ZOOOM

Innovation ecosystem report

Project ZOOOM - 3Os and IP Awareness raising for collaborative ecosystems

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List of Abbreviations

Acronym	Explanation
3Os	Free and open source software, open hardware and open data
B2B	Business to business
B2C	Business to consumer
BE	Business Ecosystem
DSSC	Data Space Support Centre
IE	Innovation Ecosystem
IP	Intellectual property
OD	Open Data
ODE	Open Data Ecosystem
OH	Open Hardware
OS, or OSS, or FOSS	Free/Open Source Software
OSSECO	Open source software ecosystem
OSSN	Open Source Service Network
PA	Public Administration
RTL	Register-Transfer Level
SECO	Software ecosystem
SME	Small and medium enterprise
VN	Value network
ZOOOM	'3Os and IP awareness raising for collaborative ecosystems' (ZOOOM) Project, Grant Agreement No. 101007385

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Executive Summary

The ZOOOM Project has as its primary objective to raise awareness about the emerging and increasing importance to generate and manage intellectual property within collaborative innovation and business ecosystems, with a particular emphasis on free and open-source software, open hardware, and open data (referred to as the 3Os).

This deliverable D2.3 “Innovation ecosystem report” aims to assist key stakeholders within the different layers of the 3Os innovation ecosystem to understand and align their strategy and business model with the complexity characterising each ecosystem. To achieve this, the deliverable takes advantage of the adopted case-oriented approach and literature review applied and implemented respectively in the D2.1 “Literature review of business cases in 3Os” and D2.2 “Case study report”.

In order to enable the key stakeholders of this project to navigate the complexity of applying innovation as a business strategy and model, we open the discussion by clarifying the differences among the types of ecosystems recognised in the business literature. Clarifying the distinctions among various types of ecosystems in the business literature is not merely an academic exercise; it is a practical necessity for those seeking to employ innovation as a strategic tool. By understanding the unique characteristics, players, strategies, and interactions within different ecosystem types, stakeholders can make informed decisions, forge effective partnerships, and navigate the complexities of the modern business landscape. This initial step is foundational for the ZOOOM Project in its pursuit of aligning business models with the dynamics of open-source innovation ecosystems, providing a solid footing for the subsequent stages of the project.

The central elements of the different types of ecosystems and their evolution, i.e., leadership and alignment of incentives and values for the value proposition implementation, are discussed more in detail in relation to the legal perspective in order to underline how some licensing terms affect the dynamics, incentives and value creation processes within the different ecosystems.

The discussion is complemented with two sources of evidence aimed at enriching this understanding with context-specific and case studies-based insights. Together, the case studies review and the interviews allow the ZOOOM Project to map out roles, strategies, and players within the 3Os innovation ecosystems more comprehensively.

Findings result in a holistic view that encompasses both the theoretical underpinnings and the practical realities of ecosystem dynamics.

By exploiting the main findings, the report concludes indeed by proposing a multilevel ecosystem framework for the 3Os, where different players are identified and connected in the different types of ecosystems both innovation based and business focused. Additionally, key players within the 3Os innovation ecosystem create feedback effects that sustain the vitality of other interconnected ecosystems.

1. Introduction

In the last few decades, social science and management studies have recognised that interfirm networks can enable firms to achieve much more than they could achieve individually (Chesbrough, 2003). By crossing the firm's boundaries and applying a systematic approach to innovation strategy, companies are not any more members of a single industry, but are rather part of an ecosystem that crosses a variety of industries and communities (Moore, 1993; Rothschild, 1990). In analogy with the biological concept of ecosystems, the economic system is here understood as an entity in which organisations and consumers are living organisms. Here, economic and non-economic actors work both cooperatively and competitively to develop new products, services, satisfy customer needs, and eventually incorporate the next round of innovations. A company's innovation strategy is indeed the result of the company's coevolving capabilities and competencies in relation to the evolving environment around a shared value proposition (Jacobides et al., 2018).

Ecosystems have been approached with different concepts (Gulati et al., 2012). Broadly speaking, they are defined as *networks* or *structures* that dynamically evolve through the interaction between various actors (Weber & Hine, 2015; Wallner & Menrad, 2011). However, "ecosystem" is a quite diffuse concept that takes different meanings in different research fields.

As innovations are seldom created in isolation and as companies face challenges to obtain required capabilities to create novel innovations, the paradigm of *open innovation* becomes more relevant (Chesbrough 2003; Xie & Wang, 2020). Open innovation emphasises companies' abilities to use external partners and innovations as a part of their internal innovation policy. This is in contrast to the traditional vertical mode where the organisation's R&D activities lead to an internally developed product (West & Gallagher, 2006). In order to harness various stakeholders to contribute to the creation of external innovations, *open innovation ecosystems* are formed. In these ecosystems, interconnected partners share their knowledge and capabilities with each other following openness principles. Differently from general innovation ecosystems, in open innovation ecosystems openness principles, such as transparency, inclusivity, and sharing of intellectual property, are fundamental in ruling the ecosystem relations. These principles ensure that knowledge and resources flow freely among participants. Previous studies have shown that organisations performing the R&D activities within a network of actors, may create unique synergies and access novel resources otherwise not available. This is relevant especially for start-up's and small companies with limited resources. The ability or performance of an innovation ecosystem is related to the focal firm's external relationships with other players in the ecosystem, like suppliers, complementary firms, customers and competitors (Song 2016).

Key questions that are often raised in the literature on ecosystems include: How to develop mutually beneficial ecosystems, rather than "winner takes all" marketplaces or technology platforms, whose dominant players set the terms of coordination, collaboration, and competition (see Valkokari 2015)? What are the effects of different strategies related to the 3Os on the innovation capability of the heterogeneous set of socio-economic actors? Why do some inter-organizational collaborations happen in ecosystems rather than in other forms, such as supply chains or alliances? What kinds of collaboration and coordination behaviours are we likely to observe within ecosystems (see Jacobides et al. 2018)? If firms gain from others participating in an ecosystem, but cannot fully control them, what does that imply for how they attain advantage? How does the value of resources and capabilities differ depending on the role firms take within the ecosystem (hub vs. participants) (see Jacobides et al. 2018)?

In this report, we shall analyse the ecosystem trend in the context of the 3Os. In particular, we consider: a) Business-related motivations for engaging or not in an ecosystem; examples can be different facets of strategic management, fear of losing competitive advantage/aim to gain competitive advantage, and lack/presence of community-building capabilities; b) The potential role that a company can play in an ecosystem; c) The challenges of being involved in ecosystems (competition vs. cooperation). Such aspects will be framed in terms of the peculiarities of the 3Os. The discussion will be based on two sources of evidence aimed at gaining better understanding of impacts of innovation strategies at ecosystemic level: first, a literature review; and second, interviews conducted by the ZOOOM partners. Finally, by exploiting the main findings resulting from the two sources of evidence, we implemented a multilevel ecosystem framework for the 3Os.

2. The ecosystems trend in the 3Os

In terms of historical developments, Gomes et al. (2018) argued that the innovation ecosystem concept has partly come as a reaction to the value capture and competitive focus that was prevalent in the pre-existing business ecosystem literature, and that the innovation ecosystem concept puts more emphasis on value creation and collaboration. Similarly, the shift from the concept of business ecosystems to innovation ecosystems is framed in terms of a change in focus from *competition* to *collaboration* (Granstrand & Holgersson 2020). For instance, Dell'Era et al. (2020) describe how important firms have leveraged openness to achieve strategic and commercial aims. In open innovation, value capture mechanisms depend on four key assets: reputational assets, organisational assets, intellectual and human assets, and technological assets.

So, there are many potential benefits of joining an ecosystem, such as basing one's work on the experience of others (expertise sharing). This is true for any kind of ecosystemic interactions between businesses, but is especially important when it comes to companies' engagement in the 3Os. As Kelsey Hightower, technologist at Google and open-source advocate, said: "Open source is about collaborating; not competing".[1]

However, Moore (1993) put equal focus on collaboration and competition:

> In a business ecosystem, companies co-evolve capabilities around a new innovation: they work cooperatively and competitively to support new products, satisfy customer needs, and eventually incorporate the next round of innovations (p. 76).

Joining an ecosystem with overlapping communities and customers can, in fact, have a negative impact on short-term profits and generate new types of challenges. According to Jacobides et al. (2018), the very things that make it easy to capture value within an ecosystem make it harder to recruit and retain members. Indeed, ecosystems compete for members, which may decide to shift to another ecosystem if the conditions no longer favour them.

Ecosystems, in the open-source world, thus involve a complex nexus of competitive and collaborative factors. This is well enucleated by Rikki Endsley, Senior open source community marketing at AWS:[1]

[1] https://www.rocket.chat/blog/open-source-quotes

> I didn't intend to stay in tech when I got into it, but the people are what really kept me here. In this career, you get to continue working with the same people in different ways. In open source, you get to work with your competitors. I have friendly relationships with people who work at companies that are our technical competitors, and that's normal. That's the way this industry is supposed to work.

2.1. Types of ecosystems

Present-day ecosystems are global and cross the boundaries of firms, value chains, and nations. Therefore, setting an ecosystem's boundaries can be difficult. However, the definition of boundaries is crucial for making sense of ecosystems, mapping their evolution, the cooperation and competition challenges, and the effectiveness of the companies' strategies (Gulati et al. 2012; Korhonen & Snäkin 2005; Post et al. 2007). In the realm of management literature, there is a highlighted emphasis on the necessity of categorising the type of ecosystem one aims to investigate, especially when delving into the intricacies and developmental trajectory of these complex systems. Based on Valkokari (2015) and Jacobides et al. (2016), we outline below four types of ecosystem concepts to describe the meta-organisations between economic actors: Business, Knowledge, Innovation, and Platform Ecosystems.

Business Ecosystems

In the realm of Business Ecosystems, the primary focus of analysis centres on individual companies and how the focal firm adapts its network of connections to efficiently and effectively deliver its value proposition. This approach highlights the economic outcomes and the interwoven business relationships among various stakeholders, particularly the direct economic benefits experienced by ecosystem participants. The field of strategic management places significant emphasis on business ecosystems as potential sources of competitive advantage for individual companies (Adner 2012; Iansiti & Levien 2004). Moore (1996) provides a definition for a business ecosystem as "an economic community upheld by a network of interacting organisations and individuals – the fundamental components of the business world." Milinkovich (2008) views a business ecosystem as a consortium of companies and other entities that collaboratively generate and capture value by pooling their resources. Typically, these entities revolve around a central, prominent company or are closely tied to a specific platform.

For example, the mobile ecosystems centred around dominant market players such as Apple, Samsung, and Nokia, and the ensuing competition among them, serve as a widely recognized illustration of business ecosystems (also see Jacobides et al. 2018). Otto et al. (2019) present a concept of data ecosystem and describe it as follows: "*A Data Ecosystem is characterized by diverse relationships in a network of multiple actors such as organizations, companies, individuals or technical components e.g. machines or software. The actors of the ecosystem engage in data sharing to contribute in pursuing common goals and value propositions."* . Even if the authors emphasise that data ecosystems are drivers for innovation, the data ecosystem is presented as a specific type of a business ecosystem, in which all participants form common value propositions based on data thanks to the mediating and orchestrating role of some of the leading players of the ecosystem. With regard to the emerging technologies, the blockchain technology is already mature to be applied and widely adopted e.g. for supply chain management. In this field, mainly business ecosystems are formed, where focal firms define standard and procedures, and open ecosystems around open sourced protocols are still scarce (Gonczol et al. 2020)

Knowledge Ecosystems

Focus on the creation of new knowledge through joint research work, collaboration, or the development of a knowledge base. In other words, the main focus is *exploration* rather than *exploitation*. Indeed, exploitation activities include things such as refinement, choice, production, efficiency, selection, implementation, and execution. Exploitation refers therefore to developing incremental innovations based on old certainties. Conversely, exploration activities include search, variation, risk-taking, experimentation, play, flexibility, discovery, and innovation. It refers to looking for new possibilities and innovation is mainly radical. In this type of ecosystem, knowledge sharing and knowledge creation are central activities. Open-source communities are a well-known example of this ecosystem type based on knowledge exchange (Koening 2012).

Innovation Ecosystems

The primary focus is on promoting interactions that can empower the innovative performance of an individual or a group of participants engaged in the ecosystem (Granstrand & Holgersson, 2020). Another vital element involves nurturing innovative startups geared towards technological advancements within designated regional hubs or clusters (Engel & del Palacio 2011; Yu & Jackson 2011). An example of a successful regional cluster nurturing startups is the Odense Robotics cluster in Denmark that has become a world-leading ecosystem for robotics companies. Important factors contributing to the growth of the Odense ecosystem are: 1) seed and venture structure to bridge the gap between start-ups and investors, 2) a facilitator taking care of targeted measures to create a shared vision and offering ecosystem access to potential newcomers, and 3) collaboration of the industry with the local university (Charisi et al. 2021). Similarly, in the field of quantum computing ecosystems are emerging to speed up innovations, since wide collaboration is required to overcome the high barrier to entry. At this point, a combination of capital, experience in experimental and theoretical quantum physics and deep knowledge is required, and thus players need to find the right balance between collaboration and competition (McKinsey & Company 2021).

The Innovation ecosystems serve as a pivotal bridge connecting the exploration of novel knowledge and its exploitation for collaborative value creation within business ecosystems. Therefore, key players in innovation ecosystems encompass innovation policymakers, local intermediators, innovation enablers, and financial supporters (such as venture capitalists or public funding agencies) (Valkokari 2015). In the context of innovation ecosystems, intermediators hold a crucial position by linking diverse participants, facilitating interactions, and fostering mutual dependencies among them (Burt 2004). In simpler terms, intermediators themselves establish a platform within innovation ecosystems (Valkokari 2015). Silicon Valley frequently serves as a notable example. Hence, within the innovation ecosystem, the financial network supporting the participants, including companies, research institutes, and other technology developers, has recently been identified as one of the pivotal drivers of success (Claryssen et al. 2014).

Valkokari (2015) summarises in the table below the differences between the three types above in terms of their outcomes, interactions, actor roles, and logic of action.

	Business Ecosystems	Innovation Ecosystems	Knowledge Ecosystems
Baseline of Ecosystem	Resource exploitation for customer value	Co-creation of innovation	Knowledge exploration
Relationships and Connectivity	Global business relationships both competitive and co-operative	Geographically clustered actors, different levels of collaboration and openness	Decentralized and disturbed knowledge nodes, synergies through knowledge exchange
Actors and Roles	Suppliers, customers, and focal companies as a core, other actors more loosely involved	Innovation policymakers, local intermediators, innovation brokers, and funding organizations	Research institutes, innovators, and technology entrepreneurs serve as knowledge nodes
Logic of Action	A main actor that operates as a platform sharing resources, assets, and benefits or aggregates other actors together in the networked business operations	Geographically proximate actors interacting around hubs facilitated by intermediating actors	A large number of actors that are grouped around knowledge exchange or a central non-proprietary resource for the benefit of all actors

Table 1: Peculiarities of business, innovation, and knowledge ecosystems. From Valkokari (2015).

Platform Ecosystems

The central theme revolves around how entities organise themselves in relation to a platform. In this context, the ecosystem encompasses not only the platform's creator but also all the providers of complementary offerings that enhance the platform's value for consumers. This platform ecosystem adopts a "hub and spoke" configuration, characterised by numerous peripheral firms linked to the core platform through shared or open-source technologies and technical standards. In the case of IT-related platforms, these standards may take the form of programming interfaces or software development kits. When these complementors connect to the platform, they not only contribute to complementary innovations but also gain direct or indirect access to the platform's customer base (Jacobides et al. 2018). Within a platform ecosystem, a fundamental element of a product acts as an intermediary, facilitating interactions among a wide array of other components or complements and potential end users. A classic example is Nintendo, where the gaming console serves as the stable core that mediates the relationship between various components, complements, and end users, including controllers, games, screens, and so forth.

It should be noted that different types of ecosystems can overlap with one another, depending on the specific market or technological areas involved, so it is not always feasible or profitable to draw clear-cut distinctions. To narrow down the discussion, this report will mostly focus on two facets of ecosystems: a) Company-level considerations (business ecosystems); b) Innovation processes that are generated by open-source developments (innovation ecosystems).

It is also important to stress that, in the management and organisational literature, ecosystems need to be distinguished from the following entities:

- *Open-Source Service Networks:* an archetype business model that aims to overcome exchange problems in the coordination between firms (Feller et al. 2008).
- *Value Networks:* entities of several connected individuals/organisational actors that transform and transfer various complementary resources and capabilities (Morgan et al. 2013).
- *Business Networks:* The variety of actors is the major difference between a business network and an ecosystem. Ecosystems typically include more actors than a network (Heikkilä & Kuivaniemi 2012). A business ecosystem is composed of several layers, which correspond to differing levels of commitment to the business: the ecosystem's core business layer consists of the parties forming the heart of the business, such as the business network actors such as suppliers, a focal firm, distributors, and customers (Moore 1993).
- *Open Source Communities:* Either loosely organised, ad-hoc communities or formally structured communities of contributors who share an interest in meeting a common need, ranging from minor projects to huge developments, which they carry out using a collaborative development environment. The concept represents one of the most successful examples of high-performance collaboration and community-building on the Internet (Soriano et al. 2008). In many cases, ecosystems relating to the 3Os involve also one or more OS communities, but the two things should be conceptually separated.

2.2. Key characteristics of ecosystems

Before analysing business and innovation ecosystems relating to the 3Os, it is worth considering some general features of ecosystems in all their forms. Jacobides et al. (2018) put forth a theory of ecosystems, positing them as a distinct solution to the challenge of coordinating activities among different firms, separate from traditional methods such as alliances, supply chains, or market-based interactions. Their theory delves into several crucial facets of ecosystems, including modularity, coordination, complementarity, standardisation, and co-specialization.

- *Modularity:* Ecosystems serve as a means to effectively coordinate a network of interconnected organisations, each with substantial autonomy. This coordination is made possible by employing a modular architecture, where distinct components of the ecosystem represent individual organisations, separated by discrete stages of the production process. Technological modularity permits these interdependent components to be designed, produced, and priced by various actors with minimal coordination requirements, as long as they adhere to predetermined and agreed-upon interfaces.
- *Coordination:* To be valuable, ecosystems must address the need for coordination that exceeds what markets can provide, yet does not necessitate a central authority. Ecosystems offer processes and rules for resolving coordination challenges, fostering alignment through established rules of engagement, standards, and codified interfaces.
- *Complementarity*: Ecosystems stand out by providing a framework where various forms of complementarities in production and consumption can be managed and coordinated without the need for vertical integration. The emphasis lies in maximising benefits by engaging or participating in a group of firms with complementary roles or designing the most effective ecosystem structure, which varies depending on the perspective considered. In ecosystems, prices and qualities are not fixed but left to vary and be chosen based on the preferences of end users. Often, the goal is to collaborate with other firms to secure a larger customer base.
- *Standardisation*: Within an ecosystem, interdependencies tend to be standardised within each role, requiring new skills in ecosystem design. Consequently, the relationships between sets of actors may vary, some being unique, others supermodular, generic, or specific. However, these relations can be described at the role or group level rather than the individual dyadic level. While the interactions among ecosystem members may resemble webs of alliances, they are standardised and tailored for each role within the ecosystem.
- *Co-specialisation:* In terms of mutual dependencies among ecosystem actors, rather than being confined to individual sets of relationships, participants can tap into a broader range of options. For unique dependencies, this approach enables the creation of dedicated partnerships capable of fulfilling specific requirements and supplying or procuring necessary resources.

The literature also draws parallels between business ecosystems and concepts from the life sciences (Valkokari 2015):

- *Interbreeding*: Ecosystem actors demonstrate their ability to generate novel outcomes by amalgamating artefacts, skills, and ideas. These diverse business, knowledge, and innovation outcomes serve as distinguishing factors among ecosystems.
- *Competition and Cooperation*: Ecosystems inevitably foster both competition and cooperation, mirroring the natural processes of species selection and adaptation. Although man-made ecosystems have often been portrayed as positive and collaborative systems, akin to their biological counterparts, they too exhibit a blend of competition and cooperation within the realms of business, knowledge, and innovation ecosystems.
- *Symbiosis and Reciprocity*: The interactions and interdependencies within man-made ecosystems are multifaceted, aligning with system-level objectives that draw ecosystem actors closer together. Much like biological ecosystems, these entities coexist, collaborate, and evolve through intricate symbiotic and reciprocal relationships, collectively forming a larger ecosystem. Thus, the dependencies among ecosystem participants significantly influence outcomes, success, and the mobilisation of resources within the ecosystem (see also Adner & Kapoor, 2010).
- *Organisation*: Ecosystems are not entirely self-organised entities; rather, they represent organisational designs held together by the shared purpose and operational modes agreed upon by their members, whether through formal or informal means .

2.3. Regulation of Ecosystemic Interactions

As we saw in the business ecosystem description, one of the most important elements seems to be leadership and alignment of incentives and values for the value proposition implementation (Jacobides et al., 2016). These elements are central in mapping the evolution of ecosystems as well (Moore, 1993). Some ecosystems accept indeed any participant who agrees to a minimal set of rules, whereas elsewhere membership is strictly controlled, whether by committee or by the hub — if there is one. Rules pertaining to hierarchy or membership may change over time, as with Facebook (Claussen et al., 2013). It is important to understand how membership rules vary, what drives this variation (and its competitive impact), and how this relates to standards (open vs. closed; proprietary or sector-wide), modularity, and the nature of complementarities.

Feller et al. (2008) conducted an investigation into the social aspects, rather than the legal ones, that underlie the success of Open Source Service Networks (OSSNs) - a prevalent business model designed to address coordination challenges among firms. Their analysis revealed that, in order to efficiently deliver a comprehensive solution ("whole product") to customers, OSSNs must facilitate member firms' access to and exchange of critical strategic resources, including skills, competencies, experiences, knowledge, and customer contacts.

In traditional business networks, legal contracts are employed to coordinate and protect exchanges, enabling the acquisition of strategic resources. However, these contractual arrangements, along with the legal recourse available in case of breaches, entail significant overheads in terms of implementation and lack the necessary flexibility.

In contrast, OSSNs place a central emphasis on macroculture, which encompasses shared assumptions and values guiding actions and shaping typical behaviour patterns. Similarly, when member firms deviate from shared norms, values, and objectives, the application of collective sanctions becomes a potent tool for coordinating and safeguarding exchanges. At the network design level, controlled access and reputation are also utilised to ensure that only those least likely to disrupt network operations, whether due to incompetence or misbehaviour, are allowed to participate. This approach streamlines the coordination and protection of exchanges. Limiting network membership for strategic purposes aids in coordinating exchanges, not only by reducing network size (enhancing interaction visibility) but also by simplifying collaboration among members through the reduction of variability in participant types.

If we look at the regulation of ecosystemic interaction from a legal perspective, the choice of the licensing terms sets strict rules for the activities that take place within the ecosystem, and hugely affects the dynamics, incentives and value creation within the ecosystem. Licensing of open assets – irrespective whether software, hardware or data – has two central aspects, the inbound licensing from the FOSS community to an organisation and the outbound licensing from the organisation to the community. Inbound licensing has been addressed in the ZOOOM interviews and ZOOOM Case study report with the user-aspect. Outbound licensing has been addressed in the ZOOOM interviews and ZOOOM Case study report with the maker or contributor -aspect. The former (inbound licensing) emphasises licence compliance and the latter (outbound licensing) licence strategy, as on the contributor side there are more strategic decisions that can be taken.

The dynamics of the FOSS licensing is based especially on reciprocity, as shown in ZOOOM D1.1. Non-reciprocal licences are permissive licences that allow the derivative works to remain proprietary, e.g., MIT, BSD and Apache 2.0. Reciprocal licences require the derivative work to be licensed under the same terms as the original work and distribution of binaries requires the availability of the source code. Strong copyleft licences, such as GPL, place conditions on all derivative work and all compiled binaries, whereas weak copyleft places such conditions only to individual files within a project, not to other files. This allows for instance the use of a library that is licensed under a copyleft licence in proprietary programs, an example of such being LGPL or MPL.

The choices to be made on reciprocity – between non-reciprocal and reciprocal, and additionally between strong or weak copyleft – have direct effect on those ecosystem members that use the open asset. In other words, the strategic decisions made by the maker/contributor sets restrictions on those ecosystem members that use the open asset, setting them requirements for licence compliance. Therefore, the choice on the licence terms affects the balance in the ecosystem.

A maker/contributor company may wish to allow a wide use without reciprocity by choosing a non-reciprocal licence. This approach might be useful for instance in cases of an innovation ecosystem, aiming for wide applicability and aiming towards more future oriented goals. Or alternatively, a maker/contributor company may want to use reciprocity as wide as possible by choosing a strong copyleft licence, causing further code to be free or open in the same manner as the original work. This kind of an approach could be useful for instance if a company aims for building jointly with a community a strong multi-purpose platform, and the business income of the company comes from other sources than the platform itself. It should be noted, that depending on the case, choosing a reciprocal licence may affect the whole ecosystem, or it may be one part of the ecosystem that is affected. These partial effects can be observed in the most apparent way in the weak copyleft licences, in which the effects of reciprocity are limited to individual files, making it clear what part of the business of the other ecosystem members are affected and what part can be left for proprietary business. Such an approach could be useful for instance in cases where a company has a strong position in its business ecosystem for its own business but wishes to boost it with indirect effects through the additional offerings of the other ecosystem members.

During the lifetime of the ecosystem, a company may choose, from time to time, to make strategic decisions on balancing how much direct business it wishes to generate and how much it strives for in-direct effects. For instance, in case a maker/contributor company decides to shift the licence base from GPL to LGPL, it also allows proprietary software to be created by the ecosystem members.

Example of the regulation of ecosystemic interactions – Case OpenHW Group

OpenHW Group is a global organisation that focuses on providing an infrastructure for open-source hardware development. OpenHW Group operates as a non-profit consortium where hardware and software designers collaborate on the development of open-source cores, related intellectual property, tools, and software. The organisation hosts several project communities that publish collaboratively developed software and hardware openly in the public domain. The organisation facilitates the intricate dynamics, governance mechanisms, and licensing choices that shape collaborative ecosystems.

One fundamental aspect of OpenHW Group's ecosystem is the management of membership and contributor rules. OpenHW Group adopts an inclusive approach to ecosystem management with a broad range of participants. The group achieves this by facilitating various working groups, which further comprise several task groups focused on specific aspects like cores development, verification, software tools, and hardware platforms. This approach allows OpenHW Group to strike a functioning balance of openness while still ensuring that contributors align with the group's values and core objectives.

OpenHW Group's licensing practices also play a pivotal role in shaping the dynamics, incentives, and value creation within the ecosystem. With a strong emphasis on open source principles, the group encourages the use of reciprocal licences, such as the GNU General Public License (GPL), promoting a culture of reciprocity and collaboration among members. However, some non-reciprocal licences (e.g., MIT, BSD, Apache 2.0, Solderpad v2.1) are also utilised in the ecosystem. This flexibility accommodates a diverse array of business models and strategic objectives.

OpenHW Group's flexibility in licensing allows for strategic adjustments over time. Companies participating in the ecosystem can fine-tune their licensing choices, reflecting shifts in their business goals at each time. For instance, transitioning from the GNU General Public License to the GNU Lesser General Public License demonstrates a willingness to allow proprietary software while still fostering collaboration. OpenHW Group exemplifies how the regulation of ecosystemic interactions through licensing can be a useful tool in striking a balance between open collaboration and business objectives.

3. ZOOOM data collection and results

The ZOOOM partners conducted a literature review based on various methodologies (see Deliverable 2.1). First, we conducted bibliometric and topic modelling analyses based on the Scopus database. Second, we manually categorised the dataset into the three types of open knowledge and the four technologies on which the ZOOOM project focuses: open software, open data, open hardware, AI, Blockchain, Quantum & Internet of Trust, and Robotics. Finally, we selected a number of papers and book chapters from the literature and analysed them thoroughly in order to extract information about case studies, best practices, main licensing strategies, and main business models, as well as major insights about ecosystems and value creation/capture aspects.

Based on the bibliometric literature review, “Ecosystems” is among the top 10 most relevant terms in the dataset, with a significant increase after 2014. Likewise, “Communities” is a central topic, too: 8.87% (68 items) of the dataset is organised around it.

3.1 Free/Open Source Software Ecosystems

Dahlander and Magnusson (2008) identified three primary approaches through which firms harness the potential of communities, as evidenced in case studies of companies like Mysql, Cendio, Roxen, and SOT.

- *Accessing Communities to Expand Resources*: Firms often tap into communities to broaden their resource base. They do so by embracing what the communities develop and investing effort in integrating this work with components developed internally. This adaptive approach allows firms to benefit from community-driven innovations without significantly altering the direction of community development. Cendio is a company, analysed by the authors, which took this approach.
- *Aligning Firm Strategies with Communities*: Some firms seek to influence community development by incentivizing individuals to collaborate with the community. These incentives enhance both the community's and the firm's reputation and provide the firm with a degree of control over the direction of community efforts. This strategic alignment effort involves allocating resources to manage both the firm and the community effectively. MySQL is a case of a

company that needed to build a sufficiently large community and engage actively with the community to create a virtuous development cycle.

- *Assimilating Communities for Integration and Knowledge Sharing*: Certain firms find it necessary to cultivate a substantial community to foster a virtuous development cycle. However, building and sustaining communities is a complex endeavour. Establishing a community is only the first step, as attracting and retaining members requires sustained interest and engagement. Two case firms encountered challenges in motivating community participants over time, primarily related to providing meaningful tasks and maintaining activity. Both Roxen and SOT founded a community but then had issues with attracting new members; SOT tried to influence community developments by offering incentives to individuals to work with the community, to enhance both its and the firm's reputation, and give the firm more scope for controlling the direction of community developments.

Morgan et al. (2013) present a set of propositions and constructs for modelling the value creation and capture processes within Open Source Software (OSS) networks. OSS offers businesses value by granting them access to the wealth of knowledge and innovation capabilities residing within Value Networks (VNs). These VNs consist of interconnected individuals and organisational actors that transform and share various complementary resources and capabilities. VNs facilitate open, transparent interactions among all members, a departure from the transaction-centric focus found in traditional inter-organizational relationships.

In the realm of OSS, many firms opt for a conventional approach, concentrating on bilateral agreements within high-density networks comprising familiar partners. However, it's worth noting that participants in these high-density OSS VNs often share close relationships, fostering personal connections and choosing this traditional networking method for collaboration with a select few partners. Simultaneously, firms also engage in low-density VNs, continually seeking new connections and relationships to enhance their innovation potential. Knowledge emerges as a critically important resource that organisations aim to leverage within these networks.

Sample indicators for value creation, as proposed by Morgan et al. (2013), include:

- Firms perceiving benefits from reduced development and maintenance costs.
- Firms recognizing improved visibility, leading to the acquisition of new customers.

- Firms acknowledging the advantages of accessing external expertise.
- Firms identifying enhancements in their software development processes.

Franco-Bedoya et al. (2017) evaluate the current state of the art in OSS ecosystems (OSSECOs) research and analyse the unique characteristics of this type of ecosystem. In their literature review, they found three common elements across ecosystem definitions: a community of actors, a set of relationships and an environment. For an OSSECO, the community of actors includes collections of products, projects, software solutions and businesses; the environment refers to shared market and technological platforms.

The authors identified the following explicit differences between OSSECOs and the other SECO types:

- The software development process in OSSECOs is decentralised and collaborative. This also allows co-evolution of the OSSECO community with its associated project.
- Project contributions and collaboration: In OSSECOs, the role of contributors in the OSS community is essential; the OSS community is therefore a key stone actor in the ecosystem. The number of active contributors can be seen as an indicator of the health and quality of an OSSECO.
- Governance: In OSSECOs, decisions about the software and its direction are made by the community of contributors, or in some cases by a benevolent dictator, rather than by a specific company.
- Co-* concepts: OSSECOs offer new capabilities for creation, innovation and development, compared to proprietary SECOs. Co-* concepts include, for example, co-evolving, co-operation, co-development and co-creation between different entities.

Based on their combination of various ecosystem definitions and analysis of the characteristics of OSSECOs, the authors conclude with definition of an OSSECO: A software ecosystem (SECO) placed in a heterogeneous environment, whose boundary is a set of niche players and whose keystone player is an OSS community around a set of projects in an open-common platform.

Burström et al (2022) define a software ecosystem (SECO) as a set of direct stakeholders and indirectly linked stakeholders, who together create value for customers and end-users with software products and services that have some level of relationship to each other. The ecosystem serves a market through the exchange of information, resources, and artefacts.

Teixeira et al. (2015) listed driving forces for firms to cooperate with the competitors (coopetition):

- Heterogeneity of resources, as each competitor holds unique resources that are best utilised in combination with other competitors' resources
- Shorter product life cycles, convergence of multiple technologies and increasing R&D and capital expenditures
- Rapidly changing consumer preferences
- Speed and magnitude of technological changes
- Need to speed up innovation efforts
- Aim at setting up standards and platforms

According to Haim Faridian & Neubaum (2021) firms need to simultaneously develop value capturing and value creating capabilities in a dynamic environment, making ambidexterity (i.e. the simultaneous pursuit of exploration and exploitation) the superior mode. Ambidexterity can be facilitated through exploration- and exploitation-oriented network ties that improve asset positions. The asset positions are central to developing intrapreneurial capabilities, such as innovation development, commercialization and licensing. The authors present open source ecosystems as an example, where networks of actors, such as free agent developers, affiliated agents, established organisations and new ventures, contribute to the development of nonproprietary innovations in the software industry. Even if the strategic objectives behind establishing network ties may vary between exploration-oriented and exploitation-oriented actors in the ecosystem, sharing of knowledge and innovations with network members enable firms to leverage the assets of others. For example, new ventures can benefit from voluntary efforts within the ecosystem to improve quality of the code and as a result, decreased overall development costs. On the other hand, the established actors can be exposed to new approaches and radical code modules in the ecosystem with new ventures, which improve code novelty. Effective use of these inter-organisational relationships supports all types of firms in pursuing ambidexterity.

Further, Haim Faridian and Neubaum (2021) provide insights on how firms can manage the intellectual property rights of knowledge assets in open networks to facilitate the monetization of innovation in various ways. They claim that actors in open source ecosystems benefit from a variety of licensing agreements, depending on whether they are focused on exploration or exploitation. Transfer of tacit knowledge, which is a central objective in creating exploration-oriented links, requires open interactions. These are better facilitated under lax IP rights. In contrast, exploitation-oriented ties benefit from rigid IP rights, which allow innovators to capture value from their innovations and mitigate the threat of appropriation by imitators. As an example, the authors point out that the success of the 2nd generation open source firms, such as MySQL AB and Trolltech, was due to the dual licensing model.

Linux Foundation publication by H. Chesbrough (2023) sought to measure the perceived value of OSS by individual firms, instead of the societal focus of OSS. A survey targeted CEOs and CTO/CIOs of Fortune 500 companies. The benefits derived from using or contributing to OSS for the respondent's organisation, which 50% or more of the respondents regarded as very high or high, were:

- Cost savings (66.5 %)
- Faster development speed (65.6 %)
- Open standards and interoperability (63.2 %)
- Active community for knowledge exchange (58.93 %)
- Independence from proprietary providers (54.5 %)

According to the survey, the primary costs associated with the use of or contribution to OSS for the respondent's organisation were "*Cost to reduce legal uncertainties regarding licensing*" and "*Switching cost from proprietary to OSS.*". Over 20 % of the respondents had chosen that High or Very high costs were associated with the use of or contribution to OSS related to those categories. Interestingly, *Costs for training* were rated as High or Very high by 18.7 % of the respondents, while 23.0 % rated that No costs were associated with the training.

Community creation was mentioned as one benefit (Very high benefits), but Community building costs were also mentioned to cause very high costs (individual open responses).

3.2 Open Hardware Ecosystems

Open hardware (OH) is still a developing topic, however, according to Hassan et al. (2022), it has the potential to succeed in a similar way as FOSS. The concept of Company-Community Collaboration (known as "C3"), which refers to a radical innovation approach, finds significant impetus in open-source principles. FOSS has played a significant role in the disruption of entire industries, opening up new opportunities for global economic growth (see Heitmann 2012). Organisations have been compelled to seek partnerships and integration with the local entrepreneurial ecosystems that are drastically pushing the boundaries of the organisations due to the linked growing requirement to capture fresh information and ideas (Boutillier et al. 2020). The relationship to copyright law, to name one, is one of the fundamental differences between the operational environments of OH and OSS ecosystems, according to Kauttu (2018). When developing OSS, copyright protection arises automatically upon the creation of the end product, that is the code. As copyright is typically not applied to a three-dimensional utilitarian product, this process typically does not apply to the OH creation (Beldiman 2018; Katz 2012, 2015; Rosen 2005). In terms of OH communities, the majority tend to be made up of teams with fewer than 10 members, and only a very tiny number of open-source product development (OSPD) projects have several dozen or more participants (see Bonvoisin et al. 2018).

In contrast to FOSS, Mellis and Buechley (2012) note that collaboration on (electronic) OH frequently relies on the sharing of "alternative versions" as opposed to collaborating on a single standard version. They make connections between the challenges of working with the same easily accessible parts (and materials), the need for more developed software tools for collaboration, and the costs associated with prototyping; to which the need for standard procedures and open infrastructures, among other things, can be added (see Neves, Mazzilli, 2013).

The engagement of businesses in OH communities is central to C3. Despite certain similarities between the classic open innovation approach and C3 in terms of the permeability of the company's boundaries to permit interchange with product users, they differ greatly on a number of fronts: C3 aspires for a novel strategy where external partnerships with OH communities take place in circular dynamics as opposed to linear value creation as in the case of open innovation. According to this, the focus should shift from "territorialized" firm in-house development to open collaborative development within an OSH community as a platform for collaborative innovation (see Gay, Szostak, 2020).

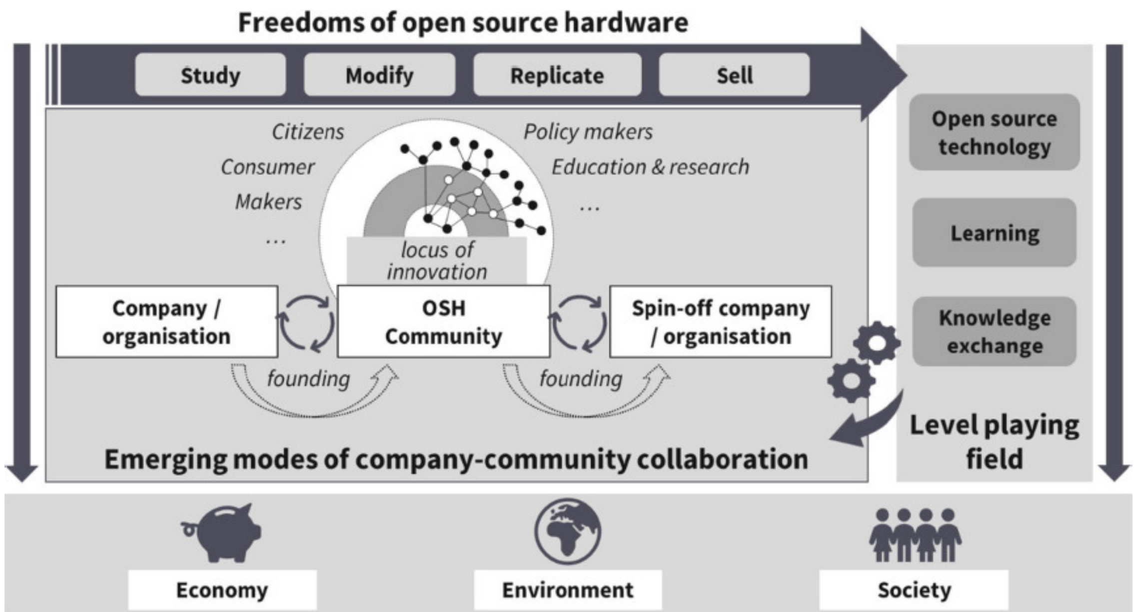

Figure 1: Company-community collaboration transition (Hassan et al., 2022)

According to Hassan et al. (2022), there are two points of departure for C3 to kick off transformational processes toward the converging goals of stakeholders within OH communities: a) Initiating new OSPD initiatives are established companies or entrepreneurs who are seeking progressive methods to the diversification of new products and/or new markets; b) Inspiring new spin-off organisations and businesses with an innate focus on open source-related (business) activities are OSPD projects.

The collaborative and innovative nature of OH communities fosters and draws a variety of enterprises and organisations that support beneficial societal and/or environmental impact (Li et al. 2017). However, the OH community, a socially constituted collection of diverse actors who co-create OH goods, is the source of value co-creation in C3 (Mies et al. 2019). The two emerging C3 modes are shown in Figure 1, and the C3 transition of stakeholder integration as a result of the freedoms of OH and the level playing field they produce is shown.

In contrast to "innovation communities," OH communities' goals are established by what the authors refer to as the "voice of the community" as the driver for innovation. This elicits various socio-ecological-economic dynamics and fosters cultural engineering that promotes consumer and citizen engagement as the key component of value capture (see Powell 2015). Furthermore, while a healthy ecosystem in an atmosphere of open standards is essential, it also offers an IP valuation conundrum, claims Carballo (2005). In order to accept new relevant IP, businesses require filters and techniques to reduce risk in an open environment. This IP may be sown by ecosystem pioneers and other major businesses, but it may also emerge from fresh, innovative, and agile businesses. Additionally, a new IP filter shouldn't be overly strict in an open environment because doing so can prevent network effects from ever bootstrapping. Such a filter should be automatically provided by the open development process (as is the case with Linux) through the decisions of version committees and developers when making derivatives.

On the other hand, switching from design to meta-design presents another chance for an ecosystem of contributors with shared interests to grow and defeat the impulse for divergence, according to Bonvoisin and Boujut (2021). In other words, creating product meta-models enables the creation of several variants rather than just a single product. Meta-design is described by Fischer & Scharff (2000) as "activities, processes, and objectives to develop new media and environments that enable users to act as designers and be creative." Metamodels are described as 'information to produce a range of linked models, a family of designs' by Kyriakou, Nickerson, and Sabnis (2017). They discovered while mining the 3D model sharing website Thingiverse that 3D metamodels are reused more frequently than the 3D models they produce, indicating that metamodels provide a stronger foundation for a community to grow on.

Bonvoisin et al. (2021) have identified two fundamental archetypes that categorise OH projects:

- *Isolated Innovators*: These projects are characterised by a limited willingness to engage in co-design efforts. Typically, they choose to disclose their designs only after reaching an initial stable state. Their primary objective is to emphasise transparency and, to some extent, the potential for replication, though not necessarily accessibility. Consequently, the community surrounding such projects often comprises followers, replicators, or users rather than active developers.
- *Development Communities:* In contrast, development community projects exhibit a strong inclination toward co-design with their surrounding community. These projects tend to adopt an early release policy, making working documents regarding the product and the product development process accessible at an early stage. As a result, the development community usually comprises a core group of dedicated individuals alongside the dynamic, albeit occasionally unstable, participation of community members.

Role	Meaningfulness	Practicality	Critical mass	Deployment	Legal issues
Industry	Contribute more; develop alternative business models	Provide basic tools for free; reduce cost and simplify chip prototyping path	Take a leap of faith and work with the OSH community	Build customizable appliances; make prototype fabrication more accessible	Simplify agreements
Community (academics and hardware enthusiasts)	Develop more components; increase usability; provide design flows	Develop effective design tools; provide free field-programmable gate array (FPGA) farms	Build reusable hardware platforms; build tools to organize emerging critical mass	Develop tools for post-manufacturing test	Create template agreements for various use cases

Table 2: Efforts required to enable an open-source hardware ecosystem (from Gupta et al. 2017).

In their study, Gupta et al. (2017) emphasises the OH problem as a motivator for further involvement from the hardware sector as well as the development community inside the open-source ecosystem. Even though a developer might not use a hardware design right away, it is always possible to reuse and modify RTL (Register-Transfer Level) designs. The interchange of components is greatly facilitated by well-defined interfaces, which increases the value of exchanging hardware designs.

The OH community and its initiatives are anticipated to grow naturally as components, platforms, and open-source development cycles mature, particularly as hardware design techniques become more feasible. More people are likely to become involved in chip design as a result of factors like the expanding maker movement, where users seek to build the products they use, and the appearance of startups like ASIC businesses originating from bitcoin mining OH (see github.com/fpgaminer/Open-SourceFPGA-Bitcoin-Miner). The development of popular consumer hardware products like DJI drones and GoPro cameras may be aided by these initiatives.

Academic institutions can play a key part in this by organising educational programs to draw in more students, such as implementing practical hardware projects at the college freshman level and creating hardware projects to benefit the OH community. Open-source hardware platforms are projected to become more widely used by students, enthusiasts, and startup businesses, which will increase awareness of OH and provide incentives for participation. This process can be sped up by the collective knowledge and experience of the industry.

While there may be some early reluctance, publicly available widely used IP could ultimately help the hardware business, much as the software industry gradually realized the advantages of contributing to OSS. For developers starting new ideas, proven IP from suppliers that may be improved through collaboration with the open-source community and maintained collectively can dramatically lessen entry barriers. In particular, IP licensing may be disrupted, but the industry will probably adapt with creative solutions, much like how the software industry adopted the software-as-a-service model.

Furthermore, similar to how the promotion of Linux helps an entire ecosystem, the promotion of OH can have knock-on consequences that help related enterprises. Basically, enabling innovative designs will result in a variety of options, ultimately helping the hardware sector as a whole (Gupta et al. 2017).

As a different approach, Li and Seering (2019) argue that embracing ecosystems as a core competency plays a pivotal role in shaping a firm's business model and its ability to create value. According to their viewpoint, when an open-source hardware firm integrates its community, customers, suppliers, and partners into a value chain, it effectively spreads risks across all stakeholders. This strategic approach makes the open-source firm more resilient in the face of market fluctuations.

The concept of ecosystems as a core competency is more commonly observed in well-established open-source hardware firms. The open-source nature of their products allows a wide array of stakeholders to align their business activities around the product. By adopting the ecosystem as a core competency, company leaders must systematically design their business model, forging connections among various resources to create positive value loops.

However, one potential challenge is that managing inter-organizational relationships within such ecosystems can become intricate and costly as the firm seeks to optimise each stakeholder's interests. An illustrative example is SeeedStudio19, which not only sells open-source products but also operates an online marketplace for third parties to sell their open-source products. They also offer design services, maker spaces, and complete idea-to-manufacturing services. Additionally, they finance customer projects in the hope of making a profit. A comprehensive network of revenue streams, extending from idea development to production and business operations, is demonstrated by SeeedStudio. Despite seeing strong revenue growth between 2005 and 2015, they have recently faced difficulties with cost management because of the complexity brought on by the involvement of various stakeholders (Li and Seering, 2019).

Ultimately, open-source hardware ecosystems play a vital role in democratising technology, fostering innovation, and enabling collaborative hardware development. They are part of a broader digital ecosystem concept and are gaining attention in the quest for technological sovereignty following the OSS ecosystems in a different way as aforementioned.

3.3 Open Data Ecosystems

Van Loenen et al. (2021) propose a paradigm shift in OD systems, advocating the transition from traditional "one-way street" OD systems to OD ecosystems. These ecosystems not only prioritise data accessibility but also consider the broader context for OD utilisation. The unique value of the ecosystem perspective lies in its emphasis on the intricate relationships and interdependencies between social and technological factors, which significantly influence the effectiveness of OD activities.

Within such ecosystems, data is not a one-time transaction but is rather continually circulated among data providers and users. Intermediaries, acting as bridges between data providers and users, play a vital role in OD ecosystems by creating additional value. OD ecosystems can manifest at various levels, including among data providers, data users, and intermediaries. Furthermore, the scale of OD ecosystems can vary widely, spanning from within institutions, countries, and regions to different disciplines and domains. However, case studies analysed by Van Loenen et al. (2021) reveal that identifying genuine open data ecosystems can be challenging. Many existing ecosystems suffer from imbalances between data supply and demand, exclusion of specific user groups and domains, linearity, and a lack of skills training.

Zuiderwijk-van Eijk et al. (2016) investigated challenges in commercial value creation in open data ecosystems. According to their study, the four main categories that influence value creation by companies in the open data ecosystem are: 1) A lack of specific formulation of how commercial open data value creation can take place, 2) Ill-formulated, complex and ill-structured information about how companies can create commercial value in open data ecosystems, 3) Interdependencies between stakeholders and potential risks of uncertainty in commercial open data value creation, and 4) A lack of criteria for finding solutions and a non-exhaustive set of solutions for commercial open data value creation. The authors suggest policy guidelines to stimulate creation of commercial value.

Kamarioutou and Kitsios (2022) argue that the absence of a well-defined value ecosystem and business models represents a significant barrier to the widespread adoption of available data in services and applications. Developers often struggle to harness data for creating applications due to technical challenges, including complex data formats and interfaces. To address these issues, they present an open data ecosystem business model canvas (Figure 2).

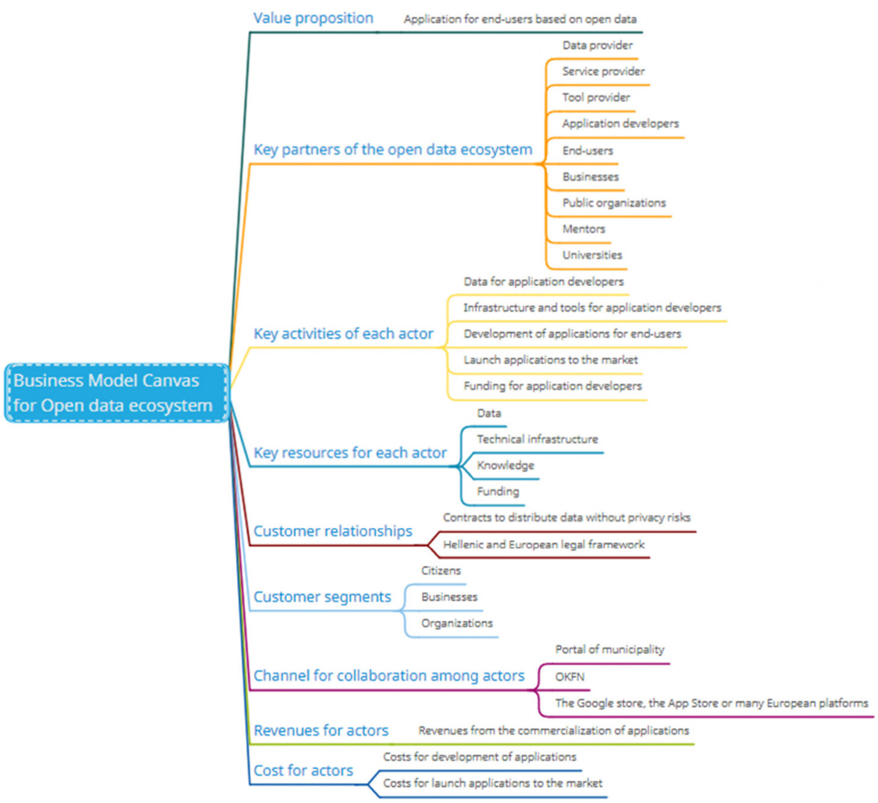

Figure 2: Open data ecosystem business model canvas. From Kamarioutou & Kitsios (2022).

The aforementioned Van Loenen et al. (2021) and Kamarioutou & Kitsios (2022) address <u>open data</u> ecosystems (OD ecosystems) from the perspective of open data. Runeson et al. (2021) broaden the concept of open <u>data ecosystems</u> (ODEs) to cover also other areas of data than mere open data. This means that the open data ecosystems covered by Runeson et al. (2021) covers data from the whole spectrum of openness, from closed to open and everything in between that can be categorised as shared data, see ODI spectrum[2]. From this point of view, the focus turns towards

[2] see Open Data Instute's definition of data spectrum, 'The Data Spectrum' <https://www.theodi.org/about-the-odi/the-data-spectrum/> accessed 26 February 2023

accessibility and partial openness instead of to the strict categories of open data. Data spectrum has been addressed in more detail in ZOOOM D1.1.

One prominent example of ODEs are the data spaces driven by the European Strategy for Data, and initiatives established thereunder. The aim is that the common European data spaces will ensure that more data become available for use in the economy and society, while keeping the companies and individuals who generate the data in control[3]. Data spaces are designed to make it easier for business and other organisations to share and use data across borders (organisational, geographical or industry/domain borders). Participation in common European data spaces is open to all actors that respect EU rules and values and comply with the rules defined in the scope of each EU data space. As a result of the data spaces initiatives, numerous data ecosystems that follow similar design principles are emerging in Europe. More information about the initiatives and related data ecosystems can be found e.g. through the Data Spaces Support Centre (DSSC)[4]. DSSC Glossary describes a data ecosystem as a loosely coupled set of autonomous parties engaging in data sharing. The glossary underlines that data sharing refers to a full spectrum of practices related to sharing of any kind of data, including open data and the many forms of sharing non-open data.

Runeson et al. (2021) derive a conceptual model of ODEs and emphasises that ODEs must be value driven. Runeson et al. (2021) synthesises the conceptual model under four higher level groups of aspects, including altogether nine sub-level themes and visualises their interconnections as follows (*Figure 3*).

[3] A European Strategy for data | Shaping Europe’s digital future (europa.eu)
[4] https://dssc.eu/

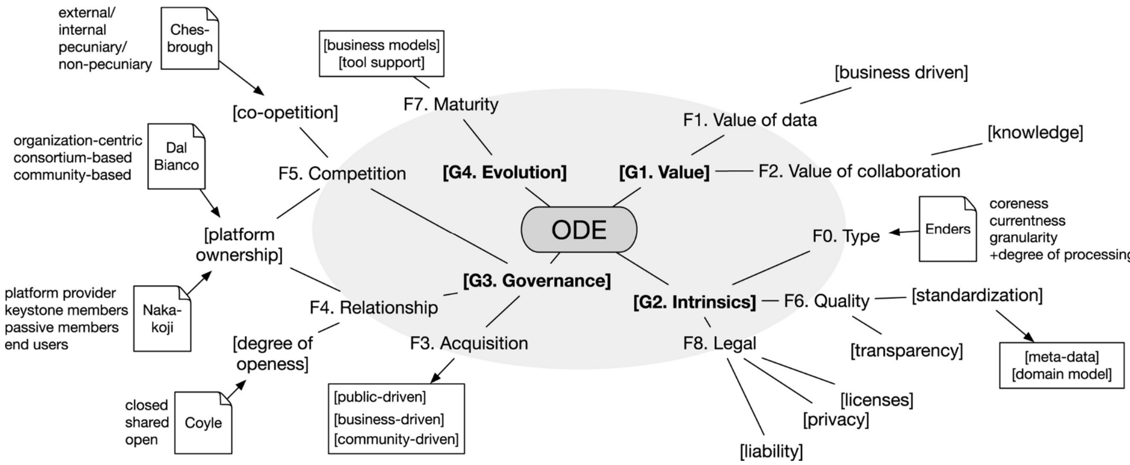

Figure 3: A conceptual model of Open data ecosystems, sub-level themes and their interconnections as visualised by Runeson et al. (2021).

Finally, Runeson et al. (2021) makes the following nine propositions for ODEs:

P1:
ODEs are driven by the value of data or value of collaboration.

P2:
The value of collaboration is impacted by the competition between actors.

P3:
The type of data and its characteristics impacts the degree of openness.

P4:
Standardized meta-data and domain models are core quality attributes for data.

P5:
Legal frameworks must be developed to support ODE evolution.

P6:
There is a need for an independent platform provider to ensure trust in an ODE.

P7:
ODE initiation may be public-driven, business-driven, or community-driven.

P8:
It should be established how to integrate ODEs into an organisation's business model.

P9:
Tools to support ODEs and enable data sharing should be developed and standardised.

The ODE conceptual model generated by Runeson et al. (2021) crystallises the core elements that an ecosystem aiming for data sharing needs. These needs should be compared to the needs of the open source software ecosystems, in case of hybrid ecosystems aiming to cover data sharing and open source software. Such hybrid ecosystems may be found for instance in the area of AI. Comparisons to the needs of open hardware ecosystems are similarly important, in case the hybrid ecosystem contains open hardware.

4. Insights from the ZOOOM Case Studies

The ZOOOM partners conducted in-depth interviews with 25 companies based in the EU area (i.e., Austria, Finland, Italy, Slovenia, and Switzerland), the activities of which involve the 3Os in various forms, with a special focus on AI, Blockchain, Quantum, and Robotics. The selected companies have a track record of delivering innovative products and services that incorporate open technologies.

The sample included companies of various sizes and types, for instance, startups, SMEs, and large enterprises, as well as B2B or B2C, product-based, service-based, and consulting-based businesses. Compared to the other technological areas, Quantum and Robotics are underrepresented due to their relatively minor role in the contemporary business landscape. Other activities pursued by companies include additive manufacturing and cybersecurity.

The ZOOOM partners implemented a shared protocol to harmonise the primary data collection process and avoid inconsistencies. One of the interviews was conducted in writing, while the rest were semi-structured and explorative and lasted about 60 minutes each. Major topics explored in the interviews are:

- A company's approach to IP management related to open software, open hardware, and open data

- A company's perspective on the trade-offs between the opening of its products and using a closed, proprietary strategy
- The relevance of the 3Os in value generation and capture in a company's business
- How IP strategies tend to change in response to changes in business and the lifecycle of a company and, vice versa, how changes in business strategies affect IP management
- Whether the questions above depend on the size of a company and their industry
- Challenges, barriers, and opportunities of adopting the 3Os in relation to firms' characteristics (e.g., company routines, core competence) in contrast to traditional strategies

Here, we shall focus on the ecosystemic perspectives arising from the interview data.[5] A variety of questions explored how open software, hardware, and data generate value in a given industry and the specific ecosystem(s) in which the company is involved. We also investigated how companies have adapted (or plan to adapt) to this fast-changing context. Below is a summary of the questions relating to these topics:

- What open-source software, open hardware, or open data ecosystems/communities are you involved in?
- What is the role of your organisation currently in the ecosystems?
- How did it change over time? e.g., do you think that the boundaries of your company are changing in terms of legal responsibility and innovation strategies?
- What was the initial reason for joining/linking to your ecosystem(s) and community?
- What are the main benefits and challenges for your business relating to collaborations in an "open ecosystem"?
- What steps is your company taking to adapt to this fast-changing environment?

The interviewed companies are mainly aware of being part of ecosystems involving economic and non-economic players, cooperating and competing through both value creation and capture processes. All companies recognized the advantages of being embedded in one or more ecosystems where the creation of new knowledge is

[5] For a comprehensive analysis of the interviews data, see D2.2.

facilitated by joint research work, collaboration, expertise sharing, or the development of a common knowledge base to which communities of developers, too, contribute. Ecosystems growing around the 3Os can be recognized as *knowledge ecosystems,* where knowledge sharing and knowledge creation are central activities. As suggested by Koening (2012), open-source communities are a well-known example of knowledge ecosystems.

However, each company identifies itself into specific roles depending on the strategy, the main business, and the network structures of the company. The Table below summarises the main ecosystemic roles in which the interviewed companies identified themselves.

Roles	**Instances**
System Integrators, Platform Developers, Enablers	7
Focal Firms	2
Innovators	2
Other Types of Networks	2
Distinctive Community Roles	9

Table 3: Summary of the main ecosystemic roles of the companies interviewed by ZOOOM.

In each of the analysed case studies, companies are engaged in activities that resonate with ecosystem models described in the literature, particularly business, innovation, knowledge, and platform ecosystems (see above). Companies involved in these ecosystems are creating environments where participants collaborate, share resources, and collectively innovate. The examples below underscore how ecosystem thinking can drive business success in an interconnected and rapidly evolving world, reinforcing the ideas presented in the literature on ecosystems. The case studies confirm the multi-layered structure of the ecosystems emerging in the 3Os environment (see §5 below).

System Integrators, Platform Developers and Enablers

Various interviewed companies identify themselves as having an integrating or enabling role across various organisations and industries:

- *System integrator for reusing IP (both OSS and OD):* One company defined their role as system integrator for reusing IP across different audiences, in particular Public Administrations (PAs). For them, the ecosystem is seen as a distinctive approach to making business, i.e., as a business model (see Li and Seering 2019). By facilitating the sharing and integration of IP, companies acting as OSS and OD system integrators create a collaborative environment where various stakeholders can contribute and benefit depending on their own strategies and views. The reuse of OSS and OD in multiple PAs demonstrates the value of interoperability and data sharing, which are key features, for instance, in the emerging picture of smart cities. As emphasised by the literature on ecosystems, a well-orchestrated ecosystem can drive innovation through cross-pollination of ideas and resources. Notably, system integrators are not identified as focal firms of these ecosystems. This element invites questions about the evolution of these ecosystems and the opportunities for systems integrators to eventually legitimate themselves as focal firms (Moore 1993).

- *Platform developer for OD:* This role consists of integrating OD for both the PAs and public services companies, such as transport companies. By providing a platform that connects a diversified set of stakeholders, this kind of ecosystemic strategy, adopted by one company in our dataset, fosters a networked environment where data flows seamlessly, enabling better decision-making and efficiency improvements, also providing the basis for future innovations and applications. Ecosystems thrive on relationships between participants and the mutual benefits they gain from interactions for the implementation of their own value propositions. There is not, indeed, a common value proposition at the core of the ecosystem, but there is a platform enabling the implementation and delivery of each value proposition. This evidence aligns with the literature's view that ecosystem models encourage collaboration, resource sharing, and value co-creation.

- *Platform developer and system integrator for OSS:* One firm bases its strategy on the provision of a comprehensive platform of services OSS and the integration of different standards for removing barriers. The strategy also needs to align the platform to the principles of the communities to take advantage of the contribution of different players. The removal of barriers and the alignment of the platform to generally recognized standards allow external players to easily join the ecosystem. This strategy straights ecosystems that are known for their ability to break down value chains, and industries, and enable seamless collaboration. This firm could be identified as the focal firm of emerging ecosystems that did not reach the legitimization phase.

- *Enablers (Technical Solutions Providers):* Four companies enable new ways of doing business by helping other companies to cross the boundaries of their value chains and industries. For instance, one company focuses on enabling a fair data economy in the context of the EU data spaces. Another company creates connections between companies along an additive manufacturing value chain. Such a company sees “openness” as a password for potential partners including researchers: competitors are implementing their technologies in their attempt to be open; other companies can put their IP (closed) on their systems. Finally, two companies are initiators in an environment where not many companies provide similar services (OSS, OD, AI, simulations, modelling, and engineering automation). More generally, the strategy, here, is to see the ecosystem as a tool for reaching the differentiated goal. Ecosystems are known for their ability to bring together players with complementary skills and resources to tackle complex challenges. This strategy highlights how ecosystems can serve as vehicles for addressing broader societal and regulatory goals, a point emphasised in the literature on ecosystems (Appio et al. 2019).

Example of the role of the Enabler – case Datafund

Datafund assumes multiple roles within the ecosystem, positioning themselves as users, contributors and integrators. They provide technical solutions and integrations that facilitate a fair data economy extending into the emerging data spaces. Their mission is to empower individuals to control their data. They achieve this by developing tools that allow individuals to manage, anonymize and also monetize their own data. This approach not only empowers users but also incentivizes contributions to open-source projects, ensuring the availability of a robust infrastructure for data management. They recognize the value of transparency and openness within the decentralised technology industry and actively contribute to open-source projects to increase visibility in the Swarm ecosystem and position themselves as trusted members of the community.

Their commitment to enabling a fair data economy and their active role in data spaces exemplify the transformative power of open-source principles. By empowering individuals to control their data and contributing to the open-source community, this company not only benefits its own business but also fosters collaboration and trust within the evolving landscape of data spaces. As data becomes increasingly critical in the digital age, companies like this play an important role in shaping a more transparent and empowered data ecosystem.

By actively participating in open-source projects, promoting ethical data practices, and fostering collaboration and trust within the ecosystem, Datafund not only contributes to its development but also helps shape its values and future direction. Companies like this help create an environment where data can be managed and utilised in a fair and transparent manner, ultimately benefiting individuals and businesses throughout European data spaces.

Focal firms

Two companies declare to have the role of defining a common value proposition for the players of an OSS business ecosystem. Their strategy is to provide direction, setting standards, and facilitate coordination among ecosystem participants. By acting as a central point of reference for different types of firms, the focal firm establishes a sense of cohesion and shared purpose among the diverse stakeholders.

Example of the role of a Focal Firm – Case Qt Company

One of the case companies (Qt) stated to be the focal firm of an open source software ecosystem. As a provider of software development frameworks and related development tools for desktop embedded and mobile devices, they rely heavily on the open source community for further innovation and developing their core assets. As a focal firm, they use a dual licensing model so that their customers can buy a commercial licence for the products but products are also available with open source licences (several versions of GPL and AGPL). In addition to individual developers, organisations like KDAB, AudioCodes, Intel, Blackberry and Woboq have also joined the development community. Also their customers use the community to check the technical maturity of their products and often the open source community acts as a supporting sales channel for customers who want to check the products in more detail.

The case company (Qt) also provides community management services and organises community events like Qt Contributor Summit. The management of the open source project is handled by the Qt Project, a coalition of companies and individuals. The community describes itself as *a meritocratic, consensus-based community.* The project has consulted the FSF about the licences and their compatibility over time.

There is a fine distinction between innovation and business ecosystem in this approach, but both aspects are clearly visible and both ecosystem types support one another in a symbiotic relationship. A rich and lively innovation ecosystem (=development community) signals the competence of the focal firm to potential customers and acts as a showroom for the customers (=business ecosystem).

Innovation ecosystems

Companies active in OSS apply a strategic approach that combines open-source collaboration, access to universities, and cross-disciplinary interaction to reach high innovation performance. By partnering with universities, the company gains access to emerging talents, leveraging a population of skilled and passionate professionals. This approach not only accelerates innovation but also positions the company at the forefront of the market, unlocking new possibilities and reshaping the industry's trajectory. The collaborative strategy accelerates the development of new materials, shapes, and applications, allowing the company to stay ahead of industry trends.

Other network roles

Two companies can be considered as part of a smaller co-creation network where more than one actor has access to shared assets and open technologies, e.g., libraries or software. In the context of blockchain technology, where both companies work, cooperation and interoperability are crucial, allowing such companies navigate a space with minimal competition and emphasizes mutual benefits.

The use of shared resources is regulated “informally”, rather than by strict legal mechanisms, consistently with the notion of Open-Source Service Network (see Feller et al. 2008). As explained above (§2.3), OSSNs help deliver a comprehensive solution ("whole product") to customers by facilitating member firms' access to and exchange of critical strategic resources, including skills, competencies, experiences, knowledge, and customer contacts. OSSNs are based on a shared macroculture, which encompasses both assumptions and values.

Community roles

Through the interviews, we identified a variety of community roles. Within smaller communities, several companies play the role of contributors to OS libraries and plugins. They actively engage in enhancing and expanding open technologies, sharing valuable resources, code, and solutions. This collaborative contribution benefits not only their organisation but also the wider community that utilises the OSS. Two companies have a Community Leadership and Management role, namely, they established a community around their platform of OSS services and they facilitate all types of interactions within the community. Finally, one company providing blockchain solutions is actively involved in the promotion of ethically-sensitive business and finance devoted to decentralisation and transparency (see https://www.zbxitalia.it/filosofia). These various roles foster a community-based approach to innovation.

5. Multilevel Ecosystem for the 3Os

Ecosystem Governance and Licensing Dynamics: The RISE Project Case Study

The RISE (RISC-V Software Ecosystem) project, spearheaded by the Linux Foundation Europe, promotes collaborative software development tailored for RISC-V cores. This global initiative aims to bridge the compatibility gap between RISC-V cores and high-level operating systems. The project's open-source ecosystem involves both software and hardware components and comprises several layers of licensing models and governance structures.

At the foundation of this open-source ecosystem lies the RISC-V open hardware instruction set architecture (ISA). On top of this base layer lies the core component of the operating system, the Linux kernel, which acts as the bridge between the hardware and higher-level software components. Debian, a free software community distribution, sits as another layer, providing a vast array of precompiled software bundled in a format for easy installation.

Each layer, while distinct in its function, is bound together by their licensing agreements and governance practices. At the hardware level, RISE ensures transparency by employing the BSD licence for its chip designs and the Creative Commons licence for the actual ISA documentations. The Linux kernel, in turn, is governed by the GNU General Public License (GPL), mandating that any modifications to the kernel must remain open-source. The Debian distro employs various different licences (e.g., GPL, Apache License, MIT License). While the distribution may include non-free repositories with proprietary software, Debian adheres to a social contract which stipulates that the core system itself must always remain free and must never require any proprietary components to operate.

The RISE project, in its endeavour to accelerate the development of the RISC-V software ecosystem, navigates this multi-layered landscape. Its affiliation with the Linux Foundation Europe highlights a comprehensive approach to licensing, balancing the needs of open-source principles with proprietary imperatives. The project's governance model, with the Governing Board providing strategic direction and the Technical Steering Committee offering technical insights, ensures that licensing decisions align with both community and industry objectives.

Overall, the RISE project serves as an example of the multi-layered governance and licensing dynamics required to foster open collaboration between different stakeholders from individual contributors to industry giants. Through its layered licensing, meticulous documentation, and open communication channels RISE ensures that each stakeholder can commit to licensing agreements, contribution guidelines, and the overarching vision of the project.

By exploiting the main findings resulting from the two sources of evidence, i.e. the literature review on case studies related to the 3Os and the primary data obtained through the interviews conducted by the ZOOOM partners, we implemented a multilevel ecosystem framework for the 3Os (Figure 4).

In the framework, results are presented by three ecosystemic layers: 3Os innovation ecosystem; the OSS, OH, and OD innovation ecosystem (IE); and the OSS, OH, and

OD business ecosystem (BE). Following the main literature on different types of ecosystems, evidence shows that among three layers, the 3Os present two main types of ecosystem: the innovation and the business ecosystem.

Specifically, Layer 1, which refers to the 3Os innovation ecosystem, provides the foundation and resources for innovation across the three domains, i.e., data, software, and hardware. At this level, innovation emerges from the activities taking place at the interplay between the three different open innovation ecosystems.

Layer 2 drives innovation through open contribution in each specific domain (OSS IE; OH IE; OS IE). In these three open innovation ecosystems, the key elements are cooperation, knowledge, and resources sharing. For all these ecosystems relations focus on innovation and open contribution. At this level, the shared resources and knowledge are domain specific, meaning that the different economic and non-economic actors interact around a common vision about the evolution of knowledge in the specific domain of action. It is important to underline that in the OH IEs, players identified as crucial sources of innovation not only economic and non-economic actors specialised in the specific domain, but also economic players specialised in the fields of both OD and OSS.

In Layer 3, the main focus is instead value creation and capture in relation to focal firms defining the evolution of the domain and the relations. Companies within the same open business ecosystem (BE) are often interdependent, and their relationships are characterised by complementary, modularity and co-opetition. Specifically, companies aim to complement each other's offerings to provide holistic solutions to customers. For example, an operating system provider and software application developer in the same ecosystem create value together. Moreover, these ecosystems are often structured in modules. This feature allows companies to specialise in specific components or services, increasing efficiency. Lastly, companies in the same business ecosystem interact under the principle of co-opetition. In each of these specific domains collaboration can lead to mutual benefits, and companies might cooperate on standards or infrastructure while competing for market share. At this level an important player is the focal firm. This player is the one adapting the set of relations to efficiently and effectively deliver the value proposition at the core of the BE.

Among the different players identified in the three layers of the framework, a central role is played by the communities that have been recognised especially in relation to the open innovation ecosystems. These communities can be composed of developers, enthusiasts, experts, or other stakeholders who share common interests or goals in the development of new ideas. Communities are the bedrock of bottom-up dynamics related to knowledge sharing and resulting in innovation based on informal institutions. As for the former element, communities often foster collaborative innovation by bringing together individuals with diverse skills and perspectives. They contribute to open source software (OSS) projects, but also open hardware (OH) and open data (OD) projects sharing knowledge, information and collectively solving problems. Here, the sustainability of ecosystems depends on the engagement and vitality of these communities, but also on the respect of these informal institutions keeping the communities alive and trustable. When communities are active and engaged, they contribute to the long-term health and growth of the open innovation ecosystem as a whole.

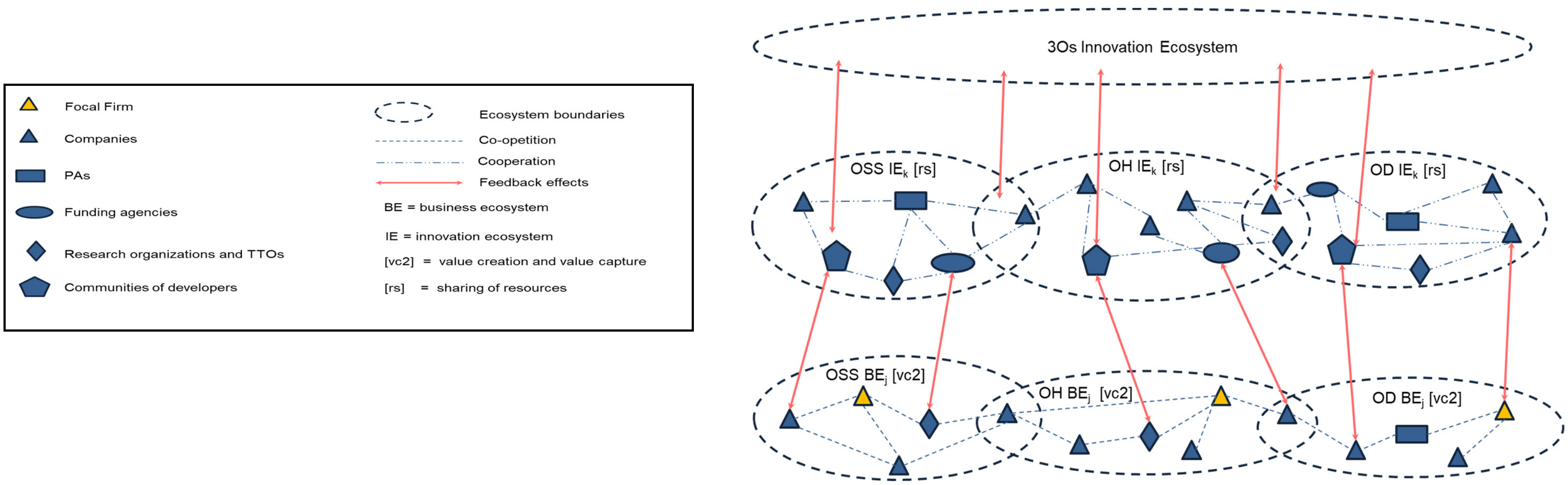

Figure 4: A multilevel Ecosystem Framework for the 3Os.

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