’s standards. When suitable solutions are developed outside of SSOs, there is “no need or intention to reinvent the wheel” (Upsilon). Upsilon also gave an example: “Broadband Forum is a very worthy club. They do great work. Some of the solutions they develop, they want to see adopted within the ETSI or 3GPP framework. And in many cases, ETSI and 3GPP want to use that work.” So in these cases, ETSI or 3GPP can adopt or refer to external work.

When technical work is planned to be brought into SSOs by consortia, consortia can prepare entire solutions and then enter these into SSOs: “This means that it [consortium] is a kind of ‘run-up’ organisation that then tries to steer standards in 3GPP into a certain direction.” Tau also indicated that 3GPP is often actually happy when that happens because work in 3GPP can be simplified—because communication is easier and people understand why certain things fail in standardisation. Xi also claimed that this procedure can simplify standardisation: „You can more rapidly develop it [a piece of work] with a group of companies that are really committed and interested. And then, when you have things like basic agreements and a first set of specifications available, then you can bring them back into 3GPP.“ Oftentimes, when ideas are not sufficiently mature to be pursued within 3GPP, proofs of concepts and trials “are usually also driven in industry consortia or industry associations, external of 3GPP” (Xi). In a similar vein, Psi stressed: “When you bring something into standardisation, then usually you already have experience with it. […] The technical feasibility is generally already confirmed, so it is not just speculation and ideas, but it is about giving a more or less formal form to something you have.” This idea also lies behind the creation of the model of ETSI ISGs: They work “like an incubator environment”, and solutions can be brought into (quasi-)formal SSOs when they “prove to be successful” (Upsilon).

Developing technical solutions for the purpose of getting them included in standards made by (quasi-)formal SSOs is the idea behind the concept of pre-standardisation. And once firms have invested time and human resources into developing a certain solution within a consortium, they will sometimes push hard to get it into a standard. Upsilon described such a scenario: “Ten companies can say ‘we think this is the right solution’ and then clearly, they have discussed that before. […] And then typically ten other companies might come in with the alternative solution being proposed. And it's very obvious that there has been an awful lot of discussions beforehand about which really is the best solution." (Upsilon). Omicron even thinks that such practice entirely changes standardisation because "in small groups, where people know each other, one tries to force standards through" (even if they are possibly technically inferior).

Consortia are not only utilised to push technologies into standardisation, but also to give consideration to business requirements. Phi pointed out that "3GPP is a pure technology standardisation body", but also stressed that "one needs to start from the business side and ask: 'From a business point of view, what do we actually want to achieve?'". Besides, he claimed that "technology is always just 30 to 40% of the solution, we also need to achieve a common understanding of business". Many consortia are not doing actual technology work, but rather look at requirements, they may not "do standardisation, but rather define […] what is required from standardisation" (Chi). Discussions on (business) requirements can then take place within consortia, and the results can then be handed over to standardisation.

2.5.6 Summary of interview results

As the previous paragraphs have made clear, there are many determinants playing a role in the emergence of industry consortia, as summarised in Figure 2-2. The determinants presented in the figure result from the coding scheme, as illustrated in Figure 6-2 of Appendix A.

First, there are environmental determinants, which in this case mostly consist of technological evolutions that lead to demands on standardisation. In the current environment, the most relevant and pressing developments concern the evolution towards 5G and the IoT. The two determinants with the supposedly most direct impact on the phenomenon are grounded in the current structures, rules, and processes of formal standardisation, and on the other hand the (perceived) advantages and opportunities of industry consortia. Industry players may try to circumvent certain aspects of formal standardisation by turning to industry consortia for some aspects. However, as previously stressed, industry consortia do not always compensate for perceived shortcomings of established (quasi-)formal SSOs, but rather provide "add-ons" to the work of SSOs. The (perceived) advantages and opportunities of industry consortia are affected by the process of setting up new consortia, and their structures and rules. It may not always be straightforward or easy to initiate and establish a new consortium, or to work within the structures and rules of existing industry consortia. Besides, the relationship between consortia and (quasi-)formal SSOs can be quite multifaceted, meaning that it can take various forms. Some consortia may be relatively independent of formal standardisation efforts in the industry, while others may be more or less dependent on them or even directly contribute.

Thus, all these determinants play a role when examining the phenomenon of industry consortia in telecommunications. In the following, I use these identified determinants in order to discuss the boundaries of SSOs, and link my findings with the academic literature.

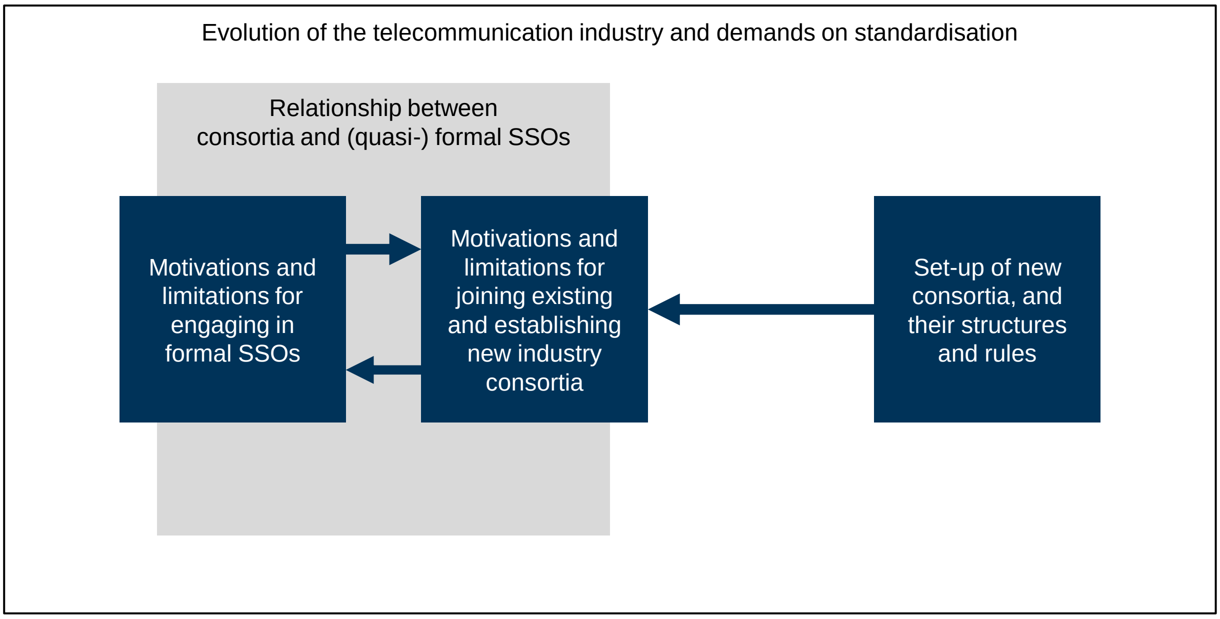

Figure 2-2: Determinants of the emergence of industry consortia

2.6 Analysis of the determinants of the emergence of industry consortia and the boundaries of SSOs

In this section, I aim to create a linkage between the theoretical background presented in the literature review and my interview results, as laid out in <ins>Section 2.5</ins>.

When looking at the fundamental literature on the boundaries of the firm (Coase 1937; Richardson 1972; Williamson 1981), the idea is that once the cost, whatever form they may take (e.g. time, money, human resources), of transactions within a firm become higher than the transaction cost on the market, transactions will be handled outside the firm. Williamson (1973) identifies two groups of factors within organisations that may cause some kind of friction, and that go beyond the idea of transaction cost: human and transactional factors. Human factors stem from human attributes and include factors such as opportunism and bounded rationality. In contrast, transactional factors pertain to the characteristics of the transactions themselves, such as uncertainty.

I have found the idea of transaction cost regarding SSOs to come up repeatedly within the interviews: Whenever (quasi-)formal SSOs are perceived to be too ponderous, slow, or inefficient, firms may turn to alternatives, which can be existing or new industry consortia. As previously explained, based on Williamson (1973), transaction cost are not the only factors determining the boundaries between markets and hierarchies. From the interviews, it also becomes clear there is more to the phenomenon of the emergence of industry consortia. Judging from the interviewees' perspective, consortia exist for a variety of reasons. I use the framework of Oliver (1990) to elaborate on the detailed determinants of the emergence of industry consortia.

As already pointed out in the literature review, in contrast to the original framework by Oliver (1990), I am not primarily interested in why IORs form in the first place, but rather which aspects drive firms into new IORs that can be set out to complement or substitute existing ones. Still, the six contingencies presented by Oliver are suitable for building the basis for an elaboration on the boundaries of SSOs. However, the term "contingencies" does not seem to be fitting in this context. Contingencies, according to Cambridge Dictionary[22], are "something that might possibly happen in the future, usually causing problems or making further arrangements necessary". In the context of reasons for IOR formation, contingencies would then be understood as events or situations a firm may be confronted with that make the formation of an IOR appealing to firms. When it comes to consortia formation, as described in Section 2.5, firms initially consider or decide to form or join consortia due to a mixture of internal reasons (e.g. they have developed a novel technology) and rather external events or situations they are confronted with (e.g. there are key developments in the industry needing to be addressed). It is difficult to disentangle these two aspects since there is often an interplay between them. Therefore, I will use the term "reasons[23] for consortia formation" to refer to the mixture of internal and environmental factors that make firms initially consider or decide to form or join consortia. Based on the original six critical contingencies, as presented by Oliver, I will present an adapted scheme on the boundaries of SSOs. I will also use the concept of facilitating conditions of critical contingencies. In the framework presented in the following, facilitating conditions impact how exactly the reasons for consortia formation play out. Facilitating conditions can both consist of internal and firm-specific aspects as well as environmental factors. I have identified three facilitating conditions for the phenomenon at hand. Figure 2-2 presents the determinants of the emergence of industry consortia, as identified in the interviews. The outer three rectangles can be associated with conditions or reasons for consortia formation, while the inner two are more relevant to the reasons for consortia formation. Hence, aspects described within the relevant sections flow into the construction of the associated parts of the scheme.

[22] See https://dictionary.cambridge.org/dictionary/english/contingency (retrieved on 12/10/2020).

[23] The terms "reasons" and "contingencies" are also in some parts used interchangeably by Oliver 1990.

2.6.1 Boundaries of SSOs and reasons for consortia formation

In the following, I will explain the framework created for an understanding of the boundaries of SSOs, starting with reasons for the formation of consortia (based on the original framework by Oliver 1990). I have formulated seven reasons, keeping four of the original contingencies (partially re-defined), and adding three new ones. I keep the original order of the contingencies or reasons, adding new elements where appropriate.

Asymmetry

Interviewees have repeatedly mentioned that the formation of industry consortia can be related to power motivations. This is especially the case when it comes to designing the structures and rules of consortia so that certain firms are especially influential in the decisions of the consortium, while others have fairly limited rights. This implies that firms do not directly control and influence other firms or their resources, but have the option to control the possible actions that other firms can take in the context of the consortium. Hence, they can exert some sort of indirect control over how others can use their resources. To name one example, consortia may have tiered membership structures in which elevated tiers (i.e. the ones with the most rights) are only open to a defined group of firms or a limited number of firms. Founding firms can then make sure that they can strongly influence key decisions taking place in consortia, and perhaps also make sure they can promote their technologies. In consequence, firms may be motivated by the option of having asymmetry between members within a consortium, mostly in terms of power and influence.

Since rules and processes of established, mostly formal SSOs are perceived to be relatively strict and rigid (and also subject to antitrust regulations), firms may decide to turn to a new or existing industry consortium to pursue certain objectives. This could for instance make sense when they wish to promote a proprietary technology.

Common goals

This reason for consortia formation is closely related to the contingency of “reciprocity” posed by Oliver (1990). Here, I would like to emphasise common interests in goals instead of actual reciprocity. Naturally, consortia are frequently initiated when firms have common interests or goals. In addition, strategic complementarities play a role whenever different industry players have different areas of (technological) expertise, or different positions in the value chain. Many interviewees stressed that a consortium can only generate the necessary momentum when the major players in relevant areas are present in the consortium. The exact member composition that is needed of course depends on the exact focus and objectives of the consortia. When, for example, an IoT consortium is to be established, it makes sense to have players across the telecommunications value chain (e.g. vendors, operators) represented as well as relevant verticals, and perhaps IT firms.

The pursuit of common interests is especially relevant when groups of firms feel that their requirements are not sufficiently considered within formal standardisation. Alternatively, new groups of firms may feel the need to align and hold discussions prior to entering standardisation, for instance because they work on relatively new technological concept and solutions. Furthermore, when a single firm wishes to market a proprietary technology with the help of a consortium, it would look for firms with complementary competencies to establish a consortium.

Efficiency

As mentioned at the beginning of this section, the idea behind efficiency (or lack thereof) is quite dominant in the fundamental literature on the boundaries of firms. Industry consortia are popular because of their (mostly) small size and the strong commitment of members as only interested firms are present. In addition, processes can be designed to be relatively sleek and straightforward.

In order to pursue a certain objective, technology, or solution within formal SSOs, firms may not be satisfied with the expected output (e.g. probability of success) in comparison to their input (i.e. time and human resources needed for standardisation). Additionally, many interviewees mentioned that processes within formal SSOs can be too slow for their taste, and some other firms may not be as invested in certain work as they would want them to be. Moreover, some work may be blocked irrespective of its technological or societal merit, but due to business considerations. In consequence, firms may be motivated by the lack of efficiency within formal SSOs, and hence turn to consortia for some endeavours.

Information / Hedging

This reason, which is added to Oliver's original list of contingencies, concerns decisions that firms need to take regarding their technological direction. Many interviewees believe that it is crucial for firms with stakes in standardisation decisions to enter their bets in different (technological) directions by joining various consortia, some of which may promote competing approaches. Hence, they have the option of hedging by observing various options before settling on one direction. This can be due to business considerations, that is, firms would like to avoid investing resources (e.g. in R&D) in technologies unlikely to succeed in standardisation.

Furthermore, development cycles and technological feasibility play a central role here: Once a standard is "frozen" (i.e. fixed), the basic infrastructure for the deployment of mobile networks needs to be more or less ready. Hence, firms finding themselves early in the telecommunications value chain need to have a precise idea where standardisation is headed. So they are in need of sufficient information in order to support their decisions on their technological direction.

Even though one could argue that participation in established (quasi-)formal SSOs could already be sufficient to gather information about the technological direction of the industry, many firms look for additional opportunities to communicate and collaborate with other players outside the environment of established (quasi-)formal SSOs. For instance, this is due to smaller groups and smaller ranges of activities that allow for more targeted discussions. Besides, since consortia may be more likely to work on relatively novel technologies, new and promising perspectives can be identified early on.

Novelty

This new aspect has already been touched upon in the description of the previous reason for consortia formation, and is also an addition to the traditional list of contingencies. Industry consortia tend to be more likely to work on very novel technologies than established (quasi-) formal SSOs. In these established organisations, since the focus is on working on the final standards, there is no space for the consideration of very novel technologies. This makes sense because mostly these technologies are not yet tried and tested, meaning that proofs of concepts and prototypes are still to be done. In some cases, technologies may also not be directly relevant to mobile telecommunication standards. This is currently the case with some technologies coming from IT: Some of them (e.g. Software-defined Networking (SDN)) are likely to become relevant soon, while others (e.g. applications) fulfil more of an “add-on” role with respect to mobile telecommunications.

In the context of 5G and the IoT, novel technologies also tend to concern industries not represented in 3GPP, so players from these industries can be included in industry consortia. Many interviewees pointed out that it would generally be desirable to have new industries (verticals) represented in 3GPP. However, they also expressed concerns pertaining to the large size of 3GPP, and also the feasibility of inclusion due to differing mindsets and industry conventions.

Uncertainty

Oliver (1990) understands the contingency of uncertainty to encompass environmental uncertainty and calls it “stability” or “predictability”. In the case of industry consortia, I find uncertainty regarding technological developments, and, as a consequence of this, business uncertainty. Especially whenever there is a new generation of standards to be defined, there is substantial uncertainty regarding the technologies included. This also pertains to the question whether a new generation builds upon the preceding generation (as it was the case with UMTS), or upon a new technological basis. Such developments can put firms in vulnerable strategic positions, since a large part of their revenue may come from technologies included in earlier generations. Hence, the technological uncertainty evolves into a business uncertainty.

Additionally, new technologies may also allow for new ways of realising certain use cases, questioning the business model of some firms. One major contributor to this is the likely increase in the role of software in telecommunication networks. Some interviewees thought that the realisation of network functions through software could lead to a situation where specialised hardware is rendered less and less important. The virtualisation of network functions is then one enabler of novel technological concepts, such as network slicing[24] that allows verticals to operate and manage their own networks, in theory without a specialised network operator. Many interviewees consider such developments to be extremely relevant to the near future of telecommunication networks, yet, much of the related work is currently done outside of formal SSOs and 3GPP. However, it seems that there are some considerations to include more of this work.

Recognition

This reason for consortia formation is very much related to the original idea of legitimacy as proposed by Oliver (1990). Aspects such as reputation, image, and prestige do not seem to be overly relevant when it comes to industry consortia. Rather, this happens the other way round: The presence of large and important firms in a consortium enhances the consortium's reputation. This is why founders of consortia usually pay close attention to the membership composition of the organisation.

However, when a firm perceives a lack of recognition with regards to its technological developments or general interests, consortia can potentially provide remedy. They provide an opportunity to drive technological legitimacy (similar to the idea of Lerner and Tirole 2006) by promoting a certain idea, solution, or technology. Hence, this reason for consortia formation is somewhat related to novelty: When an idea, a solution, or a technology is not yet mature and established in the industry, firms may get together in a consortium to further develop and/or promote it. In other cases, firms may get together because they see an opportunity to promote their interests, which may not be directly related to technology. For instance, when groups of firms feel that their needs and requirements are not sufficiently taken into account in standardisation, they can form consortia to make themselves heard.

In the original framework, Oliver includes the contingency of necessity that would imply that consortia are formed due to legal or regulatory requirements. This is not the case, rather on the contrary: As mentioned above, firms rather turn to industry consortia when they perceive that the rules of formal SSOs are too strict or rigid for their purposes. These aspects hence relate to the efficiency contingency.

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[24] https://www.zdnet.com/article/how-network-slicing-may-determine-the-success-or-failure-of-5g-wireless/ (retrieved on 20/04/2020)

2.6.2 Conditions affecting reasons for consortia formation

It is important to point out that even though many of the previously mentioned reasons for consortia formation are in some way based on perceived shortcomings of SSOs, boundaries of SSOs are not just determined by these shortcomings that drive firms to other organisations. Most of the reasons for consortia formation also include aspects that pertain to useful additions to the existing landscape of (quasi-)formal SSOs, sometimes also with the aim of facilitating the work of (quasi-)formal SSOs. On the other hand, one may argue that consortia do not always constitute useful additions, they are in some cases set up for the purposeful circumvention of (quasi-)formal SSOs. The exact way reasons for consortia formation play out is substantially influenced by conditions. Conditions can be internal or external to the firm and impact how and to what extent reasons for consortia formation translate into actions. Hence, next, I will describe three conditions identified from the interview data. All three are closely related to the industry environment that relevant firms operate in.

Ease/difficulties of setting up new organisations

Industry consortia can take a long time and a lot of effort to be set up. This is not just dependent on the starting conditions and the objectives of the consortium, but mostly the regulatory environment. Even though, as previously stated, firms are relatively flexible when it comes to the rules and processes of consortia, they need to be defined and laid out in bylaws (or similar documents).

Depending on what firms expect to gain from the work of the consortium, it may make sense for firms to either support the set-up of the consortium, or alternatively use existing organisations or infrastructures. This can for instance be existing (quasi-)formal SSOs, other consortia, or offerings such as ETSI ISGs.

Existing firm relationships

This conditions is related to the first one insofar as it poses the question of whether it is “worth it” to set up a consortium. As explained in the in the introduction as well as the literature review, the general level of communication, cooperation, and collaboration in the telecommunications industry has for a long time been quite high. This does not just take place via official channels such as SSOs, but also via unofficial channels, for example bi-lateral communication between single managers. People in the industry tend to know each other because they have for a long time been working together within standardisation.

These existing relationships may lead to a situation where work can be done without setting up a consortium, for example within an R&D alliance between two firms. On the other hand, these existing relationships could imply that it is relatively easy to get relevant players together and get them to collaborate.

Cooperation environment

This condition pertains to potential or needed links of industry consortia to formal SSOs. When a consortium is expected to contribute to or influence standardisation in some form, linkages of some kind are needed. Linkages can either consist of formalised relationships on the organisation-level, or single firms bringing work from one organisation into the other.

Thus, this condition pertains to how likely formalised, organisation-level relationships are to be established. If this is not an option, the membership roster of the consortium becomes more relevant since key players are then required to bring the consortium's work into formal SSOs.

Table 2-4 shows ways how each condition may affect how the reasons for consortia formation, as outlaid in the previous section, pan out.

Table 2-4: Conditions of relationship formation and their effect on the reasons for consortia formation

Reasons for consortia formation	***Facilitating conditions***		
	Ease/difficulties of setting up new organisations	**Existing firm relationships**	**Cooperation environment**
Asymmetry	Firms may evaluate potential gains against cost of setting up a consortium and then decide for or against consortia formation.	Firms may have very little to plenty of knowledge on the set-up and goals of other firms in the industry, and may or may not be in close contact with them. This may hamper or facilitate consortia formation and set-up.	Firms may be able to influence other firms' positions or behaviour in formal standardisation. Firms can also join forces to potentially influence the work of formal SSOs via the work of consortia.
Common goals			
Efficiency		Firms may evaluate whether existing firm relationships are suitable and sufficient or whether it makes sense to form consortia.	Firms may evaluate potential efficiency gains from doing work in consortia against a potentially more complex and diverse cooperation environment.
Information/ Hedging			Collection of information on the direction of standards and the industry may be facilitated once firms have more numerous and stronger links to formal SSOs via consortia memberships.
Novelty			Novel ideas, solutions, and technologies may be more likely to make their way into formal SSOs
Uncertainty			Uncertainty is reduced when a consortium's influence on the work of SSOs is sufficiently high
Recognition			The promotion of technologies or interests can be more or less effective depending on the number and strength of consortia's links to formal SSOs

2.7 Implications and limitations

As the previous sections have made clear, firms join, initiate, and establish new industry consortia for manifold reasons. Based on semi-structured interviews with industry experts, I systematically identified and then described reasons why firms may feel the need to turn to industry consortia. In line with Oliver (1990), I then tried to classify the reasons mentioned, and bundle them. More precisely, I formulated six reasons for consortia formation, namely asymmetry, reciprocity, efficiency, anticipation/ hedging, novelty, stability, and promotion. In addition, I identified three conditions affecting the way these reasons translate into actions.

The aim of this paper was to help a systematic understanding of the emergence of industry consortia, and their relationship with already existing (quasi-)formal SSOs. There seems to be a conundrum around the fact that in spite of the existence of multiple (quasi-)formal SSOs, and opportunities for collaboration between firms, industry consortia are being formed. In the literature to date, the pre-standardisation character of industry consortia tends to play a rather dominant role. I find that in some cases, pre-standardisation indeed plays an important role for setting up new industry consortia. In the current technological environment dominated by topics around 5G and the IoT, interviewees emphasised that consortia can be useful to get together with representatives from miscellaneous industries. Within consortia, firms can then discuss requirements, use cases, and other relevant topics, and telecommunication firms can then feed the results back into formal standardisation. This implies that in the current, and probably even more in the future, technological environment, consortia could become more and more relevant. One can expect stakeholders in mobile telecommunication technologies to become more numerous and increasingly diverse. Thus, work in 3GPP would need to consider an increasing amount of heterogeneous demands. All interviewees agree that consortia can then be extremely useful in order to organise and boil down these demands before they enter 3GPP.

Getting back to the discussion of whether consortia are set up to complement or substitute (quasi-)formal SSOs, in pre-standardisation cases consortia can indeed be considered to complement (quasi-)formal SSOs. In contrast, sometimes firms are actually motivated by (perceived) shortcomings of existing (quasi-)formal SSOs to turn to industry consortia. However, the substitution character of consortia in these cases usually only pertains to a rather small piece of the work of (quasi-)formal SSOs. For instance, this could happen for technologies where there is resistance from members within 3GPP, or when 3GPP processes are perceived to be too slow or ponderous. It is important to note though that many motivations for setting up industry consortia are not directly motivated by inherent shortcomings of (quasi-)formal SSOs, but rather by outside opportunities and circumstances. Consortia can in some cases also develop own standards, which for instance happens for Bluetooth[25] (Bisdikian 2001).

Interestingly, many interviewees spot difficulties and shortcomings when it comes to standardisation in 3GPP, but they still think that 3GPP should not and will not be replaced anytime soon. Even though most of them said that consortia have a clearly complementary role with regards to (quasi-)formal SSOs, many also made clear that whenever something cannot be done in 3GPP, consortia could come in handy. This implies that at least for some fractions of the 3GPP work, consortia could work as a replacement. While some interviewees think that the emergence of consortia can in many cases be desirable to ease the workload of 3GPP, this development could also be problematic. For one, the intricate landscape of industry consortia could be difficult to monitor, especially for small firms. As has become clear in the interviews, the formation of industry consortia is often a rather informal process “between pals” where a manager from one firm gets in touch with managers from other dominant firms (whom he already knows) to discuss the possibility of initiating a consortium. Such events can be desirable in a way that potentially promising technological developments can be furthered in a quick and informal way. On the other hand, they imply that there are considerable advantages for firms who are already well connected anyway, because they know (or get informed about) where relevant things are about to happen. Also, consortia may give firms more room to push certain solutions. They can flexibly design the structures and rules of industry consortia, and hence to some extent get away from the rather rigid processes of (quasi-)formal SSOs. Assuming that consortia will increasingly proliferate, consortia could be a way of enforcing the existing market structures, and hence make dominant firms even more dominant.

While this paper aims to capture as many views on and aspects of industry consortia as possible, it could be helpful to supplement these by insights from a larger number of smaller firms, or firms from the IT industry or verticals. In addition, it would certainly interesting to offer more of a process or temporal perspective where consortia and their formation are observed over time.

[25] Bluetooth was initially developed in the Bluetooth Special Interest Group that is still in charge of maintaining and further developing the technology. However, the standard is published by IEEE under 802.15 WPANs (wireless personal area network).

3 Industry consortia in mobile telecommunications standards setting: Purpose, organisation and diversity[26]

3.1 Introduction

Since the 1980s, the mobile telecommunications industry has evolved rapidly, from various first generation analogue standards, to second-generation GSM, third-generation UMTS/WCDMA, and fourth-generation LTE standards.[27] This evolution has not only changed the performance of telecommunication networks, such as data rates and latency, but in many respects also the underlying technologies. Standards impact potential uses as well as organisations and individuals, as we see with 3G, which was the result of a convergence between traditional telecommunications and the IT industry (Leiponen 2008). For 5G standards in the making, this convergence is happening on an even larger scale, involving the Internet of Things (IoT), Industry 4.0, various vertical sectors, and more.

Technical standards are important for both technical and business reasons. Technically, it is crucial that various types of user equipment can communicate with each other, and that large numbers of components and (sub-)systems are interoperable (Belleflamme 2002; David and Steinmueller 1994). Business aspects matter because standards can become very dominant due to prominent network externalities (Bekkers et al. 2002). This dominance results in standards significantly impacting the terms of competition, and industry players having strong commercial interests in a standard's design (Bar and Leiponen 2014; Besen and Farrell 1991; Chiao et al. 2007). For some firms, standards imply "the danger of being put at a disadvantage" because their specific design can affect a firm's success or failure (Genschel 1997, p. 610). Thus, most firms in the industry tend to be heavily involved in standardisation, and consequently with SSOs.

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[26] This Chapter is based on the publication "Industry consortia in mobile telecommunications standards setting: Purpose, organisation and diversity", accepted for publication at Telecommunications Policy, co-authored with Joachim Henkel and Rudi Bekkers. My contribution to the paper is summarised in Appendix D (signed by my co-authors).

[27] GSM: Global System for Mobile Communications; UMTS: Universal Mobile Telecommunications System, known outside of Europe as W-CDMA: Wideband Code Division Multiple Access; LTE: Long Term Evolution.

Formal Standards Setting Organisations (SSOs) play a crucial part in the creation of standards. The first digital mobile telecommunication standard, GSM, came with the new European Telecommunications Standards Institute (ETSI) in 1987/88 (Dalum et al. 1999; Funk and Methe 2001), and the emerging Third Generation Partnership Project (3GPP) enabled the UMTS/WCDMA standard. 3GPP, which is a partnership of regional SSOs like ETSI, is currently the central global organisation creating mobile telecommunication standards. The regional SSOs participating in 3GPP (currently seven) are called Organisational Partners.

Since the 1980s, firms have increasingly formed smaller and more informal standards-related organisations, so-called industry consortia, to co-exist with established SSOs (Genschel 1997; Hawkins 1999). Nowadays, most of the large industry players are involved in a multitude of consortia (Hawkins 1999). The literature shows that industry consortia play an increasingly important role, in particular in fostering technological development (Baron et al. 2014; Baron and Pohlmann 2013). Existing studies typically focus on the pre-standardisation function of consortia, i.e., how consortia help firms coordinate prior to taking part in formal standard setting (Delcamp and Leiponen 2014).

Existing categorisations of consortia (Biddle 2017; Delcamp and Leiponen 2014; Pohlmann 2014) usually involve few categories and a limited set of indicators (age, founding year, member composition, or contractual/legal form). This approach is adequate if categorisation is just one step in a wider research process. However, a more detailed process of classification or taxonomy is needed to fully understand consortia's role in standardisation. So far, we lack comprehensive insight in 1) why firms form or join consortia, and 2) the variety of consortia and their diverse objectives. These two aspects are tightly connected: Firms' motives for forming and joining consortia can be expected to be reified and reflected in the characteristics of consortia, more precisely in their organisational set-up. Also, building a thorough empirical basis capturing the different forms of existing consortia can help us shed more light on the motives for consortia formation. A taxonomy can help inform firms' choice of consortium membership, especially if standardisation resources are limited. Moreover, it can strengthen policy evaluation: while many consortia clearly support the advancement of technology and the telecommunications industry as a whole, others might misuse their role to influence the market. These issues are difficult to assess, given the sometimes opaque nature of consortia. A taxonomy could also be helpful for the identification of relevant ICT standards developed by consortia, for instance by bodies such as the European Multi Stakeholder Platform on ICT Standardisation (known as the MSP[28]).

[28] See https://ec.europa.eu/digital-single-market/en/identification-ict-specifications (retrieved on 28/07/2020).

To build a taxonomy, we study the field of mobile communications as addressed by 3GPP. While there are many other areas of standardisation, focusing on a single one allows us to derive meaningful results and avoid bias from unobserved variance. We selected this area for three reasons: Its size and general importance with respect to technology and markets; its considerable technical breadth, stemming from its multifaceted nature; and alignment with earlier studies, such as those by Leiponen (2008) and Delcamp and Leiponen (2014). While we cannot guarantee our results are fully generalisable to other areas of standardisation, we expect that our choice of 3GPP will allow us to observe all important motives to engage in standardisation.

We identified 100 consortia and collected data on them through interviews and desk research. These initial steps enabled us to devise an assessment scheme. Guided by a principal component analysis followed by a cluster analysis, we identified common themes and patterns, resulting in a taxonomy of six different types of consortia: Large industry and technology influencers, high-level concept developers, established standards developers, young technology specialists, small industry and technology influencers, and SSO-hosted industry drivers.

Our study contributes to the literature on the economics and management of standardisation in telecommunications, especially the role and impact of industry consortia (Baron et al. 2014; Delcamp and Leiponen 2014; Hawkins 1999; Rosenkopf et al. 2001; Simcoe 2012). We aim to shed light on the various forms of consortia as well as firms' rationales for setting up and joining these organisations.

We start by examining the literature on SSOs and consortia in Section 3.2, before describing our methodology in Section 3.3. We then discuss the insights from our in-depth interviews in Section 3.4. Section 3.5 introduces our dataset and sample of consortia. Section 3.6 presents the results of our analysis, and Section 3.7 concludes.

3.2 Background

3.2.1 Standards and SSOs

When talking about standards in the field of telecommunications, the literature usually refers to explicit standards agreements, or a "set of technical specifications" (David and Steinmueller 1994, p. 218), crafted in dedicated SSOs. We interpret "SSOs" as organisations "that collaboratively develop standards, including 'traditional' standards development organisations [...] as well as the myriad consortia, alliances, and Special Interest Groups (SIGs)" (Bekkers and Updegrove 2012, p. 5). They are associated with the development, definition, updating, and maintenance of formal standards (International Telecommunication Union 2014). The term

"SSO" is often used interchangeably with Standards Development Organisations (SDOs) (International Telecommunication Union 2014). Although these terms may mean the same, the actual range of organisations known as SSOs or SDOs varies considerably.

In this paper, we use the term "SSOs." Based on the International Telecommunication Union (2014) classification, we differentiated formal and quasi-formal SSOs. Formal SSOs are formally recognised[29] by national or international authorities. For instance, in the European Union such recognition is reflected in the publication of formal SSOs (the European Standardisation Organisations, ESOs, and national standardisation bodies) in Regulation 1025/2012 of the European Parliament and the Council (European Parliament and Council 2012). Formal SSOs are generally assumed to meet all the criteria for open standards as defined by the World Trade Organization (2000). They include national bodies (such as British Standards Institution BSI and German Institute for Standardisation DIN), regional bodies (such as ETSI) and global bodies (such as ITU).

Quasi-formal SSOs are organisations that are in virtually every aspect similar to formal SSOs: they are large, have attained a status and position that is quite comparable to that of formal SSOs, and are also generally assumed to meet all the criteria for open standards as defined by the WTO. What distinguishes them from formal SSOs, however, is that they do not enjoy the formal recognition by a national or supra-national authority. In the field, the term quasi-formal SSOs is specifically used for the three following organisations: IEEE, IETF, and W3C (Contreras 2017b; ECSIP Consortium 2014). The standards these bodies develop and promote are indeed well-established in the industry, such as the IEEE 802.11 series of standards (popularly known as 'Wi-Fi') developed by the IEEE, the TCP/IP standard developed by the Internet Engineering Task Force (IETF), and the HTTP standard for rendering internet pages developed by W3C. According to Simcoe (2014), these organisations' standing is based on their past success. Even though quasi-formal SSOs "typically lack enforcement power", strong network effects in industries such as telecommunications can have a self-enforcing effect on standards written by these organisations (Simcoe, 2012, p. 307).

The importance of technical standards in the telecommunications industry has increased steadily since the 1980s, mainly thanks to international and data communications (Bekkers et

[29] While the vast majorities of countries in the world has a system with formal recognition of SSOs by governments, the US is a notable exception. In the US, the American National Standards Institute (ANSI) has the role to accredit US organisations that develop standards, and ANSI itself serves as the official U.S. representative to ISO.

al. 2002; Cargill 2002). The technological progress in this field is closely linked to standardisation. Since the third-generation UMTS/WCDMA standard, work on mobile[30] telecommunications standards has been centred around 3GPP. Initiated by ETSI and the Japanese Association of Radio Industries and Businesses (ARIB) (Bekkers and West 2009), 3GPP was built as a “collaborative alliance” of regional telecommunication-focused SSOs in North America, Europe, and Asia, called Organisational Partners (Bar and Leiponen 2014). They steer 3GPP’s general direction via their representatives in the Project Coordination Group (PCG).

When it comes to developing standards, Technical Specification Groups (TSGs) coordinate the technical side by managing work items, and create Working Groups (WGs) to do the actual development work.[31] However, while 3GPP defines the technical specification of a standard, the 3GPP work results are transferred into actual, formal standards by the regional SSOs.[32]

3.2.2 The emergence of standards-related industry consortia

In addition to SSOs, new types of standards-related organisations have emerged since the 1990s (Cargill 2002). Although diverse, these organisations are summarily referred to as standards-related “industry consortia” (from now on we will refer to them as “consortia”), described in the literature as alliances of like-minded companies (Cargill 2002; Pohlmann 2014) or “special-interest groups” with narrower interests than (quasi-)formal SSOs (Chiao et al. 2007). Consortia are perceived as alliances catering specifically to standardisation (Pohlmann 2014), or as fora where firms can coordinate “technological and market development activities”, thus where members pursue goals “well beyond standards-setting as such” (Hawkins 1999, p. 162). Leiponen (2008) finds that firms form and join consortia to learn from each other as well as generate and exchange new technological knowledge. Some consortia develop their own standards, such as the Bluetooth Special Interest Group (Bluetooth SIG) (Keil 2002).

In line with our technology selection discussed above, this literature review specifically focuses on—but is not limited to—consortia in the field of mobile telecommunications.

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[30] We apply the common convention that “mobile communications standards” concern so-called “cellular” technologies, aiming to offer seamless services over a wide area (GSM, UMTS, and LTE). In contrast, “wireless communications standards” focus on shorter distances (Wi-Fi and Bluetooth, and cordless phone standards).

[31] For details, see http://www.3gpp.org/ftp/Information/Working Procedures/3GPP WP.pdf (as of August 2019).

[32] See http://www.3gpp.org/about-3gpp/partners (as of May 2019).

In some ways, consortia are fundamentally different from SSOs. Pohlmann (2014, p. 1) notes that "participation in consortia is less bureaucratic, [and] more efficient in reacting to market needs." Despite the similarities to formal SSOs, consortia have more freedom to design their structures, rules, and processes. For instance, they can be more restrictive (Pohlmann 2014) when it comes to admitting new members or assigning leadership positions. Most consortia are initiated and set up by a small group of founding members, who can then decide the exact terms of collaboration. Also, because of their smaller size, consortia may not have what is described as a "dominant position" in competition law, allowing them to engage in a wide range of activities. In contrast, formal SSOs (or their members jointly) often enjoy such a dominant position and are thus more limited in what they are allowed to do—especially regarding commercial matters.[33]

Studies comparing (quasi-)formal SSOs and consortia highlight that firms form and join consortia to influence the work on standards in (quasi-)formal SSOs (Bar and Leiponen 2014; Delcamp and Leiponen 2014; Leiponen 2008; Pohlmann 2014), thus serve a "pre-standardisation" purpose (Delcamp and Leiponen 2014). Standards-related technology discussions and development presumably take place in consortia outside formal organisations because consortia are perceived to be faster and more efficient (Keil 2002; Pohlmann 2014); also because firms can influence the standardisation path prior to actual standardisation work in formal organisations like 3GPP. This could mean that as many of their own technologies as possible are included in a standard, or that the standard is "compatible" with many of their existing solutions and products. Firms holding property rights that are essential for implementing a standard "can receive substantial royalty revenue", and "firms that influence the technical specifications early on can align system features with their own complementary assets" (Leiponen 2008, p. 1906).

In most cases, "pre-standardisation" implies that only parts of standards are developed within a consortium, not entire standards or specifications. But consortia can also fully develop a standard or specification before handing it over to another, usually larger and more established organisation. For instance, the first version of the Bluetooth technology was published in 1998 by the Bluetooth Special Interest Group (SIG). In 2002, a newer version was ratified by IEEE as 802.15 (Personal Area Networks), while the Bluetooth SIG still maintains and updates the specifications.[34] A slightly different scenario took place in the field of Wireless Local

[33] See, e.g., the ETSI Guidelines for Antitrust Compliance (European Telecommunications Standards Institute, 2011).

[34] See http://www.bluetooth.com/specifications/bluetooth-core-specification/ (as of May 2019).

Area Networks (WLAN). Here, IEEE developed and standardised the original (and later) standards under 802.11,[35] while the Wi-Fi Alliance certifies whether specific products conform to IEEE 802.11 and manages the trade name "Wi-Fi" for these certified products.

A topic of debate in the literature is whether industry consortia supplement or partly replace (quasi-)formal SSOs (Blind and Gauch 2005; Hawkins 1999). In line with the idea of pre-standardisation taking place in industry consortia, the main theory is that consortia rather "supplement the formal standard setting process" (Baron et al. 2014, p. 22). However, categories are not exactly clear-cut, and the term consortium is sometimes used interchangeably with quasi-formal SSO (see Simcoe 2014). For the purpose of this paper, our definition of industry consortia is: "*Collaborative alliances of organisations which offer a forum for the discussion, development, coordination of development, testing, certification, and/or promotion of technologies or technology systems, but not recognised as formal SSOs or quasi-formal SSOs*."

Note that, within this definition, consortia can develop technologies; they can contribute these to standardisation by (quasi-)formal SSOs, or publish standards themselves, in which case they perform similar roles as (quasi-)formal SSOs. They can contribute to standards or not work on standards at all, yet still be very relevant for technical evolution in the industry. Our definition of consortia only includes organisations that are at least to some extent involved with technical aspects, so we exclude organisations solely occupied with non-technical issues. This is illustrated in Figure 3-1, which shows our understanding of industry consortia in relation to (quasi-)formal SSOs and non-technical industry groups. Non-technical interest groups focus only on non-technical rules of the industry (for instance relating to intellectual property). Thus our definition of consortia does not include them.

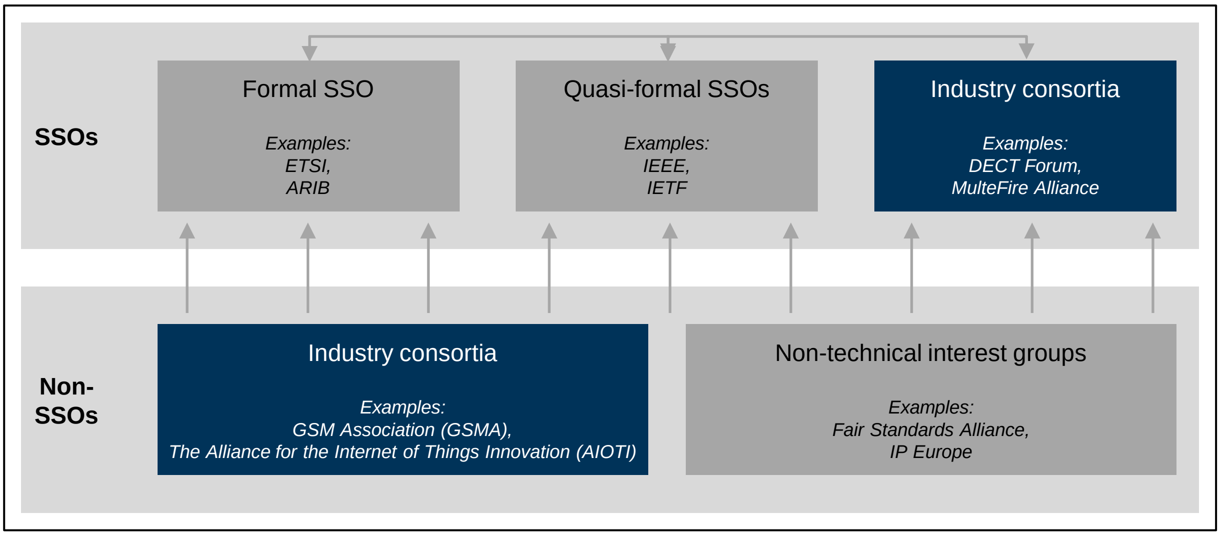

Figure 3-1: Relationships between industry consortia, formal and quasi-formal SSOs

[35] See http://standards.ieee.org/standard/802 11-2016.html (as of May 2019).

3.2.3 Reasons for joining and committing to industry consortia

Hagedoorn (1993, p. 372) examines, on a general level, the reasons why firms engage in technology partnering, which he understands as "interfirm cooperation for which a combined innovative activity or an exchange of technology is at least part of their agreement." He identifies three categories:

1. Motives related to basic and applied research and some general characteristics of technological development, including for instance the reduction and sharing of uncertainty in R&D.
2. Motives related to concrete innovation processes, including for instance technology transfer and technological leapfrogging.
3. Motives related to market access and search for opportunities, including for instance offering new products and entering new markets.

The relative importance of these motives is one of the main determinants of the mode of cooperation that the partners choose. There is a wide array of diverse organisational modes for technology partnering (Hagedoorn 1990), including strategic technology alliances (Hagedoorn 1993; Hagedoorn and Duysters 2002), joint research pacts and research joint ventures and research corporations (Hagedoorn 1990), inter-firm R&D partnerships (Hagedoorn 2002), and mergers and acquisitions (Hagedoorn and Duysters 2002).

A specific form of technology partnering, and in particular of forming strategic technology alliances, is cooperation in the realm of standardisation. According to Wiegmann et al. (2017, p. 1371), standardisation "aims to resolve situations where involved actors prefer a common solution to a problem, but have not yet agreed which option to choose." Firms in the telecommunication industry are eager to take part in standardisation for a variety of reasons. The overarching motive of participating in standardisation is of commercial nature, since "commercial stakes attached to standards and patents" are high for firms in the industry (Chiao et al. 2007, p. 905). More specifically, Keil (2002, p. 206) summarises that "firms that are able to control winning standards experience high returns while firms supporting losing technologies might be effectively locked out of the market."

Industry consortia are an even more specific case of inter-firm cooperation. In general, similarly to technology partnering and strategic technology alliances, they often involve what Hagedoorn and Duysters (2002, p. 168) call "combined innovative activity or an exchange of technology." Yet, in a broader sense, they could rather be seen as alignment mechanisms, since they are usually not confined to these two activities in a narrow sense, but also enable discussion and coordination between firms in the industry (Axelrod et al. 1995; Baron and Pohlmann 2013; Delcamp and Leiponen 2014).

While there is a rich literature on the modes and motives of technology-related inter-firm collaboration, as reviewed above, firms' reasons for getting (and remaining) involved in industry consortia have not yet been systematically studied. This question is particularly interesting in the context of standardisation in telecommunications, since there are already numerous (quasi-)formal SSOs allowing firms to get together, coordinate, and collaborate. Why is it that consortia are formed even though all these organisations already exist—and why does it make sense for firms to initiate, establish, and commit to industry consortia?

As already mentioned above, there are two competing views on the role of industry consortia: Consortia can either supplement or compete with (quasi-)formal SSOs (Blind and Gauch 2005). The prevailing view in the literature seems to be that industry consortia play a supplementary role with regards to (quasi-)formal SSOs. Blind and Gauch (2005, p. 38) find that there are "intensive contacts" between consortia and (quasi-)formal SSOs, and that several formal standards "have a predecessor in the consortia world", and note that both observations point toward a complementary relationship. Even though Baron et al. (2014, p. 22) find that "some consortia substitute for more formal SSOs and issue their own standards", along with Weiss and Cargill (1992), they emphasise the complementary role of consortia. This complementary role is also salient in the previously mentioned pre-standardisation function of industry consortia (Delcamp and Leiponen 2014; Leiponen 2008). This means that consortia can create technical specifications to be handed over to more formal SSOs, but they can also "offer opportunities to discuss, test, or promote certain technologies" (Delcamp and Leiponen 2014, p. 36).

In contrast with this view are the contributions that regard industry consortia as competitors of (quasi-)formal SSO. They understand consortia as standardisation venues, which implies that standards or parts thereof are actually made within consortia. For instance, Wiegmann et al. (2017) differentiate between committee-based, market-based, and government-based standardisation, and note that standardisation through cooperation can also happen within consortia. When consortia perform functions substitutive to those of (quasi-)formal SSOs, firms will consider various criteria when choosing one or the other. On the plus side, as discussed in the previous section, consortia are perceived as faster and more efficient (Keil 2002; Pohlmann 2014), and allow more freedom regarding the design of structures and rules (Pohlmann 2014). On the other hand, they may lack the enforcement strength of (quasi-)formal SSOs (Simcoe 2012).

When examining more specific examples of industry consortia, one comes across a large variety of organisations, and also understandings of consortia. Keil (2002) takes a closer look at the case of the Bluetooth standard, as created and maintained by the Bluetooth Special Interest Group (SIG). He stresses the importance of alliance design that he thinks "plays a critical role", balancing "speed of standards development" and "standard penetration in the market place" (Keil, 2002, p. 206). He identifies a few critical design parameters, encompassing the balance between openness and closedness, partner selection, and the filling of critical roles. In the context of the Bluetooth SIG, he further argues that standards development can happen faster than in (quasi-)formal SSOs. In comparison to market-based mechanisms, the cooperation and collaboration within the alliance allows for "drawing upon the knowledge and capability of firms from several industries thus allowing for solutions that are better geared towards these industries" (Keil 2002, p. 211). van de Kaa et al. (2009) and van de Kaa and Bruijn (2015) make clear that it is not always one consortium or one SSO involved in the making of standards, but that there is often an entire ecosystem or network, sometimes including different industries and product markets. van de Kaa and Bruijn (2015) shed light on the development process of the IEEE 802.11 (Wireless LAN) standard. They argue that "the network around IEEE 802.11 may be seen as an example of an organisation where technical experts spontaneously come together in committees and consortia and together develop and promote a common platform" (van de Kaa and Bruijn 2015, p. 586). They further emphasise the importance of the rules, especially decision making process, in order to make sure that participants are sufficiently encouraged to take part in the process, and also continue to stay involved. In the case of small and medium-sized enterprises (SMEs), Blind and Mangelsdorf (2013) find that their participation in standard setting is to some extent motivated by opportunities to gain access to other firms' knowledge.

3.2.4 Types of consortia

Existing studies differentiate between standardisation-related and R&D consortia, and between technical and marketing-oriented consortia (Delcamp and Leiponen 2014). Pohlmann (2014) characterises consortia by member quantity, membership levels, business spectrum, and industry sector. Focusing on consortia's technological objectives, Simcoe (2014) distinguishes "single platform" and "single standard" consortia.[36] He states that single platform consortia are similar in size to national SSOs, while single standard consortia are much smaller.

Biddle (2017) adopts a different approach of grouping consortia that is structural or functional in nature. The taxonomy he develops comprises three types: 1) incorporated consortia, 2) contractual consortia, and 3) umbrella consortia. The difference between these types lies mainly in their legal status: While incorporated consortia are "distinct legal entities, typically

[36] According to Simcoe, these types of consortia co-exist with Standards Developing Organisations (SDOs) which he characterises as "multiplatform / multi-industry." He defines both SDOs and consortia as SSOs.

formed by a collection of interested companies and founded by such companies", contractual consortia, as the name suggests, are based on contractual relationships between participants. Umbrella consortia, in turn, are non-profit incorporated organisations that host other consortia under a defined framework.

Attempts to classify consortia are impeded by the fact that consortia are often opaque (Delcamp and Leiponen 2014). As a result, existing classifications are typically limited to few general characteristics such as founding year and number of members. We aim to extend the literature by including qualitative data available through websites and documents provided by consortia. Despite realising that consortia are flexible in devising their structures, processes, and rules, existing studies do not include an in-depth analysis of whether consortia utilize this flexibility. This is also due to the nature of the information: It is qualitative and not easy to find, often "hidden" in bylaws or other documents. That said, we believe this information is relevant for assessing consortia's role in the telecommunications industry. If, as the majority of the literature suggests, consortia wield a great deal of influence in standardisation and hence the steering of industry development, a more detailed look at consortia is called for.

3.3 Methodology

3.3.1 Approach

We aim to build a taxonomy of industry consortia and thereby aid our understanding of this phenomenon. Taxonomies can help organise data and objects, and hence provide an overview (Archibugi 2001; Pavitt 1984). They can be useful for simplification (Milligan and Cooper 2016) and can reduce "the complexity of empirical phenomena to few and easy to remember categories" (Jong and Marsili 2006, p. 214). We used an inductive approach, meaning that our taxonomy was based on patterns observed in data on consortia. The inductive approach is appropriate because there is no well-established and comprehensive theory of consortia that could serve as a basis for a deductive approach.

To gain an overall understanding of consortia, we conducted semi-structured interviews with 13 industry and standardisation experts (for a list of interviewees, see Chapter 2, Section 2.5), lasting in total twelve hours. Interviewees included individuals active in consortia as well as in (quasi-)formal SSOs, while we also interviewed representatives of major telecommunications equipment vendors and a network operator. When formulating the interview guidelines, we took into account the literature exploring concrete phenomena in standardisation, or providing precise descriptions of standardisation processes, such as Bekkers et al. (2002), Besen (1990), Delcamp and Leiponen (2014), Hawkins (1999), Keil (2002), and Leiponen (2008). The guidelines were continuously refined in an iterative process based on experience from previous interviews. The interviews were recorded, transcribed, and coded in NVivo. To facilitate open conversations, we informed interviewees that their identity would remain confidential.

For the quantitative analysis, in line with our chosen focus, we selected consortia in the field of 3GPP/ETSI using the Gesmer Updegrove classification[37], both those in the core area and those fulfilling an “add-on” function. To ensure data availability, we included only consortia that were active at the time of data collection.[38] We collected the data from online lists created by Gesmer Updegrove[39] and Raising Standards[40], as well as a free text online search. We also asked interviewees to name any relevant consortia missing from our list, and we added organisations accordingly. In total, we identified 100 consortia active in mobile telecommunications. Thanks to the combination of search methods we are confident our list is as good as complete.

For systematic data collection, we inductively built a classification scheme with 44 items, comprising qualitative and quantitative indicators. We manually collected these indicators from the consortia websites, relying in particular on the “About Us” sections (see Section 3.3.2 for details). To mitigate the (inevitable) issue of missing values, we imputed these in three different ways (see Appendix B, Section 8.3 for details). We then conducted a principal component analysis (PCA) to reduce the number of variables. The resulting data we fed into a cluster analysis (CA) to group similar consortia together, using different approaches for robustness (see Appendix B, Section 8.3 for further details on the PCA and CA analyses). Finally, we describe the clusters based on the arithmetic means in the underlying classification items.

We note that our findings from interviews and those from the analysis of consortia websites show some discrepancies. However, this is natural and due to the differing nature of the data sources: Information provided on websites is carefully presented and formulated, and is supposed to let a consortium appear in a certain way. In contrast, interviewees did not receive the questions beforehand, implying that they formulated their responses spontaneously. As a result, they sometimes emphasised different aspects than the respective website did. The discrepancies we observe (which do not include contradictory findings) are thus not a cause for

[37] See https://www.consortiuminfo.org/links/#.X3OfAGgzZPY.

[38] We considered including discontinued consortia, and tried collecting data and information via Internet archives. However, we found data to be highly incomplete, since many websites had been taken down and we were not able to find archives of them. We thus decided to exclude discontinued consortia from our analysis, to avoid concerns around methodology and data availability biases.

[39] See http://www.consortiuminfo.org/ (data retrieved until September 2017). See also Updegrove 2016.

[40] See http://www.raisingstandards.eu/ (data retrieved until September 2017).

concern, but rather an indication that the data triangulation achieved by our multi-method approach increases robustness of the findings and provides us with a richer picture.

3.3.2 Classification scheme and data collection

Our classification scheme to collect data started with an analysis of the consortia's websites, to give us a general idea of their characteristics, and to spot any special or unique aspects. Comparing the consortia's structures, rules, and processes with those of formal and quasi-formal SSOs (specifically ETSI respectively IEEE), further helped us to narrow down key characteristics, complemented with a literature review (also see Section 3.2) and information from interviewees. The resulting classification scheme (see Appendix B, Section 8.2) contains 38 items based on qualitative information and six quantitative variables, amounting to 44 items.

The qualitative items relate to the consortia's objectives, technological focus, rules, and processes. We specifically aim to shed light on organisational characteristics often hidden within bylaws or documents, and which have not been considered in earlier studies. They include membership admission and voting rules, plus ease of access to membership tiers and leadership positions. Raters converted the 38 qualitative items into quantitative items. In preparation, each qualitative item was described in a summary document, together with the exact definitions of the scale for that item. Most items were rated on a Likert scale, some using binary variables. The definitions of the items and scales were adapted and refined after a test run of 13 consortia, performed independently by two raters.

The refined scheme was then used for the rest of the sample. Data collection took place between August 2017 and June 2018. Two raters independently assessed each consortium and we discussed deviations to obtain a final assessment for each item. We also collected data on the founding year, which allows us to calculate the age of the consortia with respect to the data collection endpoint in June 2018. Furthermore, we added the number of members and their identity, as well as the degree to which consortia members were attending 3GPP meetings between 2010 and 2016. From the records of meetings on the 3GPP website, we extracted information on participants and their firm affiliation. We had to match firm names manually to identify overlaps with consortia member rosters. We captured meeting representation using four variables: the number and percentage of consortium members that were highly active in 3GPP Technical Specification Groups (TSGs) and in Working Groups (WGs). We operationalize 'highly active' as being in the top quartile of all participants in TSG/WG meetings with respect to the number of meetings with at least one representative of the member organisation. We used the absolute number as well as the percentage of consortium members to ensure large consortia were not automatically assumed to have stronger 3GPP linkages due to their high number of members.

3.4 Insights from interviews

The main aim of our interviews was to gain insight on firms' rationales for forming or joining consortia. We first discussed the role and purpose of consortia, especially regarding formal standard setting within 3GPP and its Operational Partners like ETSI. We summarise the insights from our interviews below.

An overarching theme raised by interviewees is that market players are free to shape consortia in line with their needs and goals. While the structures, rules, and processes of large and established SSOs are usually already defined and rather rigid (and significantly constrained by competition law), the aims and workings of newly formed consortia are up for discussion among (founding) members. As one interviewee put it: “The motive is always that the creators have the control. They set the rules of engagement [...] how who can have what and who can do what.” This aspect affects all the topics described below, and partly explains why we observed such a wide variety of consortia.

Thanks to the large number of existing and continuously emerging consortia, firms have ample choice. But active participation in consortia (and in SSOs, for that matter) requires manpower, for attending meetings or drafting specifications, making involvement in a larger number of consortia costly. Firms keep a watchful eye on the industry landscape, and emerging relevant consortia. A manager of a large network vendor asserted that it is important to “keep track of what the industry landscape looks like—whether maybe organisations are forming that you are not invited for or part of.” Then firms decide, usually based on their business strategy, which consortia to join. However, some interviewees suggested that many firms do not yet have a coherent strategy for observing and detecting interesting consortia. Many interviewees stressed it was vital for firms not to miss out on important developments, which are sometimes proposed by consortia.

Our interviews enabled us to identify rationales for firms forming or joining consortia, based on the five objectives discussed in the following sections.

3.4.1 Objective 1: Add-on technology development

Consortia may not just contribute to or impact standardisation, but also develop “add-on” technologies. These include technologies that often (but not always) complement 3GPP technologies—basically “on top of the 3GPP access network architecture” (comment by a manager at a large vendor). Examples are Open Source Software (OSS) applications. Whenever a consortium's technologies are very close to 3GPP technologies, a large overlap between firms in 3GPP and the relevant consortium is deemed useful.

Concerning the current evolution toward 5G and the Internet of Things (IoT), some cellular technology uses affect firms outside the ICT industry. One interviewee emphasised that “the scope of application within 5G will be much broader than only mobile broadband”, and he sees the need to “interact [...] with lots of other industries not represented in 3GPP.” Most interviewees do not think it is necessary or even possible to include firms from these industries in 3GPP itself, which they already view as large and ponderous. They believe the best way to interact with other industries is through external consortia.

3.4.2 Objective 2: Early technology development and circumventing political interest

Consortia can act as “upstream” organisations to 3GPP, where technical ideas and approaches are “prepared” for formal SSOs. This especially happens when very novel ideas are proposed. Then, proofs of concept and trials can take place within industry consortia, external to 3GPP. Once proofs of concept and trials are successfully completed, ideas can be brought into formal standardisation. Otherwise, as one SSO secretariat staff member remarked, novel technologies could be rejected or ignored in formal standardisation. Standardisation participants may perceive the use of these technologies as too risky and be reluctant to rely on immature technology.

Work may also be done outside 3GPP amid political resistance to a certain technology. Political resistance can arise when firms have a stake in another technology contested by the new one, or rely on different technology. Two interviewees mentioned the example of MulteFire, an LTE-based technology operating in an unlicensed and shared spectrum, and in some respects competing with Wi-Fi. As many firms within 3GPP, especially network operators, have a stake in using licensed spectrum (and may have a stake in Wi-Fi insofar unlicensed spectrum is used), it makes sense for firms involved in MulteFire to do the first stage of development within a consortium. Interviewees said that it is generally easier and less costly for them to remain within 3GPP. However, one interviewee commented that if they “foresee it will be cumbersome to drive the work in 3GPP due to political resistance”, they are likely to drive it elsewhere, for instance within consortia. Most interviewees agreed, and recognise the risk of promising technologies being blocked or lacking support within 3GPP.

3.4.3 Objective 3: Promote group interests

Consortia can also promote the interests of a certain group of firms or industry not directly related to a specific technology or group of technologies, such as commercial interests linked in a wider sense to technology. For instance, a consortium could promote cost-efficient technologies in general, and not concentrate on promoting specific technological solutions. Establishing a new consortium allows founding members to purposefully lock out specific (competing) interests, by restricting (new) membership access, voting rights, or access to leadership positions.

3.4.4 Objective 4: Speed up the standards development process

Consortia can help accelerate standards development, both full standards and parts of them. Our interviewees thought this may be because of participants' heightened interest and commitment, or the (mostly) smaller size and like-minded groups, which make it easier to reach consensus, or the use of novel tools and processes. Furthermore, parts of 3GPP standards can be driven outside 3GPP, then later brought back into the 3GPP standardisation process. Firms tend to do this if something is "very important to them" and they know 3GPP will be too slow for their needs (ETSI Board member and standardisation manager at large vendor). Another interviewee, however, claimed that working in a consortium is "rarely faster" because before starting the actual development work, founder members need to determine the organisation's processes and rules, which takes a substantial amount of time.

3.4.5 Objective 5: Anticipate key technological developments

Industry players want to be embedded in a large network of firms so that they can closely monitor the industry landscape and thus anticipate and respond to major technological developments. Anticipation is key for firms aiming to maintain or achieve an advantageous position in the market. A manager of a large vendor stressed that it is crucial to "make sure that you are at the forefront of research." An SSO secretariat staff member added that "the industry will sometimes enter their bets in two or three different directions, and then see which one wins." Hence, some firms are part of consortia that support competing solutions. By diversifying in this way, firms are more likely to spot key developments early and act accordingly. One industry expert even claimed "if you don't spot where the next technology is going and what you need to develop for it, then you're dead."

Anticipation is also highly relevant for development cycles. Once a standard is frozen, the infrastructure is probably more or less ready to be deployed, and compatible products are on their way. Firms higher up the value chain, such as infrastructure vendors or manufacturers of cellular modules, must provide (almost) market-ready solutions very soon after the standard is fixed. As one interviewee pointed out, "you have to sort of [...] know what is happening in five years." This especially applies to hardware, with its long development cycles.

3.5 Investigation of 100 consortia

This chapter describes several characteristics of our consortia sample, and provides some descriptive statistics. The average founding year of the consortia in our sample is 2005 (median 2007), which amounts to a mean age[41] of approximately 13 years (median 11 years). The average number of member firms is 186 (median 97), excluding pure adopter members not taking part in development activities.

As shown in Figure 3-2, the founding years of the consortia in our sample are distributed between 1984 (plus one observation from 1958, omitted in the graph), with an overall upward trend and some variation. The overall trend is at least partly due to survivor bias, since we only consider active consortia. The pronounced peak around 2015 coincides with heightened public interest in 5G, and the first attempts[42] to understand and define use cases and requirements for the new standard. The 5G Infrastructure Public Private Partnership (5G PPP), a joint initiative between the European Commission and the European ICT industry, was launched in 2014. That is when the first publicly known small 5G trials took place; trials on a larger scale were started in 2016 (see Gold 2016). After 2016, we observe a drop, which is partly due to data cut-off (we froze the list of consortia in September 2017).

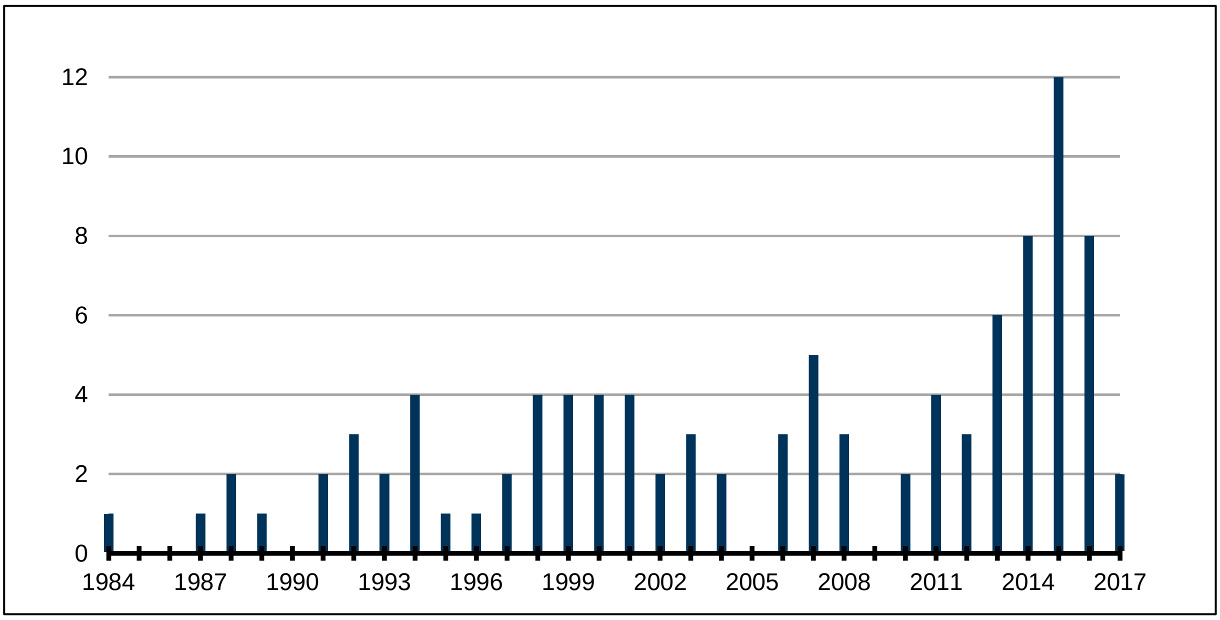

Figure 3-2: Number of consortia by founding year

[41] This is the age as of June 2018, which is the endpoint of data collection.

[42] In 2014, the European Commission published an article “5G: a new philosophy in connectivity” (European Commission, 2014), and there are numerous reports on understanding 5G (such as GSMA Intelligence, 2014).

Focusing next on objectives (or purpose), Figure 3-3 shows how many consortia state a certain aspect as their primary or secondary objective on their website. We take the most emphasised objective as primary, and the other ones as secondary. The two leftmost objectives in the figure are directly related to technology development, while the next two indirectly relate to it (existing technologies can be certified and marketed). The next three pertain to standardisation, and the final two to market and societal issues.

In total, 62 consortia indicate they are involved in developing mature technologies, and 48 in early-phase technologies (an individual consortium might be involved in both mature and novel technologies, hence the total of 110). Quite a few consortia (51) are involved in certification (a well-known example is the Wi-Fi Alliance, which certifies products based on the IEEE 802.11 series of wireless LAN standards). Certification activities often go hand in hand with marketing activities. This makes sense, because if a consortium arranges the certification of products according to a certain standard, it will also want to promote this standard—hence, certification and marketing activities may indicate that consortia promote a certain standard or group of standards, even if they do not formally list this as a goal. Many consortia (58) aim to develop standards; examples of such standards are ZigBee and LoRa. Even if a consortium does not officially publish a standard (any more), the maintenance and further development may still be done within that consortium (we already mentioned Bluetooth as an example of this). Furthermore, 52 consortia explicitly mention their aim to formally contribute to a standard, mostly via official liaisons and partnerships. Twenty-nine consortia indicate that they contribute informally through their members, but how they do this is difficult to gauge.

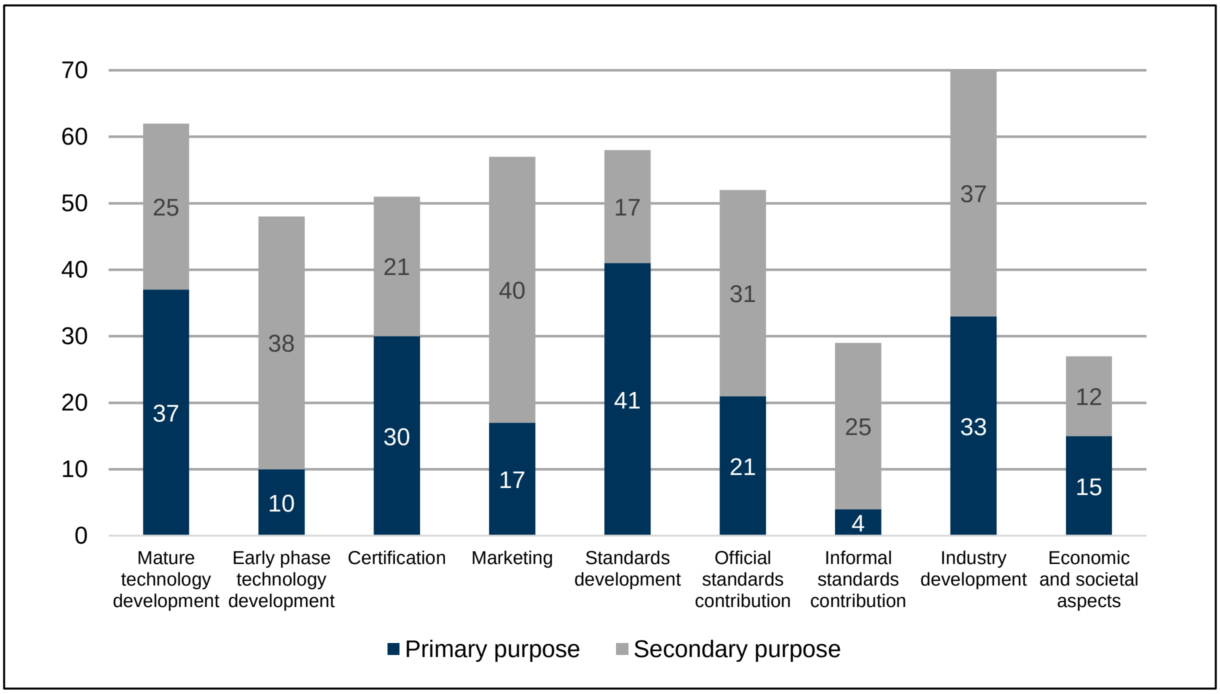

Figure 3-3: Number of consortia listing a specific primary or secondary objective

A frequently (n=70) mentioned objective, not directly linked to technology or standards, is industry development—which we perceive as furthering overall industry evolution and technological progress. A similar goal (n=27) is to address economic and societal aspects, such as supporting society with technological developments.

A closer look at technologies (see Figure 3-4) shows that around half of the consortia (53) work on network architecture and infrastructure (software, hardware, and protocols), 19 are involved in computer engineering or cloud computing, and 14 create solutions for non-ICT industries (so-called verticals). In terms of technological breadth, most consortia (63) are "in the middle", that is to say they focus on technology systems and solutions (such as small cells or device-to-device communication). Very few consortia (6) focus on specific technology components or methods (like SIP[43] or CDMA). A total of 31 consortia concentrate on wider and higher-level topics such as the Internet of Things, or mobile networks.

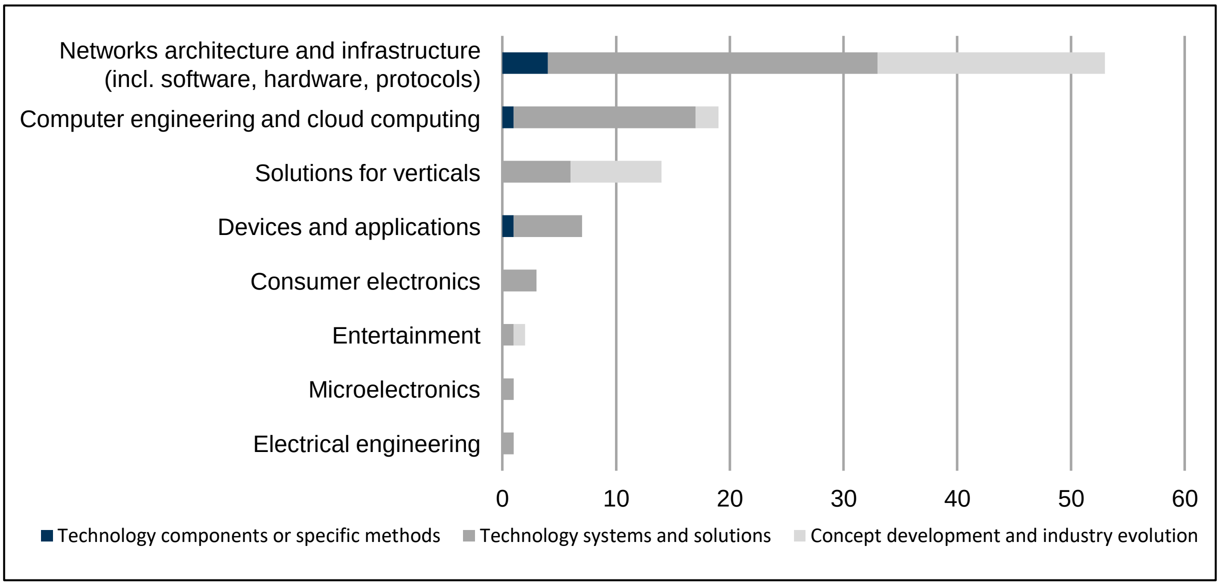

Figure 3-4: Consortia's technological breadth

In terms of participating in 3GPP meetings, on average 20 members (i.e. member firms) per consortium are in the upper quartile of 3GPP TSG meeting representation, and 22 in the upper quartile of WG meeting representation. This amounts to approximately 20% respectively 22% of the members of an average consortium. The most active firms have taken part in 26-28 meetings in each TSG. However, these numbers can differ considerably depending on the size[44] of a consortium—large consortia tend to have higher absolute overlaps with 3GPP meet-

[43] SIP: Session Initiation Protocol.

[44] Also, in very rare cases (e.g. GSMA), more than one of a firm's subsidiaries are represented in a consortium. These subsidiaries are counted separately because they may pursue different business

ings, while percentage overlaps are often higher for smaller consortia. We found that 66 consortia have formalised ties with 3GPP, in the form of Market Representation Partnerships or other formalised collaborations, and 49 have formalised ties with 3GPP Operational Partners. Because most Organisational Partners (and many consortia) do not keep a public database of their partnerships and collaborations, we could not capture all the ties between these organisations. Twelve consortia in our sample are ETSI Industry Specification Groups (ISGs),[45] and are thus hosted and supported by ETSI. Even though ISGs work under the ETSI umbrella, they are accessible to both ETSI members and non-members, and can adopt their own voting rules and work programs (though all ISGs must apply the ETSI IPR policy).

When it comes to transparency and accessibility[46], most consortia impose some restrictions. Comprehensive information on structures and processes is often not presented directly on the website, at least not to the same extent that (quasi-)formal SSOs provide them. Obtaining this information requires reading the bylaws or policy documents. Although these documents are usually easy to find via web pages, one often has to comb through (usually lengthy) texts meticulously. The same applies to membership information and processes or participation options. Thus, firms interested in joining a consortium can find it cumbersome to obtain extensive information. Also, most consortia have a tiered membership structure, and restrict access to upper membership tiers (usually those with the most far-reaching rights). Such privileges also have repercussions on assigning leadership positions, since only a few firms can influence these decisions. As we will later see, these exclusiveness issues can be associated with prerogatives and advantages of founding members. However, it is not always the case that founding members secure these privileges for themselves. The large majority of consortia are initiated by a set of interested corporate or non-corporate actors, also called promoters. Hence, we believe the sheer presence of promoters in a consortium is not a distinguishing factor— rather, it is the footprint that some of these promoters leave in the rules and structures of consortia. Moreover, the information on promoters is often not public[47] or incomplete, which is why we do not include this information in order to avoid a potential bias.

interests. Given that such cases are rare, the outcome would largely remain unchanged if they were merged instead.

[45] For information on ETSI ISGs, see http://www.etsi.org/about/how-we-work/how-we-organiseour-work/industry-specification-groups-isgs (retrieved on 28/07/2020).

[46] Here, “accessibility” refers to how easily an interested firm can become an influential member of a consortium.

[47] It is plausible that such promoters have no interest in disclosing this information.

3.6 A taxonomy of industry consortia

Ultimately, we aim to group consortia in a systematic and objective way, and do that by creating a taxonomy. To achieve this, we used clustering algorithms to group consortia according to their similarities and differences. We used principal component analysis (PCA), followed by cluster analysis (CA). The first step reduced a large number of variables to a smaller set of components. The second step grouped all the consortia into clusters. These clusters, each described and analysed in terms of their characteristics, form the basis of our taxonomy.

3.6.1 Principal component analysis

Principal component analysis allows us to group variables into factors according to their correlations, and hence to reduce the dimensionality of the dataset. To ensure our results are robust, we build on three datasets (see Appendix C, Section 8.3) obtained using three different methods of dealing with missing values. For all three datasets the Barlett test of sphericity indicated that the data is suitable for factor and principal component analysis ($p < 2.22e{-16}$). To determine the number of components, we used the nFactors algorithm[48] to compute and inspect the eigenvalues, optimal coordinates, and acceleration factor, as well as a parallel analysis. Based on these indicators, in all three cases, we built seven components. We conducted PCA with varimax rotation, then examined the factor loadings in order to interpret the resulting factors. To analyse these factors, we checked for the highest loading of each variable, concentrating on loadings above 0.5. Based on the loadings, we computed factor scores for both solutions, and each consortium.

Although the solutions differed somewhat between our three datasets, we identified seven common “themes” (see Table 3-1). As is often the case with PCA, variables load on more than one component, and so the themes overlap.

[48] See http://cran.r-project.org/web/packages/nFactors/nFactors.pdf.

Table 3-1: Common themes of principal component solutions

Theme	Component	Description
1	Technology and standards focus	Extent to which a consortium is concerned with technology and standards development (in contrast to societal goals relating to overall industry development, and economic or social aspects). Technology and standards development may go along with marketing or certification activities.
2	Non-commercial orientation	Extent to which a consortium is supported and populated by non-corporate entities (governmental or multilateral entities/authorities).
3	Size	Number of members; also extent of (absolute) presence of consortia members at meetings of 3GPP.
4	Novelty	Consortium's young age and whether it leans toward early technology development.
5	3GPP ties and involvement	Whether a consortium has official co-operations with 3GPP, and what share of its members is highly involved in 3GPP meetings.
6	Structural transparency	Whether information on structures, processes, and work status is easily available and comprehensive, including ties with other organisations, and work documentation.
7	Information provision and accessibility	Ease of access to a consortium, i.e. whether an interested firm would be able to find all relevant documents regarding membership (bylaws, IP rules, conditions) and how easily a firm can gain influence in the organisation (voting rights, access to leadership positions). Also: lack of advantages and privileges for founding members.

3.6.2 Cluster analysis: Approach

To identify types of consortia, we ran a cluster analysis that groups consortia according to their proximity in the seven-dimensional space defined by the results of the principal component analysis. We applied two clustering algorithms with various parameter combinations to refine and check our results.

First, we used the Density-Based Spatial Clustering of Applications with Noise (DBSCAN) algorithm.[49] The advantage of DBSCAN is that one does not have to specify the number of

[49] For details on the DBSCAN algorithm, see http://cran.rproject.org/web/packages/dbscan/dbscan.pdf.

clusters beforehand.[50] Consequently, DBSCAN was the first step in obtaining a rough overview of groupings. However, the clustering results were indeed rough (in the sense of yielding a small number of clusters), and in the absence of a second algorithm, difficult to interpret. K-means helped us refine the results, providing a more granular clustering with well-defined characteristics for each cluster. We applied both DBSCAN as well as the k-means algorithm with various parameter inputs for each dataset.

To find suitable *epsilon* parameters for DBSCAN, we inspected the distances to the nearest neighbour, checking three, four, and five neighbours for each consortium. These numbers also corresponded with the minimum points parameter to be defined for the DBSCAN algorithm. We used the average distances to the nearest neighbour as guiding value for trying various parameter combinations. Finally, we kept one DBSCAN solution per dataset, based on parameter combinations providing more than one cluster and a reasonably low number of noise points.

For k-means clustering[51], the number of clusters k to be formed has to be defined in advance. To determine a suitable number, we used three approaches, namely the Elbow and Silhouette, as well as the Gap Statistic[52].

Based on the above considerations, we decided to build six cluster solutions, and compare overlaps and characteristics to achieve a more robust result[53]. We inspected cluster overlaps by first comparing all the clusters obtained by k-means, and computed the percentage overlap

[50] To use DBSCAN, one must first define two main parameters: the size of an *epsilon* neighbourhood as well as its minimum number of points. The algorithm starts at a random point, then checks its pre-defined neighbourhood for points at most epsilon distance from the starting point. If that number is at least as large as the pre-defined minimum, a cluster is built. If not, the point is defined as noise. However, if there is another cluster with a core point at most *epsilon* from our starting point, the two clusters become one. This process continues until all clusters and noise points are defined. Then, the algorithm assigns border points to the clusters.

[51] We used the Hartigan and Wong algorithm: it forms k clusters by dividing all the consortia into groups. It does this by first adding each data point to the cluster with the centroid closest to it.

[52] As the Gap Statistic indicated only forming one cluster, which is not in line with the two other indicators, we dismissed the Gap Statistic results.

[53] The advantages of DBSCAN are that the number of clusters does not have to be defined beforehand, and it can build clusters in various forms and sizes. In our case, it formed one large, and one or two small clusters. Increasing epsilon can reduce the number of noise points, but the largest cluster usually becomes even larger. The extent of similarity within the single clusters can vary; DBSCAN tends not to recognise these differences, and constructs very few clusters. On the other hand, k-means forced us to pre-define the number of clusters, and build clusters of more similar size and form.

between two clusters. Specifically, we wanted to see what share of consortia showed up in two clusters if they were from different cluster solutions. We selected the cluster combinations with the highest overlapping consortia, then built and described six final clusters comprising combinations of two to three initial clusters. We then compared the characteristics of the newly constructed clusters with the two DBSCAN clusters.

3.6.3 Cluster analysis: Results

We obtained a taxonomy consisting of six clusters of consortia, which we named as follows (in order of decreasing average size of consortia in the cluster):

- **Cluster 1**: Large industry and technology influencers
- **Cluster 2**: High-level concept developers
- **Cluster 3**: Established standards developers
- **Cluster 4**: Young technology specialists
- **Cluster 5**: Small industry and technology influencers
- **Cluster 6**: SSO-hosted industry drivers

Since the outcomes from the three datasets were similar, we just present one set of results (the set in which variables were imputed using assumptions). Our detailed descriptions of each cluster include a radar graph presenting scores for the dimensions described in Table 3-1[54]. The numbers in the radar graph show the arithmetic mean of factor scores for all consortia in the respective cluster. Factor scores relating to one component/dimension have a mean of zero, such that a positive value indicates an above-average score.

[54] Due to the slight differences between the PCA solutions summarised in Table 3-1, a "theme" in Table 3-1 is somewhat less clearly defined than a "dimension" in the cluster analysis that follows.

Cluster 1 comprises “large industry and technology influencers.” They often emphasise broad technological concepts combined with goals relating to furthering industry development and economic or societal issues. Although some are involved with the development of novel technology, their main focus is then the maintenance or enhancement of mature technologies. Most consortia in this cluster are very large (639 members on average) and their average founding year is 1999, which means that their average age was 19 years when we collected our data. This age is significantly higher than the average of consortia in other clusters. We noted slightly above-average levels of transparency: Information on structures and processes, as well as most policy documents, are usually publicly available and easy to find. However, comprehensive information on membership options and work documentation is missing in some cases. In many cases, we also observe restricted access to membership tiers, meaning that new consortia entrants cannot enter upper tiers. Consequently, certain (groups of) firms enjoy privileges regarding the assignment of leadership positions. We found quite a few formalised 3GPP co-operations, and average levels of 3GPP meeting representation. This was also reflected in the consortia’s goals—many organisations plan to contribute formally to standards. This cluster has five consortia, including the GSM Association (GSMA), oneM2M, and the Wi-Fi Alliance.

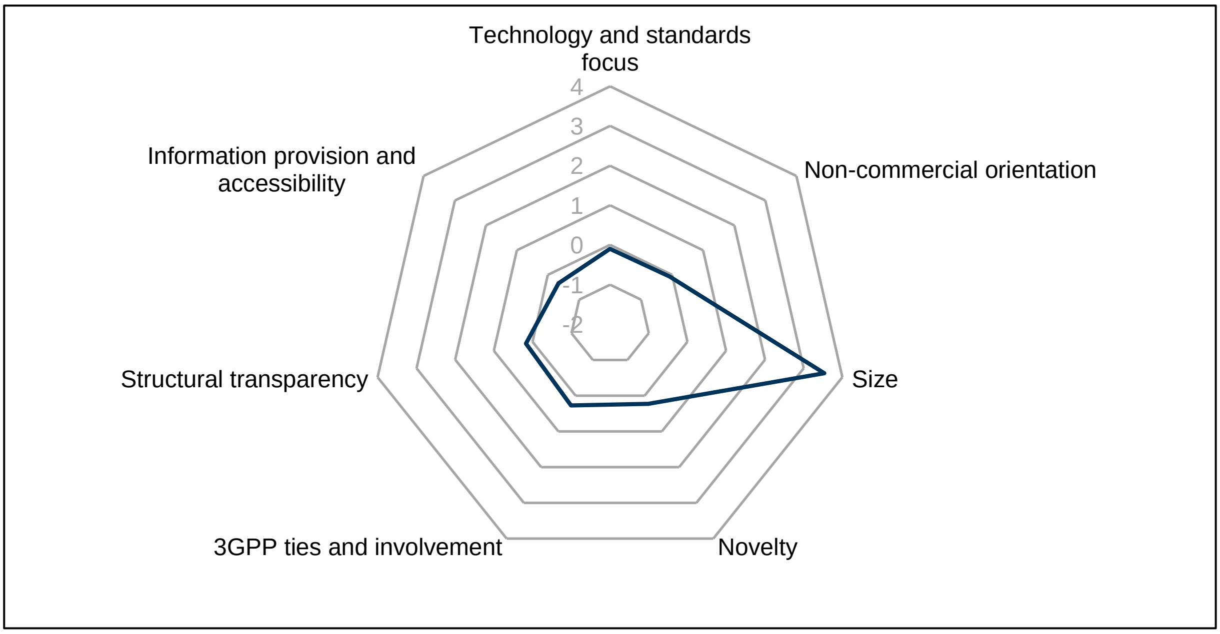

Figure 3-5: Average factor scores for Cluster 1 - Large industry and technology influencers

Cluster 2 are the "high-level concept developers" because this group focuses on industry development as well as economic and societal goals, rather than technology development. For that reason, these consortia are frequently supported or joined by government or multilateral entities. They tend to work on very broad technological concepts rather than specific and well-defined technologies. They have 329 members on average, and are of a higher age than the average consortium in the dataset (mean founding year 2002, corresponding to an average age of 16 years). Even though some information on structures is missing or incomplete, consortia in this group tend to exhibit above-average levels of transparency. Membership tiers and leadership positions are mostly easily accessible to all firms. 3GPP ties do not seem to be particularly strong, there are mostly no formalised 3GPP co-operations, and meeting representation is relatively low. Consortia in this cluster include the Alliance of the Internet of Things Innovation (AIOTI), 5G PPP, and DigitalEurope.

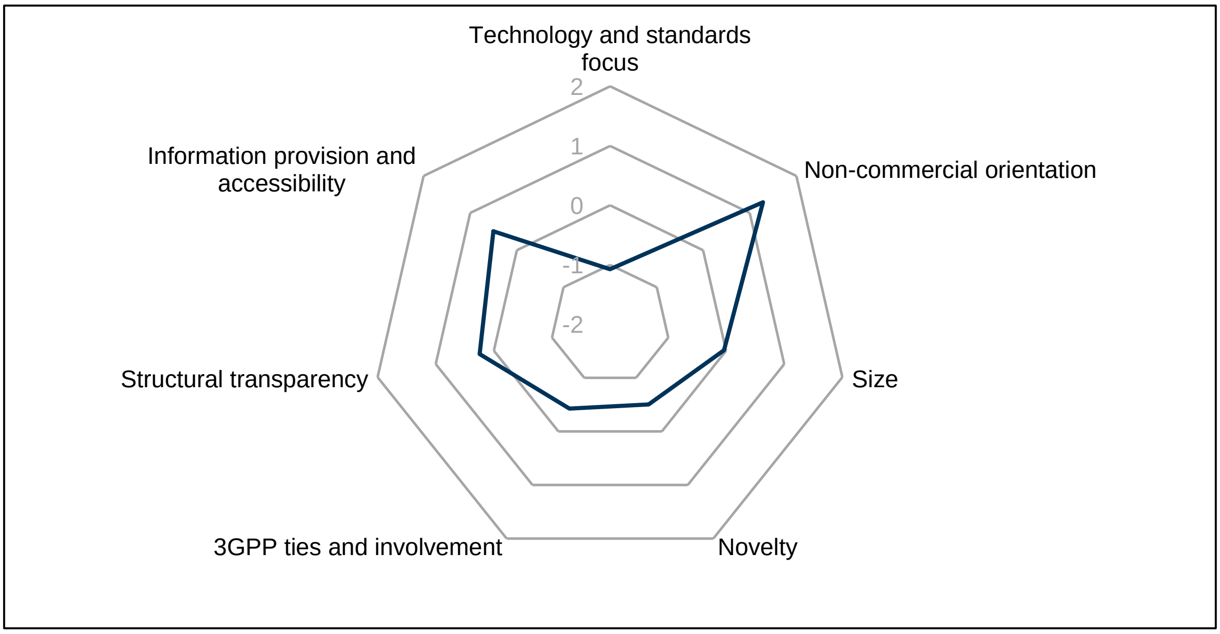

Figure 3-6: Average factor scores for Cluster 2 - High-level concept developers

Cluster 3, what we call the "established standards developers", comprises consortia that focus on the maintenance and enhancement of mature technologies. They often engage in standards development, sometimes promoting them with certification and marketing tools. This means they can compete with 3GPP in some respects. The consortia have an average of 224 members, and are of mature age (mean founding year 2000, corresponding to an average age of 18 years). Their transparency ratings are average as they provide a moderate amount of information on their structures, processes, and rules, while some details are not clear. Most of their membership tiers are accessible, although certain (groups of) firms enjoy privileges when it comes to assigning leadership positions. There are very few formalised co-operations with 3GPP, and 3GPP meeting representation is below average. This cluster has 32 consortia, including Bluetooth SIG, Broadband Forum, and DECT Forum.

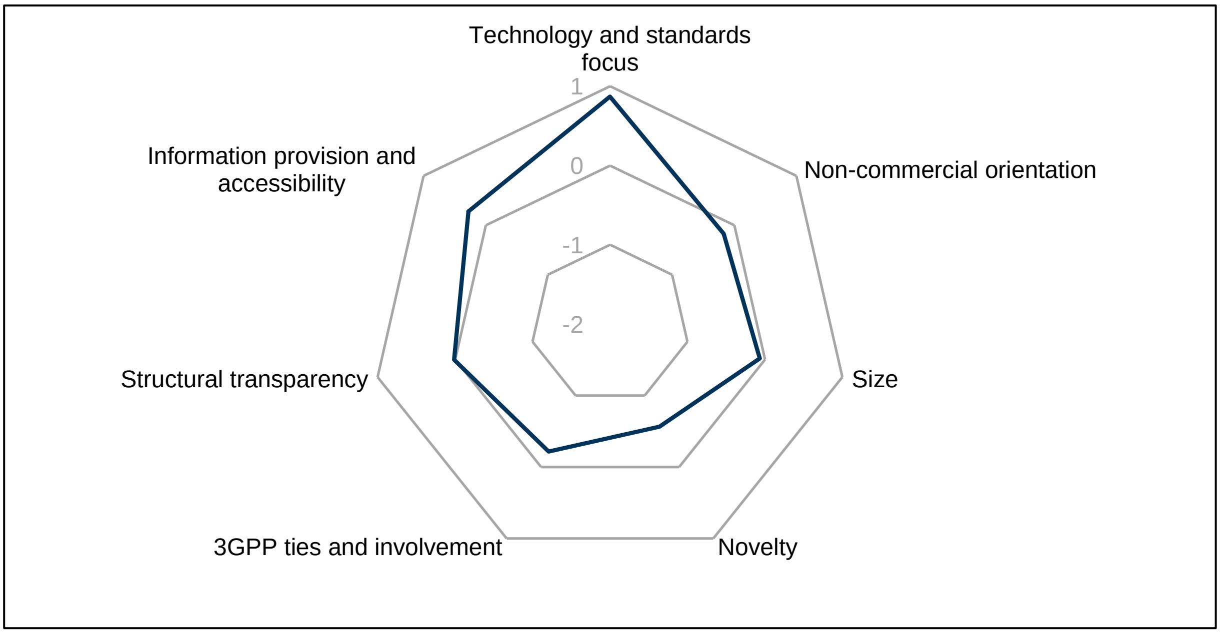

Figure 3-7: Average factor scores for Cluster 3 - Established standards developers

We call **Cluster 4** the “young technology specialists.” In contrast to the other clusters, the majority of consortia in this cluster works on novel technology. They include Open Source organisations such as CloudFoundry, Eclipse, and Open Platform for NFV (OPNFV). Many of these organisations are part of the Linux Foundation (which thus can be seen as an umbrella consortium in the sense of Biddle 2017). Most of the consortia are involved with software development, and standards development is not much of a concern. They are smaller than the average consortium in the sample (107 members on average) and of young age (mean founding year 2013, corresponding to an average age of five years). Transparency levels are high, especially regarding work documentation; many organisations have openly accessible depositories or Wikis. Although participation is usually easy, we did find restrictions regarding access to leadership positions. The 14 consortia in this cluster are mostly independent of 3GPP, and exhibit below-average 3GPP meeting representation.

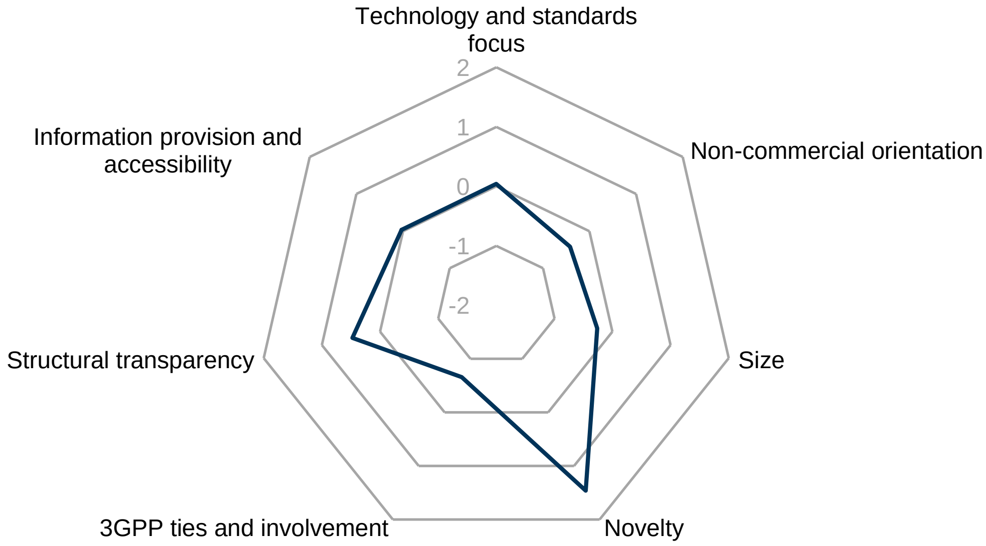

Figure 3-8: Average factor scores for Cluster 4 - Young technology specialists

Cluster 5, the “small industry and technology influencers”, pursue a mixture of industry development, economic and societal objectives. In rare cases, technology development is part of the mix. Many consortia focus on high-level technology concepts rather than specific technologies, and sometimes do marketing and certification. The consortia in this group are small (90 members on average) and their mean age is slightly above the sample average (mean founding year 2004, corresponding to an average age of 14 years). They score relatively low for transparency, especially in providing key information on their organisations, and documents such as bylaws and IP rules. As some impose very high restrictions on access to membership tiers, new members are often denied access to the highest tiers. Additionally, certain (groups of) firms have greater leadership privileges, and application processes can be unclear. Many consortia in this group have formalised ties with 3GPP, and aim to formally contribute to standards. We found relatively high 3GPP meeting representation. There are 15 consortia in this cluster, including the 5G Automotive Association (5GAA), Next Generation Mobile Networks (NGMN), and MulteFire.

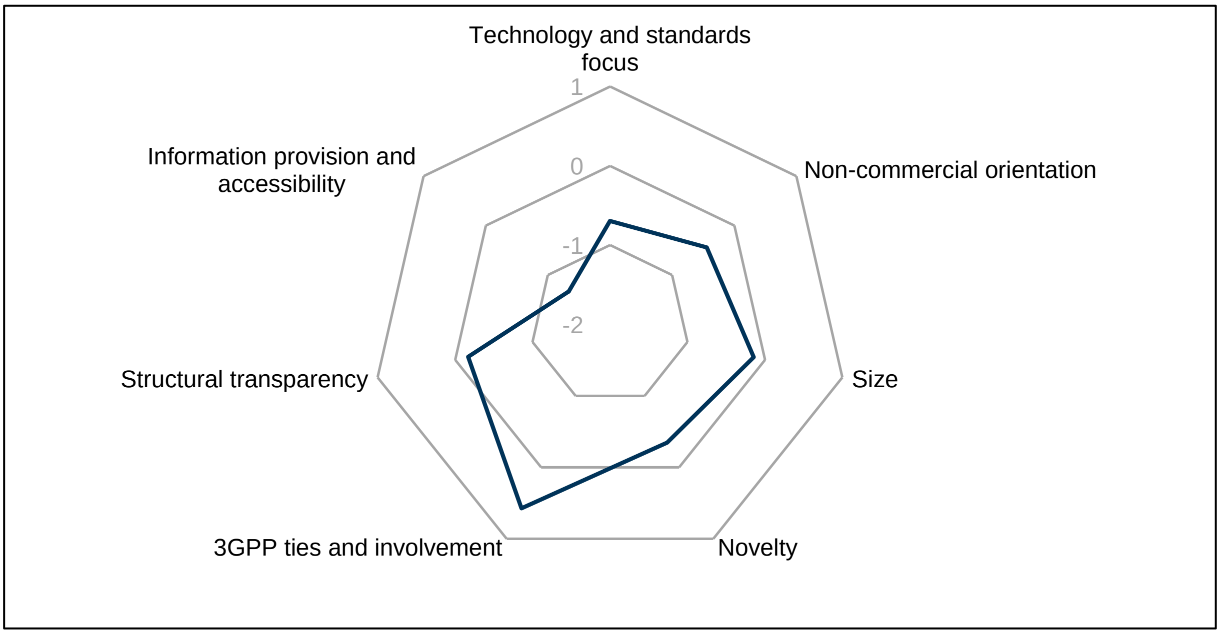

Figure 3-9: Average factor scores for Cluster 5 - Small industry and technology influencers

The consortia in **Cluster 6**, the "SSO-hosted industry drivers", pursue various goals, such as industry development and early technology and standards development. Most consortia are very small (28 members on average) and of very young age (mean founding year 2014, corresponding to an average age of four years). In terms of transparency, the picture is mixed. Comprehensive information on membership structures and participation options is sometimes hard to find, as is work documentation. Although it is easy to access and be a part of SSO-hosted industry drivers, not all membership tiers are accessible to new members. All eight of the consortia in this cluster are ETSI ISGs, and thus hosted by ETSI. They are often supported or populated by non-corporate entities, such as multi-laterals or government agencies. Non-ETSI members, however, are restricted in the activities and positions available to them. There are also formalised 3GPP co-operations, and a large share of members regularly participate in 3GPP meetings.

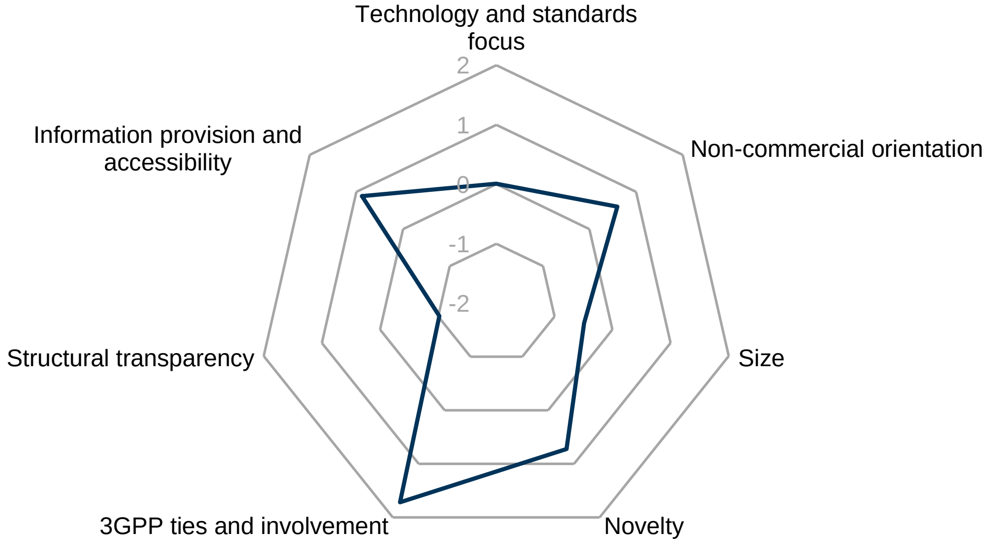

Figure 3-10: Average factor scores for Cluster 6 - SSO-hosted industry drivers

Overall, consortia clearly have a very diverse range of objectives as well as characteristics. They differ not only in "obvious" characteristics, such as size and age, but also in transparency, accessibility, and exclusiveness.

We discovered that although not every consortium is involved with standards development or contributions, they are not necessarily irrelevant to standard setting. Some organisations still have formal co-operations with 3GPP, and/or a high presence in 3GPP meetings (see small industry and technology influencers). In contrast, consortia that develop, maintain or enhance their own standards (see established standards developers) are often independent from and may even compete with 3GPP. Many Open Source organisations (see young technology specialists) also do not formally interact with 3GPP, however, their technologies can still serve as a kind of add-on or competition to 3GPP.

There are also large differences between the groups with strong 3GPP ties, either via formalised co-operations or meeting presence (see SSO-hosted industry drivers, large industry and technology influencers, small industry and technology influencers). They differ in their scope, as they work on specific novel or mature technologies, but also broad concepts. Interestingly, unlike the other groups, they are exclusive regarding access to membership tiers and leadership positions. Thus a firm newly entering a consortium may often not be able to become an upper-tier member and consequently will have less influence in assigning leadership positions or not be allowed to nominate candidates.

3.7 Conclusions and implications

To better understand the phenomenon of industry consortia, we first explored the reasons why firms establish and join industry consortia. We find that even though there is a large body of literature tending to strategic (technology) alliances, and other forms of inter-firm cooperation of collaboration, firms' rationales for their involvement in consortia in particular has not been systematically and comprehensively analysed yet. Based on semi-structured interviews with industry experts, we identify five rationales for joining and forming industry consortia.

Some of these rationales are related to (perceived) shortcomings of established (quasi-)formal SSOs, and hence point toward a substitutive relationship with them; however, other rationales indicate that consortia have a supplementary character, that is, they constitute additions to the existing landscape of (quasi-)formal SSOs.

The diversity of roles that consortia can fulfil suggests a large variety of such organisations, in terms of both objectives and organisational set-up. This is indeed what we find in our classification of 100 consortia active in the field of mobile telecommunications. Our taxonomy yielded six groups: (1) large industry and technology influencers, (2) high-level concept developers, (3) established standards developers, (4) young technology specialists, (5) small industry and technology influencers, and (6) SSO-hosted industry drivers. What facilitates the diversity of consortia is the fact that they are more flexible than formal SSOs in shaping their structures and processes, and determining what one interviewee called the "rules of engagement." This diversity chiefly relates to transparency, accessibility, and exclusiveness. Interestingly, legal status, which is the basis of the categorisation used by Biddle (2018), does not correlate with our cluster allocation, and thus appears to be an independent dimension. Overall, we believe the solid insights into the diversity of industry consortia that our study provides will improve our understanding of industry dynamics and standardisation in particular.

In addition to the taxonomy of consortia, our study yields several other interesting findings. First, some consortia's officially proclaimed goals and focus areas might not entirely match their actual work. Some goals are formulated in a rather vague fashion[55], which leaves outsiders wondering about the actual nature of a consortium's work. This seems to be the case for some consortia claiming to pursue broad industry, societal, and economic development goals (rather than actual technical work).

Second, some consortia restrict the acceptance of new members, or restrict their subsequent influence. This restrictiveness can in some cases be related to founding members securing advantages for themselves: In the Telecom Infra Project consortium, only the firms belonging to the member category "sponsors" can appoint representatives for the board of directors, and the number of sponsors is limited to nine. The bylaws[56] also state that "all new sponsors must be approved by a majority vote of all current sponsors." In the case of 5GAA, platinum members can nominate board members, and gold members can propose candidates for the board[57]. To put this in context, platinum membership is limited to twelve organisations, eight of these founding members. Interestingly, consortia that impose restrictions on new members often have strong ties with (quasi-)formal SSOs. We therefore believe that such consortia are especially influential for the standard setting route and overall technological advancements. Also, the restrictiveness of these organisations allows a few leading firms to enjoy substantial steering and shaping freedom. Thus, even though we recognise the need for industry consortia and their contributions, it may be prudent for policymakers to closely monitor and assess consortia. Our taxonomy can help inform this monitoring and assessment. It can then also help policymakers identify areas and consortia that require their attention—for instance because due to their rules and structures, they allow certain firms to obtain sizeable advantages. Furthermore, our taxonomy could be valuable for bodies such as the European Multi Stakeholder Platform on ICT Standardisation (MSP), which has the role to advice the EC on the identification of ICT standards (which, once approved, can then be referenced in European public procurement).

Third, some consortia may help technological advancements in the industry, and hence societal progress. This is the case where consortia aiming to advance novel and promising

[55] For instance, the Alliance for Internet of Things Innovation (AIOTI) says they "aim to strengthen the dialogue and interaction among Internet of Things (IoT) players in Europe, and to contribute to the creation of a dynamic European IoT ecosystem to speed up the take up of IoT" (see http://aioti.eu/, as of March 2020); Next Generation Mobile Networks (NGMN) states they give "guidance to equipment developers and standardisation bodies, leading to the implementation of a cost-effective network evolution" (see http://www.ngmn.org/about-us/vision-mission.html, as of March 2020).

[56] See http://cdn.brandfolder.io/D8DI15S7/as/q7rnyo-fv487k-d2tvpc/Bylaws-Telecom Infra Project.pdf (retrieved on 28/07/2020).

[57] See http://5gaa.org/membership/5gaa-membership/ (retrieved on 28/07/2020).

technologies meet substantial resistance from major industry players. However, some small firms may not possess the necessary means or momentum in the market to initiate consortium activities and promote their technologies. Our interviews even suggest it may in some cases make sense to restrict and limit access to a consortium, and especially to leadership positions—for instance, in cases where political resistance from a number of firms is to be expected, but the technology to be developed or promoted looks promising. Being open to participation from all firms may then imply that interesting technologies could be blocked by powerful parties.

Our taxonomy can also help scholars understand the consortia landscape, and its impact and role in the industry. It can also support firms in deciding which consortia to establish or join, because participation is costly, especially in terms of manpower. Our interviewees emphasised that belonging to a wide variety of consortia benefits firms in the industry as this helps them anticipate and impact key technological developments. A taxonomy can thus help identify various types of consortia of interest to a firm.

Our study's approach and outcomes have several limitations. While we believe that our focus on 3GPP-related consortia is well justified and allows us to observe all important motives to engage in standardisation, it may still present a limitation in terms of our findings being representative for other technological fields. Thus, a careful analysis of consortia in other fields could be interesting for comparison. Future studies could also incorporate a time dimension in the analysis, have a dynamic view of when firms enter consortia, and observe changes in consortia's operations over time. Moreover, we did not include 15 of the 100 consortia in our sample in the final clusters. This is because we only classified consortia in an overlap between at least two clusters of two different solutions. Adopting this approach, 15 consortia did not really fit any cluster. Finally, from general impressions, one would expect many consortia to promote standards, and put this forward as a primary objective. However, this objective was not emphasised by our interviewees, and does not explicitly follow from our analyses of consortia website. Still, the objectives of "marketing" and "certification" essentially amount to promoting a standard. Overall, by including a multitude of dimensions and consortia characteristics in our analysis, and triangulating quantitative data with interviews, we hope to get as close to the actual goals and activities of consortia as possible.

4 Implications of industry consortia memberships: Information, control, and strategic patenting

4.1 Introduction

Being well-connected or having a "central" position within a network of peers is generally recognised to be beneficial for firms, especially when it comes to novelty creation (Gilsing et al. 2008). In a similar vein, Gulati et al. (2000, p. 203) associate such networks with "access to information, resources, markets, and technologies", which can then lead to "advantages from learning, scale, and scope economies". Above all, being well-connected may offer competitive advantages by "increasing […] cognitive salience of some competitors relative to others" (Gnyawali and Madhavan 2001, p. 432).

In the context of standardisation in mobile telecommunications, inter-firm collaboration and cooperation have historically been indispensable for the functioning of technologies and hence the industry as a whole. Naturally, in telecommunications, compatibility of technologies is key. Thus, standards ensuring compatibility (or interoperability) so that "products manufactured by different producers" can "work together" (Sirbu and Zwimpfer 1985, p. 35), have always been relevant for industry players. Due to this historical background, established players have long been in close contact with each other, in some way or another, and hence "unwritten rules or informal codes of conduct" (Powell 1990, p. 305) have emerged. Additionally, an extensive landscape of formal standard setting organisations (SSOs), and related organisations, has been emerging, to establish an institutional framework for standardisation activities.

Part of this institutional framework is the rules on handling intellectual property (IP) relevant for standards. Most prominent in scholarly discussions are issues related to the declaration and licensing of standard essential patents (SEPs). Simply put, patents can be understood as essential for a certain standard when they are "indispensable in order to manufacture a product or offer a service based on the standard in question" (Bekkers et al. 2011, p. 1001) without infringing the patents in question. Hence, ownership of SEPs is very much sought-after because firms aiming to offer these products and services "cannot opt for alternatives" (Bekkers et al. 2002, p. 1145): They promise high licensing revenues and an advantageous negotiating position in cross-licensing arrangements (Bekkers et al. 2011).

Most formal SSOs require patent owners to identify and then disclose or declare essential patents themselves (Bekkers et al. 2011). However, many SSOs remain vague on the exact required modalities of disclosure, leaving firms with some flexibility. For one, this flexibility relates to the timing of disclosure. Formal SSOs usually do not specify exactly at which point in the standardisation process the declaration is supposed to happen (Bekkers et al. 2012). For firms wishing to obtain a large number of SEPs, it makes sense to file for standards-related patents once they have come to a relatively accurate assessment on the exact specifications of the standards in question. This is usually close to key decisions in the standardisation process. This means that firms may strategically place inventions and apply for patents, especially given the sought-after ownership of SEPs. Often, these patents are then characterised by a short time span between their application and their disclosure date (Bekkers et al. 2012): When a firm aims to get a patent included in a standard, it wishes to achieve maximum conformity with the standard (Berger et al. 2012). It is most likely to achieve this by finalising the patent application close to the date of key standardisation decisions. Once these decisions have been made, firms participating in standardisation are urged to declare relevant SEPs—leading to a relatively short time span between patent application and declaration as SEP.

Apart from formal SSOs, other standards-related organisations and forms of cooperation have been emerging, among them industry consortia (henceforth also referred to as just “consortia”). Delcamp and Leiponen (2014, p. 36) find that industry consortia play an “increasingly central role […] in coordinating technology development”, and that “consortium participation facilitates coordination of firms' innovation activities” (Delcamp and Leiponen 2014, p. 45). Even though there are several understandings of industry consortia and their goals and purposes, there is broad agreement that they have some kind of impact on standardisation activities in formal SSOs. However, scholars find different ways of how industry consortia impact formal standardisation activities: they can help the “coordination of firms' innovation activities” (Delcamp and Leiponen 2014, p. 45), including “co-ordinating technology with emerging market demands” (Hawkins 1999, p. 162), prepare technologies for standardisation (also often called “pre-standardisation”) (Leiponen 2008; Simcoe 2014), or produce and/or endorse standards (Baron et al. 2014; Lerner and Tirole 2006; Pohlmann 2014). In Chapter 2, I further delve into firms’ rationales for initiating and getting involved in consortia, and also find that firms may decide to circumvent resistance or lengthy processes within formal SSOs by doing work in industry consortia. Ultimately, the question is whether consortia’s impact on standardisation activities also translates into patenting and SEP declaration activities.

If, as many previous contributions claim, pre-standardisation is a major aspect of why firms take part in consortia, considerations around the positioning of patents should be an important part of this—especially because we know that firms generally covet ownership of essential IP. Baron et al. (2014, p. 23) claim that consortia can contribute to a more targeted patenting around standards: “Our results suggest that consortia can […] in some cases, mitigate intensive patenting around the standard when it is wasteful for the firms.” This provokes the question as to whether firms participate in consortia to be able to engage in more targeted patenting, and therefore obtain more (potentially) valuable patents.

Participation in consortia generates an intricate network of collaborating firms. Hence, I am wondering to what extent a well-connected position within this network can be associated with certain patenting and disclosure activities. More precisely, the question is whether being connected to many relevant peers allows firms to design and apply for patents that they already know are likely to be included in a standard. As mentioned above, this would mean that firms create patents with the sole (or main) purpose of having them included in a standard. As I will later explain, this often implies that these patents are declared shortly after their application date, usually once the relevant parts of standards are finalised. In the context of this paper, this behaviour will be considered a case of strategic patenting[58]. Now, the question is whether strategic patenting behaviour may be linked to firms making use of their network, and which mechanisms are at work. According to Gulati (1998, p. 296), there are two potential mechanisms based respectively on "informational advantages" and "control benefits actors can generate by being advantageously positioned". I first aim to explore and explain the relationship between a firm's position within the network induced by consortia and its patenting and disclosure activities. Further, I would like to disentangle information and control aspects associated with being well-connected, and try to trace back patenting and disclosure activities to these two aspects.

By diving deeper into the relationship between consortia memberships and patenting and disclosure behaviour, I aim to contribute to the literature on standardisation and essential patents in standards. Even though the functioning of formal SSOs is well understood, and patenting behaviour has been extensively looked into, the connection between consortia memberships and patenting behaviour has not been analysed yet. But comprehension of this relationship could shed further light on the phenomenon of industry consortia, and ultimately help firms and policymakers make informed decisions on how to deal with them (both with regards to business as well as regulation). In order to gain a deeper understanding of industry consortia, I also use the results from Chapter 3, including the definition and taxonomy of consortia.

In the following, I will first present and discuss literature relevant to the topic, which helps build my hypotheses, and then move to network and regression analyses in order to examine the relationship between industry consortia memberships and patenting and SEP disclosure in the realm of standardisation. I conclude that generally, a large number of consortia memberships generally seems to be associated with short time spans between patent application and disclosure. However, it is also evident this relationship pans out differently depending on

[58] There are different understandings and measures of strategic patenting, which will be discussed in Section 4.2.2.

the kind of "connectedness" (i.e. how closely connected firms are with their peers), and the type of firm.

4.2 Literature review

In the following, I will review literature contributions related to the role of industry consortia as well as patenting behaviour in standardisation, especially strategic patenting.

Setting standards in telecommunication is mostly in the responsibility of formal standard setting organisations (SSOs) that encompass "those that are recognised as such by public authorities" (Bekkers et al. 2011, p. 1002). Technical specifications for mobile telecommunication standards are made within the working groups and technical specification groups of the 3rd Generation Partnership Project (3GPP). It is usually firms that drive most of the work on technical specifications within 3GPP groups, which implies that standardisation is mostly industry-driven (Leiponen 2008). It is important to note that even though standards are *created* within 3GPP, 3GPP itself is not an SSO and cannot *set* standards. Rather, 3GPP was initiated as a partnership between the regional SSOs, called Organisational Partners, including The European Telecommunications Standards Institute (ETSI)[59]. It is them who "convert the Technical Specifications and Technical Reports approved by the Partnership Project into national/regional deliverables" (see Article 47 of the Working Procedures of the Third Generation Partnership Project (3GPP) 2020a).

4.2.1 Essentiality and SEP disclosure

In the process of the creation of technical specifications for a standard, participating firms are urged to disclose/declare IP that they deem essential for using a standard, "to prevent the situation in which standards could not be implemented in practice due to the existence of patents covering inventions related with these essential components of the product or service in question" (Bekkers et al. 2011, p. 1001). Now, the question is what exactly makes IP (usually concerning patents) essential to a standard. Bekkers et al. (2011) describe essential patents as "patents that are indispensable in order to manufacture a product or offer a service based on the standard in question" (p. 1001). This understanding of essentiality, referring to technical essentiality, usually leaves out commercially essential patents "which cover methods of imple-

[59] ETSI is a recognised regional standards body under Regulation 1025/2012 (see European Parliament and Council 2012.

mentation that produce dramatic cost reductions or quality improvements" compared to alternatives (Bekkers et al. 2012, p. 6). However, Bekkers et al. (2012) also argue that the distinction between technically and commercially essential patents can be difficult: Some features of standards may be implemented in different ways, which means that implementers can ultimately decide which exact technology or solution to implement. From a technical standpoint, the question is whether all patents underlying these different technologies should be deemed essential. But from a commercial standpoint, there are probably some technologies among these that are superior with regards to cost or quality. As the definition of commercial essentiality leaves some room for interpretation, the question would be which technologies exactly can be considered superior, and which patents would then be considered essential.

The exact understanding and definition of essentiality can differ between SSOs, thus, for the purpose of this paper, I understand essentiality in line with ETSI. This decision makes sense in light of my source of disclosed SEP data (see Section 4.4), which is the ETSI database. The ETSI database contains data on SEPs declared pertaining to 3GPP standards. The ETSI definition of essentiality (see Directives of The European Telecommunications Standards Institute (ETSI) 2013, Guide on Intellectual Property Rights (IPRs)) reads as follows:

"ESSENTIAL as applied to IPR means that it is not possible on technical (but not commercial) grounds, taking into account normal technical practice and the state of the art generally available at the time of standardisation, to make, sell, lease, otherwise dispose of, repair, use or operate EQUIPMENT or METHODS which comply with a STANDARD without infringing that IPR. For the avoidance of doubt in exceptional cases where a STANDARD can only be implemented by technical solutions, all of which are infringements of IPRs, all such IPRs shall be considered ESSENTIAL".

To summarise, this definition implies that: a) essentiality is understood in a technical, and not a commercial, sense; and b) essential patents cannot be circumvented when a firm wishes to comply with the associated standard. Point b) also implies that in cases when there are more than one implementation of standards features, all patents necessary for these implementations are considered essential.

The nature of standardisation, the standardisation process, and treatment of IP in this context, bear several potentials for frictions, conflicts and other difficulties. Firstly, there is an inherent tension between standards and IP since standards are made to be "diffused widely" (Bekkers et al. 2002, p. 1145), while intellectual property rights (IPRs) aim to control diffusion. Blind and Thumm (2004, p. 1585) find "several studies of conflicts within a formal standardisation process due to interests of patent-holders". Friction and conflicts may not only be between patent holders, but naturally, issues between patent holders and users arise as well. In this context, Lemley (2002) argues that SSOs can mediate between IP owners and users to resolve some of these issues. SSOs can do so in various ways—when it comes to disclosure and licensing of essential IP, “there is a remarkable diversity among SSOs in how they treat IP rights” (Lemley 2002, p. 1891).

Firstly, not all SSOs ask for a list of specific patents (or pending patent applications) that may be essential to a standard. Some SSOs permit so-called “blanket” patent disclosures which means that firms can claim that they own essential patents, but they do not necessarily have to name specific patents. However, ETSI in particular does not allow[60] for blanket disclosures.

In the particular case of ETSI, each member is encouraged to “use its reasonable endeavours […] to inform ETSI of essential IPRs in a timely fashion” (see Annex 6 of Directives of The European Telecommunications Standards Institute (ETSI) 2020, p. 39). Obviously, this formulation leaves some room for interpretation. In cases where a firm submits a technical proposal, it is encouraged to “draw the attention of ETSI to any of […] [its] IPR which might be essential if that proposal is adopted”. However, ETSI does not clearly define when exactly in the standardisation process disclosure of (potentially) essential IP has to happen. Hence, disclosing firms may decide to declare SEPs only after the formal approval of a standard (Bekkers et al. 2012). In consequence, various scenarios regarding the timing of disclosures/declarations are possible. Kang and Bekkers (2015, p. 7) take a closer look at these scenarios. Firms can bring in a technology “that was already developed and patented long before discussions on the standards began”. On the other hand, firms may come up with inventions and apply for patents during the standardisation process, which means “the patent filing is parallel in time to the standardisation effort” (p. 7). Some of these inventions, and hence patents, may stem from challenges occurring in the standardisation process, and are thus beneficial to the standard. In other cases, “companies may try to apply for patents and get this technology included in the standard, even if it does not offer great improvements or technical merit to the standard” (p. 7).

As previously mentioned, firms generally covet ownership of SEPs, mostly because of the (perceived) high value of these patents. This is mainly due to two reasons: Ownership of SEPs 1) generates licensing revenue, and 2) helps with negotiating beneficial cross-licensing arrangements (Bekkers et al. 2011). Firms hope to generate especially large revenue from SEPs (in relation to comparable non-essential patents), and have bargaining chips for cross-licensing negotiations (Bekkers et al. 2011). One frequently used indicator of the importance or value of a patent is citations: “A first look at citation patterns reveals that SSO patents receive many more cites than other patents from the same technological field and application year, suggest-

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[60] In its IPR Policy, ETSI requires declaring firms to provide an IPR Information Statement Annex with their declaration. In this document, they need to list the relevant patents (see The European Telecommunications Standards Institute (ETSI) 2020.

ing that they are more important or more valuable” (Rysman and Simcoe 2008, p. 1921). However, the question is whether (supposedly) essential patents receive more cites because they have been included in a standard, or whether these patents and associated technologies “were already on their way to prominence (e.g. patents with a high technical merit)”, and were thus selected for the standard (Bekkers et al. 2012, p. 3). Furthermore, Berger et al. (2012) shed more light on filing behaviour regarding essential patents and stress that firms may actively “tinker” with relevant patents during the standards development process (i.e. make amendments, add claims, delaying of grant decisions) so that these patents can actually be considered essential. In contrast, Bekkers et al. (2017) further look into whether and under which circumstances declared SEPs can be assumed to be more valuable than comparable patents. They carefully examine the relationship between SSOs’ choices of disclosure rules and (among others) the kind of patents disclosed as well as forward citations. Surprisingly, they find that patent disclosure to ETSI is negatively associated with the number of citations (but positive for all other studied SSOs). They argue that this could be due to ETSI’s mandatory specific disclosure policy stating that firms cannot enforce patents that they have not previously disclosed, however, they are not punished for declaring “patents that are only vaguely related to a standard” (Bekkers et al. 2017, p. 8). Since ETSI does not allow for blanket disclosures and patent holders need to explicitly list potentially essential patents, patent holders may try to play it safe by listing as many patents as possible. Still, even though the actual value of SEPs seems to be disputable, Bekkers et al. (2012, p. 2) argue that there is a “strategic ‘race’ to own essential patents” (p. 2).

This strategic race, together with the declaration policies of many SSOs, is thought to lead to over-declaration or over-disclosure—since “the actual determination whether a particular patent is essential to a standard is initially left to the patent holder”, even though the ultimate decision on essentiality can only be made by a court (Contreras 2017a, p. 15). This is enhanced by the nature of the standardisation process, that is, the inherent uncertainty regarding the final contents of a standards documents, and as to whether a patent’s claims (and their interpretation) imply that the patent is or will be essential to the final standard (Contreras 2017a). This aspect, together with the evidence found by Berger et al. (2012), suggests that firms have some room to navigate standardisation and patenting in a way that allows them to strategically draft, amend, apply for, and disclose patents. And considering the value that is commonly attributed to SEPs, they may be encouraged to use this room to their advantage.

4.2.2 Strategic patenting

When talking about patenting behaviour in general and strategic patenting in particular, it makes sense to discuss motives to patent first. Patenting can be used to pursue defensive as well as offensive goals. The former means that firms primarily aim to protect their own inventions, while the latter means they mainly constrain competitors (Blind et al. 2006).

One obvious motive to patent is the prevention of copying, which allows patent owners to directly profit from an invention/innovation through commercialisation or licensing. However, there are several motives that go beyond that. Patents can also be used to block competitors by not allowing them to patent related inventions, which would be a rather offensive strategy. In contrast, a defensive strategy could be the use of patents to prevent lawsuits. (Cohen et al. 2000)

Another aspect that may motivate firms to patent their inventions is the potential improvement of their position in cooperations with other firms, and in negotiations with partners, licensees, rivals, and the financial sector (Blind et al. 2006; Cohen et al. 2000; Cohen et al. 2002). Cohen et al. (2000) argue that this is often the case in complex product industries (e.g. telecommunications equipment and semiconductors). Also, according to Blind et al. (2006), patents could be a means of incentivising R&D personnel, or be used as performance indicator. The motives mentioned in this paragraph are referred to as “motives to patent” (Cohen et al. 2000) or “strategic motives to patent” (Blind et al. 2006). However, there seems to be no consent in the literature as to what exactly constitutes “strategic” motives.

In the context of telecommunication standardisation, strategic behaviour in the realm of patenting is usually understood with regards to the creation and declaration of alleged SEPs. Given the desirability of SEPs, and the vagueness of some SSOs’ rules, especially regarding the timing of disclosure, firms tend to make use of opportunities for strategic behaviour. From previous contributions, we know that this can pertain to several aspects of the invention, standards making, and patenting process. First of all, there are several reasons for bringing patents into a standard, including potential advantages in cross-licensing negotiations and increased licensing revenues (Bekkers et al. 2011). However, it is not the sheer pursuit of ownership of patents and SEPs that constitutes strategic patenting. To sum up, I understand strategic patenting to refer to firms applying for patents with the sole (or main) purpose of getting them included in a standard as SEP.

One way of increasing the likelihood of a patent becoming essential to a standard is to make frequent amendments to patents or add claims to achieve maximum congruence between patents and standards (Berger et al. 2012). In this paper, however, I put particular emphasis on timing of patent applications and SEP disclosures as an indication of strategic patenting activities. This is where the phenomenon of “just-in-time inventions” (Kang and Bekkers 2015) come in. More precisely, Kang and Bekkers (2015, p. 2) observe that patenting activity regarding “about-to-become claimed essential patents is much higher during or just before” standardisation meetings than otherwise. This suggests that some firms tend to closely observe standardisation activities, and once they have a relatively clear idea on the direction of a standard, they file for patents which they expect to be essential to the standard in question.

Firms likely obtain precise knowledge on the contents of a standard close to the point in time of key standardisation decisions. At this point, it is important to stress that telecommunication standardisation is a rather incremental process. That is, 3GPP standards are usually divided into a number of (parallel) releases, which are again divided into stages.[61] The work results are laid down in technical specifications. All technical specifications of a Release are "frozen"[62] (or finalised) once "the functionality of the Release is stable—i.e. that all new features to be included in the Release have been defined and that all new or modified functionality required to implement those features has been incorporated into the specifications" (Third Generation Partnership Project (3GPP) 2020b, p. 19). This implies that key standardisation decisions are not only the ones where an entire standard is frozen, but also those where technical specifications and releases are finalised.

As previously pointed out, firms participating in standardisation probably know most about the likely final contents of standards or parts thereof when key standardisation decisions are imminent. Hence, it makes sense to file applications for patents related to a particular standard close to the point of key decisions on the relevant standard. Then, it is to be expected for patents coming from strategic patenting endeavours to have a relatively short gap between application and SEP declaration dates. Bekkers et al. (2012, p. 24) argue that "patents that are declared essential immediately after application (and often well before they issue) are likely, though not certainly, motivated by the ongoing standards process". Bekkers and West (2009, p. 88) find that these patents tend not to build the basis for other inventions later since they are often "based on applied rather than basic research".

The term "strategic patenting" in the context of standardisation in telecommunications can be understood in other ways as well. For one, Bekkers and West (2009, p. 86) suggest that strategic patenting could become evident when patents are "filed well after the corresponding standardisation effort had begun". They add that the technology focus of firms' patents could be an indicator of strategic patenting, more precisely "if firms' patenting is primarily focused at a particular standardization effort (here UMTS) rather than more broadly on mobile telephony or telecommunications" (Bekkers and West 2009, p. 88). While these two indications of strategic patenting are well-justified and relevant, the measurement of strategic patenting in these two contexts is likely to be difficult and imprecise. In the former case, the question is what

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[61] See https://www.3gpp.org/specifications/67-releases (retrieved on 21/09/2020).

[62] This means that from this point on, "only essential corrections are permitted" (Third Generation Partnership Project (3GPP) 2020b, p. 7.

exactly the "corresponding standardisation effort" is (i.e. an entire standard such as LTE or technical specifications that are part of it). Additionally, due to the nature of telecommunication standards, patents are often not only relevant to just one standard, but to the ones building upon it as well. This could also become an issue in the latter indication of strategic patenting. Thus, in the following, I will focus on the previously explained understanding of strategic patenting—the timing of a patent's application in relation to key technical decisions in standardisation and hence its disclosure as SEP.

When it comes to measuring strategic patenting in this context, there are two different ways of measurement that I am aware of. One focuses on the timing of patent applications in relation to the timing of standardisation efforts and decisions. Bekkers and West (2009, p. 86) argue that strategic patenting is probably happening when "the patents were filed well after the corresponding standardisation effort had begun". More precisely, strategic patenting could be measured using the "timing of initial IP disclosure relative to the dates of key technical decisions for a particular standard" (Bekkers et al. 2012, p. 24). However, Bekkers et al. (2012) also object that this information is often very difficult to obtain. Alternatively, they suggest to use the time gap between the patent application and its disclosure to an SSO (the declaration lag), which I will also use for this paper: "Patents that are declared essential immediately after application (and often well before they issue) are likely, though not certainly, motivated by the ongoing standards process" (Bekkers et al. 2012, p. 24).

It is important to stress that it is not just firms using standards in their products that engage in activities around strategic patenting (or the race for essential patents more generally). It is also firms that "amass patents not for the sake of producing commercial products" (Cohen et al. 2019, p. 1). This means that they purchase patents (or entirely patent portfolios), or conduct research in order to obtain patents, but do not use these patents in own products or services (e.g. InterDigital). Rather, they monetarise their patents solely through patent licensing. I will refer to these firms as "non-practising entities" (NPEs), in line with Delcamp and Leiponen (2014). Some NPEs act as "patent trolls" (Cohen et al. 2019) or "patent sharks"—"patent holding individuals or (often small) firms" (Reitzig et al. 2007, p. 134) that "appropriate profits from innovation solely by enforcing patents against infringers" (Fischer and Henkel 2012, p. 1519).

4.2.3 Inter-firm connections, industry consortia, and standardisation

As stressed initially, telecommunications firms have historically always had the need to cooperate with other firms. This especially pertains to the making of standards. Telecommunication standards can become very dominant, mostly due to strong network externalities (Bekkers et al. 2002). Hence, involvement in the making of standards becomes extremely relevant to firms being affected by standards. In addition, Bar and Leiponen (2014, p. 2) stress that "standard setting presents opportunities for early information exchange", which generates even more of an incentive for firms to be involved in standardisation, and hence in SSOs.

However, in the sphere of inter-firm connections in telecommunications, it is not just participation in standardisation as such that is relevant. There are several other ways in which firms collaborate and cooperate. Many of these can be classified or understood as strategic alliances, which Gulati (1998, p. 293) defines as "voluntary arrangements between firms involving exchange, sharing, or co-development of products, technologies, or services". According to Eisenhardt and Schoonhoven (1996, p. 136), alliances are formed due to "strategic needs and social opportunities". They further specify that "strategic alliances arise when firms in vulnerable strategic positions need the resources that alliances bring or when firms in strong social positions capitalise on their assets to create alliance opportunities" (p. 137). This is precisely the case in the telecommunications industry: Many firms (i.e. managers from these firms) are connected via their involvement in standardisation anyway, which generates opportunities for them to get in touch outside of standardisation, and to form new alliances (Rosenkopf et al. 2001). On the other hand, the formation of alliances may be grounded in strategic needs.

One form of strategic alliance grounded in strategic needs is industry consortia (henceforth also referred to as just "consortia"). I define industry consortia (see Chapter 3 for more details on the derivation of this definition) in the following way: *In the context of standardisation in the telecommunications industry, consortia are collaborative alliances of organisations which offer a forum for the discussion, development, coordination of development, testing, certification, and/or promotion of technologies or technology systems. Consortia are not formally recognised by any national or supra-national authority.* Hence, according to this definition, "consortia can develop technologies; they can contribute these to standardisation by formal SSOs, or publish standards themselves". Delcamp and Leiponen (2014, p. 36) emphasise that they play a "central role […] in coordinating technology development in many different technology fields and industries", and that consortium participation facilitates coordination of firms' innovation activities" (p. 45). Prior research also suggests that consortia, at least some, matter for influence in standardisation (Delcamp and Leiponen 2014; Leiponen 2008). A more extensive discussion on the role of industry consortia in standardisation can be found in Chapter 2.

It is important to note though that there are various types of consortia. In the paper presented in Chapter 3, I and my co-authors have analysed a sample of 100 industry consortia, and come up with six categories of industry consortia. These categories differ in their membership composition, as well as their goals and organisational set-up.

4.2.4 Network positions and competitive advantage

The question is whether membership in consortia also relates to strategic patenting. In order to examine this relationship, I understand the entirety of firms' consortia memberships as a network of firms, in accordance with Gulati (1998). Bekkers et al. (2002, p. 1159) studied the connection between ownership of essential IPR and firms' network position (regarding strategic technology agreements) in the GSM market, and find that since the late 1990s, there have been five dominant[63] firms (Ericsson, Nokia, Siemens, Motorola and Alcatel), and that "two of these firms (Motorola and Nokia) are characterised by both a strong position with regard to the ownership of essential IPRs and a central position in the network of strategic technology agreements in mobile communications".

Gulati et al. (2000, p. 207) argue that "the structural pattern of a firm's relationships is unique and has the potential to confer competitive advantage". More precisely, they argue that a firm's history and earned reputation allows them to acquire tie characteristics that competitors cannot easily imitate. Powell (1990, p. 305) even finds that "by establishing enduring patterns of repeat trading, networks restrict access", which can lead to a situation where "opportunities are […] foreclosed to newcomers, either intentionally or more subtly through such barriers as unwritten rules or informal codes of conduct". This seems to be the case for most firms in the telecommunications industry where many inter-firm connections have been growing and intensifying over a long time, with generations of technology building upon each other, and various repeating interactions within SSOs.

Since I aim to analyse the implications of firms' positions in the network of industry consortia, I would like to understand which approaches to take when looking at the implications of such networks. As explained in the introduction, there are mechanisms determining the influence of such networks that are of specific interest to this project: 1) informational advantages, and 2) control benefits. I will get back repeatedly to these two mechanisms in the next section.

4.2.5 Centrality, patenting, and SEP disclosure behaviour

When talking about network positions, the most important concept is centrality. Centrality can be understood and calculated in various ways. Three important indicators of centrality are degree, eigenvector, and closeness centrality. Degree centrality pertains to the number of direct ties (in this case of a firm), and thus "might be of concern in studies of popularity and activity of actors" (Frank 2002, p. 385). In particular, a high degree of centrality can come along with

[63] According to their market share in switching, base stations, and mobile terminals.

the “potential for activity in communication” (Freeman 1978, p. 219). For eigenvector centrality, it matters most that firms are connected to other firms that are themselves highly connected, hence we are talking about indirect ties. Eigenvector centrality is an “appropriate measure when one believes that actors’ status is determined by those with whom they are in contact.” (Bonacich and Lloyd 2001, p. 199). Bar and Leiponen (2014, p. 2) examine firms’ position in an interfirm cooperation network and their involvement in standardisation, and they find the measure of eigenvector centrality to be especially relevant, in a sense that “directly connected to others who are well connected is beneficial”. However, it does not just matter who firms are connected to, but also how close they are to all other firms in the network (Fershtman and Gandal 2011). This is where closeness centrality comes in. As opposed to degree and eigenvector centrality, closeness centrality is not a local measure of centrality, but rather refers to “structural properties of the network” (Frank 2002, p. 386).

When we combine the notion of centrality with the concepts of informational and control benefits bestowed by network positions, the question is which factors exactly can make a network of peers beneficial for firms. When it comes to informational advantages, Bar and Leiponen (2014, p. 20) note that “connections can be beneficial for learning about new technologies and rivals’ strategies”. Powell (1990, p. 304) further stresses that “networks are particularly apt for circumstances in which there is a need for efficient, reliable information [...] you trust best information that comes from someone you know well”. Hence, on the one hand informational advantages encompass the content of information, but also the reliability and trustworthiness of this information. The concept of control benefits is somewhat less dominant in the technology and innovation management literature. However, this concept is still very relevant in the context of standardisation since when a firm is able to “control [of] the content” of a standard, it can “impose differentially higher costs on their rivals” (David and Steinmueller 1994, p. 222).

Ultimately, the aim of this project is to understand the relationship between a firm’s network position, more precisely within the network induced by industry consortia memberships, and how it goes upon handling its IP with respect to standards. As I have previously stressed, I am especially interested in whether more central firms are more inclined to strategic patenting behaviour in the context of standardisation—meaning that they tend to declare patents as essential to a standard shortly after the application has been filed. To my knowledge, the relationship has not been comprehensively analysed. In addition to the question about a general relationship between centrality with regards to consortia memberships and an inclination towards strategic patenting, the question is whether it matters which “kind” of centrality and being connected in most beneficial. This does not just pertain to the three notions of centrality previously introduced, but also to the type of industry consortia. In consequence, these aspects also inform which mechanism of connectedness most likely affects this relationship, whether it is informational advantages or control benefits.

To conclude with this literature review, it has become clear that the phenomenon of strategic patenting itself has been examined in some detail already. However, I specifically examine whether being well-connected matters when it comes to a firm's engagement in such behaviour.

4.3 Hypotheses

Based on the literature contributions reviewed in the previous section, I formulate three hypotheses. As previously explained, the overall goal is to shed light on the relationship between connectedness within industry consortia and strategic patenting behaviour in relation to standards. In accordance with Bekkers et al. (2012), strategic patenting is reflected in a short time span between the application for a specific patent and its declaration/disclosure as essential to an SSO. The shorter this time span, the more likely the underlying invention is motivated by strategic considerations. With regards to the computation of this time span, it is important to mention that the starting point is always the priority[64] date (or earliest filing) of a patent family. This implies that for each patent in the sample, I calculated the time span between the priority date of the relevant family (i.e. the filing of the first application for a patent family) and the declaration date of the patent itself. Details on the exact understanding of patent families within this study can be found in Section 4.4.

Further, I understand "connectedness" as two aspects (that are obviously somewhat correlated): 1) the number of memberships[65] in industry consortia, and 2) centrality in the network that is formed by the entirety of firms' consortia memberships. In terms of how this relationship plays out, I expect two mechanisms to play a role, namely informational advantages and control benefits that firms can attain from being consortia members. Figure 4-1 provides a schematic overview of the general idea of the hypotheses presented in the following.

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[64] The concept of priority rights has been agreed at the Paris Convention for the Protection of Industrial Property in 1883. It states that "anyone who files a patent application has the right to file an identical application in another signatory country of the Paris Convention within a certain time frame without being exposed to the risk that their own first application may be assessed as novelty destroying in subsequent application procedures in other jurisdictions" (see https://e-courses.epo.org/wbts_int/litigation/Priority.pdf, retrieved on 31/08/2020). This implies that two patents that have at least on priority in common likely cover a similar invention.

[65] The term "membership" refers to a binary indicator whether a firm is a member in a specific consortium or not. It does not capture more detailed aspects such as how many representatives a firm sends to consortia meetings.

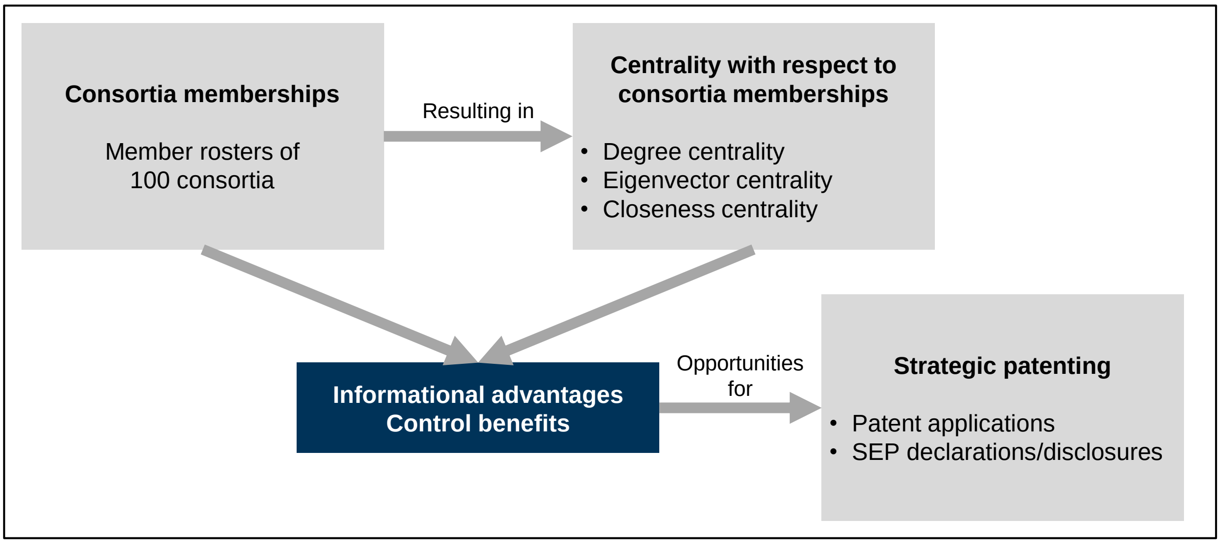

Figure 4-1: Schematic overview of hypothesis

Even though both information and control are likely playing a role in the relationship depicted in Figure 4-1, I assume informational advantages to be the major mechanism at work. Industry consortia in particular are only really relevant for strategic patenting when consortia activities take place *before* standardisation activities, and are targeted towards standardisation. In cases where firms aim at *controlling* the direction of consortia activities in order to influence standardisation activities, one can assume that they have already conducted (at least some of) the relevant research, and have hence already applied for a substantial amount of patents. This would imply that the time span between patent application and SEP declaration should be relatively large. In contrast, when firms gain *informational* advantages, firms should be able to gather abundant information on the (expected) directions of standards, and then cover relevant inventions with patents accordingly. This behaviour likely shortens the time span.

Firstly, I hypothesise that *firms with more consortia memberships tend to exhibit shorter time spans between patent application and declaration than ones with fewer memberships* (**hypothesis 1**). The idea is that firms with many memberships are able to collect information on various technologies from various sources, and are potentially also able to gauge sentiments and identify promising technologies. Some firms are present in consortia covering competing technological solutions, thus, they could engage in diversification and work on competing solutions.

However, as previously mentioned, probably not all consortia memberships are equally relevant for strategic patenting. The reasoning for this is two-fold: Firstly, not all consortia equally aim to contribute to standardisation in formal SSOs in some form, which can also be due to its technological focus. For instance, consortia working on add-ons (e.g. applications) to mobile telecommunication standards may not touch upon topics directly related to the work in formal SSOs. Secondly, it is also about the momentum that consortia are able to create.

More precisely, the question is whether firms may be able to obtain more relevant information from one consortium in contrast to another. Differences may arise because some consortia have relatively small memberships or do not include major players. Thus, it is not just relevant what consortia (and their members) want to achieve, but also what they can realistically achieve. I hypothesise that *there are some consortia categories that are associated with shorter time spans between patent application and declaration, while others are associated with longer time spans, or are irrelevant* (**hypothesis 2**). In terms of consortia categories or types, I use the taxonomy developed in Chapter 3. It includes the following six types of consortia:

Table 4-1: Categories/types of consortia (see Chapter 2)

Category name	Primary characteristics
Large industry and technology influencers	• Very large (639 members on average) • Relatively established (mean founding year 1999) • Emphasise broad technological concepts combined with goals relating to furthering industry development and economic or societal issues
High-level concept developers	• Relatively large (329 members on average) • Relatively established (mean founding year 2002) • Focus on industry development as well as economic and societal goals, rather than technology development
Established standards developers	• Relatively small (224 members on average) • Relatively established (mean founding year 2000) • Focus on the maintenance and enhancement of mature technologies; they often engage in standards development
Young technology specialists	• Small (107 members on average) • Very young (mean founding year 2013) • Majority works on novel technology; include Open Source organisations
Small industry and technology influencers	• Small (90 members on average) • Slightly above-average age (mean founding year 2004) • Pursue a mixture of industry development and economic and societal objectives; rarely work on technology development
SSO-hosted industry drivers	• Very small (28 members on average) • Very young (mean founding year 2014) • Hosted by ETSI; pursue various goals, such as industry development, early technology and standards development

The next hypothesis results from the first one insofar as a large number of consortia memberships often translates into centrality. I hypothesise that *more central firms in the firm network induced by consortia memberships exhibit shorter time spans between patent applications and declarations than less central ones* (**hypothesis 3**). I expect all three previously mentioned centrality indicators, namely degree, eigenvector centrality, and closeness centrality to play a role. However, I expect closeness centrality to be particularly relevant in order to gauge the technological direction of the industry. High levels of closeness centrality implies being able to “get to” all other firms in the network relatively easily, which means that central firms can collect information from a multitude of sources.

One could argue that most of the strategic patenting behaviour is enabled by participation in 3GPP because this is where the actual technical specifications are made. When again considering the mechanisms of information and control in networks, one would presume that presence and participation in 3GPP group meetings can help with both. In general, one could expect that control benefits are dominant because by taking part in actually creating the technical specifications, firms are in control of what the final specifications look like. This would imply that firms already have inventions and patents in place, and would like to influence standards in a direction that is favourable for them—meaning that specifications are line with their previous R&D, and include (some of) their inventions and hence patents. On the other hand, informational advantages obtained from participation in 3GPP could be used for strategic patenting in a way that firms obtain a more or less precise idea about which direction a standard will probably take, and then cover relevant technologies with patents. This would then imply a relationship between 3GPP participation and strategic patenting. Thus, it makes sense to include 3GPP meeting participation as one of the control variables in the analysis.

4.4 Data

The data for this project stems from two main datasets: 1) A dataset of consortia membership data, and 2) a dataset of patents declared as essential to ETSI. In the following, I will provide some more detail on the two datasets, and the datasets for the final analysis.

Consortia membership data

The consortia membership data comes from the study presented in Chapter 3. For this project, we have extracted membership rosters of 100 consortia between June and September 2017 (for list of consortia, see Appendix B, Section 8.1). Firm names have been manually harmonised, arriving at 9,835 unique firm names. Hence, the basis for this project has been a matrix consisting of f firms and c consortia ($f \times c$ matrix), its entries being either 0 or 1. I have transposed this matrix ($c \times f$ matrix), and then multiplied it with the initial matrix to arrive at a matrix of only firms ($f \times f$ matrix). Each entry of the final matrix thus denotes the number of common consortia memberships between two firms. We thus have a weighted[66] graph, since we would like to know about the number of common consortia memberships between two firms, and not just about their existence. The $f \times c$ matrix, and the adjacency matrix resulting from it, are the starting point for the depiction of the firm network induced by consortia memberships, and the computation of centrality indicators.

Disclosed patents data

The dataset of declared patents encompasses patents disclosed to ETSI[67] (ETSI database) between 2016 and 2018, while only patents belonging to ETSI projects with reference to 3GPP were extracted. The application numbers of the patents were then matched with the Patstat database to retrieve more details on each patent, most importantly the application filing date. Based on the filing date and the declaration date (coming from the ETSI database), I then computed the difference between the application and declaration date. In line with Bekkers et al. (2012), I call this difference the "declaration lag". The declaration lag will take centre stage in the following analyses.

The patent data was then cleaned, making use of the patent family indicator provided by ETSI. More precisely, the ETSI definition of a patent family[68] is the following: "'Patent family shall mean all the documents having at least one priority in common, including the priority document(s) themselves. For the avoidance of doubt, 'documents' refers to patents, utility models, and applications therefor." (see Annex 6 of Directives of The European Telecommunications Standards Institute (ETSI) 2020, p. 45). Hence, in order to avoid double-counting of essentially the same inventions, I have only kept the earliest (declared) filing for each family because this date is closer to "the point in time at which the technology that is covered by the patent has been developed" (Bekkers and West 2009, p. 86). In case of duplicates where the same patent was declared for more than one project, I have kept the earliest disclosure.

In some cases, the ETSI family indication was missing or incomplete. In these cases, I ran additional checks, using indicators such as title, earliest filing date, and publication numbers. Whenever the title, the declaring firm and the earliest filing date were similar, I manually checked the patent using Espacenet. Then, if patents were similar except for the patent office,

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[66] This implies that the adjacency matrix does not contain entries that are either 0 or 1, but the values of the weights (McGlohon et al. 2011). The weights are the common consortia memberships between two firms.

[67] ETSI database: http://ipr.etsi.org/

[68] There are several definitions and concepts of patent families, depending on how many priorities patents share (see https://www.wipo.int/edocs/mdocs/aspac/en/wipo_ip_bkk_12/wipo_ip_bkk_12_www_238983.pdf, retrieved on 31/08/2020).

I only kept the earliest filing (because these patents are then likely to cover the same invention, only in different countries or regions). In some cases, I also manually checked the priorities and publication numbers listed on Espacenet in order to identify additional patents that likely cover the same invention. After this data cleaning process, I arrived at 14,584 patents. Using manual harmonisation of firm names, I was able to identify 66 declaring firms[69]. For each firm, I then matched the number of consortia memberships, merging this dataset with the previously described consortia membership dataset. This also includes consortia memberships per category of consortia (see Table 4-1 of for an overview of consortia categories). I then added the centrality indicators computed based on the consortia membership data.

Additional data

Based on the information from the two main original datasets, I added new indicators. Firstly, I included some firm characteristics. For one, I included the general firm category: Based on the literature and analyses of membership rosters, I expect vendors[70], (network) operators[71], and the previously mentioned NPEs[72] to be especially relevant. Apart from firms' primary focus areas, I consider their size. I measured[73] firm size by the overall number of declarations the firm has made in the observation period. In order to approximate patenting and declaration behaviour of some key firms, I generated dummies for the five firms in the dataset with the most patents declared.

Additionally, I would like to capture technology/standards categories by taking into account the standards a specific patent is related to. For this, I used the information on projects provided

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[69] I removed 200 patents originally owned by Alcatel-Lucent from the dataset since Alcatel-Lucent was acquired by Nokia in 2016. Even though this is arguably a small number of patents in relation to the overall dataset, these patents do not allow for inference with regards to the relationship between consortia memberships and the length of declaration lags.

[70] Firms primarily planning and building telecommunication networks; examples include Ericsson, Huawei, and Nokia.

[71] Firms operating telecommunication networks and offering services to end customers; examples include Vodafone and Telefonica.

[72] As NPEs, I understand firms not using a patented invention in products. In some cases, they also conduct research to produce patents themselves, and are involved in formal SSOs. However, I have not defined university research institutes as NPEs because I assume that they do not "produce" patents with the main aim of monetarising them (even though this may be a profitable by-product of their research).

[73] I have also collected information on revenue and number of employees. However, one or both of these indicators were not available for some relevant firms, especially for some NPEs. Hence, I decided to refrain from using these indicators.

in the ETSI database. Then, I classified[74] these projects according to the GSM, UMTS, LTE/LTE-A, and 5G standards, and IoT patents (based on ETSI information[75]).

As previously mentioned, 3GPP participation could play a major role in firms' strategic patenting. Hence, based on data collected on 3GPP meeting participation[76], I calculated the same network indicators as for the industry consortia for each firm involved, and matched this information to the patent data set accordingly.

The resulting datasets were then used for the analyses that will be described in the next two sections.

4.5 Methodology

In terms of data analysis, I use social network analysis, followed by regression analysis that is guided by the hypotheses laid out in Section 4.3.

Network analysis

For network analysis, I used the igraph[77] package of R. As a first step, I aim to visualise the network relationships by plotting the network induced by consortia memberships. The network is visualised based on the graph including the firms and their connections: "A graph $G = (V, E)$ is an abstract object formed by a set V of vertices (nodes) and a set E of edges (links) that join (connect) pairs of vertices." (Brandes and Erlebach 2005, p. 7) Hence, each firm constitutes a vertex or node, and each connection between two firms constitutes an edge or link. In the case of industry consortia, the graph is weighted, which means that there are multiple edges between two nodes (McGlohon et al. 2011), in this case firms may meet in multiple consortia. It is also undirected since it is unlikely that most communication between firms only happens

[74] In cases where more than one standard is mentioned for a project, I use the most recent one.

[75] https://portal.etsi.org/webapp/ContextHelp/WorkProgram_help.asp?type=CODES_KEYWORDS (retrieved in January 2020).

[76] 3GPP participation captures firms' presence in 3GPP working group and technical specification group meetings between 2010 and 2016. Information was obtained from meeting records on the 3GPP website. Individual participants were matched according to their firm affiliation, and firm names harmonised manually.

[77] https://igraph.org/r/doc/igraph.pdf

one-directional. The graph then builds the basis for the visualisation of the network, for which I utilised two different algorithms[78] in order to show two different kinds of layouts[79].

After having visualised the network of industry consortia, I calculated three centrality indicators for each node (also based on the graph of nodes and edges): degree, eigenvector, and closeness centrality. The basic idea of computing centrality indices is that centrality indicates "an order of importance on the vertices or edges of a graph by assigning real values to them" (Koschützki et al. 2005, p. 19). As previously mentioned, the three centrality indicators cover three different concepts, since "there is no centrality index that fits all applications and […] the same network may be meaningfully analysed with different centrality indices depending on the question to be answered" (Koschützki et al. 2005, p. 17). Degree centrality of a node is calculated by "the number of edges incident upon that node" (Borgatti and Everett 1997, p. 254), and hence indicates how many "direct" contacts a firm has. In contrast, eigenvector centrality assesses nodes' status by "those with whom they are in contact" (Bonacich and Lloyd 2001, p. 199), and it is calculated based on the eigenvectors of adjacency matrices (Koschützki et al. 2005). While degree and eigenvector centrality are primarily local measures, closeness centrality focuses on the entire network: It is "the inverse of the sum of all distances" (Fershtman and Gandal 2011, p. 72) between a node and all other nodes in the network. Thus, it indicates how far away a certain node is from each other node in the network. Freeman (1978) adds that closeness determines the independence of a node. While there are numerous other centrality indicators are available, betweenness centrality seems to be another very frequently used one. Betweenness centrality is "defined as the proportion of all geodesics between pairs of other nodes that include this node" (Fershtman and Gandal 2011, p. 85), so basically it indicates how many times a node stands "between" two other nodes, so "contacts between other actors that are via this actor" (Frank 2002, p. 385). However, I decided not to use this indicator because the mechanisms of informational advantages and control benefits attained through industry consortia are likely not affected by actors controlling or influencing the communication between two other actors.

[78] Namely the annealing algorithm by Davidson and Harel (https://igraph.org/r/doc/layout_with_dh.html) (Davidson and Harel 1996), and the GEM layout algorithm (https://igraph.org/r/doc/layout_with_gem.html) (Frick et al. 1995).

[79] The GEM algorithm emphasises symmetry, and hence produces a star-shaped network graph, while the annealing algorithm more clearly exhibits groupings in the network.

Regression analysis

Within the regression analysis, I aim to answer the central question of this paper, namely if there is a relationship between a firm's position in the firm network induced by consortia memberships, and their strategic patenting activities in standardisation—and if there is one, what the most relevant factors affecting this relationship are.

In order to obtain a good overview over the data, and especially the declaration lag variable, I first used descriptive statistics such as correlation analysis and histograms. These descriptive statistics then also inform the design of the regressions. In the regression analysis, the declaration lag was used as the dependent variable, and the previously mentioned variables included in the data (see Section 4.4) served as independent variables.

In the following, I will describe the exact analysis procedure and its results, which will then be interpreted and discussed.

4.6 Regressions and results

4.6.1 Descriptive statistics

The final dataset for the following analyses contains 14,584 patents declared as essential to ETSI in the years 2016 to 2018. Means, standard deviations, minimums, medians, and maximums for the key (numeric) variables in the dataset over all these patents are summarised in Table 4-2). The three centrality measures refer to centrality stemming from consortia memberships (hence the abbreviation "cons" in brackets). "Number consortia memberships" shows the total number of consortia memberships of the patent owners, and the numbered versions display the number of memberships within each of the six consortia categories considered (see Section 4.3 for a list). The table below, Table 4-3[80], then provides the same descriptive statistics over all patent holders in the sample.

[80] Note that the variables presented in the two tables differ slightly, depending on whether it makes sense to calculate descriptive statistics on the patent- and/or firm level.

Table 4-2: Descriptive statistics for key numeric variables in the dataset, over all patents examined

Variable	N	Mean	St. Dev.	Min	Median	Max
Declaration lag in weeks	14,584	334.85	233.63	14.00	271.57	2,749.43
Degree centrality (cons)	14,584	0.57	0.24	0	0.68	0.83
Closeness centrality (cons)	14,584	0.63	0.13	0	0.68	0.73
Eigenvector centrality (cons)	14,584	0.66	0.31	0	0.81	1
Number consortia memberships	14,584	40.62	22.44	0	50	74
Number consortia memberships 1	14,584	3.70	1.54	0	4	5
Number consortia memberships 2	14,584	5.15	3.11	0	5	10
Number consortia memberships 3	14,584	13.50	7.23	0	15	26
Number consortia memberships 4	14,584	5.13	3.78	0	6	12
Number consortia memberships 5	14,584	7.47	4.39	0	8	13
Number consortia memberships 6	14,584	2.13	1.55	0	2	5

Table 4-3: Descriptive statistics for key numeric variables in the dataset, over patent holders in the dataset

Variable	N	Mean	St. Dev.	Min	Median	Max
Number of declarations	66	221.88	424.78	1	24.5	1,543
Degree centrality (cons)	66	0.28	0.25	0	0.27	0.83
Closeness centrality (cons)	66	0.44	0.27	0	0.56	0.73
Eigenvector centrality (cons)	66	0.29	0.29	0	0.24	1
Number consortia memberships	66	16.38	18.25	0	11.5	74
Number consortia memberships 1	66	1.98	1.95	0	1.5	5
Number consortia memberships 2	66	1.91	2.53	0	1	10
Number consortia memberships 3	66	5.58	6.06	0	4.5	26
Number consortia memberships 4	66	1.83	2.81	0	1	12
Number consortia memberships 5	66	2.53	3.45	0	1	13
Number consortia memberships 6	66	0.82	1.25	0	0	5

181 of the patents were declared essential for UMTS, 5,811 for LTE or LTE-A, 4,428 for 5G, and 61 for IoT (the rest is undefined[81]). The five largest declaring firms in the sample are Nokia, LG, Samsung, Huawei, and Qualcomm. The majority of the patents was disclosed in 2017 (5,007 patents), and 2018 (7,7787 patents). Priority dates are further spread out (see Figure 4-2), patents were applied for between 1964 (one patent) and 2018, with a peak[82] in 2016 (2,112 patents).

When examining the declaration lags of the patents in the sample, it makes sense to visualise them in histograms (see Figure 4-3). The mean declaration lag is at 334.9 weeks (dotted line), while the median is at 271.6 weeks (dashed line). The minimum lag lies at 14 weeks: This is a patent[83] declared by Fujitsu; the priority date is in July 2016, and it was declared in October of the same year. The maximum lag is 2,749 weeks, and it belongs to a patent[84] filed by LG in 1964, disclosed in March 2017. Due to the large difference between the minimum and maximum declaration lag in the sample, it is rather difficult to obtain an overview from the histogram containing all patents. Hence, Figure 4-4 depicts declaration lags until the third quartile only. This histogram clearly shows an accumulation of patents around a declaration lag of approximately 100 to 150 weeks. To be able to put these numbers in context, it makes sense to keep in mind how long it takes to "make" a standard: In the case of the LTE standard, the project was initiated in November 2004 (Third Generation Partnership Project 2006), and Release 8 of the LTE standard, the "base of the first wave of LTE equipment" [85], was frozen in December 2008. This means that it took around 200 weeks to "make" the LTE standard (while, of course, the time span for creating new Releases[86] of existing standards can be much shorter).

[81] Some of the project information obtained from ETSI could not be mapped to standards, either because the project was not defined or not defined clearly (e.g. just "3GPP").

[82] It seems that much of the work on 5G-relevant specifications has been started between 2015 and 2017 (see https://www.3gpp.org/dynareport/SpecList.htm?release=Rel-15&tech=4&ts=1&tr=1, retrieved on 28/05/2020).

[83] This is a Japanese patent titled "Method and device for determining uplink control channel resource" (JP20160142890).

[84] This is a Swiss patent titled "Rückschlagventil für Rohrleitungen" (CH19640008195).

[85] See https://www.3gpp.org/technologies/keywords-acronyms/98-lte (retrieved on 27-05-2020).

[86] See https://www.3gpp.org/specifications/67-releases for current timeline of Releases (retrieved on 27/05/2020); 3GPP members are currently working on Releases 16 to 18.

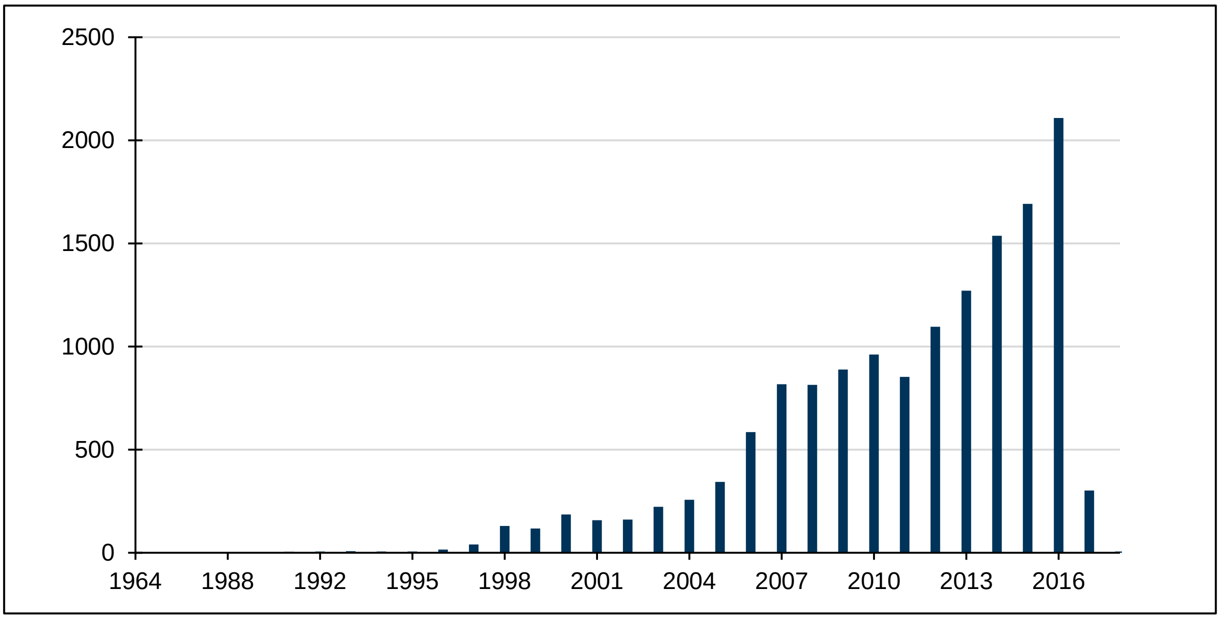


Figure 4-2: Number of patents for each priority year in the sample

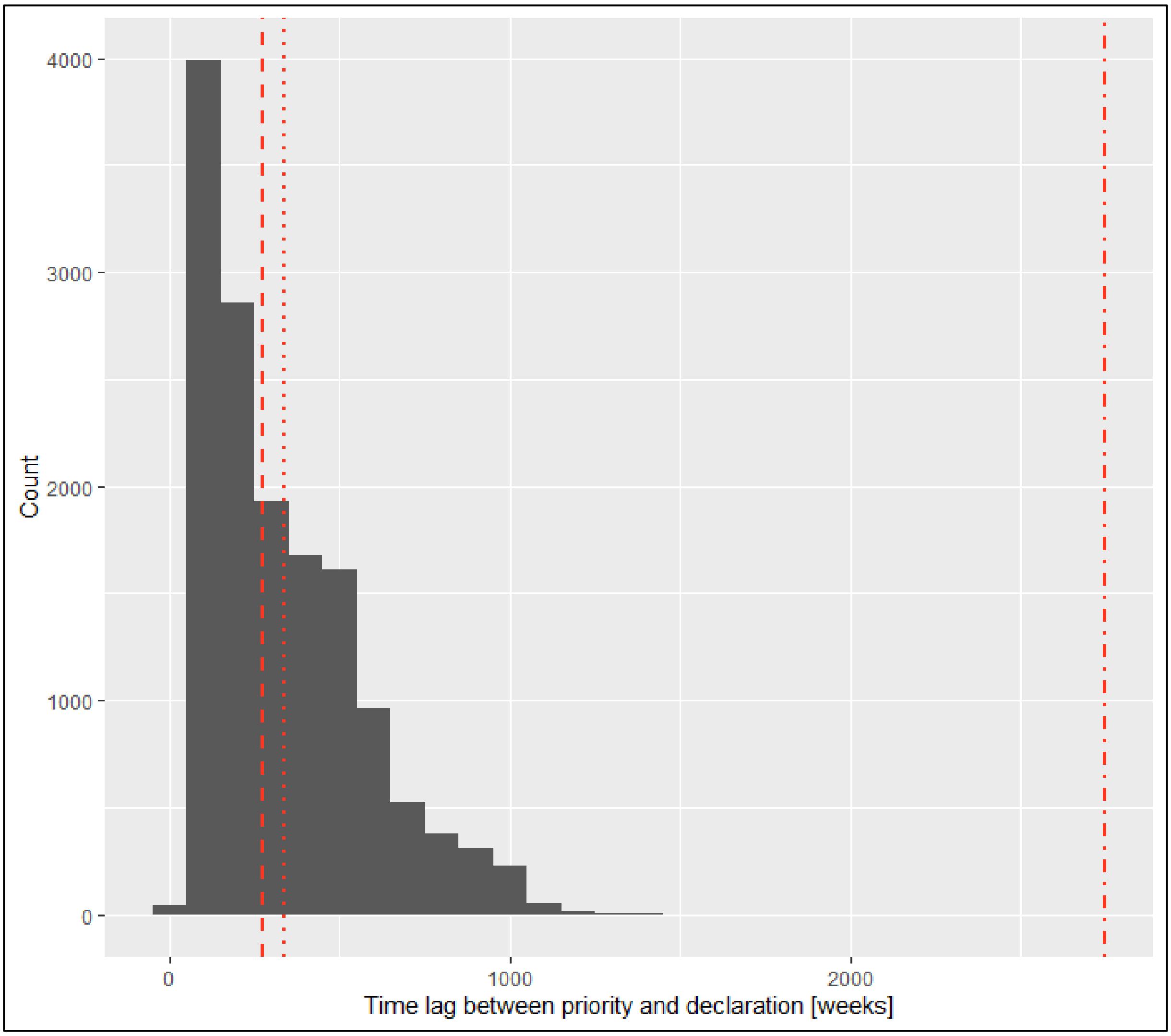


Figure 4-3: Histogram of declaration lags in the sample

(median, mean, max)

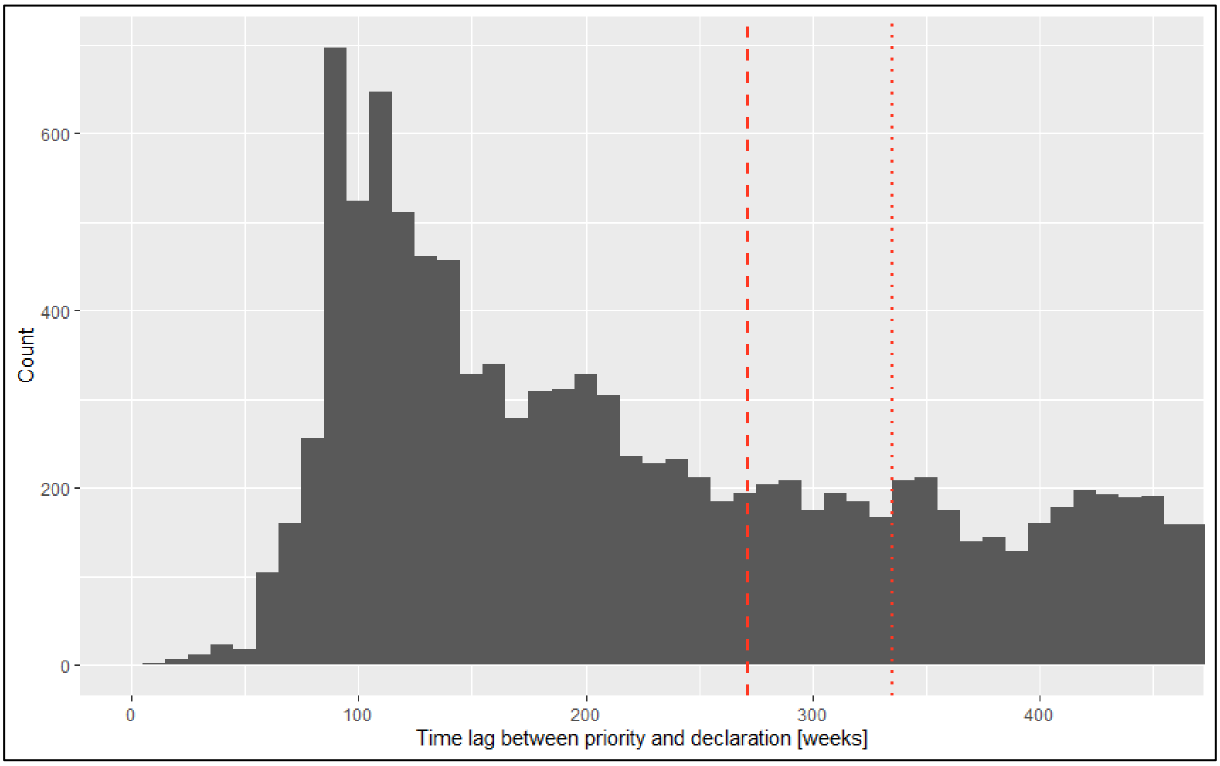


Figure 4-4: Histogram of declaration lags in the sample; until third quartile (median, mean, max)

I also took a closer look at the declaration lags of different categories[87] of firms, especially vendors, operators, and NPEs (for histograms per category, see Appendix C). The distribution of declaration lags is different between the three categories of firms. While vendors tend to exhibit a strong peak of patents at around 100 weeks, the majority of operator patents are more evenly spread out between approximately 50 and 300 weeks. For NPEs, there seem to be a peak around 500 weeks.

Now that we have looked at the distribution of declaration lags, I am also interested in how they are related to the number of consortia memberships. Due to the apparent differences between the histograms, I analysed the correlations between consortia memberships and the length of declaration lags per firm category[88] (see Table 4-4 to Table 4-6). There seems to be a significant correlation with overall consortia memberships for vendors, there are some significant correlations with memberships in all six consortia categories (three of them negative,

[87] Together, these three categories account for around 40% of patents in the dataset. It has to be noted that Electronics firms and firms delivering components for mobile telecommunications also each boast a large number of declared SEPs, however, I restricted myself to the three groups of firms most prominently discussed in the standardisation literature and telecommunication news reports.

[88] Note that “number consortia memberships” in the table captures the consortia memberships remaining when one has already accounted for the memberships within consortia of categories 1-6.

three positive). For operators, there seem to be significant positive and significant relationships throughout, except for consortia of category 1. In contrast, for NPEs, all relationships are negative and significant.

In the following, after a short detour to the firm networks built by industry consortia, I will further delve into these relationships via regression analysis.

Table 4-4: Correlations between the number of consortia memberships (total and per category) and the declaration lag; for patents owned by vendors

Variable	1	2	3	4	5	6	7
1. Number consortia memberships							
2. Number consortia memberships 1	.00						
	[-.03, .03]						
3. Number consortia memberships 2	.60**	.09**					
	[.58, .62]	[.06, .12]					
4. Number consortia memberships 3	.84**	.09**	.11**				
	[.83, .85]	[.06, .12]	[.08, .13]				
5. Number consortia memberships 4	.95**	.17**	.70**	.78**			
	[.95, .95]	[.14, .20]	[.68, .71]	[.76, .79]			
6. Number consortia memberships 5	.75**	.13**	.88**	.30**	.72**		
	[.73, .76]	[.10, .15]	[.87, .89]	[.27, .33]	[.71, .74]		
7. Number consortia memberships 6	.91**	.06**	.36**	.95**	.91**	.43**	
	[.90, .91]	[.04, .09]	[.34, .39]	[.94, .95]	[.91, .92]	[.41, .45]	
8. Declaration lag in weeks	-.01	-.06**	.43**	-.28**	.08**	.25**	-.11**
	[-.03, .02]	[-.09, -.03]	[.40, .45]	[-.30, -.25]	[.05, .11]	[.22, .27]	[-.14, -.08]

Note: Values in square brackets indicate the 95% confidence interval for each correlation. * indicates p < .05. ** indicates p < .01.

Table 4-5: Correlations between the number of consortia memberships (total and per category) and the declaration lag; for patents owned by operators

Variable	1	2	3	4	5	6	7
1. Number consortia memberships							
2. Number consortia memberships 1	.67**						
	[.62, .72]						
3. Number consortia memberships 2	.86**	.33**					
	[.83, .88]	[.25, .40]					
4. Number consortia memberships 3	.97**	.55**	.84**				
	[.97, .98]	[.49, .61]	[.82, .87]				
5. Number consortia memberships 4	.68**	.95**	.30**	.56**			
	[.63, .72]	[.94, .96]	[.22, .38]	[.50, .62]			
6. Number consortia memberships 5	.81**	.58**	.67**	.74**	.54**		
	[.78, .84]	[.52, .63]	[.62, .71]	[.70, .77]	[.48, .60]		
7. Number consortia memberships 6	.88**	.30**	.95**	.90**	.27**	.72**	
	[.86, .90]	[.21, .37]	[.94, .95]	[.88, .91]	[.19, .35]	[.67, .76]	
8. Declaration lag in weeks	.37**	.08	.42**	.38**	.15**	.25**	.41**
	[.30, .45]	[-.01, .17]	[.34, .49]	[.30, .45]	[.06, .23]	[.17, .33]	[.33, .48]

Note: Values in square brackets indicate the 95% confidence interval for each correlation. * indicates $p < .05$. ** indicates $p < .01$.

Table 4-6: Correlations between the number of consortia memberships (total and per category) and the declaration lag; for patents owned by NPEs

Variable	1	2	3	4	5	6	7
1. Number consortia memberships							
2. Number consortia memberships 1	.99**						
	[.99, .99]						
3. Number consortia memberships 2	1.00**	.99**					
	[1.00, 1.00]	[.99, .99]					
4. Number consortia memberships 3	1.00**	.98**	1.00**				
	[.99, 1.00]	[.98, .98]	[.99, 1.00]				
5. Number consortia memberships 4	1.00**	.99**	1.00**	1.00**			
	[1.00, 1.00]	[.99, .99]	[1.00, 1.00]	[.99, 1.00]			
6. Number consortia memberships 5	1.00**	.99**	1.00**	1.00**	1.00**		
	[1.00, 1.00]	[.98, .99]	[1.00, 1.00]	[1.00, 1.00]	[1.00, 1.00]		
7. Number consortia memberships 6	1.00**	.99**	1.00**	1.00**	1.00**	1.00**	
	[1.00, 1.00]	[.99, .99]	[1.00, 1.00]	[.99, 1.00]	[1.00, 1.00]	[1.00, 1.00]	
8. Declaration lag in weeks	-.29**	-.34**	-.27**	-.27**	-.27**	-.27**	-.27**
	[-.36, -.22]	[-.41, -.26]	[-.35, -.20]	[-.34, -.19]	[-.35, -.20]	[-.34, -.19]	[-.35, -.20]

Note: Values in square brackets indicate the 95% confidence interval for each correlation. * indicates $p < .05$. ** indicates $p < .01$.

4.6.2 Network analysis

Before shedding light on the relationship between consortia memberships, resulting centrality in the network induced by these memberships, and strategic patenting, it makes sense to take a closer look at the network itself.

As previously explained, I have computed three centrality indicators for each firm represented in at least on industry consortium: degree, eigenvector and closeness centrality. Figure 4-5 shows the five most central firms for each centrality indicator. The three indicators each result in almost the same list of firms: Huawei and Intel are consistently the two most central firms, followed by Nokia. Ericsson also appears on each of the lists, and Fujitsu on two of them. For eigenvector centrality, Samsung is listed instead of Fujitsu.

	Degree centrality	Closeness centrality	Eigenvector centrality
1	Huawei	Huawei	Huawei
2	Intel	Intel	Intel
3	Nokia	Nokia	Nokia
4	Fujitsu	Fujitsu	Samsung
5	Ericsson	Ericsson	Ericsson

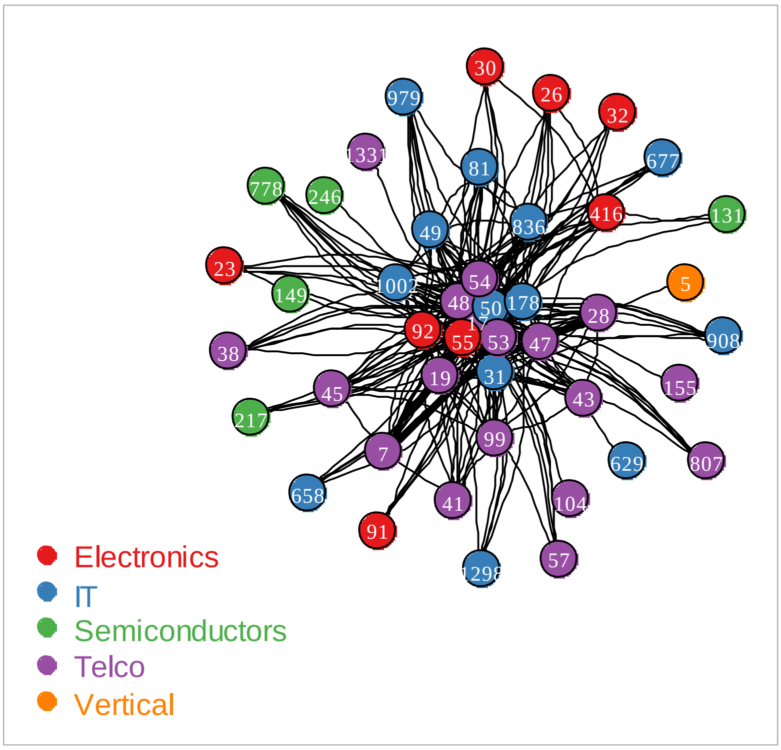
Figure 4-5: Most central firms in the firm network induced by consortia memberships, ordered by centrality indicators

When visualising the firm network resulting from consortia memberships (see Figure 4-6), results are fairly similar. There are many firms represented in very few consortia, however, for better visibility, they were dropped[89] from the graph. In the final network graph (Figure 4-6),

[89] An edge list has then been obtained from the adjacency matrix, resulting in 2,884,348 edges or connections between two firms. According to the weight of each edge (i.e. the number of connections or common consortia memberships of two firms), edges have been deleted step-wise based on the mean weight of edges overall. The final graph only shows edges with a weight higher than 16, resulting in 45 firms.

firms are also colour-coded[90] according to their primary industry affiliations (verticals consist of non-ICT firms), and the circles each depict one node or firm with their allocated ID. The graph shows the firm network resulting from consortia memberships as arranged by the GEM[91] layout algorithm (Frick et al. 1995). The firms located in the centre of the graph are listed on the right hand side of the figure. Generally, telecommunication firms (marked "telco" in the network graph) are most present, and naturally, we also find the firms named in Figure 4-5 above in the centre. There is only one vertical represented, which is Bosch (firm number 5). However, one could argue that Bosch is not technically a vertical since the firm operates within ICT as well (but has been classified as a vertical since it operates in several other sectors). While there are numerous firms with very few connections, there are some edges with high numbers of connections: Huawei and Intel have 54 consortia memberships in common, Huawei and Ericsson 51 memberships, and Huawei and Nokia 51 memberships as well. Hence, vendors seem to be relatively well represented in industry consortia.

In the following, the obtained centrality indicators will be included in regression analysis.



17	Huawei
19	AT&T
31	Cisco
47	ZTE
48	Ericsson
50	Intel
53	Nokia
54	Qualcomm
55	Samsung
92	NEC
178	Fujitsu

Figure 4-6: Network plots of firm network induced by consortia membership (GEM algorithm)

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90 Note that this categorisation differs from the one used later in the regression analysis. This is because the aim of the graph is to provide a relatively rough overview over industries represented in the network.

91 See also https://igraph.org/r/doc/layout_with_gem.html for the R package.

4.6.3 Regression analysis

The overall aim of the regression analysis is to identify and potentially quantify relationships between industry consortia memberships and the length of declaration lags. As previously explained, the regression analysis is based upon a dataset (see Section 4.4) including 14,584 patents declared to ETSI between 2016 and 2018. Hence, the regression analysis will be run on the patent level ($n = 14{,}584$). The analysis process encompasses six basic regressions where I successively add control variables, and interaction terms. Additionally, I have formulated three more regressions for the three hypotheses. For more information on the variables and the underlying data, see Section 4.4.

Prior to delving into the actual regressions, it makes sense to look at correlations between key variables included in the regression. As we can already see, there is a significant negative correlation between closeness centrality of a declaring firm and the declaration lag of a declared patent. The same can be observed for the overall number of consortia. We can also see that the size of a declaring firm (approximated by the overall number of its declarations) is positively correlated with the declaration lag of a declared patent. Naturally, the three centrality measures are highly correlated, even though they measure three different views on centrality. Centrality of a firm is also positively correlated with its overall number of consortia memberships. This correlation is weakest for closeness centrality since, as previously pointed out, it does not directly result from the connections made by entering consortia. We will later see whether these correlations are reflected in the regression results as well.

Table 4-7: Correlation table for key variables in the regression

Variable	**1**	**2**	**3**	**4**	**5**
1 Declaration lag in weeks					
2 Number of declarations per firm	.03**				
	[.01, .05]				
3 Degree centrality (cons)	.00	.62**			
	[-.02, .02]	[.61, .63]			
4 Closeness centrality (cons)	-.13**	.54**	.82**		
	[-.15, -.12]	[.53, .56]	[.81, .82]		
5 Eigenvector centrality (cons)	-.00	.63**	.99**	.80**	
	[-.02, .01]	[.62, .64]	[.99, .99]	[.79, .80]	
6 Number consortia memberships	-.02**	.62**	.96**	.74**	.97**
	[-.04, -.01]	[.61, .63]	[.96, .96]	[.73, .75]	[.97, .98]

Note: Values in square brackets indicate the 95% confidence interval for each correlation. * $p < .05$. ** $p < .01$.

In all regressions presented, the natural logarithm of the declaration lag (i.e. the time span between patent application and declaration to ETSI) acts as dependant variable (DV). In the most “basic” configuration of the regression (*regression 1*), there are 13 independent variables (IV): degree, closeness, and eigenvector centrality in the firm network induced by consortia memberships (for each declaring firm), the absolute number of consortia memberships in total and per consortia category[92] for each firm, as well as three dummies for the firm category (either vendor, NPE, or operator). Since the magnitude and direction of correlations between the number of consortia memberships and the length of declaration lags differ between firm categories (see Section 4.6.1), I also considered interaction terms between firm category (vendor, NPE, and operator), and the total number of consortia memberships (*regression 2*). In *regression 3*, I added the natural logarithm of the number of patent declarations per firm as a firm-level control variable. Next, I added dummies for the five largest declaring firms in the sample, namely Nokia, LG, Samsung, Huawei, and Qualcomm (*regression 4*). These dummies were included to approximate patenting and disclosure behaviour, since the largest declarers may also be expected to engage in strategic patenting. For *regression 5*, patent-specific controls on the standards category were included (UMTS, LTE/LTE-A, 5G, IoT). As a next step (*regression 6*), 3GPP participation in the form of degree, closeness, and eigenvector centrality were added. All regressions were run using Ordinary Least Squares (OLS) with clustered standard errors (clustered by firms). Results for regressions 1 to 6 are shown in Table 4-8.

In the following paragraphs, I will elaborate on the regression results using the hypotheses developed in Section 4.3.

Table 4-8: Regressions including various independent variables on consortia memberships

	Dependent variable: declaration lag in weeks [log]					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Degree centrality (cons)	4.848***	6.031***	6.317***	3.571	2.614	3.149
	(1.743)	(1.914)	(2.012)	(2.318)	(2.316)	(2.012)
Closeness centrality (cons)	-2.662***	-1.736***	-1.789***	-1.662***	-1.442***	-0.812*
	(0.500)	(0.429)	(0.376)	(0.482)	(0.413)	(0.441)
Eigenvector centrality (cons)	0.637	0.824	0.854	1.085	0.192	0.230
	(1.480)	(1.469)	(1.433)	(2.793)	(2.824)	(2.516)

[92] Note that the inclusion of all consortia categories does not lead to multicollinearity since not all consortia included in the dataset are actually categorised. However, in the case when all consortia categories are included in a regression, the variable of total consortia membership actually captures the remaining consortia, i.e. the non-categorised ones.

Number consortia memberships	-0.020	-0.051*	-0.054*	-0.035	-0.022	-0.026
	(0.018)	(0.029)	(0.030)	(0.028)	(0.028)	(0.028)
Number consortia memberships 1	-0.214***	-0.254***	-0.276***	-0.271*	-0.178	-0.340**
	(0.082)	(0.094)	(0.105)	(0.164)	(0.158)	(0.155)
Number consortia memberships 2	0.159***	0.133***	0.130***	0.073	0.089	0.106
	(0.033)	(0.039)	(0.040)	(0.090)	(0.085)	(0.069)
Number consortia memberships 3	-0.089***	-0.088***	-0.087***	0.029	0.061	0.016
	(0.020)	(0.016)	(0.017)	(0.049)	(0.054)	(0.063)
Number consortia memberships 4	-0.124***	-0.075	-0.069	-0.034	-0.041	-0.077
	(0.031)	(0.047)	(0.049)	(0.069)	(0.064)	(0.073)
Number consortia memberships 5	-0.033	0.017	0.017	-0.106	-0.129*	-0.068
	(0.025)	(0.049)	(0.050)	(0.069)	(0.069)	(0.080)
Number consortia memberships 6	0.272***	0.274***	0.259***	0.069	0.018	0.043
	(0.058)	(0.063)	(0.063)	(0.150)	(0.152)	(0.130)
Vendor (Dummy)	-0.169**	-1.010*	-1.101*	-3.002***	-2.866***	-1.885**
	(0.084)	(0.583)	(0.591)	(0.767)	(0.709)	(0.815)
NPE (Dummy)	-0.168	0.397**	0.440**	0.384	0.377*	0.614***
	(0.211)	(0.194)	(0.180)	(0.251)	(0.216)	(0.236)
Operator (Dummy)	0.277	0.561*	0.677*	0.987***	0.852**	1.053***
	(0.221)	(0.329)	(0.376)	(0.354)	(0.331)	(0.314)
Number of declarations per firm (log)			0.035	0.005	-0.001	-0.050
			(0.038)	(0.044)	(0.047)	(0.048)
Nokia (Dummy)				0.052	0.065	0.144
				(0.221)	(0.238)	(0.211)
LG (Dummy)				0.828*	0.726	0.364
				(0.453)	(0.457)	(0.541)
Samsung (Dummy)				0.571	0.809**	0.705
				(0.375)	(0.407)	(0.461)
Huawei (Dummy)				-1.997***	-2.226***	-1.231
				(0.566)	(0.583)	(0.789)
Qualcomm (Dummy)				0.545	0.394	-0.042
				(0.438)	(0.429)	(0.554)
UMTS patent					0.797***	0.798***

					(0.217)	(0.216)
LTE/LTE-A patent					0.127*	0.114
					(0.075)	(0.079)
5G patent					-0.100	-0.101
					(0.162)	(0.165)
IoT patent					-0.232	-0.201
					(0.190)	(0.195)
Degree centrality (3GPP)						0.087
						(0.794)
Closeness centrality (3GPP)						-0.768
						(0.888)
Eigenvector centrality (3GPP)						1.231
						(0.835)
Number consortia memberships * Vendor (Dummy)		0.016	0.018	0.072***	0.071***	0.045**
		(0.012)	(0.012)	(0.020)	(0.018)	(0.022)
Number consortia memberships * NPE (Dummy)		-0.058***	-0.054***	0.022	0.027	-0.019
		(0.017)	(0.016)	(0.044)	(0.043)	(0.047)
Number consortia memberships * Operator (Dummy)		-0.010	-0.011	-0.014	-0.011	-0.018
		(0.012)	(0.012)	(0.010)	(0.009)	(0.013)
Constant	6.419***	5.900***	5.716***	5.885***	5.816***	5.815***
	(0.235)	(0.199)	(0.277)	(0.357)	(0.317)	(0.351)

Note: *p**p***p<0.01

Hypothesis 1: Firms with more consortia memberships tend to exhibit shorter time spans between patent application and declaration than ones with fewer memberships.

The regression results generally support this hypothesis, but with reservations. To further investigate this hypothesis, I have three two additional regressions (*regressions 7, regression 8*, and *regression 8a* shown in Table 4-9). In *regression 7*, I removed the number of consortia memberships per category, and instead only used the total number of consortia memberships. This makes sense because in the configurations of *regressions 1-6*, the coefficient of the total number of consortia membership does not actually capture the role of the total number of memberships, but rather the role of consortia not included in the six categories presented separately. In *regression 8*, I also added the quadratic number of consortia memberships to the configuration of *regression 7*. This is because the relationship between the number of consortia memberships and the length of declaration lags may not be a linear one.

Both additional regressions include terms capturing the interaction between firm categories (vendors, NPEs, and operators) and consortia memberships. This implies that it is so far not possible to say something about the "general" role of consortia membership regarding the length of declaration lags, including all categories of firms. This is why *regression 8a* does not include the interaction terms.

Table 4-9: Regressions on the role of the number of total consortia memberships

	Dependent variable: declaration lag in weeks [log]		
	(7)	**(8)**	**(8a)**
Degree centrality (cons)	4.688***	1.412	1.550
	(1.666)	(1.927)	(2.627)
Closeness centrality (cons)	-1.170**	-1.557***	-1.973***
	(0.567)	(0.505)	(0.489)
Eigenvector centrality (cons)	-2.311	-2.199	-3.980
	(2.106)	(1.945)	(3.042)
Number consortia memberships	-0.021	0.083***	0.102***
	(0.016)	(0.030)	(0.033)
Number consortia memberships (quadratic)		-0.001***	-0.001***
		(0.0003)	(0.0003)
Vendor (Dummy)	-2.519***	-3.018***	-0.379*
	(0.458)	(0.365)	(0.229)
NPE (Dummy)	0.538**	0.558**	0.126
	(0.246)	(0.218)	(0.193)
Operator (Dummy)	-0.386	-0.572*	-0.302
	(0.283)	(0.296)	(0.188)
Number of declarations per firm (log)	-0.028	0.031	-0.044
	(0.044)	(0.048)	(0.067)
Nokia (Dummy)	0.442***	0.547***	0.946***
	(0.118)	(0.107)	(0.179)
LG (Dummy)	0.009	-0.436***	-0.204
	(0.144)	(0.160)	(0.210)
Samsung (Dummy)	0.619***	0.248*	0.409*
	(0.127)	(0.150)	(0.215)

Huawei (Dummy)	-0.908***	-0.124	0.798**
	(0.122)	(0.254)	(0.359)
Qualcomm (Dummy)	0.072	-0.360**	-0.260
	(0.105)	(0.153)	(0.163)
UMTS patent	0.861***	0.836***	0.848***
	(0.211)	(0.207)	(0.205)
LTE/LTE-A patent	0.144	0.145**	0.122*
	(0.098)	(0.070)	(0.069)
5G patent	-0.102	-0.063	-0.098
	(0.164)	(0.163)	(0.171)
IoT patent	-0.226	-0.283	-0.175
	(0.186)	(0.207)	(0.177)
Degree centrality (3GPP)	0.817	0.024	0.736
	(1.025)	(0.866)	(0.899)
Closeness centrality (3GPP)	-1.236	0.040	-0.713
	(1.156)	(1.010)	(1.062)
Eigenvector centrality (3GPP)	0.157	0.308	0.110
	(0.621)	(0.779)	(0.776)
Number consortia memberships * Vendor (Dummy)	0.048***	0.053***	
	(0.009)	(0.006)	
Number consortia memberships * NPE (Dummy)	-0.044**	-0.048**	
	(0.022)	(0.021)	
Number consortia memberships * Operator (Dummy)	0.013	0.008	
	(0.010)	(0.010)	
Constant	5.774***	5.490***	6.206***
	(0.286)	(0.316)	(0.393)

Note: *p **p ***p<0.01

Regressions 7 and *8* indicate a negative relationship between consortia relationships and the length of declaration lags for NPEs: For them, one more membership is associated with a 4.4% decrease in the length of declaration lags. In contrast, the relationship for vendors seems to be a positive one. Furthermore, the results of *regression 8a* suggest that the overall relationship between the number of memberships and the length of declaration lags may be quadratic. However, the relatively low negative coefficient of the quadratic number of memberships suggests that the number of consortia memberships can only be associated with lower declaration lags once we get to a relatively high number of memberships. However, for NPEs, we still see a significant negative relationship: For them, one more membership is associated with 4.4 to 4.8% shorter declaration lags. In contrast, for vendors, consortia memberships seem to come along with longer declaration lags.

In *regressions 1 to 3,* namely the regressions preceding the inclusion of the dummies for the five largest declarers, there seems to be a negative relationship between the number of consortia memberships in some categories (three in *regression 1*, two in *regressions 2* and *3*), and the declaration lag. When the dummies for the five largest declaring firms are added in *regression 4*, the negative relationship between the number of memberships and the length of declaration lags mostly disappears. This suggests that the behaviour of these five firms accounts for most of the variation in the declaration lag, and that the number of consortia memberships may not actually play a role. However, as previously mentioned, in the results of *8a* (which also include the dummies for the largest declarers), there is an indication that the overall number of consortia memberships may actually be associated with smaller declaration lags once firms have joined a relatively large number of them (around 50). These regression results also indicate that the overall number of memberships matters for the length of declaration lags for both vendors and operators.

Thus, the results imply that being represented in consortia is not equally relevant for strategic patenting for all firms. Being a vendor is generally associated with significantly shorter declaration lags. But consortia memberships do not contribute to this negative relationship, rather on the contrary. For NPEs, we observe the opposite: Being an NPE generally often comes with longer declaration lags, however, NPE membership in consortia can be associated with shorter declaration lags. To further illustrate these numbers: vendor patents in the dataset exhibit an average declaration lag of around 312, while all others (all patents minus vendor patents) exhibit around 346 weeks. In comparison, NPE patents have an average declaration lag of 527 weeks. While joining one additional consortium can possibly be associated with 5.4 to 5.8% (*regressions 1* and *2*) shorter declaration lags for NPEs, we may observe 4.5 to 7.2% (*regressions 4 to 6*) longer declaration lags for vendors. This difference between NPEs and other firms in the sample may originate from the nature of their business model. A more detailed discussion on this can be found in Section 4.6.5.

Hypothesis 2: There are some consortia categories that are associated with shorter time spans between patent application and declaration, while others are associated with longer time spans, or are irrelevant.

The regression results generally support this hypothesis, but with substantial reservations. While *regressions 1* to *3* suggest some significant relationships of consortia memberships in some categories, most of the significant relationships vanish once the five firm dummies are added in *regression 4*. After the inclusion, the only consortia category that still seems to matter is category 1. As previously mentioned, *regression 8a* indicates that the overall number of consortia memberships is still to some extent associated with shorter declaration lags (especially for NPEs). Since *regressions 7* to *8a* do not include consortia memberships per category, the results point towards a stronger relevance of the overall number of memberships, rather than memberships in consortia of specific categories.

However, in *regressions 1* to *3*, we see some significant relationships between consortia memberships in specific categories and the length of declaration lags. Table 4-10 shows the results of these regressions: It displays the consortia categories as outlined in Section 4.3, together with an indication of the change in the length of the declaration lag that is associated with one additional consortia membership in one of the categories. Memberships in consortia of category 1, large industry and technology influencers, seems to be especially related to shorter declaration lags. The same holds true for consortia of category 3, established standards developers—even though the relationship does not seem to be as strong. In contrast, memberships in categories 2, high-level concept developers, and 6, SSO-hosted industry drivers, is associated with longer declaration lags.

Table 4-10: Marginal effect of memberships in industry consortia of different categories

Category name	**Relationship between one more membership in each category and length of declaration lag**
1: Large industry and technology influencers	21.4 to 27.6% shorter lags
2: High-level concept developers	13.0 to 15.9% longer lags
3: Established standards developers	8.7 to 8.9% shorter lags
4: Young technology specialists	12.4% shorter lags (only in *regression 1*)
5: Small industry and technology influencers	Insignificant
6: SSO-hosted industry drivers	25.9 to 27.4% longer lags

As previously explained, consortia of category 1 are very large (639 members on average), relatively established (mean founding year 1999), and tend to emphasise broad technological concepts combined with goals relating to furthering industry development and economic or societal issues. Consortia of category 3 are relatively small (224 members on average) and established (mean founding year 2000), and they usually focus on the maintenance and enhancement of mature technologies. Also, they often engage in standards development.

To further investigate the role of different categories of industry consortia, I have compared *regressions 6* to *8* with a new regression (Table 4-11): *Regression 9* does not include absolute numbers of consortia memberships in different categories, but instead the share of memberships in each of the categories. More precisely, the share is calculated per firm, by dividing the number of memberships in consortia of a certain category by the number of overall memberships of a firm. Hence, it gives an indication of the priority of a certain consortia category for a firm. As shown previously, in *regression 6*, all consortia memberships except for the coefficient of consortia of category 1 are rendered insignificant. *Regressions 7* to *8a* (in comparison to *regression 6*) suggest that if the number of consortia memberships plays a role for the length of declaration lags, it is rather the absolute number of memberships than memberships in consortia of certain categories. However, when looking at *regression 9*, it seems that an emphasis on memberships in consortia of category 1 could be associated with shorter declaration lags.

Table 4-11: Regressions on the role of the number consortia memberships in different categories

	Dependent variable: declaration lag in weeks [log]			
	(6)	**(7)**	**(8)**	**(9)**
Degree centrality (cons)	3.149	4.688***	1.412	0.478
	(2.012)	(1.666)	(1.927)	(1.576)
Closeness centrality (cons)	-0.812*	-1.170**	-1.557***	3.545
	(0.441)	(0.567)	(0.505)	(3.405)
Eigenvector centrality (cons)	0.230	-2.311	-2.199	-2.945*
	(2.516)	(2.106)	(1.945)	(1.513)
Number consortia memberships	-0.026	-0.021	0.083***	0.057
	(0.028)	(0.016)	(0.030)	(0.041)
Number consortia memberships 1	-0.340**			
	(0.155)			
Number consortia memberships 2	0.106			
	(0.069)			
Number consortia memberships 3	0.016			
	(0.063)			
Number consortia memberships 4	-0.077			
	(0.073)			
Number consortia memberships 5	-0.068			
	(0.080)			
Number consortia memberships 6	0.043			
	(0.130)			
Number consortia memberships (quadratic)			-0.001***	-0.001*
			(0.0003)	(0.0004)
Share consortia memberships 1				-2.938*
				(1.694)
Share consortia memberships 2				-0.432
				(1.701)
Share consortia memberships 3				-1.497
				(1.640)
Share consortia memberships 4				-3.262

				(2.769)
Share consortia memberships 5				-2.052
				(1.618)
Share consortia memberships 6				-0.196
				(2.186)
Vendor (Dummy)	-1.885**	-2.519***	-3.018***	-2.246***
	(0.815)	(0.458)	(0.365)	(0.752)
NPE (Dummy)	0.614***	0.538**	0.558**	0.977***
	(0.236)	(0.246)	(0.218)	(0.333)
Operator (Dummy)	1.053***	-0.386	-0.572*	0.101
	(0.314)	(0.283)	(0.296)	(0.332)
Number of declarations per firm (log)	-0.050	-0.028	0.031	0.037
	(0.048)	(0.044)	(0.048)	(0.039)
Nokia (Dummy)	0.144	0.442***	0.547***	0.573***
	(0.211)	(0.118)	(0.107)	(0.156)
LG (Dummy)	0.364	0.009	-0.436***	-0.359
	(0.541)	(0.144)	(0.160)	(0.274)
Samsung (Dummy)	0.705	0.619***	0.248*	0.350**
	(0.461)	(0.127)	(0.150)	(0.175)
Huawei (Dummy)	-1.231	-0.908***	-0.124	-0.188
	(0.789)	(0.122)	(0.254)	(0.305)
Qualcomm (Dummy)	-0.042	0.072	-0.360**	-0.350
	(0.554)	(0.105)	(0.153)	(0.284)
UMTS patent	0.798***	0.861***	0.836***	0.789***
	(0.216)	(0.211)	(0.207)	(0.218)
LTE/LTE-A patent	0.114	0.144	0.145**	0.127*
	(0.079)	(0.098)	(0.070)	(0.074)
5G patent	-0.101	-0.102	-0.063	-0.080
	(0.165)	(0.164)	(0.163)	(0.169)
IoT patent	-0.201	-0.226	-0.283	-0.039
	(0.195)	(0.186)	(0.207)	(0.189)
Degree centrality (3GPP)	0.087	0.817	0.024	-1.163
	(0.794)	(1.025)	(0.866)	(0.786)

Closeness centrality (3GPP)	-0.768	-1.236	0.040	0.903
	(0.888)	(1.156)	(1.010)	(0.980)
Eigenvector centrality (3GPP)	1.231	0.157	0.308	1.355*
	(0.835)	(0.621)	(0.779)	(0.787)
Number consortia memberships * Vendor (Dummy)	0.045**	0.048***	0.053***	0.037***
	(0.022)	(0.009)	(0.006)	(0.014)
Number consortia memberships * NPE (Dummy)	-0.019	-0.044**	-0.048**	-0.096**
	(0.047)	(0.022)	(0.021)	(0.039)
Number consortia memberships * Operator (Dummy)	-0.018	0.013	0.008	-0.008
	(0.013)	(0.010)	(0.010)	(0.014)
Constant	5.815***	5.774***	5.490***	5.083***
	(0.351)	(0.286)	(0.316)	(0.345)

Note: *p**p***p<0.01

Hypothesis 3: More central firms in the firm network induced by consortia memberships exhibit shorter time spans between patent applications and declarations than less central ones.

The regression results only support this hypothesis with regards to closeness centrality. *Regressions 1* to *8* point towards a negative and significant relationship between closeness centrality and the length of declaration lags. More precisely, *regression 6* suggests that a 0.1 increase in closeness centrality is associated with 8.1% shorter declaration lags—bearing in mind that in the sample, closeness centrality values of firms reach from 0 (for firms not represented in any consortia) to 0.73 (Huawei).

In contrast, higher degree centrality seems to go along with longer declaration lags, or not be relevant at all. *Regressions 1* to *3* point towards quite a strong positive relationship, however, the significance disappears in *regressions 4* to *6* once the five dummies for the largest declarers are included. Only in *regression 7*, when the membership in consortia of specific categories is removed from the regression, we see a positive and significant relationship between degree centrality and the length of the declaration lag. More precisely, in this case, a 0.1 increase in degree centrality is associated with a 46.9% increase in the length of declaration lags. In the sample, values for degree centrality reach from 0 (for firms not represented in any consortia) to 0.83 (Huawei). However, the significance once again vanishes once the quadratic total number of consortia memberships is introduced in *regression 8*.

Given the results described in the last two paragraphs and the fact that eigenvector centrality does not seem to play a role at all, we can assume that it is probably closeness to relevant peers in the network that is most relevant when it comes to the length of declaration lags. In contrast, the number of direct connections via consortia (i.e. degree centrality) probably does not play as much of a role—and if it does, there is rather a positive relationship between degree centrality and the length of declaration lags.

4.6.4 Robustness checks

From the descriptive statistics presented in Section 4.6.1, we know that there are large variations in the data regarding the declaration lag, declaration lags range between 14 and 2,749 weeks. Thus, it has become clear that there are extreme values in the dataset. Now, the question is whether the relationships obtained from regression analysis, as presented in the previous section, still hold when these extreme values are "toned down".

Hence, I chose to use the winsorizing technique to reduce the magnitude of extreme values in the declaration lag, and hence reduce their impact on the regression results. In the case of winsorizing, the values are still represented in the distribution, but at the higher or lower end, so they are "reined in" (Reifman and Keyton 2010, p. 1636). The idea is basically that extreme values are replaced by less extreme values. I utilised the "Winsorize" function of R, using the default of the 5%/95% quantile. This means that every declaration lag above or below the 5%/95% quantile is replaced by the 5%/95% quantile value. Using the winsorized declaration lag values as the dependent variable for *regressions 6* and *7* (as presented in the previous Section), there is no change in the direction or significance of the coefficients. We only observe slight changes in magnitude, however, these do not alter the implications and interpretation of the results (see Appendix C, Table 8-1). Thus, I am confident that extreme declaration lags do not overly affect the regression results, even when using the original (i.e. non-winsorized) values.

4.6.5 Interpretation of results

In general, industry consortia memberships seem to come along with shorter declaration lags. However, this relationship seems to be heavily dependent on the type of firm. For NPEs, we indeed observe a negative relationship, but not for vendors or operators. For vendors, the results even indicate that consortia memberships may be associated with longer declaration lags. In the case of operators, there does not seem to be a significant relationship at all.

The results with regards to NPEs could originate from their business models, they are often focussed on patents that are "are more likely to be infringed [and] harder to substitute for" (Fischer and Henkel 2012, p. 1519). Thus, they may aim for ownership of patents that are especially targeted towards inclusion in a standard (which strategic patents are bound to be).

However, some of the “oldest” patents in the sample, which naturally boast quite long[93] declaration lags, are held by Conversant[94] Wireless, an NPE not present in any of the consortia. So in some cases NPEs can also hold extensive portfolios of “old” patents, which is for instance the case when they purchase entire portfolios. These cases may also be the reason that generally, patents owned by NPEs seem to be characterised by longer declaration lags (than e.g. vendors). For NPEs primarily purchasing patents from other (practising) firms, it is probably not especially useful to join industry consortia. Rather, it is NPEs conducting own R&D and creating patentable inventions for whom it may be beneficial to join consortia (e.g. InterDigital, Convida Wireless).

There is another reason why the relationship between consortia memberships and shorter declaration lags is more pronounced for NPEs than it is for other firms: Perhaps established, “practising” firms in the industry, meaning firms actually using patents in their products, are well-connected in the industry anyway (firms such as Nokia, Huawei and Ericsson). This means that these firms communicate a lot outside of standardisation groups and consortia, and there is regular exchange between managers of these firms. Hence, they may not rely on consortia for information. For vendors in particular, this means that their declaration lags seem to be shorter anyway. Interestingly, Huawei patents seem to exhibit especially short declaration lags in comparison to other vendor patents. This could be because Huawei has joined the “standardisation game” relatively late—in fact, the first Huawei declaration[95] to be found in the ETSI database is from April 2005. However, this effect should be dampened to some extent by the fact that the dataset only includes patents declared to ETSI from 2018 on. It is important to note though that it is rather difficult to correctly identify the effect of consortia for some firms, especially vendors, because the large and important ones (Ericsson, Nokia, and Huawei) are represented in most of the consortia anyway.

When it comes to the relationship between consortia memberships and declaration lag length, irrespective of firm category, the marginal effect of additional memberships may differ

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[93] At the mean, Conversant Wireless has 866.29 weeks between patent filing and patent declaration. The shortest declaration lag is 426 weeks.

[94] Conversant Wireless is also accused of engaging in patent privateering in the context of IoT patents (see http://www.fosspatents.com/2020/05/nokia-fed-avanci-aligned-patent-troll.html?utm_source=feedburner&utm_medium=email&utm_campaign=Feed%3A+fosspatents%2FzboT+%28FOSS+Patents%29; retrieved on 28/05/2020). Patent privateering refers to a situation where NPEs purchase patents from their owners and enforce them, sharing the revenues with the original owners (Seidenberg 2013).

[95] Patent CN20041044425 titled “Method of selecting charging rule according to users”.

depending on the total number of memberships. More precisely, according to the regression results, additional memberships can only be linked to shorter declaration lags from a certain minimum number of memberships. Perhaps this is due to learnings when it comes to managing consortia memberships, involvement, and connections, or extracting knowledge from consortia.

The precise categories of consortia a firm is involved in do not seem to be of much relevance to its declaration lag lengths. Even though some categories seem to be related to shorter declaration lags at first, the dummies for the five largest declarers tend to take away most of the relevance. This may imply that firm strategy with respect to consortia memberships as well as patent applications and declarations is to some extent responsible for the choice of consortia as well as declaration lag lengths. The only consortia category of relevance seems to be category 1, large industry and technology influencers. This category includes very large consortia (639 members on average) that are relatively established (mean founding year 1999), and tend to emphasise broad technological concepts combined with goals relating to furthering industry development and economic or societal issues. This implies that these consortia are mostly not directly concerned with technology development, but rather with broad concepts, use cases, general requirements for standards, et cetera. So perhaps being involved in such consortia helps firms find out about the general technical direction that particular standards may take.

When it comes to centrality indicators included in the analysis, closeness centrality is linked to shorter declaration lags. In contrast, degree centrality tends to have a positive coefficient, or does not have a significant influence. More precisely, significance disappears once the dummies for the five largest declarers are included. These firms tend to exhibit a relatively large number of direct links, and thus high degree centrality, stemming from numerous consortia memberships and memberships in large consortia. Hence, the positive or insignificant relationship could be rooted in the fact that several firms have a high number of direct connections through consortia, and boast relatively long declaration lags at the same time. Eigenvector centrality does not seem to play a role at all when it comes to the length of declaration lags.

Thus, being relatively close to all other nodes (i.e. firms) in the network seems to be associated with shorter declaration lags as well. This means that whenever a firm has to take fewer "steps" in order to reach all other firms in the network, its declaration lags are probably shorter. We can relate this result back to informational advantages: Being close to all peers implies that it does not take much effort to obtain information from different sources. This allows firms to gauge the most important topics in the industry. In the hypothesis section (4.3), I expected closeness centrality to be of particular importance for shorter declaration lags because it implies that firms can "get to" all other firms in the network relatively easily. The relevance of closeness centrality may also imply that it matters to be represented in consortia that allow for access to a large number of relevant firms. This is reflected in the relevance of consortium category 1 which includes relatively large consortia. However, it is not just the sheer size of the consortia that seems to be of importance, but also the representation of players of the relevant groups in the industry. The firms with the largest number of memberships in consortia of category 1 include the major vendors (i.e. Huawei, Nokia, Ericsson, and ZTE) as well as major operators from various regions (e.g. China Mobile, AT&T, Deutsche Telekom, NTT, and Telefonica). Therefore, the finding seem to confirm what we already know from Chapter 2—for membership in specific consortia to be interesting for firms, the "right" players with momentum and reach in the market need to be represented. The "right" players are not necessarily those who are the most central, but those who allow for the best reach to all relevant peers.

Now that I have discussed the key variables of the model (with regards to the hypotheses), I will now turn to some of the control variables. Centrality with regards to presence in 3GPP meetings does not seem to play a significant role at all regarding the length of declaration lags. This seems surprising at first glance, since this is where the actual standards are made. One could argue that communication outside of 3GPP is perhaps more relevant for gathering information around key trends in standardisation and the industry.

4.7 Implications and limitations

In a nutshell, the results suggest that when firms are well-connected through several consortia, they tend to hold patents with relatively short declaration lags. This relationship seems to mainly stem from the opportunity to easily obtain information from a variety of peers. Firms can do so when, in a network, they are relatively close to all relevant peers. By obtaining ample information on trends in standardisation and the industry as a whole, firms are enabled to make informed decisions on the direction of their R&D and patenting activities, and potentially tailor the content of patents to the content of standards and technical specifications. It is crucial to note though that the relationship between consortia memberships and strategic patenting is not the same for all firms. Depending on the field of activity of a firm, implications of consortia memberships tend to be different. More precisely, industry consortia memberships seem to be especially interesting for NPEs. Furthermore, joining additional industry consortia may only be linked to shorter declaration lags when a firm has already had some experience and learnings from other consortia memberships.

Now, the question is to what extent information exchange between firms and strategic patenting would take place anyway. As frequently emphasised previously, the telecommunications industry is characterised by a substantial amount of interaction between firms, and collaboration inside and outside of SSOs. It is also clear that some of this collaboration is needed in order to produce standards with working interfaces that as many industry participants as possible are content with. Thus, I am wondering to what extent industry consortia add to this.

One could very well argue that information exchange within industry consortia is useful to support the workings of standardisation. More precisely, when firms get together in consortia, exchange information, and obtain ideas about inventions needed to support upcoming standards, the work of SSOs could potentially be made quicker and more efficient. Moreover, novel technologies could be initiated, further developed, and promoted within consortia. This would then naturally lead to patents that are developed in close connection with standardisation efforts.

On the other hand, it appears that industry consortia could to some extent enable strategic patenting and a “tinkering” with patents, with the main purpose of obtaining a better match with the precise contents of standards and technical specifications. This could render the connection between consortia memberships and strategic patenting more problematic: Firms may not obtain ownership of SEPs because they provide a suitable technology for a standard, but because they are better connected to their peers. Arguably, as I have already mentioned in Chapter 2, standardisation participants know that it is in many cases not possible for the best or most suitable technology to “win” (i.e. to be included in a standard), and that strategic considerations usually play a large role in these types of decisions. In effect, we know that it is not always the “best” technology that is included in a standards anyway (the definition of “best” is yet to be determined). But again, the question is to what extent consortia exacerbate this phenomenon. This could be especially problematic when consortia membership enables NPEs, who are not actually dependent on using standards in their products, to tailor patents to standards and then obtain a (potentially) more valuable patent portfolio. In consequence, this could then lead to aggressive royalty negotiations.

From the analysis presented in this paper, we can conclude that industry consortia likely play a role in enabling firms to engage in strategic patenting—mostly because firms can gather information on the direction of other firms regarding their standardisation efforts and intentions. Thus, consortia are a potential way of accumulating knowledge about the likely technical direction of standards to come. However, unfortunately, I am not able to conclude about the magnitude of consortia influence in strategic patenting. This is mostly due to the fact that it is not possible to collect comprehensive data on collaborative efforts and communication between firms outside of SSOs and industry consortia. In a similar vein, I can unfortunately not establish causality. More precisely, I cannot conclude that consortia engagement actually *causes* strategic patenting. Hence, it would certainly be interesting to follow a case study approach, and observe one or very few consortia and their members closely over a longer period of time.

5 Conclusion and outlook

Many firms in the realm of ICT, and especially in telecommunications, have traditionally been tightly connected through their membership and engagement in (quasi-)formal SSOs, several forms of alliances (e.g. research partnerships), and informal contacts between managers. This implies that there are already numerous opportunities for firms to get in touch and talk about issues such as technologies, standards, and overall industry development. In spite of this, there are manifold reasons why firms are interested in adding consortia to the mix, by joining existing and forming new consortia.

Consortia present firms with yet another opportunity and way to get involved in mobile telecommunication standardisation, which is why the option of engaging in pre-standardisation can be an important consideration when joining and forming industry consortia. However, it is important to emphasise that consortia are not just about influence in standardisation. Depending on their set-up, membership composition, and how established they are, consortia can also play an important role in overall industry development and the technological direction of industry—both of which are of course heavily impacted by standardisation. Consortia can also be interesting to firms because they present firms with plenty of opportunities and freedom of choice when it comes to their exact set-up, including structures, processes, and rules—which one of the interviewees coined the “rules of engagement”. On the other hand, consortia present firms with challenges and demands on resources, both financial and human resources.

In some cases consortia are initiated due to perceived shortcomings of (quasi-)formal SSOs, for instance their lack of efficiency due to their large size. However, most consortia still seem to supplement the work of (quasi-)formal SSOs. More precisely, consortia are sometimes understood to facilitate or enhance the work of (quasi-)formal SSOs by offering a place to outsource some discussions and technical work that can more easily (and potentially more quickly) be handled in a consortia environment. For novel technologies, which are not yet sufficiently mature to be brought into formal standardisation, preparatory work can then be done in consortia (e.g. feasibility studies or prototypes). The same goes for novel technologies that may be blocked within formal standardisation due to (non-technical) political reason—for instance when several firms have large stakes in established competing technologies. In this case, consortia can be useful to further study and work on these technologies. Thus, work in consortia can potentially support technological progress in the industry.

Consortia can also be expected to become even more relevant in the future. The current and future technological environment is shaped by use cases and opportunities of 5G and the IoT, and hence requirements from various industries imposed on mobile telecommunication standards. In this context, consortia can provide an opportunity for firms from various industries to get together to discuss their requirements regarding mobile telecommunication standards, and then feed work results into (quasi-)formal SSOs (which are usually dominated by ICT firms).

In contrast, consortia also provide opportunities for firms to behave opportunistically, for instance by using consortia to push inferior proprietary technologies that may otherwise not gain traction in the industry. Also, single firms may gain advantages by initiating consortia and then tailoring the rules and structures to their needs, for instance by purposefully excluding other firms or groups of firms, or restricting other firms' rights. Since there are so many options for founding firms to design the rules, structures, and processes of consortia to their advantage, there is a large variety of consortia.

This large variety can render oversight difficult. The consortia landscape is indeed rather opaque: To gather detailed information on a consortium, it is often necessarily to dig deep into its legal documents (e.g. bylaws), which can be an arduous task. This implies that it can be difficult (or impossible) for interested firms to gain insight into a consortium and whether and how they can join. In some cases, joining consortia seems to be a "who knows whom" game in which founding firms invite others to join. Hence, access to influential industry consortia, or at least to their most influential membership tiers, can be restricted to firms who are well-connected in the industry anyway.

Now, the probably most interesting question is about the implications of industry consortia, which is a question that has numerous dimensions and can be looked at from various angles. One aspect that we can attempt to measure relates to the connection between patenting behaviour of firms with regards to standardisation, and consortia memberships. More precisely, we can examine to what extent firms with more consortia memberships strategically create and adapt patents so that they are likely to become standard-essential. These patents are very much sought-after because they are generally perceived to be more valuable (e.g. in licensing negotiations) in comparison to otherwise similar non-essential patents. I find that being involved in consortia may indeed be associated with such behaviour, which I refer to as strategic patenting. Most importantly, this is the case whenever firms are close (in a network sense) to many of their relevant peers. Perhaps this is because consortia memberships, and being close to their peers, allow firms to gather information on the likely direction of certain standards, and purposefully apply for patents that they anticipate to become essential. When it comes to being close to other firms, it seems to be important to be connected to the "right" firms with momentum in the industry. In this case, the "right" firms cover different areas within the industry (including e.g. vendors and operators) and have relatively large market shares.

However, when talking about implications of industry consortia, it is important to stress that implications do not seem to be the same for all kinds of firms. In general, as mentioned in the beginning of this section, firms in the realm of telecommunications are in close contact with each other anyway, for instance through joint work in standardisation and different kinds of partnerships (e.g. research partnerships). This is because the industry and its products and services work in such a way that compatibility is crucial, which renders a regular exchange between firms beneficial and reasonable. Hence, for some firms, industry consortia may not actually make a difference with regards to the amount and quality of information on standardisation they receive. Interestingly, the association between involvement in consortia and strategic patenting activities is strongest for NPEs—firms that do not actually manufacture and offer products or services using standards. This suggests that some firms can make use of consortia to accumulate SEPs and aggressively enforce them. It may make sense for firms to do so if they are not dependent on obtaining SEP licenses themselves. Such behaviour could be problematic for technological progress.

To conclude, consortia seem to be a bit of a two-edged sword: They may be advantageous when it comes to technological advancements, mainly because they can help the promotion and further elaboration of innovative ideas, but they can be used in an opportunistic way as well. Thus, it is important to understand the landscape, and hence allow for oversight and, if necessary, regulation.

6 Appendix A: Chapter 2

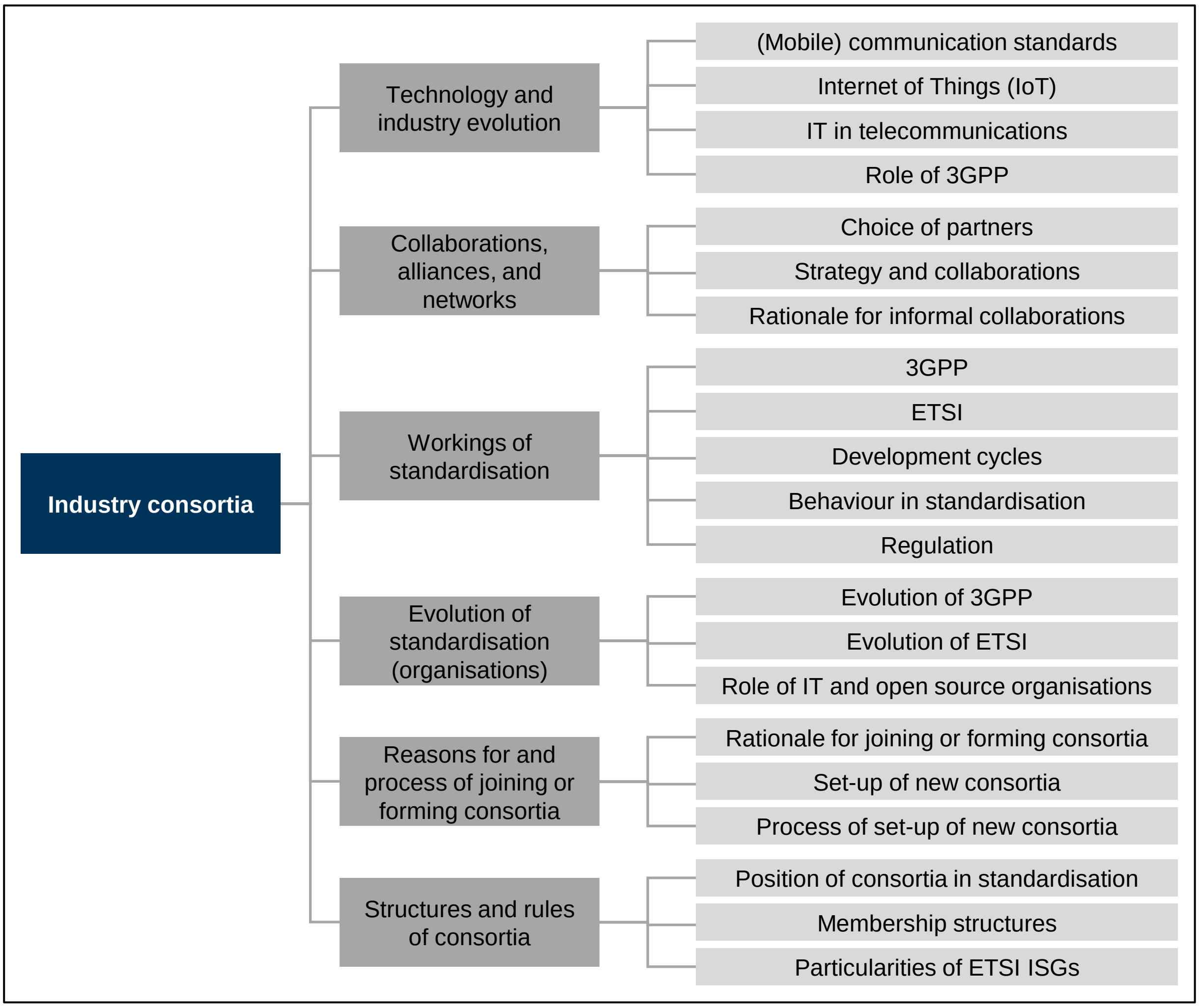

Figure 6-1: Coding tree

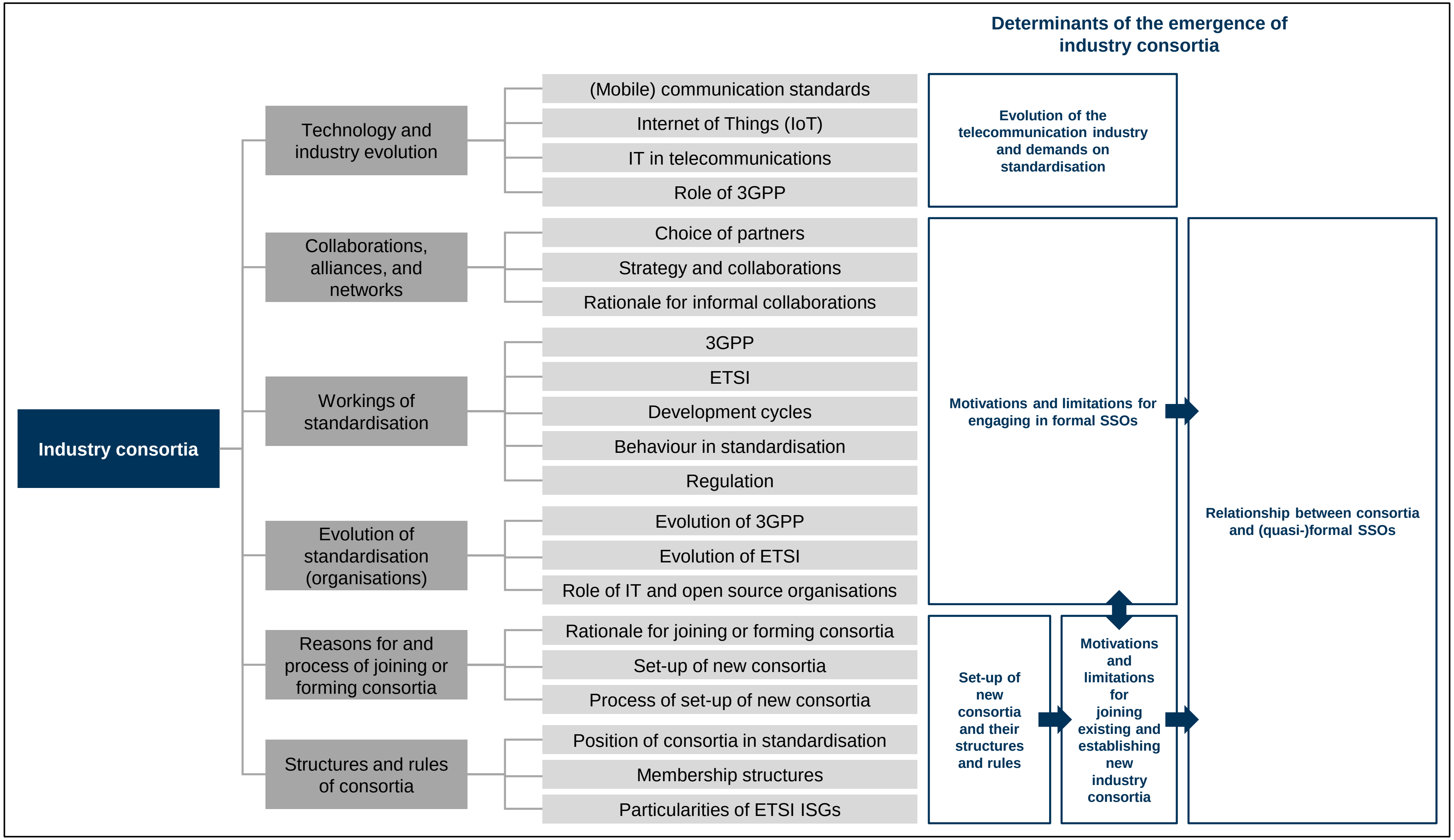

Figure 6-2: Coding tree with constructs

7 Appendix B: Chapter 3

7.1 List of consortia and their cluster allocation

The following table presents the consortia in the sample and their cluster allocation according to our cluster analysis.

Table 7-1: Consortia in the sample and their cluster allocation.

Consortium	**Cluster**
Global Certification Forum (GCF)	**1 Large industry and technology influencers**
GSM Association (GSMA)	
oneM2M	
TM Forum	
Wi-Fi Alliance	
5G Infrastructure Public Private Partnership (5G PPP)	**2 High-level concept developers**
Alliance for the Internet of Things Innovation (AIOTI)	
ARTEMIS Industry Association	
DigitalEurope	
Intelligent Transportation Society of America (ITS America)	
International Wireless Industry Consortium (IWPC)	
NetWorld2020	
North American Network Operators Group (NANOG)	
Organisation for the Advancement of Structured Information Standards (OASIS)	
Wireless Innovation Forum	
Wireless World Research Forum	
Bluetooth Special Interest Group (SIG)	**3 Established standards developers**
Broadband Forum	
CalConnect	
Car Connectivity Consortium	
DECT Forum	
Digital Video Broadcasting (DVB)	
Distributed Management Task Force (DMTF)	
Global Platform	
HomeGrid Forum	
International Multimedia Telecommunications Consortium (IMTC)	

JEDEC Solid State Technology Association

LoRa Alliance

Metro Ethernet Forum (MEF)

Mobile Industry Processor Interface (MIPI) Alliance

NFC (Near-Field Communication) Forum

Open Connectivity Foundation (OCF)

Open Mobile Alliance (OMA)

Open Networking Foundation (ONF)

Open Services Gateway Initiative (OSGI)

PCI Industrial Computer Manufacturers Group (PICMG)

Peripheral Component Interconnect Special Working Group (PCI SIG)

PoweRline Intelligent Metering Evolution (PRIME) Alliance

RapidIO

SD Card Association (SDA)

SIP Forum

Small Cell Forum

The Linux Foundation

The Open Group

Ultra HD Forum

WiMax Forum

Wireless Power Consortium

ZigBee Alliance

4
Young technology specialists

5G Test Network (5GTN)

Automotive Grade Linux

Cloud Native Computing Foundation (CNCF)

CloudFoundry

Eclipse

EdgeXFoundry

Industrial Internet Consortium

Open Compute Project (OCP)

Open Network Automation Platform (ONAP)

Open Platform for NFV (Network Function Virtualization) (OPNFV)

Open Stack

OpenDaylight Foundation

OpenFog Consortium

Telecom Infra Project	
5G Americas	**5 Small industry and technology influencers**
5G Automotive Association (5GAA)	
Car 2 Car Communication Consortium	
CBRS (Citizens Broadband Radio Service) Alliance	
Cellular Operators Association of India (COAI)	
Cellular Telecommunications and Internet Association (CTIA)	
Global Mobile Suppliers Association (GSA)	
Global TD-LTE Initiative	
MulteFire Alliance	
Next Generation Mobile Networks (NGMN) Alliance	
Open Automotive Alliance (OAA)	
Quality Excellence for Suppliers of Telecommunications (QuEST) Forum	
TETRA and Critical Communications Association (TCCA)	
Wireless Broadband Alliance	
Wireless Technology Association	
ETSI ISG Embedded Common Interface (ECI)	**6 SSO-hosted industry drivers**
ETSI ISG Intelligent Compound Content Management (CCM)	
ETSI ISG Millimetre Wave Transmission (mWT)	
ETSI ISG Mobile and Broadcast Convergence (MBC)	
ETSI ISG Multi-access Edge Computing (MEC)	
ETSI ISG Operational Energy Efficiency for Users (OEU)	
ETSI ISG Quantum Key Distribution (QKD)	
ETSI ISG Surface Mount Technique (SMT)	
App Quality Alliance (AQuA)	**n/a**
Communications Alliance	
ERTICO IST (Intelligent Transportation System) Europe	
ETSI ISG Information Security Indicators (ISI)	
ETSI ISG IPv6 Integration	
ETSI ISG Network Functions Virtualisation (NFV)	
ETSI ISG Next Generation Protocols (NGP)	
i3 forum	
IPSO (Internet Protocol for Smart Objects) Alliance	
Mobey Forum	
Object Management Group (OMG)	

Optical Internetworking Forum (OIF)
Storage Performance Council (SPC)
Taiwan Association of Information and Communication Standards (TAICS)
Trusted Computing Group (TCG)

7.2 Classification scheme

Table 7-2: Characteristics determined by a consortium's objectives

Declared purpose	**Scale**
Technology development	Incorrect / partially correct / correct
Mature technology development	
Early technology development	
Marketing	
Certification	
Standards development	
Formalised standards contribution	
Informal standards contribution	
Industry development	
Economic and societal aspects	

Technology	**Scale**
Technology focus	1 = Networks architecture and infrastructure (incl. software, hardware, protocols)
	2 = Electrical engineering
	3 = Computer engineering and cloud computing
	4 = Microelectronics
	5 = Devices and applications
	6 = Entertainment
	7 = Consumer electronics
	8 = Solutions for verticals
Breadth of technology focus	1 = Focus on technology components or specific methods (e.g. SIP, CDMA)
	2 = Focus on technology systems and solutions (e.g. small cells, device-to-device communication)
	3 = Focus on concept development and industry evolution (e.g. IoT, mobile networks)

Formal recognition	Scale
Establishment by or support from authority Membership of authorities	Incorrect / correct

Table 7-3: Characteristics determined by chosen organisational set-up

Background	Scale
Founding year (age is calculated as age = 2018 - founding year; rounded to full years) Number of members	-

Transparency	Scale
Transparency in structure and processes Transparency in bylaws and policies (or similar) Transparency in handling of intellectual property Transparency in membership/participation options Transparency in work status Transparency in work documentation Transparency in ties with other organisations	Incorrect / partially correct / correct

Exclusiveness	Scale
Clear application process Access to membership tiers Broad industry / regional representation No privileges regarding assignment of leadership positions Democratic consensus process	No information available / Incorrect/ partially correct / correct

Memberships	Scale
Dominance of corporate memberships Link between membership fees and firm size	No information available / Incorrect / partially correct / correct
3GPP TSG involvement	-
3GPP WG involvement	-

Network	Scale
Cooperations with non-formal standards-related organisations	No information available / Incorrect / correct
Cooperations with 3GPP	
Cooperations with 3GPP OPs	
Regulatory/governmental body and agency partnerships	

Intellectual Property Rights	Scale
Definition of IP rules regarding technical specifications	This statement is not applicable/ No information available Incorrect / partially correct / correct
Availability of IP list with technical specifications	
Definition of licensing rules	
Share of firms with standard essential patents declared to ETSI	-

Specialist support	Scale
Management / support by consortia specialist	No information is available / Incorrect / correct
Management / support by ETSI fora hosting	
Management / support by larger / more established organisation	

7.3 Data preparation

Some of the data we planned to collect on industry consortia was not available, mostly because the relevant bylaws or policy documentation were not made public. Consequently, 12 of our total of 38 qualitative variables are missing one or more values, and these are not randomly distributed.

To deal with these missing values, we constructed three modified datasets, imputing values in three different ways: (1) We only considered cases with complete data. (2) We imputed the missing values using a mean of the remaining values of the relevant variable. (3) We imputed the missing values based on assumptions. More precisely, we assumed that if information on a certain aspect is not provided, this aspect is handled restrictively by the consortium. For instance, if bylaws are not provided, we assumed there is restricted access to membership tiers. We deleted some variables from the datasets—mostly where a large number of values was missing, or where there were high correlations with other variables. We considered using ordered probit regressions for imputations, however, we realised that they artificially strengthened the correlations on which we based our PCA. Ultimately, we used the following three datasets[96].

Table 7-4: Summary of datasets considered for cluster analysis

Dataset	Number of variables	Number of observations (n)	Mode of imputation
1	35	83	None, only consortia with complete data were considered
2	37	100	Arithmetic mean for each variable computed
3	37	100	Missing values imputed using assumptions

We carried out the Principal PCA and cluster analysis for all three datasets, compared the results (which were very similar), and integrated the outcomes in our final taxonomy.

[96] In the dataset containing only complete cases, we removed two more variables to retain more observations.

8 Appendix C: Chapter 4

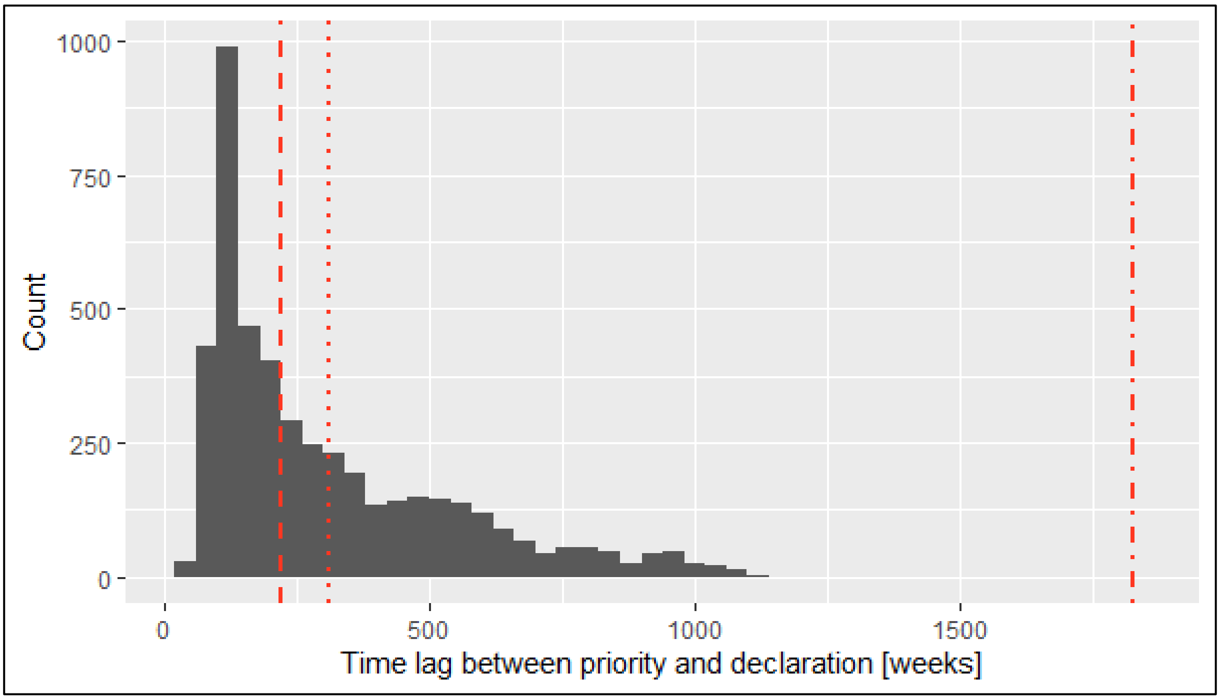

Figure 8-1: Histogram of declaration lags in the sample; for patents declared by vendors (median/mean/maximum indicated by red lines)

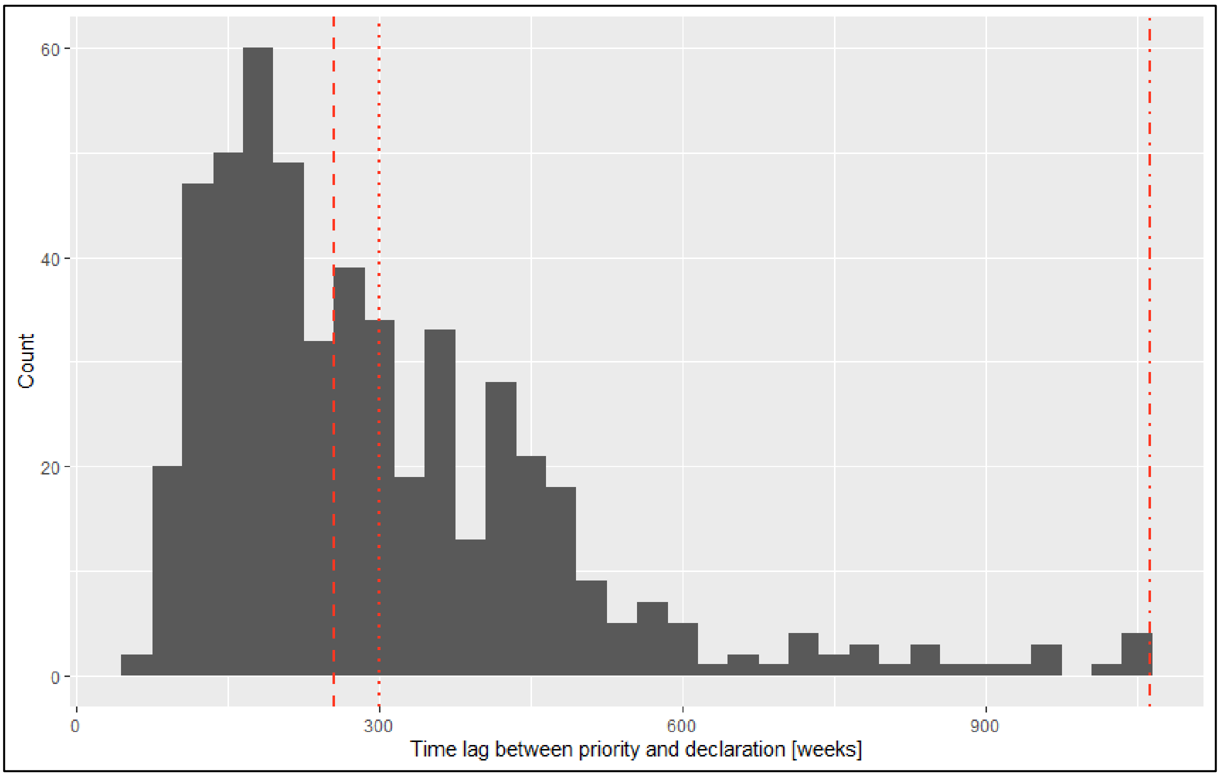

Figure 8-2: Histogram of declaration lags in the sample; for patents declared by operators (median/mean/maximum indicated by red lines)

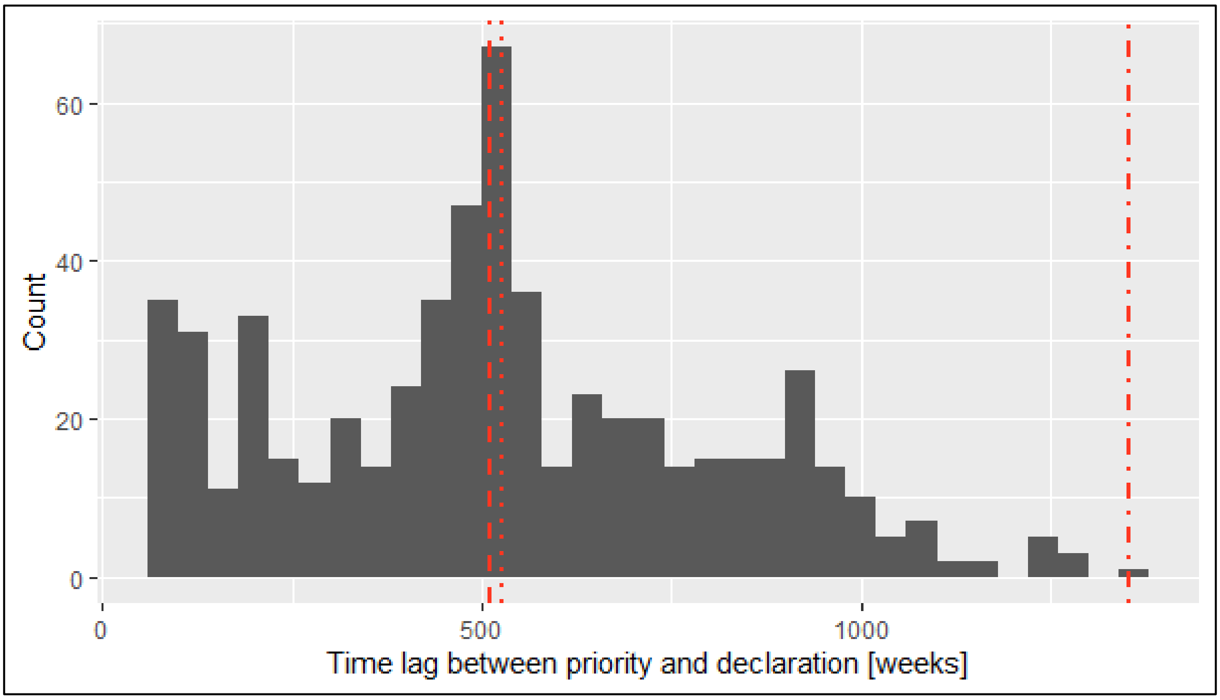

Figure 8-3: Histogram of declaration lags in the sample; for patents declared by NPEs (median/mean/maximum indicated by red lines)

Table 8-1: Original regressions 6 and 7, in comparison to regressions 6 and 7 with winsorized ("wins") dependent variables

	Dependent variable: **Declaration lag in weeks [log]**			
	(6)	**(6-wins)**	**(7)**	**(7-wins)**
Degree centrality (cons)	3.149	3.110	4.688***	4.587***
	(2.012)	(1.979)	(1.666)	(1.639)
Closeness centrality (cons)	-0.812*	-0.805*	-1.170**	-1.162**
	(0.441)	(0.430)	(0.567)	(0.553)
Eigenvector centrality (cons)	0.230	0.355	-2.311	-2.227
	(2.516)	(2.439)	(2.106)	(2.060)
Number consortia memberships	-0.026	-0.025	-0.021	-0.020
	(0.028)	(0.028)	(0.016)	(0.015)
Number consortia memberships 1	-0.340**	-0.342**		
	(0.155)	(0.151)		
Number consortia memberships 2	0.106	0.101		
	(0.069)	(0.067)		
Number consortia memberships 3	0.016	0.011		

	(0.063)	(0.061)		
Number consortia memberships 4	-0.077	-0.077		
	(0.073)	(0.072)		
Number consortia memberships 5	-0.068	-0.064		
	(0.080)	(0.078)		
Number consortia memberships 6	0.043	0.046		
	(0.130)	(0.128)		
Vendor (Dummy)	-1.885**	-1.805**	-2.519***	-2.451***
	(0.815)	(0.810)	(0.458)	(0.450)
NPE (Dummy)	0.614***	0.597**	0.538**	0.516**
	(0.236)	(0.232)	(0.246)	(0.240)
Operator (Dummy)	1.053***	1.032***	-0.386	-0.383
	(0.314)	(0.307)	(0.283)	(0.279)
Number of declarations per firm (log)	-0.050	-0.048	-0.028	-0.026
	(0.048)	(0.048)	(0.044)	(0.044)
Nokia (Dummy)	0.144	0.133	0.442***	0.424***
	(0.211)	(0.207)	(0.118)	(0.114)
LG (Dummy)	0.364	0.334	0.009	-0.002
	(0.541)	(0.533)	(0.144)	(0.142)
Samsung (Dummy)	0.705	0.629	0.619***	0.567***
	(0.461)	(0.448)	(0.127)	(0.124)
Huawei (Dummy)	-1.231	-1.163	-0.908***	-0.884***
	(0.789)	(0.769)	(0.122)	(0.120)
Qualcomm (Dummy)	-0.042	-0.065	0.072	0.056
	(0.554)	(0.547)	(0.105)	(0.104)
UMTS patent	0.798***	0.738***	0.861***	0.799***
	(0.216)	(0.204)	(0.211)	(0.200)
LTE/LTE-A patent	0.114	0.114	0.144	0.145
	(0.079)	(0.077)	(0.098)	(0.096)
5G patent	-0.101	-0.089	-0.102	-0.090
	(0.165)	(0.157)	(0.164)	(0.156)
IoT patent	-0.201	-0.190	-0.226	-0.215
	(0.195)	(0.191)	(0.186)	(0.182)

Degree centrality (3GPP)	0.087	0.058	0.817	0.789
	(0.794)	(0.773)	(1.025)	(1.006)
Closeness centrality (3GPP)	-0.768	-0.704	-1.236	-1.180
	(0.888)	(0.863)	(1.156)	(1.127)
Eigenvector centrality (3GPP)	1.231	1.236	0.157	0.153
	(0.835)	(0.814)	(0.621)	(0.613)
Number consortia memberships * Vendor (Dummy)	0.045**	0.042*	0.048***	0.046***
	(0.022)	(0.022)	(0.009)	(0.009)
Number consortia memberships * NPE (Dummy)	-0.019	-0.020	-0.044**	-0.042*
	(0.047)	(0.046)	(0.022)	(0.022)
Number consortia memberships * Operator (Dummy)	-0.018	-0.018	0.013	0.012
	(0.013)	(0.012)	(0.010)	(0.010)
Constant	5.815***	5.786***	5.774***	5.753***
	(0.351)	(0.350)	(0.286)	(0.282)

Note: *p**p***p<0.01

*p**p***p<0.01

9 Appendix D: Contribution to Chapter 3

Working Paper (accepted for publication) "Industry consortia in mobile telecommunications standards setting: Purpose, organisation and diversity"

For this article, I, Lisa Katharina Teubner, collected the data, and built the data set. Furthermore, I was responsible for data analysis. Most parts of the article were drafted by me, with suggestions from my co-authors regarding theoretical framing and content. The text was then improved and adapted in an iterative and cooperative process.

Signature Lisa Katharina Teubner

I, Joachim Henkel, agree with the above.

Signature Joachim Henkel

5.11.20

I, Rudi Bekkers, agree with the above.

Signature Rudi Bekkers

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