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RESEARCH PAPER

Archetypes of open-source business models

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Abstract
The open-source paradigm offers a plethora of opportunities for innovative business models (BMs) as the underlying codebase of the technology is accessible and extendable by external developers. However, finding the proper configuration of open-source business models (OSBMs) is challenging, as existing literature gives guidance through commonly used BMs but does not describe underlying design elements. The present study generates a taxonomy following an iterative development process based on established guidelines by analyzing 120 OSBMs to complement the taxonomy's conceptually-grounded design elements. Then, a cluster-based approach is used to develop archetypes derived from dominant features. The results show that OSBMs can be classified into seven archetypical patterns: open-source platform BM, funding-based BM, infrastructure BM, Open Innovation BM, Open Core BM, proprietary-like BM, and traditional open-source software (OSS) BM. The results can act as a starting point for further investigation regarding the use of the open-source paradigm in the era of digital entrepreneurship. Practitioners can find guidance in designing OSBMs.

Keywords Business models · Open source · Open-source business models · Strategic open source · Platforms · Archetypes · Taxonomy

JEL Classification L17

Introduction

Increasing global competition, rising R&D costs, and shortening product life cycles force firms to reconsider traditional BMs (Saebi & Foss, 2015). To face these upcoming challenges, firms are looking for alternative BMs based on more open and collaborative concepts, which is particularly observable in the technology industry (Economides & Katsamakas, 2006; Karhu et al., 2020; Koenig, 2004; Morgan & Finnegan, 2014). In light of this, the concept of *open source* enables developers to extend, build upon, or use code from others to leverage its resulting potentials, such as fueled innovation processes and increased efficiency (Fuerstenau et al., 2019; Morgan & Finnegan, 2014). Digital platforms, for example, bring together two or more parties over a digital infrastructure and use OSS as a tool to leverage network effects (Cusumano et al., 2019; O'Mahony & Karp, 2020; Parker et al., 2016; Trabucchi & Buganza, 2021). An example is Google's Android operating system based on the open-source Linux kernel, which tangibly illustrates the potential of open-source platforms. By providing a customizable open- source platform, Android attracted more developers as well as device manufacturers to use its operating system. As a result, the open-source license accelerated the operating system's market diffusion resulting in Android dominating the smartphone and tablet market in 2018 (Karhu et al., 2020; Parker et al., 2016).

OSS is also used outside of the digital platform industry as a tremendous driver for new technology: For example, blockchain technology is based on open source to allow more transparency in electronic transactions and foster trust by using open-source communities as governing institutions (Ingram Bogusz & Andersen, 2021; Perscheid et al., 2020). Several papers have identified open-source potentials, such as increased software quality, faster cross- company

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collaboration, or market diffusion (AlMarzouq et al., 2005; Morgan & Finnegan, 2014; Novotny, 2021). OSS has become indispensable for the consumer (e.g., Android, Mozilla, OpenOffice), but also in the B2B market (e.g., Linux, Kubernetes, SQL, Apache HTTP Server) as more than 90 % of software products include open-source components (Allen, 2012; Fitzgerald, 2006; Harutyunyan, 2020). Recent European studies show a high discrepancy between the increasing trend of open sourcing in the software industry and other traditional industry sectors, such as the manufacturing or the logistics sectors, which are nevertheless subject to profound digitization processes (Blind et al., 2021; Gentermann & Termer, 2019; Weking et al., 2018). Many industrial firms show great interest in open source but are reluctant to actively provide OSS due to the lack of replicable OSBMs (Gentermann & Termer, 2019). However, understanding the underlying mechanisms of OSBMs is crucial as their benefits come alongside corresponding pitfalls (Banon, 2021; Dahlander & Magnusson, 2005; Dahlander et al., 2021). For example, Elastic had to relicense its open-source search engine after Amazon launched its Amazon OpenSearch Service, exploiting the open-source product (Banon, 2021). On the other hand, Elastic's decision was controversially discussed in the open-source community as the firm had promised not to change its license model in the past (Krazit, 2021). Therefore, firms need to consider carefully, e.g., what product part they want to provide as open source, how they want to approach the community, which license they wish to use, and how revenue should be generated (Blind et al., 2021; Dahlander & Magnusson, 2005; Koenig, 2004).

Even though the topic of open source has been fundamental in IS research for many decades, it was mainly addressed from a technology-driven perspective neglecting managerial aspects (Aksulu & Wade, 2010). In the past, open source was seen as cancer for intellectual property in most eyes of prominent software vendors so empirical insights were limited to a few commercial forerunners, such as RedHat or MySQL (Greene, 2001). Thus, related research remained scarce and limited to a small number of use cases regarding OSBMs (Charvat et al., 2009; Hecker 1999). Nowadays, the use of open source is a standard tool in practice to achieve strategic goals, which is reflected by the topic's increasing importance in IS research, e.g., in platform strategies or open innovation (O'Mahony & Karp, 2020; Parker et al., 2016; Saebi & Foss, 2015). Also today, research on OSBMs is limited to providing an overview of existing BMs incorporating current technological trends or phenomena, such as software as a service or hosting, without analyzing underlying design elements (Okoli & Nguyen, 2015; Saebi & Foss, 2015). This leads to a black box regarding the successful design of OSBMs. However, a BM bridges the gap between strategical and operational concepts so that research would benefit from aligning these two topics through the lens of BMs (Al-Debei et al., 2008). IS scholars highlight the potential of open source for creating new business models (Fitzgerald, 2006; Harutyunyan et al., 2020), but also see the "obvious need to confront it with empirical reality" (Saebi & Foss, 2015, p. 211). To address this gap, we conduct an in-depth empirical study based on conceptual findings, which we summarize in the following research question:

> *How can OSBMs be characterized and differentiated based on conceptually and empirically grounded characteristics?*

To answer this research question, we (1) identify the key characteristics of OSBMs based on a taxonomic analysis and (2) demarcate OSBM archetypes based on a cluster analysis. A taxonomic analysis is used as a tool to conduct a systematic structuring of a domain of interest (Glass & Vessey, 1995). They are of highly relevant in the field of BM research and various industries as they assist in grasping their complex and often abstract nature (Möller et al., 2022; Nickerson et al., 2013). With the goal to achieve both empirical and conceptual grounding, the taxonomy design incorporates findings from several data sources. First, we conduct a structured literature review to identify the state of the art in OSBM literature that is the basis for the taxonomy. We enrich the body of knowledge with empirical data about OSBMs from multiple databases. Second, to demarcate the types of OSBMs, we draw from the concept of *archetypes*. Besides merely assisting in distinguishing different types, archetypes also help design BMs through the underlying configuration of the taxonomic patterns. We develop each archetype through *cluster analysis*, a common practice in BM research (see Remane et al., 2016 or Möller et al., 2021), and a practical approach to condense the empirical data onto a more abstract and general level. Finally, we highlight the contributions, explain limitations, and illustrate avenues for further research.

Related work

Open-source software

The higher-order concept "openness" has been deeply embedded in IS research as an important driver for technological innovation (Schlagwein et al., 2017). However, the term's conceptual ambiguity complicates a common understanding of underlying *open concepts* (Dahlander & Gann, 2010). Schlagwein et al. (2017) propose a framework for *open concepts* that differentiates between open resources, open processes, and opening effects. Opening effects focus on the strategic implications enabled by openness, such as democratized areas by reducing exclusivity and proprietary ownership (Morgan & Finnegan, 2014; Schlagwein et al., 2017). For example, open platforms refer to a type of platform governed by a collective body instead of a single entity (Asadullah et al., 2018; Eisenmann, 2008). On a more specific level, openness refers to open processes (e.g., open innovation, OSS development.) or open resources (e.g., open APIs, OSS), which are made accessible to external parties (Chesbrough & Appleyard, 2007; Dahlander et al., 2021; Schlagwein et al., 2017). Open processes differ from open resources in terms of their *architecture of participation* (Baldwin & Clark, 2006). For example, open innovation does not rely on openly accessible resources while being an open process. On the other hand, OSS can be reused in closed development processes (Schlagwein et al., 2017).

In the context of IS research, OSS is the earliest and most striking case that embeds the concept of openness in connection with IT (Schlagwein et al., 2017). Fundamentally, the term "Open Source" refers to source code that is made freely available to third parties and that was introduced by the foundation of the "Open Source Initiative" in February 1998 (Fitzgerald, 2006; Raymond & Perens, 2018). The initiative defines the following distribution terms for OSS: The program must include source code and allow its redistribution. The source code's redistribution should not be restricted (e.g., selling or giving away the OSS as a component of an aggregated software so that derived works are allowed). The license should be non-discriminatory, product and technology-neutral, and not restrict other software (Open Source Initiative, 2007). The foundation's goal was to popularize OSS, as well as define distribution terms to be more adaptable for commercial use than the former "Free Software" definition (Rajala et al., 2006). The latter led to the common misperception that free software based on open and thus "free" source code could not be monetarized (Fitzgerald, 2006; Fuggetta, 2003). Charging a license fee is also prohibited in open source, however, complementary or additional services, software, or products are viable sources of income that are permitted without violating the open-source distribution terms (Koenig, 2004; Okoli & Nguyen, 2015). OSS can be seen as the enabler for further open concepts, such as open-source development or open innovation, therefore, we focus our research on OSS and exclude related topics (Amrollahi et al., 2019; Eseryel, 2014; Saebi & Foss, 2015).

Open-source business models in platforms

The terminology of BMs arose with the advent of the Internet in the mid-1990s and has been an intensively investigated field of research since then (Zott et al., 2011). Fundamentally, a BM aims to explicate a firm's core business logic by describing how an organization creates, delivers, and captures value while generating revenue (Osterwalder et al., 2005). A BM bridges the gap between the higher-order business strategy and the operational business concept (Al-Debei et al., 2008). The heterogenous use of the definition in different domains leads to a plethora of BM frameworks, such as the Business Model Canvas (Osterwalder & Pigneur, 2010), the Business Model Navigator (Gassmann et al., 2014), or the V^4-Framework (Al-Debei et al., 2008). However, no standard definition of BMs has been established yet as "there are almost as many definitions of a BM as there are BMs (Teece, 2018, p. 41)". We chose the V^4-Framework of Al-Debei et al. (2008) as the conceptual basis of our paper as its design blocks represent the common denominator of our analyzed OSBMs (see Table A.1 in the online appendix). More specific frameworks cover single aspects, such as a context, a technology, or a domain. For example, digital BMs are based on the whole context of digital technologies, whereas the subordinate platform BMs focus on a specific technology (platforms) and its particularities (e.g., network effects) (Asadullah et al., 2018; Morgan & Finnegan, 2014; Parker et al., 2016).

OSBMs reflect the BM's concept blurriness and lack of a standard definition as each concept follows different approaches to describe OSBMs. The main characteristic of OSBMs is that the BM's value proposition is based on OSS, even though the degree of openness may vary throughout the different OSBMs (Hecker 1999; Seppänen & Helander, 2014). Some researchers focus on OSBMs as an overarching business strategy (Koenig, 2004), whereas others provide, similar to general BM frameworks, building blocks to design OSBMs (Seppänen & Helander, 2014). However, most research provides an overview of existing OSBMs and their underlying business logic. For example, an OSBM can be built around the OSS (indirect-sale models) and price physical objects (e.g., widget frosting), sell complementary services (e.g., auxiliary services), or create value by the firm's brand (e.g., franchising) (Hecker 1999; Okoli & Nguyen, 2015). Organizations can also choose to generate revenue through sponsorship or donations (funding) (Riehle, 2019). Another type of OSBM generates significant revenue streams from the software itself (direct-sale models), for example, by using different licenses regarding specific product parts. While essential parts are open source, the rest of the software remains closed (e.g., dual licensing or open core) (Dahlander & Magnusson, 2008). However, the underlying design elements of OSBMs are hardy described in most research.

An increasing number of platform literature thematizes the technological implementation of OSS and open-source strategies in platforms (Abendroth et al., 2021; O'Mahony & Karp, 2020). Many OSS offerings (e.g., Android, Apache Kafka, Docker, or PrestaShop) naturally seem to fit the platform definition. However, an integrated view aligning the topics on BM level does not exist. Therefore, we see the need to introduce the notion of platforms for our further analysis. Prior research on digital platforms can be divided into two different views. From an economic perspective, digital platforms are described as commercial networks bringing together two or more market sides to facilitate the exchange or transaction between different users, buyers, or suppliers (transaction platform) (Cusumano et al., 2019; Schreieck et al., 2016; Trabucchi & Buganza, 2021). Examples of this are the e-commerce platform eBay and the accommodation-sharing platform Airbnb (Evans & Gawer, 2016). The technological perspective focuses on the platform as a digital infrastructure on top of which other firms can develop complementary offerings, such as products, technologies, or services (innovation platform), e.g., the Android or Linux operating systems (Asadullah et al., 2018; Evans & Gawer, 2016). Nowadays, the most popular platforms, such as Apple, Google, or Amazon, share characteristics of both platform types (integrated platform) (Evans & Gawer, 2016).

Research design

Taxonomy development

Taxonomies are useful artifacts to structure a domain of interest and are vital to BM research (Glass & Vessey, 1995; Lambert, 2015; Osterwalder et al., 2005). They are used to cluster objects into specific groups based on similarities of characteristic properties (Bailey, 1994). Our taxonomy aims to close the gap between research and practice by analyzing scientific literature and empirical data to structure existing OSBMs. We use the method for taxonomy design of Nickerson et al. (2013). It consists of seven iterative steps integrating both paradigms to classification, i.e., an inductive and a deductive approach, until the taxonomy design reaches theoretical saturation (Gerber et al., 2017; Nickerson et al., 2013).

The first step begins with defining a meta-characteristic, reflecting the taxonomy's overall purpose. It is the source from which all subsequent actions are derived. As the method is iterative, the next step is defining subjective and objective ending conditions, which determine the ending of the development process (Nickerson et al., 2013). The methodological core is the alternating application of an *empirical-to-conceptual* and a *conceptual-to-empirical* approach. In the fourth step, researchers may apply a conceptual-to-empirical approach, which begins using conceptually derived dimensions empirically tested against a sample of objects in the fifth step. Alternatively, one can use the empirical-to-conceptual approach, which prescribes the inductive generation of dimensions, which are then conceptualized. Each iteration ends with the taxonomy design during the 6th step and evaluates the last step's ending conditions. The development process is repeated until the ending conditions are met (Nickerson et al., 2013).

Archetypes development

Archetypes are primordial patterns that enable their user to imitate artifact configurations and differentiate between distinct types (Davis, 1985). Our approach to developing archetypes aligns with prior studies on BM taxonomies (e.g., see Remane et al., 2016 or Weking et al., 2018), as we apply cluster analysis to the underlying database alongside their dimensions and characteristics. We use the statistical programming language *R* and the library *cluster* to develop clusters using the hierarchical cluster algorithm, based on Ward (1963) and the Gower measurement coefficient. Hierarchical cluster algorithms like Ward's are used when the number of resulting clusters is unknown as they calculate all possible cluster outcomes (Passlick et al., 2021). To determine a sensible number of clusters, we use the elbow method and visual examination through a dendrogram to gain maximal explanatory insights (Täuscher & Laudien, 2018). After estimating the optimal cluster number, we apply the Wards and K-means algorithms to the different cluster outcomes to exploit the advantages of hierarchical and non-hierarchical algorithms. Comparing the clustering results of both algorithms enhances the robustness of the results (Ana & Jain, 2003).

Taxonomy of open-source business models

Taxonomy development procedure

Following the first step of taxonomy design, we define the meta-characteristic as follows: "Design Elements for Open-Source Business Models". We required five iterations to design the taxonomy. The 1st and 2nd iterations are *conceptual-to-empirical* based on an iterative structured literature review. The last three iterations are *empirical- to-conceptual* and use the *a priori* identified conceptual lens to analyze a database of 120 objects from different organizational backgrounds (e.g., Start-Ups, non-profit Organizations, individual projects). We constructed the database through screening publicly available data, usually the website of each organization or project, and additional sources for information such as *AngelList*, *GitHub*, *SourceForge*, or *blogs*. Prior literature proposing BM taxonomies exemplifies that this way of data collection is sensible in BM research (e.g., see Hartmann et al. 2016 or Remane et al., 2016). As the data sometimes required judgment and interpretation, each object and the corresponding collected data were frequently discussed in the team of authors.

Table 1 Overview of the systematic literature review

Database	No	Search string (Title or Abstract)	Results	Refined	Selected
	1	*"open source" AND "business models"*	168	-	30
	2	*"open source" AND "value creation"*	38	-	5
Scopus AiSeL Google Scholar		*"open source" AND "community"*	1462	56	3
		"open source" AND "architecture"	263	69	1
		"open source" AND "revenue model"	4	-	1
	1.+2	Forward and backward search	-	-	12
			Final Sample:		$\sum$= 52

1st Iteration conceptual-to-empirical In the 1st iteration, we opted for the *conceptual-to-empirical* approach to find fundamental conceptual design frameworks of OSBMs. As these conceptual findings reside in the literature corpus, we follow a systematic literature review approach and generate a nexus of relevant literature. Following Webster and Watson (2002)'s recommendations, we supplement the initial findings through backward and forward searches. Explicitly, we looked for articles describing the design parameters of OSBMs in a non-trivial and non- marginal way (Levy & Ellis, 2006). The literature corpus comprises articles published in VHB-ranked journals or conference proceedings belonging to the field of IS research. We further discarded non-English written literature, literature unrelated to OSBMs and their underlying design elements, as well as literature that was not published in peer-reviewed journals or conference proceedings (e.g., theses or presentations). Table 1 summarizes our search strategy.

As per the goal to focus explicitly on ontological BM elements that thematize OSBMs, we analyze the literature corpus following the notion of *concept matrices* by Webster and Watson (2002) (see Table A.1 in the online appendix). Based on the findings in the literature, we synthesize four ontological elements as meta-dimensions for OSBMs that are congruent to the V^4-framework but adapted to the open-source context (Al-Debei & Avison, 2010):

- **Value Proposition:** The value proposition explains the overall bundle of products or services (e.g., open-source and commercial offerings) that generates value for customers (Seppänen & Helander, 2014).
- **Value Network:** Refers to all relevant elements for community building in OSBMs (Rajala et al., 2007).
- **Value Architecture:** Refers to all technological and organizational infrastructure necessary for the OSBM to function (Al-Debei & Avison, 2010).
- **Value Finance:** Refers to all elements related to generating income or the price composition (Rajala et al., 2003).

2nd Iteration conceptual-to-empirical In the 2nd iteration, we analyzed the literature corpus for design elements of OSBMs. By doing that, we integrate existing conceptual knowledge engraved in the scientific literature. Using the literature to generate initial conceptual design elements has two significant advantages: First, contrary to purely inductive work, the taxonomy is grounded in conceptual knowledge stemming from the existing literature. Second, through a detailed analysis of the literature corpus, we gain extensive knowledge about terminologies, concepts, and essential design elements of OSBMs that support all following empirical iterations. For example, we drew some elements from prior BM taxonomies that proposed design elements that are typical for any BM (e.g., Möller et al., 2019 or Täuscher & Laudien, 2018).

3rd Iteration empirical-to-conceptual In the 3rd iteration, we analyzed the first sub-sample consisting of 50 OSBMs. The first sub-sample was derived from the start-up database *AngelList*. We analyzed the sub-sample twofold. First, we checked for empirical validation of the conceptual dimensions and characteristics. Secondly, we developed new ones through comparative, inductive analysis. As a result, the *key offering* was split into *free offering* and *commercial offering*. The dimensions *customer interface*, *communication channel,* and *platform type* were added.

4th Iteration empirical-to-conceptual Subsequently, we analyzed an additional sample of 50 OSBMs from the database *SourceForge*. By analyzing open-source projects from different organizational backgrounds, we found new relevant aspects and differences in designing OSBMs. For example, individual projects or non-profit organizations would provide the complete source code of the project, whereas firms would mostly open up certain parts of the product. As the ending conditions were not fulfilled due to the new dimensions, *source code provider,* and *open-source component*, we carry out the next iteration step (Nickerson et al., 2013).

5th Iteration empirical-to-conceptual In the 5th iteration, we used a sub-sample derived randomly from both databases. The last 20 OSBMs were then analyzed and decomposed into their design elements based on the taxonomy's dimensions and characteristics. Additionally, we discussed and introduced the exclusivity of characteristics for every dimension. As no further changes were made and all ending conditions were met, we opted to end the taxonomy development. A detailed overview of the five iteration steps required to design the taxonomy dimension can be found in Figure A.1 in the online appendix.

Evaluation

To assess our results, we used the taxonomy evaluation framework of Szopinski et al. (2019). The evaluation is based on three questions: The who (i.e., subject), what (i.e., object), and how (i.e., method). As a means of evaluation, we conducted seven expert interviews with academics and practitioners that were not previously involved in the taxonomy building ("how" and "who"). Regarding the last question, we chose "the characterization and design of OSBMs" as the real-world problem to be discussed ("what"). Each interview began with a presentation of the taxonomy and the distribution of an explanatory sheet for the taxonomy (see Table A.2 of the online appendix). Due to the participants' heterogeneity, we defined an individual subject of investigation and goal for each interview.

Two interviewees with academic backgrounds and high methodological knowledge in taxonomy as well as archetypes development and/or domain knowledge were asked to evaluate the resulting artifacts. The first interviewee examined the results from a methodological perspective. After discussing the taxonomy, the five subjective ending conditions were assessed. He considered all ending conditions to be fulfilled but doubted the extendibility as it could lead to an overwhelming taxonomy. As most practitioners outside of open-source projects have little background knowledge regarding the underlying design mechanisms, we chose not to reduce the taxonomy's complexity. The second interviewee suggested minor changes in the wording of some dimensions and characteristics but found the overall taxonomy to be complete and comprehensive. As a result, we renamed the characteristics *data service*, *browser-based*, *sponsor* and *governance structure*.

Two interviewees with practical backgrounds in existing open-source projects formed the second group. These interviews aimed to apply the taxonomy to their organization's open-source projects and the identification of matching archetypes. The interviewees could not completely map their free offering as their projects provide components that can be enhanced to complete products by third parties. Therefore, we enhanced the free offering by the characteristic *component*. After evaluating the taxonomy, we compared the characteristics of the projects with the archetypes. As a result, each project could be matched to one existing archetype.

The third group of interviewees consists of persons with a practical background who aim to provide their firm's open-source offerings. Therefore, the goal was to design an OSBM based on the taxonomy and archetypes. In the case of decision-making difficulties, we suggested recommendations based on matching archetypes. As a result, each interviewee designed a suitable OSBM corresponding to an existing archetype. After discussing the taxonomy, we renamed the characteristic physical service. One interviewee suggested analyzing sub-archetypes or success factors for more precise guidance regarding the design of OSBMs, which we noted as opportunities for further research.

For the last interview, we chose an individual with academic and practical knowledge of OSBMs. A discussion point was the dimension of the source code provider as the code can be developed in cross-organizational projects. However, the dimension is non-exclusive, so the configuration can be displayed by choosing several characteristics. In summary, the interviewee agreed with the meta-dimensions and found the overall taxonomy to be complete.

Final taxonomy

The following section presents the final taxonomy consisting of four meta-dimensions **(MD1-4)**, 17 dimensions **(D1-17)**, and 75 characteristics. There is a spectrum of possible visualization options, including morphologies or mathematical sets (Szopinski et al., 2020). The object of investigation requires the morphological decomposition of designable elements in OSBMs. The decomposition is, in turn, useful for subsequent designers as it helps to combine their own OSBM from detailed design characteristics (Simon 1995). Therefore, we opted to use a morphological box to visualize the taxonomy (see Table 2). Table 2 visualize the taxonomy including the classified examples from the Taxonomy Application based on the archetypes (A1-7). A detailed description of each characteristic can be found in the online appendix (see Table A.2) as well as their percental distribution (see Table A.3).

Value proposition

Value Proposition (MD1) is the organization's ability to conceptualize a product offering that delivers value to a relevant customer segment through it (Chesbrough, 2010; Morgan & Finnegan, 2014). In OSBMs, the value proposition consists of a dichotomous product offering, as firms can hardly generate revenue from OSS itself (Koenig, 2004; Okoli & Nguyen, 2015). Therefore, the free offering is

Table 2 Final Taxonomy of open-source business models

	Dimension	Characteristics								E
Value Proposition	D1: Free Offering	Component	Software	Platform	Infrastructure	Physical Service	Data Service	None		N
	D2: Commercial Offering (D2)	Software	Platform	Infrastructure	Physical Product	Physical Service	Data Service	Franchising	None	N
	D3: Customer Value	Functional Value	Cost/Sacrifice Value	Relationship Value	Co-creation Value	Brand Value	Social Value			N
	D4: Customer Segment	Business	Public Sector	Academics	Consumer					N
Value Network	D5: Community Approach	Symbiotic Approach	Commensalistic Approach	Parasitic Approach						Y
	D6: Customer Interface (D6)	App-based	Browser-based	On-premise						N
	D7: Communication Channel	Mailing List	Documentation	Social Events	Own Forum	External Platform				N
	D8: Governance Structure	Centralized	Balanced	Decentralized						Y
Value Architecture	D9: Source Code Provider	Company	Non-profit Organization	Individuals						N
	D10: Licensing	Proprietary License	Permissive License	Copyleft License						N
	D11: OS-Component	Complete Product	Core Components	Complementary Components	None					N
	D12: Platform Type	Innovation Platform	Transaction Platform	Integrated Platform	None					N
	D13: Boundary Resource	Development	Application	None						N
Value Finance	D14: Financial Purpose	Commercial	Quasi-commercial	Non-commercial						Y
	D15: Revenue Mechanism	Direct-sale	Indirect-sale	Funding						N
	D16: Revenue Model	Subscription	Freemium	Fee	Pay-per-use	Ads	Passive Income	Financial Support		N
	D17: Price Base	User Entity	Time	Transaction	Download	Resource	Sponsor			N

Legend:
Blue – Moodle.com (A1) Orange – Apache OpenOffice (A2) Black – Tendenci (A3)
Yellow – PrestaShop (A4) Green – Sencha (A5) Purple – JunoEMR (A6)
Red – Rufus (A7)

E=Exclusivity, *Y*=Yes, and *N*=No

backed by a commercial offering to generate revenue. The value proposition can be described using 25 characteristics, which in turn are summarized by the following four dimensions:

Non-profit organizations or firms often deliver a part of their value proposition as **Free Offering (D1)**. These freely available products or services are primarily digital (e.g., software, platforms, or infrastructure) and open source, as they can be copied at marginal costs (Shapiro & Varian, 1999). In addition to the free offering, organizations provide a **Commercial Offering (D2)**, e.g., payable services or products, to enhance or complement the free offering. The

3rd dimension describes the **Customer Value (D3)**. A firm must understand and satisfy the customer's needs by creating value. In OSBMs, the customers perceive value through the product itself, price-performance ratio, customer experience, customization, or brand value (Shanker, 2012). Established foundations provide a particular brand value, such as the Apache or the Eclipse Foundation. They have a high reputation in the open- source community, increasing users' trust to participate in specific projects. The **Customer Segment (D4)** specifies the targeted customer segments, i.e., businesses, the public sector, academics, or consumers (Osterwalder, 2004).

Value network

The **Value Network (MD2)** describes the coordination of governance structures and relationships among parties (Al-Debei et al., 2008). Contrary to traditional BMs, the value network is an integral part of an OSBM as users can be a pivotal element in the value creation process (Morgan & Finnegan, 2014). Therefore, the subordinate dimensions might exceed the granularity of traditional BM concepts as firms need to carefully plan their value network to benefit the most from the open-source community (Chesbrough & Appleyard, 2007; Rajala et al., 2007). The value network's four dimensions consisting of 14 characteristics, read as follows:

The **Community Approach (D5)** describes how an organization approaches the open-source community to benefit from open innovation. Dahlander and Magnusson (2005) differentiate between firms with high community involvement and positive impact on the community (symbiotic approach), less committed but not harmful firms (commensalistic approach), and harmful firms (parasitic approach), which do not respect open-source norms and values. **The Customer Interface (D6)** refers to the type of interface to access the product or service, such as browser-based solutions or on-premise software (Möller et al., 2019). The dimension **Communication Channel (D7)** describes the organization's various means to get in touch with its users and interact with the community (Osterwalder et al., 2005). Organizations based on open source tend to communicate through various communication channels, for example, mailing lists, social events, or communication platforms, as community involvement can be crucial for their BM (Saebi & Foss, 2015). Organizations can determine the community's involvement in their development processes through the **Governance Structure (D8)**. As developers in open-source communities are often geographically distributed, coordination mechanisms, such as work distribution or decision-making rights, need to be established. We distinguish threefold between centralized (i.e., the organization controls every modification such as pull requests), balanced (i.e., the organization gives certain decision rights to proven users), and decentralized (democratic decision-making) control mechanisms (Sharma et al., 2002). The ROS[1] project, for example, adopts a decentralized approach in which developers can take the role of a core maintainer if they have a high participation rate (e.g., code contributions or reviews).

Value architecture

The **Value Architecture (MD3)** of an organization includes technological and organizational infrastructure and their configurations to deliver products and services to its customers. It includes tangible and intangible organizational assets, resources, and core competencies, such as intellectual property, licenses, or technological resources (Al-Debei & Avison, 2010; Möller et al., 2019). By integrating conceptual and empirical insights, we identify five dimensions, including 17 characteristics to conceptualize an OSBM's value architecture:

Given the nature of open source, the (initial) **Source Code Provider (D9)** can differ from the actual provider of the product offering. For example, a firm can choose to build upon an existing OSS to create an extended software version or create physical services around the OSS (Fitzgerald, 2006; Rajala et al., 2007). **The Licensing (D10)** determines the OSS's ownership structure and is an integral part of the architecture (Välimäki & Oksanen, 2005). Today, a plethora of open-source licenses exist that can be primarily categorized into three main groups: proprietary (one owns), permissive (everyone owns), and copyleft (no one owns and will own) (Välimäki & Oksanen, 2005). The success of OSBMs is mainly due to the use of adequate licenses (Fitzgerald, 2006). Following a dual-licensing strategy, for example, a firm can choose to provide basic software through an open-source license and sell the enterprise version under a proprietary license (Kim et al., 2006). The **Open Component (D11)** describes which parts of the product offer are open source. By opening certain product features or complementary components, such as boundary resources, organizations can strategically vary their degree of openness to achieve overarching goals (e.g., network effects) (Karhu et al., 2018; Schreieck et al., 2016). As many firms of the empirical findings included a platform as a base or one part of the product offering, we included the **Platform Type (D12)** as an architectural dimension and used the platform definition given in the section "Related Work" as a base for the platform characteristics. **Boundary resources (D13)** are interfaces, tools, and rules which facilitate and control the relationship between the platform owner and external parties (Karhu et al., 2020). They enable third-party developers to create applications and to interact with or extend the platform

[1] https://www.ros.org/

(Bianco et al., 2014). The provision of boundary resources is often used to foster growth and participation in platforms and open-source communities (Pellizzoni et al., 2019).

Value finance

The meta-dimension **Value Finance (MD4)** covers all aspects of costing, pricing, and revenue breakdown (Al-Debei & Avison, 2010). The last building block of OSBMs is similar to traditional BMs, with the difference that firms need to plan their revenue mechanism according to their value proposition. The value finance can be conceptualized by 22 characteristics and 4 dimensions:

The **Financial Purpose (D14)** of an organization determines the purpose of incoming revenue which is normally commercial or non-commercial (Riehle, 2019). However, one particular type of open-source project, quasi- commercial projects, can be found in the grey area: projects with small revenue that might commercialize their project professionally in the future or non-commercial projects which have an industrial background (Allen, 2012). The next dimension, the **Revenue Mechanism (D15)**, describes the logic for generating revenue. An organization can choose to price the OSS directly, generate revenue through an additional offering, or rely on funding models to sustain itself (Raymond, 2001). The **Revenue Model (D16)** describes how the revenue stream is generated (El Sawy & Pereira, 2013). OSBMs use standard revenue models, such as subscription (abonnements with time- limited free offering), freemium (abonnements with time-unlimited free offering), fees (e.g., transaction, upfront), or financial support (e.g., donations or sponsorships). The last dimension, the **Price Base (D17)**, thematizes the revenue model's basis and describes on which underlying unit the price comes together. The empirical findings show that the offering can be priced, for example, per user entity (e.g., user, company), time, resource**,** or sponsor (e.g., investor, donor).

Taxonomy application

Following the good practice in taxonomy research, we illustratively show the applicability of our taxonomy using case scenarios from the empirical sample. To classify the firms into our taxonomy, we complemented the data from the firms' websites with publicly available information on the internet. By decomposing the following BMs from our case scenarios into single elements, subsequent designers can understand the crucial elements of OSBMs and combine their BM based on our taxonomy. The examples are illustrated in Table 2.

Moodle[2] (A1) is an open-source learning management system that started as open-source project and was later led and coordinated by the eponymous firm Moodle HQ. The firm uses an open-source platform BM as it offers a broad commercial offering, such as infrastructure, physical products, physical services, and franchising options on top of the open-source platform. The project's brand value, besides its functional value, is one of its key customer values due to the software's wide distribution and its good reputation as they follow a symbiotic community approach and provide a balanced collaboration control. The main customers of Moodle HQ are academics and other businesses. A high level of user-friendliness is achieved by its diverse customer interfaces, boundary resources and communication channels. Most of the source code stems from Moodle HQ which provide the complete product, characterized as an integrated platform, as OSS under the copyleft GNU license. The firm generates revenue through indirect-sale strategies by using time-based freemium or resource-based fees as revenue models.

The **Apache Foundation**[3] (A2) is a typical example of non-profit organizations with a funding-based BM. Around 350 open-source projects are provided under the organization's umbrella. Every OSS is completely open source and free, and no direct commercial offering exists. The organization's goal is to deliver social value for its users by providing software for the public good. Apache projects are characterized by a collaborative, consensus-based development process (symbiotic community approach) and self-selected teams that actively contribute to the respective project (decentralized collaboration control). The organization provides common infrastructure and guidelines for communication channels (e.g., mailing lists, Apache forum), licensing (permissive Apache license), and boundary resources (e.g., development, application). As the Apache Foundation's financial purpose is non-commercial, the foundation relies on funding as a revenue source. However, the organization has professionalized their funding-based revenue model by using time-based sponsorships and merchandise as steady income revenue.

Tendenci[4] (A3) provides an open-source membership management platform for associations and businesses using an infrastructure BM. While the complete platform is licensed under copyleft GPL 2 license, the commercial offering comprises of hosting and physical services. To offer a satisfying customer experience, the firm focuses on providing relationship value through a symbiotic community approach and support in software customization. Furthermore, multiple communication channels (e.g., blogs, tutorials, forums, external platforms) and boundary resource increase the software's usability for customers. The open-source software itself is provided on-premise. However, the

[2] https://moodle.com/

[3] https://www.apache.org/

[4] https://www.tendenci.com/

product is designed as software as a service. Thus, the commercial BM is based on providing the needed infrastructure, cloud services and virtual processors, to run the OSS. The revenue model consists of time- and resource-based freemium abonnements.

PrestaShop[5] (A4) is an open-source e-commerce platform that uses the open innovation BM for its multiple offerings. Their open-source offerings comprise software, their platform, and data services. Their commercial offering builds on top of these free offerings by providing human services, infrastructure, a marketplace, and strategic partnerships targeting businesses as customers. Their symbiotic approach is characterized by multiple communication channels, and boundary resources. Furthermore, customers can offer their own products (e.g., modules or design features) on the Prestashop marketplace so external parties are essential for the value creation and innovation process. The balanced collaboration control fuels the open-innovation process as they welcome core developers to participate reflected in their active open-source community. The software itself is licensed under the copyleft Open Software license. Thus, revenue is generated by additional modules or hosting plans that are based on a time-based freemium BM. Additionally, strategic partnerships are described as further source of income.

Sencha[6] (A5) provides a web application development solution to design, create, configure, and test cross-platform applications under an open core BM. Their core platform is open source for individual developers, while their commercial offering provides the platform's enterprise version and support services targeting businesses. In contrast to the previous examples, the firm follows a commensalistic community approach: They provide several community channels and boundary resources to increase customer satisfaction, however, in comparison to the previous examples, the open-source offering is relatively small. Also, the collaboration control is centralized preventing members of the open-source community to be part of the central development processes. Sencha uses the copyleft GPL V3 license to prevent commercialization of their open components and a proprietary license for their commercial product version. The firm generate direct-sale revenue with their innovation platform by using an entity-based subscription revenue model.

JunoEMR[7] (A6) is a patient management platform based on the OSS called OSCAR McMaster EMR for the medical sector. However, on the firm's website, the OSS is hidden in the license agreement indicating a proprietary-like BM. The commercial offering comprises time- and user-based subscriptions for the hosted software. The firm has few interactions with the open-source community without providing many communication or boundary resources resulting in a commensalistic community approach. Accordingly, the collaboration control is centralized as contributions and participation are not promoted. The initial software is an OSS that was developed by a university and distributed under a copyleft GNU license, while the related services are provided by the firm under a proprietary license. The firm uses the direct-sale strategy without providing time-unlimited free or open-source offerings.

Rufus[8] (A7) is a software to create bootable USB drives that follows the approach of traditional OSS BMs. The provider does not offer a commercial offering. The customer value focusses on the specific function the OSS delivers for its users (consumers). As the project is provided by one initiator, the resources are limited to maintain the OSS and no boundary resources and few communication channels are provided. However, there is an active open-source community involvement on Github due to the balanced collaboration control that allows external developers to drive the project actively. Therefore, the project is considered to follow a symbiotic community approach. The complete OSS is provided under the copyleft GPL 3 license. Therefore, revenue is generated through advertisement and donations. As the financial purpose remains unclear, the project is categorized as quasi- commercial.

Archetypes of open-source business models

Archetype development procedure

Coding process The coding process is based on checking publicly available data gathered from the firm's website, existing reports or white papers, and external websites, such as CrunchBase and Github, to ensure data triangulation (Weking et al., 2020). Our taxonomy's OSBM conceptualization serves as an underlying codebook for coding the initially identified 120 samples (Hunke et al., 2021). The coding of the samples was individually performed by four authors and documented in a spreadsheet using a binary coding system (0 = false, 1 = true). After the individual analysis, each entity of the database was discussed in the authors' group to ensure validity and reach a consensus.

Data preparation Before clustering and analyzing the dataset, we prepared our database for analysis. As the perceived *customer value* is of subjective nature, we excluded the

5 https://www.prestashop.com/en

6 https://www.sencha.com/

7 https://www.junoemr.com/

8 https://rufus.ie/de/

Table 3 Open-source business model patterns and examples

Archetype (A)		Definition	Examples	N
A1	Open-source Platform BM	Provision of an open-source platform to attract users and to fuel network effects	Moodle, Kubernetes, Drupal, Stacks	9
A2	Funding-based BM	Non-commercial open-source projects that are based on voluntary work and funding	Apache Foundation, Eclipse Foundation, Safe Examen Browser, Tor Browser	14
A3	Infrastructure BM	Provision of OSS coupled with hosting services	Tendenci, ERPNext, Taiga, YetiForce	13
A4	Open Innovation BM	Firms that provide a multiple product offering and focus on enabling open innovation	PrestaShop, Sentry, Clover, Sonatype	13
A5	Open-Core Platform BM	Essential functionalities are open source, while additional proprietary features need to be purchased	Sencha, Hazelcast, SoapUI, Pilosa	21
A6	Proprietary-like BM	Proprietary-like platform and infrastructure providers with few open-source offerings	Juno EMR, Appsembler, Temasys. Proud City	11
A7	Traditional OSS BM	Provider of traditional OSS targeting the consumer sector	Rufus, TurboVNC, WinSCP, OBS project	14

dimension in the archetype evaluation to avoid uncertainties and blurriness. Then we introduced auxiliary variables to dimensions with frequently occurring multiple matching characteristics (more than two). We assume that the auxiliary variable "multiple" summarizes the common information of variables in its dimension and leads to higher expressiveness during the clustering process (Oviedo et al., 2016).

Cluster analysis We first used the elbow method (k = 4) based on the k-means algorithm to estimate the optimal number of clusters. As an alternative approach, we performed Ward (1963)'s hierarchical cluster algorithm as it generates several possible clusters by gradually merging the two nearest clusters in each step (Han, 2012). Thus, it has the advantage that an initial selection of potential cluster numbers can be identified through visualization based on the distances the objects were combined (Sarstedt & Mooi, 2019). Based on a dendrogram, a commonly used tool in IS research (e.g., Weber et al., 2022, Janssen et al., 2020, and Hunke et al., 2021), and the elbow method's result, we estimated the optimal number of clusters between four and eight (see Figure A.3 in the online appendix). We then applied the Ward and K-means algorithms using the Gower distance function with alternating distance metrics, such as the euclidean, manhattan, and binary distance method to compare the different clusters and check for robustness (Gower, 1971). During the analysis, we manually removed individual specimens, such as negative outliers based on the silhouette function, that were exotic compared to the complete dataset (Punj & Stewart, 1983). Using the Ward and K-means algorithms based on different distance methods both indicated the same negative outliers.

Qualitative phase We found consensus for maximal explanatory insight into possible archetypes for k = 7 based on a final dataset of 95 entities. The final results are based on Ward (1963)'s hierarchical cluster algorithm and the Gower (1971)'s distance function using the binary distance methods. The discrepancy between the final cluster number and the elbow method's estimated number of k = 4 can be explained as follows: As "human judgement is the single most important factor in the generation of meaningful clustering results" (Sherman & Sheth, 1975, p. 2), we manually checked the result's usefulness and perceptuality. With k = 4, the cluster groups were too superficial as, for example, commercial and non-commercial offerings based on a high degree of openness were grouped together. Therefore, we opted to increase the result's granularity by choosing a higher number of clusters. Table 3 summarizes and describes the developed archetypes. Table 4 gives an overview of the archetype's patterns as well as their dominant characteristics (100%) and further design options. The darker the field, the more often the characteristic was used in the respective cluster.

Final archetypes

Open-Source Platform BM (A1) The first archetype represents BMs that are based on open-source platforms. Providers use the platform to attract a high number of users and to fuel network effects. Most product offerings of the value proposition address the business and the customer sectors alongside. Typical of the archetype's value network is the symbiotic approach towards its users through active involvement in the OS community. This is underlined by a multitude of communication channels and boundary resources that ease the inclusion of external users. Profit is not generated through the platform itself as the source code is completely open. Therefore, only permissive or copyleft licenses are used to deliver their primary offering in their value architecture. Instead, funding and/or indirect-sale mechanisms are used to sustain the project or to generate

Table 4 Characteristics of the archetype patterns

		Archetype	1	2	3	4	5	6	7
		n	9	14	13	13	21	11	14
Value Proposition	Free Offering	Software	67%	43%	85%	69%	43%	18%	93%
		Platform	100%	64%	38%	100%	57%	9%	29%
		Infrastructure	11%	21%	31%	38%	43%	9%	7%
		Physical Services	0%	0%	0%	15%	10%	9%	0%
		Data Service	0%	7%	0%	23%	33%	9%	0%
		None	0%	0%	0%	0%	0%	82%	0%
		Multiple	0%	0%	0%	46%	29%	9%	0%
	Commercial Offering	Software	0%	0%	62%	62%	33%	55%	7%
		Platform	11%	0%	23%	92%	67%	100%	0%
		Infrastructure	33%	0%	100%	77%	76%	100%	0%
		Physical Products	56%	0%	15%	8%	0%	0%	14%
		Physical Services	44%	0%	77%	100%	86%	91%	21%
		Data Service	0%	0%	15%	31%	38%	27%	0%
		Franchising	33%	0%	8%	15%	14%	9%	7%
		None	0%	100%	0%	0%	0%	0%	50%
		Multiple	11%	0%	54%	100%	71%	100%	0%
	Customer Segments	Business	89%	43%	100%	100%	100%	91%	29%
		Public Sector	22%	29%	46%	15%	29%	45%	0%
		Academics	56%	36%	46%	0%	19%	27%	0%
		Consumer	67%	79%	38%	38%	62%	9%	100%
Value Network	Community Approach	Symbiotic Approach	100%	93%	54%	100%	52%	18%	50%
		Commensalistic Approach	0%	7%	46%	0%	48%	82%	50%
		Parasitic Approach	0%	0%	0%	0%	0%	0%	0%
	Customer Interface	App-based	11%	21%	38%	23%	5%	9%	7%
		Browser-based	78%	29%	77%	85%	67%	73%	7%
		On-Premise	89%	86%	69%	92%	90%	73%	100%
	Communitcation Channel	Mailing List	56%	57%	8%	23%	24%	0%	21%
		Documentations	89%	93%	100%	92%	95%	91%	86%
		Social Events	56%	36%	8%	77%	52%	55%	14%
		Own Forum	67%	43%	38%	62%	57%	55%	50%
		External Platform	89%	100%	100%	92%	100%	91%	100%
		Multiple	100%	79%	46%	100%	86%	82%	64%
	Collaboration Control	Centralized	33%	14%	85%	31%	95%	91%	43%
		Balanced	33%	36%	15%	69%	5%	9%	50%
		Decentralized	33%	50%	0%	0%	0%	0%	7%
Value Architecture	Source Code Provider	Company	33%	0%	85%	100%	86%	64%	29%
		Non-profit Organization	67%	86%	15%	0%	29%	73%	0%
		Individuals	0%	14%	0%	0%	0%	0%	71%
	Licensing	Proprietary License	0%	0%	15%	62%	100%	91%	0%
		Permissive License	56%	57%	31%	62%	67%	45%	14%
		Copyleft License	67%	50%	85%	54%	33%	64%	93%
	Open-source Component	Complete Product	100%	100%	85%	31%	0%	0%	100%
		Core Components	0%	0%	8%	62%	100%	55%	0%
		Complementary Components	22%	0%	8%	15%	10%	45%	7%
		None	0%	0%	0%	0%	5%	0%	0%
	Platform Type	Innovation Platform	22%	57%	46%	38%	95%	73%	43%
		Transaction Platform	22%	14%	15%	0%	0%	9%	0%
		Integrated Platform	56%	7%	15%	62%	5%	18%	0%
		None	0%	21%	31%	0%	0%	0%	57%
	Boundary Resource	Development Boundary	89%	71%	15%	100%	67%	45%	50%
		Application Boundary	89%	50%	15%	100%	33%	45%	14%
		None	0%	29%	85%	0%	33%	36%	36%
Value Finance	Financial Purpose	Commercial	11%	0%	100%	100%	90%	100%	7%
		Quasi-commercial	67%	0%	0%	0%	10%	0%	86%
		Non-commercial	22%	100%	0%	0%	0%	0%	7%
	Revenue Mechanism	Direct-sale	0%	0%	8%	69%	95%	82%	0%
		Indirect-sale	78%	14%	100%	92%	57%	27%	71%
		Funding	89%	100%	23%	69%	0%	0%	100%
	Revenue Model	Subscription	22%	14%	8%	38%	19%	91%	0%
		Freemium	22%	0%	100%	62%	81%	0%	0%
		Fee	56%	0%	15%	15%	5%	0%	7%
		Pay-per-Use	0%	0%	8%	31%	19%	18%	0%
		Ads	11%	14%	8%	0%	0%	0%	64%
		Passive Income	11%	7%	0%	0%	0%	0%	0%
		Financial Support	89%	100%	23%	69%	0%	0%	100%
	Price Base	User Entity	89%	7%	62%	46%	52%	45%	50%
		Time	44%	14%	92%	85%	81%	82%	29%
		Transaction	0%	0%	0%	15%	0%	0%	0%
		Download	0%	0%	0%	8%	0%	0%	7%
		Ressource	11%	0%	54%	31%	57%	27%	0%
		Sponsor	89%	100%	23%	69%	0%	0%	100%

revenue (value network). It is noticeable that more than half of the archetype's projects are quasi-commercial meaning that the project is primarily not profit-oriented but it has a commercial background. For example, Kubernetes[9] is a project maintained by the Cloud Native Computing Foundation. However, Google originally designed the product. Even though Kubernetes does not directly generate profit, its dissimilation could encourage users to pay for Google's commercial services, such as their cloud services (Dhawan, 2018). Therefore, most revenue models are based on financial support, in the sense that projects are subsidized by the revenue of other product segments or sponsored by firms with commercial interests. However, commercial or non-commercial firms that offer an open-source platform are also sorted into the open-source platform BM. Their revenue models, in addition to financial support, focus on selling additional products (e.g., merchandise) or physical services (e.g., support services).

Funding-based BM (A2) The second archetype consists of purely non-commercial organizations and projects. In contrast to the other archetypes, funding-based BMs do not provide a commercial offering and sustain their project with voluntary work and funding. Nevertheless, depending on the size of the organizations, professional BM structures, such as defined community building measures for the value network, licensing models in the value architecture, and financing models in the value finance, ensure the long-term maintenance of the projects. Thus, like in the open-source platform BM, community building plays a vital role as the project's success depends on active involvement. Funding-based BM use governance structures that explicitly integrate external developers in decision and developing processes. That is done either by including external developers into the core developer team through a meritocracy or through democratic decision-making processes in which the entire community can participate. In funding-based BMs, the products are licensed under permissive or copyleft licenses. The revenue mechanism is wholly based on financial support from sponsors, sometimes complemented by additional revenue models, such as memberships or advertisements. Professional open-source foundations, such as the Apache or the Eclipse Foundation, are typical examples of the second archetype.

Infrastructure BM (A3) The third archetype consists of commercial firms that provide payable web-based infrastructure, e.g., enhanced cloud computing capacities for the business sector. Their free offering is mostly OSS or a basic version of their commercial offering with limited capacities. Contrary to the previous archetypes, the community does not play an integral role in the value creation process, so almost half of the firms do not engage intensively with the community. This is reflected by the tendency towards a centralized governance structure, reduced communication channels, and the lack of boundary resources that would ease external developers' involvement. Most firms use a copyleft license for their open-source product as derivatives must also be placed under a copyleft license so that it prevents other firms from commercializing the product (Fitzgerald, 2006). That promotes the firm's BM by disseminating the OSS and avoiding potential threats by rival offerings. As the free offering is not used as a primary revenue source, firms of this archetype focus on indirect-sale mechanisms, especially hosting and computing services. The predominant revenue model is the freemium model, which offers a time-unlimited primary offering and a subscription to infrastructure or premium features.

Open Innovation BM (A4) The fourth archetype covers firms that have adjusted their BM to enable open innovation. In contrast to proprietary BM, value co-creation, knowledge transfer, and collaboration play a significant role in open innovation BMs (Saebi & Foss, 2015). The value proposition consists of a free offering based on a platform and additional features by the community. The broad commercial offering consists, for example, of premium versions or features, infrastructure, or physical services tailored for the business sector. It is characteristic that the value network differs from proprietary BM approaches as most firms are granting decision rights and higher responsibilities to proven third-party developers. The value co-creation process and knowledge transfer is supported by various communication channels and interfaces that allow browser-based and on-premise versions. The value architecture is also designed to enable an easy adaption and modification of the open-source components by providing a wide range of developer and application boundary resources. However, compared to the previous archetypes, firms with open innovation BM tend only to provide their core components as open—source products. Accordingly, firms of this archetype increasingly use the dual licensing strategy for their products, e.g., simultaneously using proprietary and permissive licenses. The value finance design block is also characterized by many revenue sources, such as physical services, additional proprietary features, service plans, or financial support.

Open-Core Platform BM (A5) The fifth archetype consists of firms providing a platform, mostly innovation platforms for development that offer their core components as an open-source product. Essential functionalities are available to the community, while additional proprietary features must be purchased. The primary customer segment of the value

[9] https://kubernetes.io/

proposition addresses businesses and consumers. Regarding the value network, open-core platform BMs are less involved with the community than comparable archetypes, such as open-source platform BM or Open Innovation BM, even though they provide multiple communication channels and boundary resources for external developers. However, the governance structure is centralized so that the firm monitors every external input (e.g., change requests or new product features). The archetype's value architecture is based on dual licensing. That is also reflected in its value finance that predominantly uses direct-sale mechanisms, sometimes complemented by indirect-sale, to generate revenues. However, the freemium revenue model ensures a time- unlimited basic offering for (private) users.

Proprietary-like BM (A6) The sixth archetype is most similar to a traditional BM. Most firms with proprietary- like BM provide no or few free offerings but are often built on or around OSS. However, the focus of the value proposition lies in the commercial offering for different customer segments. In contrast to the other archetypes, the value network is a less critical component of the BM. The commensalistic approach is predominantly observed as the company uses open-source products but hardly provides any open-source offerings in return. Therefore, the open-source community plays a less critical role in the value creation process, even though multiple communication channels are provided for their customers. The value architecture is characterized by a proprietary- like approach, as only a few core or complementary components are open source. The firm's offering, such as proprietary software or physical services, is often built on OSS. However, their main product is licensed under a proprietary license. Contrary to the open-core platform BM which seems similar to this archetype, the firms apply the subscription revenue model that does not provide a time-unlimited free offering.

Traditional OSS BM (A7) The last archetype represents organizations that provide "true" OSS as the complete software is licensed under a copyleft license. Most project structures remind of traditional OS projects, as the value proposition primarily targets individuals, and no or few commercial offerings are provided. In contrast to professional firms or organizations, an individual developer often drives the project. The governance structures, such as the community approach or the decision control, depend on the individual's choice.

For example, some developers publish code under an open-source license but do not invest further effort into building an open-source community, while others actively interact with the community. Some developers allow balanced governance structures, whereas others solely prefer to supervise their project. Due to limited resources for the value architecture, the OSS is provided on-premise on external platforms, such as Github or SourceForge. Regarding the value finance block, the financial purpose of the OSS projects is often unclear and therefore "Quasi- commercial" as the profit margins are small. Still, the commercial goal of the project is often not revealed. Most revenue is generated through donations or advertisements. The traditional OSS BMs provide OSS specific to a "developer's personal itch" (Raymond, 2001, p. 23) and sustain themselves through donations or advertisement.

Implications and limitations

Relating to BM literature, the findings increase the understanding of how OSS impacts current research. IS scholars acknowledge the potential of OS to trigger new BMs and to change the logic of traditional value creation without providing guidance on how these changes occur (Chengalur-Smith et al., 2010; Fitzgerald, 2006; Harutyunyan et al., 2020). The research field on OSBMs is still underdeveloped and lacks empirical findings (Saebi & Foss, 2015). Therefore, the paper starts with this research gap by developing a taxonomy that helps researchers understand the nature of OSBMs and their underlying elements. Furthermore, the taxonomy provides the fundament for a shared language to foster a systematic description of OSBMs. By drawing from conceptual and empirical findings, the taxonomy provides a holistic analysis and an up-to-date look into research and technological trends regarding OSBMs. The results contribute to BM research as they illustrate how OSBMs are changing the traditional BM logic by integrating the open-source community into the value creation process. Thus, the taxonomy provides guidance in opening the black box of OSBMs and triggering entirely new BMs based on openness. Furthermore, the seven archetypes support the understanding of OSBMs and demonstrate possible design options for promoting openness in existing BMs. The archetypical patterns illustrate possible options for BM innovation, such as enabling open innovation BMs. As the open-source topic is gaining importance within several industry-driven research projects, researchers can use the findings as a basis to change the logic of how to design BMs in contrast to traditional concepts (Abendroth et al., 2021; Blind et al., 2021; Gentermann & Termer, 2019). In light of the ongoing digital transformation in traditional industries, this is particularly interesting as the successful adaption of traditional BMs to the digital economy poses a challenge in research and practice (Bilgeri et al., 2017). Additionally, we complement the growing research stream of empirical firm classifications in IS research (Möller et al., 2021). In summary, we provide a conceptual base for describing, classifying, analyzing, and conceptualizing OSBMs for further BM research while ensuring practical relevance.

In OSS literature, most research stems from a technological background, such as OSS applications or development, so management aspects are understudied (Aksulu & Wade, 2010). However, open concepts based on OSS are recognized as essential tools in business strategy (Dahlander et al., 2021; Morgan & Finnegan, 2014; O'Mahony & Karp, 2020). The commercialization of OSS in the software industry has increased in recent years and former critics have adopted the open-source concept for their firms creating an extensive body of emerging empirical evidence regarding OSBMs (Novotny, 2021). However, current research lacks empirical studies on OSS and their impact on BMs. The paper contributes to this research gap by aligning the technological and managerial view on OSS through the lens of BM research. We enhance OSS literature by incorporating existing research on OSBMs and empirical findings. The developed taxonomy and archetypical patterns ease the understanding of commercializing OSS and dispel former preconceptions on this topic. The taxonomy combines essential aspects of OSS (e.g., product architecture and community building), BM design (e.g., value creation and capture), and new technological trends (e.g., platforms) from practice. As a result, a domain-specific blueprint is created presenting critical dimensions that could be further investigated from a managerial perspective. Thus, the taxonomy helps researchers in characterizing and structuring OSBMs to understand underlying design mechanisms, which were difficult to analyze in the past. Furthermore, the archetypes make openness more graspable for research as they help to incorporate abstract concepts, such as open innovation or open platforms (Asadullah et al., 2018; Eseryel, 2014). In conclusion, we contribute to the intersection of IS and strategic management research by providing managerial insights regarding OSBMs that surpass the mainly technology- driven perspective on OSS.

Regarding implications for practice, our paper provides several contributions. The research assists practitioners in comparing, analyzing, and designing OSBMs for digital technologies. Due to the taxonomy's holistic nature, the results can be applied to further industry branches, for example, manufacturing or logistics, in which open source is still rarely used. Significantly, this is important, as recent studies indicate the need for a deeper open- source understanding to enable traditional firms to successfully implement OSS in their product offering (Blind et al., 2021; Gentermann & Termer, 2019). The taxonomy facilitates the commercialization of open-source products as it grasps the complex nature of OSBMs. Therefore, the results enable practitioners who are new to open source and open-source experts to create innovative OSBMs. The seven archetypes can act as a blueprint for different design decisions that can be made to conceptualize digital BMs, which strategically enable open-source opportunities. That is especially important in times of growing digital interconnectivity, as the open-source paradigm offers a vast spectrum of potentials for platform growth and development. If practitioners design their OSBMs strategically, they can benefit from the open-source community by enabling open innovation and fueling network effects, which explains the various archetypes (open-source platform BM, open innovation BM, open- core platform BM, and proprietary-like BM) that focus on platform-based offerings. In this context, the archetypes support practitioners in choosing the optimal OSBM for their degree of platform openness depending on their ability to interact with the community and revenue mechanism. Our findings show that OSBMs from the past must be partially reconsidered as new technologies enable innovative OSBMs for value creation. For example, as-a- service offerings are gaining popularity, whereas physical products (e.g., handbooks, disks) are losing importance. Human support services as standalone BMs decrease as they are perceived as commodity services in commercial offerings. In conclusion, the seven archetypes provide practitioners with decision blueprints on designing OSBMs.

Our work is subject to typical taxonomy **research limitations** due to the subjective nature of the development process. First, the authors of this paper identified the dimensions and characteristics, which implies a degree of interpretation. Thus, other researchers might identify different dimensions and characteristics as more important. Furthermore, as our work is restricted to providing a snapshot of the archetypes in time, continuing this work in a longitudinal study would be viable to gain knowledge on the success and failure of the BMs. The analyzed sample includes only organizations that can be found when searching for the term "open source". There may be organizations providing open-source offerings without explicitly highlighting them. To gather further input, software companies, in general, could be analyzed regarding open-source offerings.

The developed archetypes allow researchers to identify **future research** opportunities. One can argue that each archetypical BM merits creating a respective specific taxonomic analysis and the derivation of lower-threshold archetypes as we provide an umbrella of archetypes that only scratches the surface. Open-source platform BM, open innovation BM, open-core platform BM, and proprietary-like BM indicate the need for further research in platform-based BMs based on open source. The shift from physical products to digital infrastructure as complimentary products should further be investigated (see infrastructure BM and proprietary-like BM). Therefore, our findings can act as the starting point for several research opportunities, such as further taxonomic analysis or the derivation of subordinate and more detailed archetypes. Further research can focus on analyzing archetypes that emerge from one another resulting in a maturity model of open-source projects. Also, success factors of existing OSBMs that enable specific open-source potentials could be of interest for practical use to create sustainable businesses. As previously mentioned, our results facilitate the development of domain-specific taxonomies that analyze industry-driven projects that include the open-source aspect, e.g., open-source industrial ecosystems[10,11] or data ecosystems.[12]

Conclusion

Our research produced a taxonomy for OSBMs based on scientific literature and empirical data. The taxonomy design elements are classified into 17 dimensions and 75 characteristics divided into the meta-dimensions value creation, value network, value architecture, and value finance. While previous research only focused on describing commonly used OSBMs based on classic OSS, we created a design framework to analyze the underlying design elements of OSBMs based on new technologies. We examined 120 OSBMs from firms, non-profit organizations, and small projects to enhance the conceptually-grounded design elements by empirical evidence. Afterward, the empirical data was used to identify seven archetypes based on clustering analysis. The derived archetypes giv e insights into commonly used OSBM patterns nowadays. Our research of the archetypes shows that cloud-based technologies, e.g., digital platforms, are high impact factors in the conceptualization of recent OSBMs. In summary, open source evolved from a user-driven paradigm to a promising business tool that fuels open innovation and digital entrepreneurship in recent years.

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[10] https://www.silicon-economy.com/en/

[11] https://open-manufacturing.org/

[12] https://www.data-infrastructure.eu/

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