Towards understanding open-coopetition – Lessons from the automotive industry

Short Paper

Abstract

Products are often co-developed in networks that embed multiple organizations. Paradoxically, such product development networks can tie rival and competing firms that cooperate with each other in an open-source way. The management of such modus operandi, where firms give up some intellectual property rights granted by law and work with competitors in an open-source way, can be very challenging as it can lead to commoditization, free-riding, and unintended spillover effects. Building upon extant knowledge in coopetition, open-source software, product development, and innovation, we conducted an exploratory case study aimed at understanding open-coopetition (i.e., cooperation among competitors in an open-source way) in the automotive industry. To do so, we leveraged publicly available naturally occurring digital data and qualitative interviews pertaining to four coopetitive open-source projects. Out preliminary results highlight the increasing complexity of the software that powers modern cars and consequent convergence of the automotive industry with the software industry.

Keywords: Coopetition, Open-Source Software, Open-Coopetition, Open-Innovation, Competitive Dynamics, Inter Organizational Networks, Automotive Industry

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Introduction

Many see products as artifacts developed by a single firm. Plenty of evidence shows however that products are often co-developed in networks (see Dyer and Singh, 1998; Lavie, 2006; Lundbäck and Karlsson, 2005). Paradoxically, such product development networks can link rival and competing firms that cooperate with each other in an open-source way. For, instance it is well known that Apple and Google cooperated with each other in the development of open-source web browsing technologies while giving up their intellectual property rights (Teixeira and Lin, 2014). Managing such open and coopetitive modus operandi, where firms give-up intellectual property rights[1], is challenging as value can erode via commoditization, free-riding and unintended spillover effects (Gnyawali and Park, 2011; Hattori and Yoshikawa, 2016; Teixeira et al., 2015).

Theoretical background

Our study builds upon cross-disciplinary studies in coopetition, open-source software, product development, and innovation. While the coopetition and product development literature partially explain why firms engage in coopetitive dynamics (Bengtsson and Kock, 2000; Quintana-García and Benavides-Velasco, 2004; Wu, 2014), open-source and innovation studies partially explain why firms freely reveal their intellectual property rights (Ulhøi, 2004; von Hippel and von Krogh, 2003; West and Gallagher, 2006). However, extant knowledge in open-source software and innovation often ignores competition (i.e., often assuming the phenomena as cooperative in nature). On the other hand, extant knowledge in coopetition and product development often emphasizes the importance of control, gate-keeping, and intellectual property rights (in sharp contrast with the values and norms of open-source software). Research explaining coopetition in an

[1]Here we must highlight that by stating ”giving up their intellectual property rights” we do not mean giving up all their intellectual property rights. Actually, many firms release the produced software under a copyleft license to protect continued openness (see de Laat, 2005, for a overview of copyleft copyright mechanisms).

open-source way (aka open-coopetition) remains scarce but gathers cross-disciplinary interest (Germonprez et al., 2013; Nguyen-Duc et al., 2019; Teixeira et al., 2015).

It is important to notice that research in coopetition (i.e., addressing both cooperative and competitive behavior) in the automotive industry has been previously studied at joint-ventures (e.g., Akpinar and Vincze, 2016; Nadin, 2009) however coopetition in an open-source way (i.e., in the open-source arena while purposively giving up some intellectual property rights granted by law) remains a largely unexplored research area. Research on open-source software ecosystems exhibiting competition was so far limited to the Information and Communications Technology (ICT) industry (see Nguyen-Duc et al., 2019; Teixeira and Lin, 2014; Teixeira et al., 2015, among a few others). Along with the same lines, research explicitly addressing open innovation between competitors is only recently taking off (Roth et al., 2020; Roy et al., 2018).

It is worth remarking then that investigating coopetition in an open-source way (aka open-coopetition) opens two theoretical issues. First, coopetition literature (e.g., Bengtsson and Kock, 2000; Quintana-García and Benavides-Velasco, 2004; Wu, 2014) fails to explain the transparency, inclusiveness and intellectual property regime of industrial open-source software ecosystems. And, second, it adds a competitive dimension to research on open-source software that so far focuses mostly on the cooperative dimension of the phenomenon (Nguyen-Duc et al., 2019; Teixeira et al., 2015). These two theoretical issues call then for the empirical research on open-coopetition, this would enhance our understanding of both coopetition and open-source software phenomena.

Empirical background

In contrast with prior research that explored the coopetitive development of complex open-source software technologies in the ICT industry (e.g., Nguyen-Duc et al., 2019; Teixeira et al., 2015), this study points the lenses to the automotive industry. Therefore approached a wide range of organizations that are involved in the design, development, manufacturing, marketing, and selling of motor vehicles. In recent decades, safety in the automotive industry become particularly important and therefore the market is highly regulated. Traditionally, the industry organizes its production around the supply chain model. At the top of the chain, Original equipment manufacturers (OEMs) have been cutting costs by relocating to the lower-cost locations. Cost reductions are also procured across the entire supply chain where Tier 1, Tier 2 and Tier 3 suppliers can struggle to deliver their parts with squeezed profit margins. During the last years, the automotive industry has slowed down in the developing countries. Emergent markets such as Brazil, India, China, Indonesia, Iran and Russia become very important. However, considerable investments make by auto-makers in Iran and Russia were recent written off due to sanctions by USA and EU. By 2023, China was the world largest producing country followed by USA and Japan. When it comes to exports, however, Germany is the largest exporter followed by Japan and USA[2]. When it comes to sales, the largest manufacturers are Toyota, the Volkswagen Group and Stellantis[3]. It is very common for automobile manufacturers to hold stakes in other automobile manufacturers and many joint ventures exist, predominately with a 50-50% stake. Furthermore, it is also common for automobile manufacturers to own stakes in their suppliers. The reach of the OEM automobile manufacturer across the supply chain is so wide that many are now directly sourcing raw materials from mines to expand the production of electric vehicles.

For many decades, there were very very few entrants to the industry. Among many barriers to entry, we can point out: (1) the extremely high amount of capital that is required to start the manufacturing process, (2) the multiple and extensive safety regulations that cars need to meet to enter the different geographic markets, (3) the brand loyalty value hold by the reigning players, (4) the economies of scale achieved by established players, (5) access to distribution channels, and (6) the pools of intellectual property that can be used by incumbents in legal retaliation to new entrants. Still, there were significant recent entries in the market. One of them is Tesla which was founded in 2003 and got an impressive number of 500,000 orders in advance for its Model 3 in 2017. It is also well known that tech giants such as Apple, Google, and Uber are also developing advanced automotive technology that ranges from integrated phone-car multimedia systems to autonomous/self-driving technology. In the last decade, the Chinese market (the largest in the

[2]Please note that European, Japanese and Korean firms account for much of USA car exports.
[3]Stellantis resulted from the merger of Italian-American Fiat Chrysler Automobiles and French PSA Group in 2021.

world since 2008) also allowed new entrants to achieve significant market share (e.g., Venucia, Green Field Motor, Qoros, Zotye). However, this is something unseen in other regions of the globe where protectionism seems to be on the rise.

Methodology

This research was conducted as part of a larger research project funded to investigate *"Open-coopetition as an R&D Management Strategy"* by a Nordic European foundation promoting research and education in the field of business administration. To depart from previous research that investigated open-coopetition in the co-production of very complex technologies that ranged from cloud computing infrastructures to virtualization and containerization platforms that involve very complex inter-organizational network dependencies (e.g., Nguyen-Duc et al., 2019; Teixeira et al., 2015), we opted to investigate open-coopetition in the automobile industry - an industry that is more familiar to a more general audience.

Given that open-coopetition remains a largely unexplored phenomenon that so far devoted few scholarly attention, we opted for conducting a conducted an exploratory case study with multiple units of analysis (see Yin, 2011) aimed at understanding open-coopetition (i.e., cooperation among competitors in an open-source way) in the automotive industry. More specifically, the research question *Why are auto-makers cooperating with competitors in the co-production of open-source automotive software?* guided our exploration. While much research explains why firms engage with open-source communities (e.g., Grand et al., 2004; Lerner and Tirole, 2002; von Hippel and von Krogh, 2003) little is know on why to do it with competitors. On the other hand, extant theory on coopetition (e.g., Bengtsson and Kock, 2000; Quintana-García and Benavides-Velasco, 2004; Wu, 2014) developed in the fields of economics and industrial marketing often contradicts with what is observed in open-source communities (Teixeira et al., 2015) - this might not be surprising as coopetition research was grounded from the more traditional steel, milk, and manufacturing industries.

Prior research on open-coopetition was so far limited to the ICT products and services, but as cars become increasingly reliant on software (Charette, 2009) it is interesting to extend prior research in open-coopetition to more traditional industries such as the automotive industry. Our efforts combined the use of archival data, interviews, and member checking. In the first stage, we collected publicly-available and naturally-occurring archival data derived from multiple open-source projects in the automotive domain. As multiple projects exist[4], we sampled our investigation to more specific projects developing In-Vehicle Infotainment (IVI) and autonomous car technologies (also known as self-driving technologies) so we could benefit from triangulating results across different projects in a similar domain.

The collected publicly-available and naturally-occurring archival, related to the sampled projects, is not a consequence of our own actions as researchers but are created and maintained by the open-source community in their own pursuits of developing and promoting open-source automotive software. We took into account many methodological notes in case study research that legitimate the use of archival data when analyzing a case (Eisenhardt, 1989; Yin, 2011) while reducing the Hawthorne observer effect (i.e., when subjects change their behavior in response to their knowing that they are being studied) (Monahan and Fisher, 2010). At a second stage, we compiled the preliminary results that emerged from archival data, and approached practitioners in the industry for interviews. Each interview had the dual goal of (1) collecting additional qualitative data, but also (2) testing e preliminary results via member checking (Thomas, 2017). Practicioners of the automotive industry were given then the possibility to informally challenge and correct our early interpretations.

Our study leverages naturally occurring digital trace data (see Shah et al., 2015) pertaining four coopetitive open-source projects in the automotive domain: 1) The GENIVI Alliance developing an In-Vehicle Infotainment (IVI) systems that powers cars sold by BMW, GM, and PSA Peugeot Citroen among others; 2) The Automotive Grade Linux (AGL) collaborative project also developing IVI systems that powers cars sold by Toyota Ford, Mazda, Mitsubishi Motors, and Subaru among others; 3) The Apollo Open Platform (AOP) autonomous car platform led by companies such as Baidu, FAW Group, Chery, Volkswagen, General Motors,

[4]See https://en.wikipedia.org/wiki/Open_coopetition for a sample of cases where automotive firms cooperate with competitors in an open-source way.

Hyundai and Daimler AG among others[5]; and 4) The TierIV autonomous car platform led by Yamaha, Toyota, NEC, Denso, Panasonic, and Toshiba among others[6]. All projects where auto-makers cooperate with direct competitors to develop software-intensive technologies in an open-source way.

We started by 'digesting' many websites officially related to the four sampled projects. The selection of the initial sources (i.e., departure points) took into consideration key guidelines on how to conduct qualitative empirical research online (Kozinets, 2009). From the initial sources, we followed many links to collect further information related to the projects — we grasped many blogs maintained by organizations and individuals that recurrently contribute to the projects as well as videos broadcasted at relevant events (e.g., Embedded Linux Conference & OpenIOT Summit, Automotive Linux Summit, FOSDEM, Consumer Electronics Show, Apollo meetup, North American International Auto Show, and the GENIVI All Member Meeting and Open Community Day among other events). Data was collected in the textual, audio and video format and it was meticulously organized within a database for later analysis (Yin, 1994, pp 94-98). Audio and video were transcribed to text semi-automatically using machine learning and speech recognition software systems. We saw, listen and read multiple times the collected qualitative material and extracted then the relevant quotations that related to our guiding "Why" type of research question. Compared to the widely used interview or questionnaire data collection methods, the use of naturally occurring data merits by being 1) fast and affordable, 2) semi-automated while leveraging advances on computational social science (see Lazer et al., 2009), and 3) reducing the Hawthorne effect (see Monahan and Fisher, 2010).

At the latest stage of our research, we conducted interviewees with two practitioners working for two automakers in Germany and Japan to comment both our description of the empirical background and preliminary results. They found our work interesting and relevant, they were given an oportunity to challenge our preliminary results, and we reduced then possible misinterpretations of the collected natural occurring data. Even if practitioners often cited many matters as confidential and often could not speak freely on firm startegy matters, the first interviews enhanced the validity of our preliminary results, gave us additional qualitative data in the form of interview transcriptions and helped us in gaining access to conduct more interviews in the future. For the end of 2023, we plan to conduct many more intereviews with practioners exposed to coopetition and open-source software in the auto industry to further report aditional findings from our research project.

Results

Even if our work is at a preliminary stage, some of our results are already significant towards understanding *Why are auto-makers cooperating with competitors in the co-production of open-source automotive software?* — the research question that guided our efforts.

The websites from leading Tier 1 automotive technology suppliers such as Bosch[7] and Renesas[8] provide evidence on the large extend in which open-source software integrated within modern automobiles. Such evidence points out that modern cars are powered by hundreds and even thousands of open-source software projects. This information on 'what specific open-source software components are integrated into each supplier offering' is disclosed due to the 'attribution' characteristic of most open-source software licenses. Any interested individual or company can use, study, modify and distribute the software for any purpose as far as they acknowledge the original open-source software project.

Rather than 'purchasing licenses' for hundreds or thousands of software components, key players in the automotive industry can just acknowledge, or in certain cases open their derivative works as well. This contrasts with traditional software business arrangements that often involve the processes of purchasing, licensing, negotiating and contracting. In this sense, integrators of open-source software (downstream from the open-source community) in the automobile industry are saving monetary costs as well as time — they jump over the overheads costs related to sourcing software in the traditional way that can involve long negotiations, formulation of legal contracts, and stipulation of diverse intellectual property arrangements (e.g.,

[5]Mostly automotive firms with large operations in China.
[6]Mostly automotive firms with large operations in Japan.
[7]See http://oss.bosch-cm.com/.
[8]See https://www.renesas.com/en-eu/products/synergy/

patents and copyrights issues, distribution and end-user licensing agreements as well as non-disclosure agreements).

To a more limited extent, some of the open-source software integrated by firms in the automotive business is distributed under the less permissive copyleft software distribution licenses such as GPL[9]. Such licenses legally force the integrators to a certain open-source software to open modified versions of the original work (i.e., licenses use copyrights law to ensure that open-source software will remain open in derivative works down the line). Therefore, some players in the industry become themselves contributors to the open-source community by sharing their modifications (often improvements) of certain open-source software. To sum up, such observed large-scale integration of open-source software makes sense for saving costs and time. Moreover, by taking what already exists and it's "freely" available in the open-source domain, there is a reduction of duplication efforts in the industry (i.e., it is harder for a traditional software house to sell something that is already ready and established under open-source terms). Here is important to notice, that we are not only talking about the production costs but also about maintenance costs as fixing bugs and fixing security vulnerabilities are not only from the interest of one firm but from the overall community.

Evidencing other interesting findings, the following quotation pertaining the development of AGL evidences our proposition that open-source software in the automotive industry is motivated not only about monetary cost savings but also about reuse, time, pace, speed, method, standardization and platform thinking.

> "Everyone knows the car manufacturers are very cost sensitive. They always worry about costs. The cost of every bolt in the car is measured and the cost of everything is what matters. So people, when they often talk to me about AGL, they say 'wow its about free software and saving money'. That is actually the farthest thing from the truth. When I talk with the car manufacturers it is about rapid innovation. So on average, using the old methodology of developing an infotainment system in the dashboard, using the old methodology which is the hundred years old supply chain, where an automotive manufacturer gives basically an RFQ, an RFP[10], he gives a complete requirements document to the supplier and says: 'give me some black box including software that does these things'. Unfortunately that model, which have been going on forever, on average takes thirty nine months to produce an infotainment system from scratch" ... "the old model of giving someone a requirements document and getting a black box and having no software reuse, that model has to end today. So, the goal is: let's build one single infotainment platform, one single telematics platform, one single ..." Dan Cauchy — Automotive Grade Linux (AGL)[11]

More disruptive than IVI technologies, the autonomous car technologies (the ones that power self-driving cars), have potential to reconfigure the overall industry — many argue that incumbents not embracing autonomous car technologies will only be able to do well for a few years to come[12]. In such conditions of product market uncertainty, coopetition theory suggests that organization will enter into cooperation to the share costs and risks in the development of new and complex technologies (Bengtsson and Kock, 2000; Gnyawali and Park, 2011; Quintana-García and Benavides-Velasco, 2004).

Across the four cases, participants recognize that the practical benefits of working in an open-source way (see von Hippel and von Krogh, 2003) can speed the development of new products. We also notice the high inclusiveness of the studied projects. Focal firms often cooperate with other firms (often competing ones). Also with universities in joint research and education activities. The most impressive investment in open-source technology is the one from Chinese search engine Baidu with the AOP, it created a fund of 10 billion yuan (1.52 billion USD) to further develop its technology jointly with other firms while reserving a big share for startups and education in universities[13]. Such inclusiveness fits well with the spirit of open-source and open-innovation, where openness allows contributions from enthusiasts, students, hackers, and academics

[9] See https://www.gnu.org/licenses/gpl-3.0.en.html for more details.
[10] Stands for request for quotation (RFQ) and request for proposal (RFP).
[11] See https://www.youtube.com/watch?v=U1v1Jt6Cgf0&t=1557s [1:56-2:53] and [4:50-5:01] for the original source.
[12] See https://www.youtube.com/watch?v=4rHvm2iPNwI for a documentary entitled "Autonomous Driving, The Revolution" where journalists, key staff from Nissan and industry analysists discuss how autonomous car technologies will change the industry.
[13] Mostly Machine Learning, Artificial Intelligence, Simulation and Computer Vision courses.

among others (see Roy and Chesbrough, 2018; Ulhøi, 2004; von Hippel and von Krogh, 2003; West and Gallagher, 2006).

High tech giants such as Google and Apple do not hide their investments in both IVI technologies and autonomous car technologies. While open-source is already integrated in the product platforms of the mobile telecommunications industry (e.g., Android and iOS) and TV industry for many years (e.g., Samsung Tizen) for many years, the auto industry is only now integrating open-source software into product platforms. As software becomes increasingly important, auto-makers fear the convergence with the software industry. Apple and Google were very successful at disrupting other industries, should auto-makers be worried? The following quote suggests that yes.

> ”in thirty-nine months, three or four of this came out“ [presenter takes a modern mobile phone from the pocket and shows it to the audience] ”iPhone or Android, and the consumer spent a thousand bucks or two thousand dollars for an infotainment system in a high-end vehicle. It is crazy! and these systems do not do nearly ten percent of what these phones do. There is really not app functionality there, there is no app store, it’s really lacking !! there is no over-the-air version upgrade“ … ”it is really lacking, so the automotive guys, they know this. And some of them are concerned and that is why they are backing this concept of AGL: to have one single platform, to change the way software is produced to cars, be more like this“ [presenter points to his modern phone once again] ” so that you can have a new system every four months, or a new upgrade every six months if you already have a car with an AGL system“ Dan Cauchy — Automotive Grade Linux (AGL)[14]

Discussion

The collected data confirms the increasing size and the complexity of the software that powers modern cars. As earlier pointed out by Charette (2009), modern cars operate around 100 million lines of software code[15]. In line with Broy (2006) and Grimm (2003), software in cars is only going to grow in both amount and complexity. Moreover, the development software development contributes to 13 to 15 percent of the cost of a modern premium car (Charette, 2009). If the relevance of software development for modern cars was previously highlighted by scholars, we pinpoint that much of such software is actually open-source. The collected evidence shows that a single car integrates hundreds to thousands of open-source software projects.

From a more theoretical perspective, the collected quantitative data suggest that auto-makers cooperate with competitors to share costs and risks in the development of new and complex technologies in conditions of product market uncertainty (as suggested by prior literature in coopetition and product development (Bengtsson and Kock, 2000; Gnyawali and Park, 2011; Quintana-García and Benavides-Velasco, 2004). Further, auto-makers give up and open some of their intellectual property to leverage the existing pool of open-source technologies so that they can legally integrate the commons pool into their own products (see West and Gallagher, 2006). Some believe that some of the practical benefits of working in an open-source way (see von Hippel and von Krogh, 2003) can speed the development of new products (e.g., autonomous cars). In addition, auto-makers also seek third party contributions from enthusiasts, students, hackers and academics among others (as reported before in cases of open-source and innovation studies Stewart and Gosain, 2006; Ulhøi, 2004; von Hippel and von Krogh, 2003; West and Gallagher, 2006) — no one should need a permit to innovate on top of their product platforms.

Above all, auto-makers fear the convergence with the software industry. In an era where cars are 1) increasingly powered by software in general and open-source software in particular, 2) connect to other mobile products such as smart-phones and tablets, and 3) integrate with a number of digital services (e.g., navigation, assistance, and entertainment), new entrants in the automobile industry, especially software-savvy organizations such as Apple and Google, can challenge the established players. After all, and in an analogy

[14] See https://www.youtube.com/watch?v=U1v1Jt6Cgfo&t=1557s [2:53-3:60] for the original source.

[15] For a comparative perspective, those are more lines of software code than the ones in recent operating systems (Microsoft Windows or the Linux kernel) or the avionics of modern airplanes (F-35 Joint Strike Fighter, Boeing’s new 787 Dreamliner or Airbus’s A380)

with the mobile telecommunications industry, Apple and Google displaced the former leaders of the mobile telecommunications industry (Motorola, Ericsson, Nokia, and RIM among others).

Future research

Our research remains at a preliminary stage. So far we relied mostly on naturally occurring data such as press releases, strategy announcements and video broadcasts from presentations at open-source summits and industry trade shows. In one direction, we will further expand our qualitative data collection efforts by interviewing practitioners in the industry. We will attempt to collect interview data both from the auto-makers as well as from different suppliers across the supply chain (i.e., Tier 1, Tier 2 and Tier 3).On the meanwhile, as we are studying software production on an open-source way, we will leverage knowledge on the Mining of Software Repositories and Social Network Analysis to make sense of digital trace data produced by the project. Here both actions (i.e., qualitative and mining of software repositories with social network analysis) can inform each other in a mix-methods research design (Carillo et al., 2017).

In one hand we will continue engaging qualitatively with practitioners (e.g., software developers, project and line managers), while on the other hand, we will attempt to make sense of the digital traces left behind by them - after all, such digital trances allow us to capture and analyze past behavior pertaining software development, coordination and communication (Hedman et al., 2013; Howison et al., 2012). We will follow the classical work from von Hippel and von Krogh (2003) on how to explore organizational issues from data produced by the open-source communities (e.g., source code repositories and bug-fixing data). Recent developments in this arena include: (1) the availability of new tools that allow us to retrieve and model co-editing networks from large source code repositories (Gote et al., 2021),(2) also new compressive tool-sets for capturing data from issue tracking systems, mailing lists, and code review systems supporting the development of open-source software projects (Gonzalez-Barahona et al., 2015) and (3) advancements on multilayer network analysis (Battiston et al., 2018; Kivela et al., 2014) that allow us to threat open-coopetition as a multi-level phenomena where individuals, firms and product platforms engage in both cooperative and competitive relationships.

Conclusion

We conclude by highlighting industrial convergence as an antecedent of open and coopetitive behaviors. Auto-makers turn to each other and cooperate in an open-source way as they fear that new and software-savvy entrants such as Tesla, Google, and Apple among other software-intensive firms that do not hide their reliance on open-source technology. By opening and developing technology in an open-source way, they leverage existing resources under the open-source domain and source potential incremental innovations from third parties. Overall, auto-makers must advance their software-related competencies to remain competitive. Partnering with direct competitors in an open source way is a novel phenomenon in the industry, but it already stretches out to most of the American, European and Asian players in the automotive industry.

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