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The architecture of innovation: how firms configure different types of complementarities in emerging ecosystems

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ABSTRACT

Ecosystems are one of the major trends today. They are based on complementarities, which can take the form of supermodularity or uniqueness and appear on both production and consumption side. Different configurations of complementarity lead to different characteristics of ecosystems with different implications. But which configuration of complementarities is beneficial in a given setting and what are the resulting consequences? We study emerging ecosystems driven by the respective orchestrator. Based on a multiple-case study, we show how and why orchestrators are leveraging different configurations of complementarities depending on, amongst others, competition on ecosystem or value proposition level and uncertainty and the resulting challenges for the orchestrator. These insights provide researchers with a better understanding of the basic mechanics of ecosystems and explain why certain types and structures of ecosystems are more likely to be seen in specific environments. For managers, it helps to sketch the development paths for own ecosystems.

KEYWORDS

Ecosystem; value proposition; ecosystem blueprint; complementarity; ecosystem management

JEL CODE

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1. Introduction: why emerging ecosystems create a new and unanswered question for firms

Over the last years, a new idea has been gaining prominence: the ecosystem concept. It has gained significance in both academic research (e.g. Cohendet, Simon, and Mehouachi 2020; Reischauer, Güttel, and Schüssler 2021; Rong et al. 2021) and in industry practice (e.g. Alturi, Dietz, and Henke 2017; Pidun, Reeves, and Schüssler 2019). Within the umbrella of 'ecosystems', several streams have emerged, with the one focusing on innovation being amongst the most recent and fastest-growing (Granstrand and Holgersson 2020; Thomas and Autio 2020). This paper is focusing on that very stream. The approach is taking existing notions of opening-up the innovation process to the next level (Barge-Gil 2010; Bogers et al. 2017; Beaudry, Burger-Helmchen and Cohendet 2021; de Faria, Noseleit, and Los 2020; Mahdad et al. 2020). From this perspective, the ultimate goal of an ecosystem is to achieve a joint, innovative, value proposition based on the collaboration of several firms, a value proposition, a single firm could not offer in isolation (Adner 2017; Jacobides, Cennamo, and Gawer 2018). This value proposition

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consists of modules provided by the partners, which are complementary to each other. In fact, only if such complementarity is present, applying an ecosystem perspective is necessary. Accordingly, ecosystems are defined as 'a set of actors with varying degrees of multi-lateral, non-generic complementarities that are not fully hierarchically controlled' (Jacobides, Cennamo, and Gawer 2018:18). Complementarity is at the heart of the ecosystem concept, since 'it is precisely this attribute that underpins the particularities of ecosystems' (Jacobides, Cennamo, and Gawer 2018:18). Thus, from a researcher's perspective, understanding complementarity is of utmost significance for an understanding of ecosystems in general (Hannah and Eisenhardt 2018; Jacobides, Cennamo, and Gawer 2018). But there is also a practical side of it: Complementarity can be either supermodular or unique and, since ecosystems involve customers and partners at the same time, it is present on both the consumption and production side (Jacobides, Cennamo, and Gawer 2018). As Jacobides, Cennamo, and Gawer (2018) point out, very different combinations of different types of complementarity on both sides lead to ecosystems with very different characteristics, challenges, and development paths. And this poses a challenge, especially for firms being involved in newly emerging ecosystems. In such emerging ecosystems, complementarity is typically being defined by a central 'architect' of the ecosystem, the so-called orchestrator. This firm comes up with a compelling 'blueprint' of the future ecosystem, which defines central aspects such as the potential value proposition, the modules the value proposition is based upon, and the type of complementarities amongst these modules (Adner 2017; Dattée, Alexy, and Autio 2018; Jacobides, Cennamo, and Gawer 2018). Thus, understanding the effects of different types and configurations of complementarities is of utmost importance for orchestrators in emerging ecosystems in order to come-up with a compelling blueprint (Adner 2017; Jacobides, Cennamo, and Gawer 2018; Lingens, Miehé, and Gassmann 2020). Since ecosystems develop in a dynamic fashion and with constant adjustments to and influences by the external environment (Dattée, Alexy, and Autio 2018; Jacobides, Cennamo, and Gawer 2018; Moore 1993), the configuration of complementarities needs to be adjusted dynamicly and in correspondance to external factors as well.

Therefore, understanding complementarity, its drivers, and effects is of twofold importance: For researchers, since an understanding of ecosystems requires an understanding of complementarities as the core concept that underpins them (Hannah and Eisenhardt 2018; Jacobides, Cennamo, and Gawer 2018). And for orchestrators (and complementors) building-up and engaging in emerging ecosystems, since they need to understand, which type of complementarity on which side is most suitable given the situation at hand. Surprisingly, there is still a major gap in literature on that very topic. This, and the corresponding calls for research (e.g. Hou and Shi 2021), (Jacobides, Cennamo, and Gawer 2018); Nambisan, Zahra, and Luo (2019); Rietveld and Schilling (2021) motivated us to address the following research question: How do orchestrators leverage different configurations of complementarities in emerging ecosystems?

In order to do so, in the subsequent literature section, we explain the literature background on ecosystems and complementarity and outline the research gap in greater detail. Given the novelty of our research question, we apply a multi-case study approach with 8 cases (Eisenhardt 1989). The resulting findings are summarised into an overarching model, which is presented at the end of the findings section. It serves as a foundation for our subsequent discussion and implications, in which we develop

several contributions to research and practice within the literature gap this paper is placed upon. And given the central relevance of complementarity for the ecosystem concept, this leads to several further implications to the field of ecosystems in general. Overall, we show how and why orchestrators are leveraging different configurations of complementarities depending on, amongst others, competition on ecosystem or value proposition level and uncertainty and the resulting challenges for the orchestrator. These insights provide researchers with a better understanding of the basic mechanics of ecosystems and explain why certain types and structures of ecosystems are more likely to be seen in specific environments. For managers of orchestrator firms, it helps to sketch the development paths for own ecosystems and develop a compelling ecosystem strategy.

2. Literature review: what do we know about ecosystems and what is the implication in the context of our research question?

2.1. The foundations of ecosystems and the role of complementarity

Ecosystems according to the stream focusing on innovation are about creating an innovative value proposition (Adner 2017; Jacobides, Cennamo, and Gawer 2018). In their seminal paper, Jacobides, Cennamo, and Gawer (2018) showed that for an ecosystem perspective to be relevant, the modules jointly forming that value proposition are complementary to each other – and this complementarity can take the form of uniqueness or supermodularity. Both forms can appear on the production and/or consumption side. It is important to note that such perspective on ecosystems is not limited to a specific phenomenon – It applies to any setting in which non-generic complementarities on both the production and consumption side are present (Jacobides, Cennamo, and Gawer 2018; Shipilov and Gawer 2020). This could be a platform (e.g. Gawer 2014), a network or alliance (e.g. Niesten and Jolink 2015; Provan, Fish, and Sydow 2007), or even settings within existing supply chains (e.g. Kapoor 2018).

We call such complementarity unique if one module of the joint value proposition cannot function without the other module or if its value is heavily dependent on other modules (Teece 1986). Thus, if one actor fails or leaves the ecosystem, then the ecosystem as a whole is likely to fail (Teece 2016). Unique complementarity on the production site is present if the joint value proposition can only be achieved by joint production standards or coordination. Uniqueness in consumption implies that the value of consuming a single module would lead to far less value compared to joint consumption with other modules (Jacobides, Cennamo, and Gawer 2018).

On the other hand, we call the complementarity supermodular if one module increases the value of the other module but each could still function on its own (Milgrom and Roberts 1990; Topkis 1998). In production, this occurs when coordinated investments in several modules lead to higher returns, higher benefits, or lower costs compared to a setting without coordination (Arora and Gambardella 1990; Cassiman and Veugelers 2006; Shipilov and Gawer 2020). On the consumption side, supermodular complementarity occurs when the use of the value proposition by one party leads to higher benefits for the other parties. A famous case for supermodularity on consumption are the so-called network effects, which are the underlying 'motor' for classical

transaction platforms such as Uber or Amazon (Kumar, Dass, and Kumar 2015; Farrell and Saloner 1985; Parker and Van Alstyne 2005).

A third type is generic complementarity – in production, a generic module can be produced in coordination but can also be produced independently. The same logic applies to the consumption side. It is important to note that an ecosystem perspective is only relevant when we can find non-generic complementarity, i.e. either supermodular or unique, on both sides because only this will lead to the very distinct conditions and characteristics of ecosystems (Adner 2017; Jacobides, Cennamo, and Gawer 2018).

2.2. The implications of complementarity for the management of ecosystems

Due to unique or supermodular complementarity on both sides, partners in an ecosystem are multilaterally dependent on each other and their relationships cannot be broken down to mere bilateral relationships (Adner 2017). Given that dependency, ecosystems position themselves as an intermediate form between market and hierarchy: On the one hand, ecosystem partners need to be aligned towards the joint value proposition. This requires a design aspect, which points towards clear hierarchies. On the other hand, the importance of modules from partners with their own agendas and the partners' multilateral dependency makes it difficult to impose a strict hierarchy (Dattée, Alexy, and Autio 2018; Jacobides, Cennamo, and Gawer 2018). These are important differentiators from mere transaction platforms or supply chains, which are characterised by bilateral relationships, hierarchies, and clear participation rules, as opposed to the multilateral nature of ecosystems and their intermediate form of governance (Adner 2017; Shipilov and Gawer 2020).

Whilst it might be possible for ecosystems to emerge self-propelled, extant research assumes that they are usually driven by focal firms (Dattée, Alexy, and Autio 2018; Jacobides, Cennamo, and Gawer 2018), which also allows such firms to use them to boost their innovation potentials. From this perspective, ecosystems are formed in a partly-designed process driven by the orchestrator. It results in significant coordination efforts for all parties involved (Jacobides, Cennamo, and Gawer 2018). Partners need to be (self-) selected, integrated, and aligned towards the joint innovation. This is a time-consuming process, which requires clear prioritisation of partners and activities and the design of complementarities when building-up and managing ecosystems (Adner 2017; Jacobides, Cennamo, and Gawer 2018). In this regard, the so-called fungibility plays an important role (see Jacobides, Cennamo, and Gawer 2018): A certain level of co-specialisation is required to adapt complementary modules to each other. This requires investments, and the more specific these investments, the lower their fungibility. Thus, the higher the fungibility the easier it might be to convince partners to commit to the ecosystem, since leaving the ecosystem in case of failure or other issues would be equally easier. On the other hand, low fungibility makes it harder to convince partners to join the ecosystem, but given the resulting lock-in effect, they are more likely to stay within the ecosystem (Autio and Thomas 2019; Dattée, Alexy, and Autio 2018; Jacobides, Cennamo, and Gawer 2018).

2.3. The gap in literature on the effects of different types and configurations of complementarities

Surprisingly, only a few works have looked at configurations of complementarities in ecosystems and their drivers and effects so far: Shipilov and Gawer (2020) developed a conceptual framework on complementarities but with a primary focus on creating an understanding of how networks compare with ecosystems. Cennamo and Santaló (2019) investigate on the innovation output of an emerging ecosystem depending on different types of complements. And Ganco, Kapoor, and Lee (2020) are showing the effect of different configurations of complementarity on processes of local vs. distant search. But whilst these works underpin the notion that the type and strength of complementarity are strongly influencing the structure, output, and required management approaches in ecosystems, they do not give specific recommendations for firms choosing or shaping configurations of complementarity in emerging ecosystems. Thus, as confirmed by a recent study of extant literature, this question remains unanswered and is in need for research (Hou and Shi 2021). This is particularly true, since research on emerging ecosystems is generally lacking (with Dattée, Alexy, and Autio (2018), Lingens et al. (2020, 2021), Ritala, Aarikka-Stenroos, and Gnyawali (2020), Wolff and Hakanen (2021) being amongst the noteworthy exceptions).

Beyond this internal perspective, ecosystems need to be studied in relation to their external environment since they are strongly influenced by the latter (Jacobides, Cennamo, and Gawer 2018). This is particularly true since ecosystems are dynamic rather than static constructs and they develop and emerge based on both internal actions and external influences (Lingens, Miehé, and Gassmann 2020; Moore 1993). However, as Hou and Shi (2021) point out in their literature review, there is still almost no research that explains, which types of complementarities are favourable under certain conditions, how this might change dynamically over time, and how the environment is driving or influencing this development. As pointed-out in the introduction and literature part, this question is of utmost importance for both a theoretical understanding of ecosystems and for firms building-up and engaging in ecosystems. This current lack of research motivated us to conduct our qualitative study as explained in the following methods section.

3. Research methodology: a multi-case study approach

Due to the novelty of our research question, we believe a qualitative case study is an appropriate methodology to address our topic (Eisenhardt and Graebner 2007; Yin 2014). This method is specifically suitable to capture patterns, trajectories, and mechanisms with increased complexity and to address novel and under-research topics (Eisenhardt, 1989). As pointed out above, our research question as well as the more general topic of (complementarity in) emerging ecosystems is still very novel and under-researched. Not only because the effects of external factors and dynamics, but it can also be viewed as a complex topic, which justifies the application of a qualitative case study. Even more than a single-case study, a multiple-case study has the potential to produce theoretical findings on a higher level of abstraction and provides a better generalisability (Eisenhardt, 1991; Eisenhardt and Graebner 2007; Ozcan and Eisenhardt 2009). This matches nicely with the

aim of our research since we are amongst the first to study different configurations of complementarity in emerging ecosystems and strive to yield over-arching and broadly applicable findings that can serve as a foundation for future works in this field.

3.1. Case selection

The sample in our multiple-case study consists of 8 cases, with the firm, more specifically the orchestrator, being the unit of analysis. The cases were selected according to several criteria. First, the cases needed to account as ecosystems according to our conceptual underpinnings (Adner 2017; Jacobides, Cennamo, and Gawer 2018). Second, the cases showed a strong variation to allow for theoretical sampling (Eisenhardt, 1991). Thus, the orchestrators being established companies as well spin-offs/joint ventures/start-ups and cases stem from very different industries (Eisenhardt 1989; Ozcan and Eisenhardt 2009). Finally, we aimed to cover all four possible setups of complementarity (supermodular/unique in production/consumption) to carve-out the differences in the approaches based on those differing types of complementarities (Eisenhardt, 1991). As our findings will reveal, not all our cases started with complementarity on both sides. Over time, almost all cases showed supermodularity and uniqueness on both sides but with very different ways of reaching that state. We understand such diverse sample of cases and developments of complementarity makes it more difficult to yield particularly deep findings. But we are doing so mainly for two reasons: First, because what makes ecosystem distinct is the presence and interplay of those different types of complementarities on both sides (Jacobides, Cennamo, and Gawer 2018). Given the lack of research, we aim to be amongst the first works to provide an initial set of findings on that crucial aspect, which will hopefully spark future research going more in-depth on individual findings. And second, doing so will certainly benefit from a very diverse sample of cases because this usually enables pattern recognition and comparison of cases (Eisenhardt, 1991). Please, see Table 1 for an overview on our case sample, which also provides insights on the key partners and orchestrators.

The Tables 2–5 (in the findings section) show in detail the type and configurations of complementarity for every single case and how these have changed over time. Also, they show the emerging pairings of cases and recurring patterns across the case sample.

3.2. Data collection

For our 8 cases, we conducted more than 50 semi-structured interviews lasting on average 30–90 minutes and followed one case (the home case) over 3 years of development (participating at strategy meetings, decision meetings with C-level executives, and more than 20 customer interviews). The in-depth interviews were collected iteratively. A first round was used to get an initial understanding of the ecosystems at hand. In a second round, we gained a detailed understanding of the ecosystem partners, their respective contributions, dependencies, and value propositions and, most of all, conducted an in-depth analysis of the complementarities and how they developed over time. This round was conducted in an iterative manner, going back and forth from data analysis, studies of literature, and further interviews (Eisenhardt, 1991). We furtherly triangulated these findings with external and internal documents, homepages, press

Table 1. Case overview.

Case	Value Proposition	Key Ecosystem Partners	Domestic Market and Number of Employees (Empl.) Orchestrator
Moving	Marketplace for moving and cleaning for private households. Customers can compare different offerings and receive support along the moving process. Further offerings for buying and transporting furniture as well as getting claims for moving and household insurances.	• Start-up as orchestrator, also running the platform • Multitude of moving companies • Multitude of cleaning companies • Multitude of companies offering furniture • Several marketing and business development partners • Insurance company	• Switzerland • Ca. 50 Empl.
Home	Marketplace with services that help customers save time, energy, and resources in real estate search, financing, retirement planning, information about real estate during ownership, refinancing, and selling	• Scale-up as orchestrator, also running the platform. In majority ownership of a large insurance firm. • Insurance company (owner of majority stakes of orchestrator) • Several banks and insurances offering mortgages • Start-up offering micro-location data • Start-up providing crucial software	• Switzerland • Ca. 350 Empl.
Sharing	Peer-to-peer car sharing marketplace. Convenience and security through opening the car via mobile phone without key handover and with integrated insurance in case of an accident	• Spin-off of several larger companies, acting as platform provider as well • Multitude of private car owners and lenders • Developer/producer of box for keyless access to the cars • Software provider • Insurance firm • Car garages	• European country (not to be disclosed) • Around 20 Empl.
3D-Printed Sole	Custom fit footwear based on 3D-printed customised soles. The ecosystem creates both ski boots as well as inlay soles for running/sports shoes.	• Start-up as Orchestrator • 3D-Scanning provider • Morphing partner and 3D-Printing partner • Sports retailer chain	• Switzerland, expansion globally • 2 Empl.
Factoring	Factoring solution for Small and Medium-sized firms exporting goods to developing countries. The ecosystem acquires accounts receivable from these clients and immediately pays the respective amount minus a fee and a risk premium. The latter is comparably low given the ecosystem's innovative approach: A software standardises the risk of the accounts receivables and an insurance firm backs-up those risks, thus creating a new asset class for investors on top.	• Start-up as orchestrator • Insurance company • Funding providers • Banks as customer interfaces	• Switzerland, expansion globally • ca. 10 Empl.

(*Continued*)

Table 1. (Continued).

Case	Value Proposition	Key Ecosystem Partners	Domestic Market and Number of Employees (Empl.) Orchestrator
Insurance	Health insurance with personalised fee based on health condition, general behaviour and living conditions of insured person.	• Start-up/Scale-up as orchestrator, providing health index • Public meta-data provider • Health insurance as customer interface • Re-Insurance company	• Several European countries • Around 40 Empl.
Mobile Payment	Payment and payment services via smartphone app, both peer-to-peer as well as for payments in-store or online. Basically, a competition to Apple/Samsung Pay with added functionalities in terms of peer-to-peer money transfers, parking pay etc.	• Orchestrator, also providing software and integration in supermarkets • Several banks • Several retailers, online shops, stores • Parking invoice operators	• European country (not disclosed) • Around 150 Empl.
Car	Several data-based services around car ownership and driving, such as personalised insurance, refuelling, connected car or data analytics. The data stems from a specifically developed "dongle" that is being connected with the car, reading-out all relevant data.	• Orchestrator, also providing software system • National leading telco provider • National leading car dealership • Several insurances • Several car garages • Several providers of gas stations	• European country (not disclosed) • Ca. 20 Empl.

Table 2. The initial architecture of complementarity when entering the market.

			Resulting Complementarity/Changes in Complementarity	
Pattern/ Case	Challenge/Goal	Solution/Approach	In Production	In Consumption
A: Moving	Mere transaction platforms based on direct or indirect network effects. Weak USP, key is to built-up network effect and large offering as soon as possible.	Quick onboarding of partners with low effort or upfront investments for fast scaling.	In between generic and unique at the beginning, onboarding possible based on standardised interfaces without major adaption of services.	Supermodularity: Moving or cleaning services can be consumed in isolation but have greater value the more offering is on the platform; indirect network effect between customers and moving providers
A: Home			In between generic and unique at the beginning, onboarding possible based on standardised interfaces without major adaption of services.	Supermodularity: Mortgages can be received directly from the issuer but large offering on the platform reduces search costs; indirect network effect between customers and moving providers
A*: Sharing			Unique due to integration of specifically developed insurance solution as well as "box" for keyless access to the cars	Single car rides offer value in isolation but the more offering is on the platform the more choices customers have; direct network effects between peers offering/ renting cars
B: Mobile Payment	Highly innovative technological solution without direct value for the customer; monetarization only in a second step via different use cases. Complex technological core requires strong co-specialisation with high costs for development and resulting risks for partners	Technological core with strong USP, difficult to copy due to complexity of solution. Core needs to have potential to enable various use cases in field with large, long-term, revenue potentials.	Core: unique, all elements of the payment solution need to be tailor-made and specifically developed for the case at hand (e.g. app, Bluetooth-sensor for the cashbox, software) Complements: generic, quick onboarding via log-in/download of app	Core: unique, the payment system can only be used as a whole, usage of individual modules almost of no value (e.g usage of app without the connection to the cashbox) Complements: supermodular. the more users, the more value for the shops. The more shops, the more frequently users can pay via the system
B: Car			Core: unique, all elements of the data collection system need to be tailor-made and specifically developed for the case at hand (e.g. sensors, connectors to the car, telemetry) Complements: generic/unique: quick onboarding via standardised interfaces without large adaptions	Core: unique, the system can only be used as a whole, usage of individual modules almost of no value (e.g. collection of data without analysis, raw data without utilisation) Complements: supermodular. the more use cases and applications, the higher the value of the system

(*Continued*)

Table 2. (Continued).

Pattern/ Case	Challenge/Goal	Solution/Approach	Resulting Complementarity/Changes in Complementarity	
			In Production	In Consumption
C: Factoring	Highly innovative value proposition. Complex technological solution requires strong co-specialisation with high costs for development and resulting risks for partners	Value proposition with strong USP, very innovative, resulting willingness of customers to pay a premium that can be shared amongst partners	Unique: All modules of the value proposition (e.g. insurance, funding, software) need to be adapted to each other or even be specifically developed	Unique: Customers can only use the value proposition as a whole but not its individual components; The latter would provide almost no value (e.g. scanning of invoices and classification of risks)
C: Insurance			Unique: All modules of the value proposition (e.g. insurance, re-insurance, health index, big data analysis) need to be adapted to each other or even be specifically developed	Unique: Customers can only use the value proposition as a whole but not its individual components; The latter would provide almost no value (e.g. specific re-insurance is of no value without the health insurance or the health index)
C: 3D-Printed Sole			Unique: All modules of the value proposition (e.g. 3D-printing, scanning, biomechanical development) need to be adapted to each other or even be specifically developed	Unique: Customers can only use the value proposition as a whole but not its individual components; The latter would provide almost no value (e.g. scanning the foot in order to create a 3D model is of low value if that model is not being used)

Table 3. Changes of architecture of complementarity towards scaling and maturity.

			Resulting Complementarity/Changes in Complementarity	
Pattern/ Case	Challenge/Goal	Solution/Approach	In Production	In Consumption
Á: Moving Á: Home Á: Mobile Payment Á: Car	Further monetarization based on additional value propositions around core offering Attempt to increase efficiency by using analytics and synergies amongst partners	Building-up additional value propositions that are supermodular to the core offerings Building-up supermodularity in production to increase efficiency	Supermodularity, based on both analytics (e.g. comparison of different pricing strategies across complementors to find optimum price, mutual benefit from marketing activities, joint usage of marketplace and resulting spread of costs amongst partners)	New value propositions being supermodular to existing ones, based on both direct and indirect network effects, e.g.: - Moving: Further offerings around moving and cleaning, e.g. buying furniture - Home: Various offerings around property search, evaluation of mortgage seekers, peer-to-peer property marketplace - Mobile Payment: Peer-to-peer money transfers, parking pay - Car: Various services around mobility (e.g. insurance, refuelling, driving safety)
ß: Sharing	Ecosystem did not scale any further due to internal struggles of orchestrator, subsequent acquisition by larger competitor			
ý: Factoring ý: Insurance ý: 3D-Printed Sole	Monetarization of innovative solutions/ technologies	Building-up additional value propositions for further customers, less focus on supermodularity but on attracting further customers; Increasing efficiency; scaling customer base	Spreading costs of production across more value propositions lead to supermdularity in production, e.g.: - Factoring: Wider set of invoices can be covered - Insurance/3D-printed sole: additional national/international sales partners	No changes compared to Table 5; Supermodularities in consumption are less of a goal but scaling the value proposition to as many customers and markets as possible

releases, and other external sources (Yin 2014). Also, we conducted interviews with further ecosystem partners and externals, who have excellent insights into the ecosystems at hand (Jick 1979). Also, since the value propositions of the ecosystems were offered to customers, they were usually published on websites, and in brochures and articles, which allowed for further triangulation and verification. During all interviews, we took notes and made sketches of the ecosystems with the interviewees during our interviews. Furthermore, all interviews were recorded and promptly transcribed, usually in verbatim (Eisenhardt 1989; Eisenhardt and Graebner 2007; Yin 2014). For an overview on our data sources, please, see Table 6.

3.3. Data analysis

Based on the cases displaying the different combinations of complementarity, we developed patterns for how the ecosystems were built-up and, in doing so, identified the

Table 4. Overview of data per case.

Case	# Interviews	Interviewee positions O = Orchestrator company C = Complementor company	Key role of interviewee 1) Top management 2) Partner manager 3) Project manager 4) Ecosystem partner	Interview duration (min)	Additional data	Source (additional data)
Moving (A)	12	Chief Executive Officer (O)	1	66 + 53	Company website	internal
		Chief Innovation Officer (O)	1	24 + 26	Company website and internal documents	internal
		Business Development Manager (O)	2	85 + 9 + 38		external
		Innovation Manager (C)	3 & 4	59	Online articles about the orchestrator in media reports	
		Chief Ecosystem Manager (C)	1 & 4	40 + 37 + 58 + 20		
Home (B)	1	Chief Innovation Manager (O)	1	34	Company website	internal
		Chief Executive Officer (O)	1 & 2	Attended around 50 internal meetings	Company website and internal documents	internal
		Innovation Manager (C)	1 & 4		20 customer interviews	external
Sharing (C)	6	Chief Executive Officer (O)	1 & 2	38 + 41	Company website	internal
		Head of ecosystems (C)	2 & 3	24	Internal company presentations	internal
		Car tenants (3) (C)	4	22 + 18 + 23	Radio & TV reports	external
Factoring (D)	10	Head of Sales & Marketing (O)	1	23 + 140 + 81 + 27 + 22 + 32 + 27 + 81 + 57	Company website documents	internal
		Innovation Consultant (C)	4	36	Online articles about the orchestrator	external
3D-printed sole (E)	4	Chief Executive Officer (O)	1 & 2	101 + 27 + 15 + 34	Company website	internal
					Blog posts & online articles	external
Insurance (F)	5	Chief Executive Officer (O)	1 & 2	80 + 44 + 46	Company website	internal
		Head of Sales Europe (O)	2 & 3	60	Blog posts, newspaper & online articles	external
		Head of Strategy (C)	4	51	Radio & TV reports	external
Mobile Payment (G)	10	Chief Innovation Officer (C)	4	55	Company website	internal
		Head of Marketing (O)	1 & 2	49	Company website documents	internal
		Head Mobile Payments (C)	4	45 + 60	Blog post, newspaper & online articles	external
		Innovation Strategist and Project Manager (C)	4	76 + 61	Radio & TV reports	external
		Former Chief Executive Officer (O)	1	99 + 58 + 58		
		Current Chief Executive Officer (O)	1	48		

(*Continued*)

Table 4. (Continued).

Case	# Interviews	Interviewee positions O = Orchestrator company C = Complementor company	Key role of interviewee 1) Top management 2) Partner manager 3) Project manager 4) Ecosystem partner	Interview duration (min)	Additional data	Source (additional data)
Car (H)	6	Chief Executive Officer (O)	1&2	36	Company website	internal
		Chief Digital Officer (C)	4	49	Internal working documents	internal
		Products Lead (O)	1 & 2	47	Blog post, newspaper & online articles	external
		Managing Director Innovation & Ventures Lab (C)	4	10 + 26	TV reports	external
		Chairman of the Board of Directors (O)	1	45		
Total	54			2521		

Table 5. Changes of architecture of complementarity to create lock-in of partners and customers.

			Resulting Complementarity/Changes in Complementarity	
Pattern/ Case	Challenge/Goal	Solution/Approach	In Production	In Consumption
I: Moving	Partners and customers can easily enter the platform but leave equally easy.	Lock-in effect by increasing co-specialisation, also to increase stability given competing ecosystems. This co-specialisation needs to lead to higher value for customers and partners	uniqueness, by stronger integration of complementors by admin/ pricing software; Integration of customers based on personal support in the moving process	No changes compared to table 2
I: Home			uniqueness, by taking-over the background check of customers	No changes compared to table 2
II: Sharing	Already some lock-in due to the keyless access box and specific insurance that requires some level of integration of partners		No changes compared to table 2	
III:Mobile Payment	Already strong lock-in of partners into core due to high levels of co-specialisation due to unique modularity. Customers are locked-in based on USP and unique position of value proposition on the market		No changes compared to table 2	
III: Car				
IV: Factoring				
IV: Insurance				
IV:3D-Printed Sole				

challenges that occurred throughout the process as well as the factors influencing it. We started from the initial complementarities when the ecosystems' value propositions were offered on the market for the first time and looked at the changes of that complementarity over time. We followed the ecosystems over a time of several years until the value propositions either showed both types of complementarities on both sides or once they seemed to be in a stable condition without projected major changes in complementarity. This can lead to a potential limitation since we do not know whether the ecosystems will change again in the future. However, since we are focusing on emerging ecosystems, we view this limitation as being acceptable, since our aim is to show how orchestrators can configure complementarities at the start of an ecosystem initiative. Since all ecosystems brought their value propositions to the market and adopted them to the challenges they were facing, at the end of our data collection/analysis, we view all cases entering the 'expansion' or even 'leadership' phase according to Moore (1993), which hints towards them becoming established ecosystems. Thus, we believe this is the right moment to stop the analysis (please, also see Dattée, Alexy, and Autio 2018). In our analysis, we studied the complementarities on both sides, and we specifically looked at the reasons for changes of those complementarities. In this sense, aspects surrounding co-specialisation and fungibility, the influence of competition, and lock-in of partners appeared to be the most interesting ones, which is why our findings section is strongly focusing on these. Whenever unsure, we went back to our respondents to gather additional information on those mechanisms. Accordingly, the data analysis followed an iterative approach, with constant iterations between emerging findings and literature. Throughout our findings section, we are explaining the complementarities and their

Table 6. Changes of architecture of complementarity because of competition.

			Resulting Complementarity/Changes in Complementarity	
Pattern/ Case	Challenge/Goal	Solution/Approach	In Production	In Consumption
a: Moving	No changes compared to table 5 since competition has not increased significantly over time	No specific adaptions to competition since competition remained low	No changes compared to table 5	No changes compared to table 5
b: Home	Increasing competition by other mortgage and home platforms	Development of further, unique, value proposition (property search), which is increasing the value of the core value proposition and vice versa	No changes compared to table 5 in terms of core offering. But further value proposition (property search) based on uniqueness; Its modules can be used in isolation (e.g. property valuation, property search) but are offering less value than a combined usage that allows for, amongst others, total-cost-of-ownership calculations	No changes compared to table 5 in terms of core offering. But additional value proposition (property search) is supermodular to core offering: both can be used in isolation (e.g. searching for property without getting a mortgage from platform; getting a mortgagae for existing property) but combined they offer more value (search, all necessary cost calculations and the cheapest mortgage from one hand with few clicks)
b: Sharing	Fierce competition in the mobility sector from the beginning onwards	USP from the beginning onwards due to specialised, unique, modules (keyless access box and insurance)	No changes compared to table 5	No changes compared to table 5
c: Mobile Payment c: Car c: Factoring c: Insurance c: 3D-Printed Sole	Already strong USP due to high levels of co-specialisation due to unique modularity of the core technology/value proposition		No changes compared to table 5	

changes and use the Tables 2–**5the one presented byHome and Moving** to show those aspects in detail.

Two of the authors conducted the within-case analysis independently from each other and subsequently discussed their perspectives. This was followed by a cross-case analysis to compare the emerging patterns and derive approaches depending on the complementarities. Specifically, we discovered patterns of emerging results and sought to understand how and why these patterns were different from each other (Ozcan and Eisenhardt 2009). The following sections show our findings. The order of the sections from 4.1 to 4.4

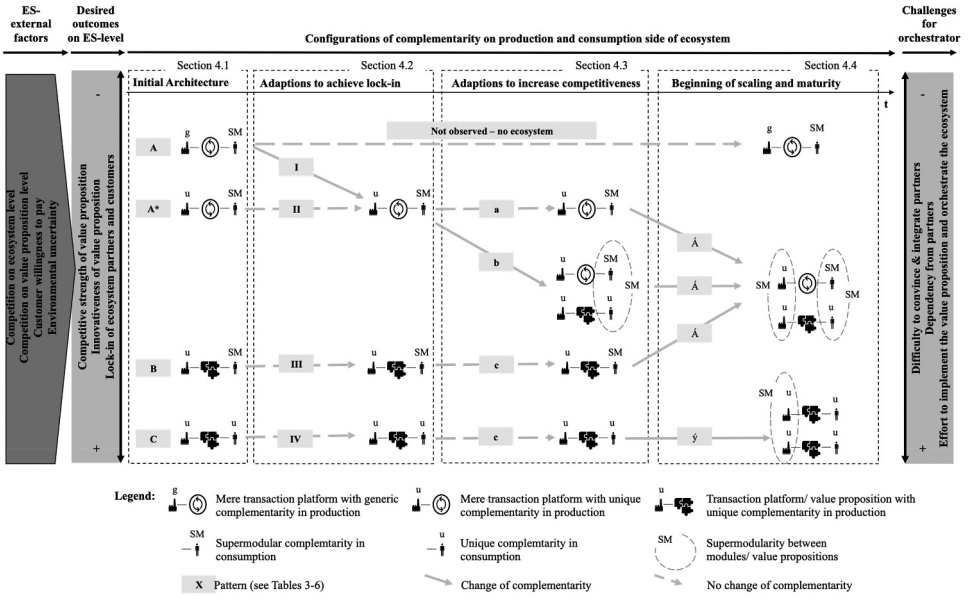


Figure 1. Overarching model of findings.

indicates the temporal order, in which complementarities were being implemented or changed. They are summarised by a model (please, see Figure 1) introduced in section 4.5 that shows the temporal order of the observed patterns, trajectories of the resulting developments of the ecosystems and, thus, connects the findings sections.

4. Findings: how firms configure different types of complementarities in emerging ecosystems

4.1. The initial architecture of complementarity when entering the market

In three cases (Moving, Home, and Sharing), the initial idea for the ecosystem was that of a 'traditional' transaction platform – In the case of Moving, it is all about connecting moving and cleaning companies with private households. Home is about offering mortgages, and Sharing is a peer-to-peer car rental platform, basically the AirBnB for cars. For a quick onboarding of partners, the orchestrators in the Home and Moving case were focusing on supermodularity in consumption and generic complementarity in production. The standard moving services or mortgages provided by the partners were sold via the platform, without significant integration of those and resulting low co-specialisation. This allowed for easier onboarding of the complementors and, consequently, facilitated building-up a network effect based on complementarity on consumption (e.g.: the more mortgages offered via the platform, the more attractive it is for the customer, the more customers are going to use the platform, and the more it becomes attractive for the mortgage provider, and so on). Thus, at this stage, both cases would not even account as an ecosystem since there was only generic/weak unique modularity present on the production side. In the Sharing case, there was unique complementarity present from the very beginning onwards: instead of just connecting private car lenders and car

tenants, they integrate a special box into the lenders' cars, which allows for keyless access, thus simplifying the rental process. On top of this, an integrated and specifically developed insurance is taking over all potential damages caused by the tenant. Thus, Sharing can be considered a sub-pattern of the one presented by Home and Moving (see Table 2).

The cases 3D-Printed Sole, Factoring, and Insurance represented a different pattern at the beginning: The cases were characterised by unique complementarity on both sides. In the Factoring case, the orchestrator, together with the ecosystem partners, started an ecosystem initiative with the goal to create an innovative factoring solution for small-and -medium-sized firms (SMEs). This value proposition required intense coordination and co-creation of modules, leading to uniqueness on the production side. Since customers can only buy all modules together and, given their strong co-specialisation, those modules can only be consumed together, this results in uniqueness in consumption as well. Same for the cases 3D-Printed Sole and Insurance (for a description of the respective value propositions, please, see Table 1).

In the cases with uniqueness on both sides, the value propositions were highly innovative, because they were the first on the market and, given the uniqueness in production, they were more difficult to copy. But this was also necessary due to the required levels of co-specialisation, which caused significant up-front investments by the complementors, as the CMO of the factoring case describes:

> *We have been working for 4 years to ensure our niche product is really good*

But, in return, they were hoping for a superior and very innovative product that allowed for long-term earnings and differentiation once it would be on the market. Accordingly, these ecosystems started with a strong focus on understanding the customer's pain points and sketched a superior solution that would outperform everything that was there already, as in the Payment case:

> *The customer does not download an extra app for everything, our solution offers everything conveniently from one source. [. . .] Whatever you need when it comes to cashless transactions is covered, such as parking, donations and so on*

Based on the resulting strong business case, orchestrators could convince the partners to commit to the ecosystem and stay with it, despite of the low fungibility caused by significant co-specialisation. The CEO of the 3D-Printed Sole case describes that as follows:

> *That's why you have to totally convince people, in the sense that they can't drop you, because you can't just go to the next one*

Finally, the cases Mobile Payment and Car represent a third initial pattern, which is a mix of the two described above. The orchestrator of Car built an ecosystem to achieve an innovative device, which can be integrated into a car to collect and analyse a wide variety of car data. As with the cases described above, uniqueness in production was necessary to co-develop all modules needed for this device, and, since those modules are only work in combination with each other, this leads to uniqueness in consumption as well. But the collection and aggregation as well as analysis of car data per se is worthless. It only served as a foundation for additional services the orchestrator intended to add on top of that unique core. Same for the Mobile Payment case. At the beginning, in both cases, the

orchestrators had only rough ideas on the use cases they might enable with that unique core. But that vision was enough: They knew that such unique core, being the only one on the market and very difficult to copy, would allow them to build-up a variety of use cases. This is also shown by the following quotes:

> *'In the beginning, we went into depth on the payment issue [i.e. developing the unique core], before we went into breadth'* (G) and: *'But you can't buy anything big with it [the core]. It will only be of use when you start sharing this data with the ecosystem, because then you can use it as a foundation for further services'*

These findings are summarised and presented case-by-case in the following table:

4.2. Adaptions of the architecture of complementarity to create lock-in of partners

After an initial phase, in which the value proposition developed successfully on the market, the architecture of complementarity in some of our cases changed again. There was a major driver for that: lock-in effects. A core challenge in all cases characterised by supermodularity in consumption was to retain the partners. The underlying motor in such cases were direct or indirect network effects. And these require quick onboarding of partners to increase the number of complements on both sides of the platform (Gawer 2014). Quick onboarding, with low levels of co-specialisation, however, usually means that partners can leave equally easily. And this can lead to a collapse of the network effect (Jacobides, Cennamo, and Gawer 2018).

In the Moving and Home cases, the orchestrators where aware of that problem and of another one, that was directly related to that: The orchestrators realised that they had to integrate the complementors into the platform to improve customer value and, most of all, get a better control over the complementors. In the Moving case, for instance, there was an issue with complementor firms finding customers via the platform and subsequently trying to close the business directly with the customer to avoid the platform's transaction fees. As a response, the orchestrator moved away from just being a mere transaction platform where complementors and customers are only weakly integrated (besides a log-in). Instead, they assigned employees to personally manage the customer's moving process on the one hand and, on the other hand, offered administration and tax software for the moving firms. Thus, the value proposition changed accordingly:

> From just *'offering comparable, transparent, easy to book, online moving' to 'simplifying the complicated and unpleasant moving process for the customer as much as possible'*.

Also, they created a tool for pricing recommendations, improved the tool for the processing of private orders, and developed software to digitise internal processes related to the move, as the CEO explained:

> *These services were a request from certain complementors and we did this in order to collect even more data and to achieve a better lock-in effect*

Same in the Home case: Instead of just offering a platform comparing interest rates for mortgages, the platform quickly took over even the process of validating the customer as well. That process is normally being conducted by the issuer of the mortgage. However,

customers tend to approach several issuers (e.g. banks or insurances) to get the lowest fee and each of them needs to do the full customer check whilst only one will ultimately sell a mortgage. Home is conducting the process centrally, in compliance to the individual issuer's rules, saving them costs and effort.

Thus, as already described in section 4.1, the orchestrators tried to create a further lock-in effect. However, to not create unnecessary barriers to enter, they tried to do so by offering a tangible added value for the complementors. In the moving case, besides the software solutions for administration, the service offering for partners was extended. The home case offers its partners added value, creating lock-in effects by linking banks and insurance companies more and more closely, so that mortgages are ultimately released via the platform. Thus, banks are saving time since they do not need to conduct a review of potential mortgage customers.

Taken together, all three cases characterised by supermodularity on consumption switched from generic complementarity in production to unique in production. The necessary integration of the complementors leads to higher degrees of co-specialisation and lower fungibility, making it potentially more difficult to convince the complementors to join the ecosystem and to build-up network effects by rapid scaling (Dattée, Alexy, and Autio 2018). However, it also allowed for better control and lock-in of the complementors and customers. In an attempt to address this trade-off, in all three cases, the aim was to offer complementors and customers a value-add in return for the necessary higher co-specialisation and reduced fungibility of investments: The free software in the Moving case, the increased efficiency in the Home case, and keyless access and handover plus insurance in the Sharing case.

The cases characterised by unique complementarity in production and consumption, however, had a lock-in effect by default due to the strong co-specialisation: If a partner has invested significant time and resources for building a value proposition based on unique modules, arguably, this partner will not leave the ecosystem once that value proposition is on the market and creates returns. Thus, whilst it might be easy to convince partners to commit to the ecosystem but more difficult to retain them in case of supermodularity in consumption and generic complementarity in production, the situation is exactly the other way round in cases of uniqueness on both sides. But the reasoning is the same: The increased co-specialisation and reduced fungibility needs to be compensated, in this case, by making the complementors a part of a superior value proposition and resulting business case.

The cases characterised by supermodularity on consumption but a core based on unique modules (Car and Mobile Payment) show a mixture of both perspectives: Due to the unique core, the platforms showed a strong USP (Unique Selling Proposition) and were quite unique on the market. This made is very attractive for potential complementors to join, as the CEO of Car stated:

> *We check for partners and approach them. But the partners are also coming by themselves. They approach us by themselves and say 'hey, we definitely want to work with you'. As for instance [mentions the name of a partner]. And then, we listen to what they are offering and ask ourselves whether this is interesting for us. If so, we sit together and make a plan on how to integrate them".*

Thus, even so the complementors providing modules with supermodularity on consumption were not bound to the core based on unique complementarities and increased co-specialisation, they stick to the ecosystem because it offered a unique value for them (in the Car case: access to customer data; Payment case: additional convenience for end-customers and efficient payment services). Similar to the cases with supermodularity in consumption without an innovative core, the partners were bound to the ecosystem by that additional benefit. But that was not created after the go-to-market, but before as a part of the platforms' innovative core. As a consequence, the complementors were bound to the ecosystem but, since there was not a major co-specialisation with the ecosystem's core, they could be removed more easily without harming the ecosystem:

> *'Yes, for sure, we would always remove a partner if needed. Sure, we have a letter of intent and, in later stages, a contract. But this can be cancelled on a monthly basis. In case we realise that it does not work with that partner, we are not getting along with each other, then, for sure, we would end that collaboration very quickly. Makes no sense to have someone in the ecosystem who does not deliver value'.*

These findings are summarised and presented case-by-case in the following table:

4.3. Adaptions of the architecture of complementarity because of competition

Another change of the architecture of complementarity happened due to the USP of the value proposition: Our analysis has shown that the intensity of competition and the market environment determine which type of complementarity is appropriate. The three cases starting with supermodularity on consumption (Moving, Home, Sharing) did not face significant competition in the beginning, since they were amongst the first on the market. As an example, the CEO of Moving stated:

> *'There was no single offer comparable to ours in this fragmented and heterogenous market for moving companies [. . .]. We do not have so much direct competition. [. . .] The online comparability of moving services and us accompanying the customer through the entire moving process, plus the additional services around it, that doesn't exist on the market'.*

The same was true in the Home and Sharing cases. By contrast, in the Home case, there was not much competition either, but only at the beginning. Within a few years, around 10 different competitors hit the domestic market and started gaining market share. Such ecosystem, characterised by supermodularity on consumption, is merely integrating existing solutions customers could source elsewhere as well. Thus, they do not offer a significant USP. If competition is rising, it becomes essential to create a USP for the ecosystem:

> *'A key was, from my perspective, to find out where we can deliver the greatest added value for the customer. There are various ecosystems that came up recently. And, therefore, we need to find out what we can credibly deliver on top of what we already have and what we as an ecosystem are really good at and better than others'.*

Thus, we see a major difference in the development of the ecosystems characterised by supermodularity on consumption: The ones that had never been facing a massive competition (especially Moving) continued with their existing architecture of

complementarity. In case of rising competition, however, they were trying to create an additional USP.

In the case of Home, this happened by adding unique modules to the ecosystem, which were supermodular to the existing ones: Jointly with two new partners, the orchestrator created a completely new solution for property search (including price estimations) based on uniqueness in consumption and production. It could work as a stand-alone solution but is being offered via the platform of Home. In doing so, it is unique in production and supermodular in consumption to the core value proposition of Home (the transaction platform for mortgages): Customers using the property search would not only find a property but also receive estimations for the property's market value, total costs of ownership, and so on. The fees of the cheapest mortgage (provided by the mortgage platform) are automatically included into that calculation (leading to uniqueness in production). And whilst both, the mortgage platform and the property search, would work in isolation, they create most value for the customer when being used together (leading to supermodularity in consumption).

A similar situation was present in the Sharing case. However, in that case, even though the very specific offering of the ecosystem was unique on the market, there were a multitude of other services around mobility present on the market already and international competitors such as Uber posed an additional threat as well (the ecosystem orchestrator was being acquired by one of those existing competitors several years later). Thus, the specific solution offered had to be competitive from the very beginning onwards. The means to achieve that end was similar to the Home case: the unique modules (insurance and the keyless access) were added as further, supermodular, modules to the core value proposition.

The same pattern, but from the perspective of a failure case, can be observed in the Home case 1.0. The orchestrator in this case, a leading insurance, was building-up an ecosystem based on supermodularity in consumption and weak uniqueness/generic in production. But several other large banks and insurances were doing the same, based on the same architecture, in the same market. However, they did not add any unique modules. Ultimately, the ecosystem never managed to grow and differentiate itself against that competition. Since the insurance had majority stakes in the orchestrator of Home, they decided to discontinue their own ecosystem activities and become a mere complementor in the ecosystem of Home, which was chosen to built-up the solution based on uniqueness in production and consumption. As the Head of the Ecosystem initiative of Home 1.0 stated:s

> *. . . [the orchestrator of Home] is better than us when it comes to building-up unique services, so we shift the role of the orchestrator to them. We are still in control of the ecosystem because of our stakes but we let them do more of the work*

Thus, whilst Home 1.0 was discontinued, the ecosystem initiative of the orchestrator was furtherly driven by the orchestrator of Home, but his time with an approach that relied on uniqueness in consumption and production to cope with the competition, as explained above. This clearly hints towards uniqueness in production and consumption being more suitable in competitive setups.

Accordingly, the cases starting with uniqueness in consumption and production (e.g. Factoring, 3D Printed Sole, Insurance), were being built-up in very competitive markets

from the beginning onwards. In the factoring market, there have been many traditional solutions around the assignment of credit for years:

> *The market is very small, but we can offer an alternative to factoring, where there are already many players.*

But the fully unique solutions have a strong USP and offer something, others can't:

> *What makes us unique is that we are still the only industrially manufactured individual product in the footwear sector.*

And the very same logic is present in the Insurance case:

> *The reason for this is certainly because the competition hasn't slept at all. [. . .] Maybe that's why we deliberately do things differently. [. . .] What definitely makes us unique is the setup with such strong firms that have built the solution together.*

The cases characterised with uniqueness in production and consumption that are commercialising themselves via supermodularity in consumption (Car, Mobile Payment) were in a similar situation. Their unique core created a strong USP, which did not force them to add further unique complements. It has to be noted that Mobile Payment was founded as an answer of established payment providers to Apple Pay and Samsung Pay. Thus, per definition, they were significant competition from the beginning onwards. However, due to their unique core, they managed to compete, even though they did not add further unique complements outside of the core (we will provide more insights on that matter in the following section). These findings are summarised and presented case-by-case in the following table:

4.4. Further adaptions of the architecture of complementarity towards scaling and maturity

After the successful go-to-market, all our cases went through further changes of their architecture of complementarity. In an attempt to scale the ecosystems, orchestrators in some cases characterised by supermodularity in consumption (Home, Moving, Sharing) were focusing first on establishing direct or indirect network effects. For instance, Home and Moving tried to increase the number of mortgage/Moving providers on one side, Sharing of private lenders willing to offer their car on the platform, and all platforms performed intensive marketing on the customer side to increase the number of users. All of this can be expected based on existing literature on platform ecosystems (e.g. Farrell and Saloner 1985; Parker and Van Alstyne 2005). However, very soon, they tried to add further offerings to their ecosystems to support the network effects and increase revenues. To do so, all additional offerings were supermodular to the existing ones. In order to achieve that supermodularity, the new offerings were built around the existing core. The CEO of Moving explains that very nicely:

> *'Focus, focus, focus [. . .]. The most difficult topic of them all is to develop a first core.[. . .]. In the beginning you need one or two core market fits to earn money, retain users and generate growth. With limited resources, it is therefore essential to address an issue relevant to the customer and to strengthen the core offering'*. And another quote of the same person:

> *How can we achieve higher customer satisfaction, better stickiness [. . .] Does it really fit into our USP, into our branding, into our platform thinking.*

As described in the previous section, competition remained weak in the Moving case, which is why they were able to focus on adding supermodular modules around the initial core offering. Whilst this might not have created a particularly strong USP, it allowed them to address more customer demands, increase revenues, and support the existing network effects. Over time, an e-shop for vouchers was added to the moving case, followed by automated SMS and emails to act as a reminder function for customers. Final cleaning, removal insurance and a box store were also added to make the offering more attractive for customers by allowing them to use multiple services together.

Same for the cases with supermodularity in consumption, which started based on a unique core (Car, Mobile Payment): Extending the offering was particularly important, since it took a comparatively long time and many resources to build that core. Once it is ready, the orchestrators tried to commercialise it as much as possible:

> *The customer does not download an extra app for everything, it must come conveniently from one source. [. . .] Whatever is lost through mobile payment in cashless transactions must also be covered, such as parking, donations and farm stores, etc.*

In comparison, the cases starting with uniqueness in consumption and production, without any supermodular complementarity, were scaling differently. In all those cases, it took a few years (1.5–3) to bring the initial value proposition to the market due to the challenges arising through high levels of co-specialisation (see previous sections). But once the value propositions were on the market, orchestrators tried to scale by simply selling more products and without trying to extend the core offering. This is, since those cases were all focusing on bringing that very innovative value proposition, characterised by a strong USP, to the market. And if an ecosystem has such strong value proposition, it is no surprise that the orchestrators were focusing on selling the products or services as often as possible.

In all cases, they did so (besides the usual marketing activities) by adding further customer interfaces to the ecosystem: 3D-Printed Sole involved further sporting goods retailers. Factoring involved further banks and brokers to sell their solution. And Insurance attracted more insurance companies willing to sell their product to their existing customers as a white-label solution. It became obvious in all these cases that, after investing so much time, effort, and resources into the development of the respective product, the ecosystems were focusing on just selling those products and generate returns. In case further products were added to the portfolio, the main driver was not complementarity but to utilise the existing technologies and create additional products or services without major development costs, as the CEO of the 3D-Printed Sole case explained:

> *Everything we do is always based on the same technology and on the same basic idea, which is to bring truly customised sports goods to the market.*

Accordingly, besides the 3D-printed ski boot, they also created inlay soles for running, cycling, or hiking shoes. Same in the factoring case: They were focusing on their core factoring solution but built further factoring solutions, based on the same approach and same technologies. This was done by integrating further insurance companies, which

allowed them to insure different risks and, thus, create a wider range of factoring solutions. But they focused on maintaining the ecosystem as it was without major changes, as the CMO explains:

> *'It was basically because of the insurance. They did not want to cover other types of risks. So, to extend our factoring solutions to different credit needs, we had to work with further insurance companies'.*

Unlike the cases that were based on supermodularity in consumption, the aim was not to increase the effect of supermodularity on consumption. Instead, it was about attracting more and different customers:

> *We have a strong core, that's great. But no matter how strong the core is, if it is simply attractive to too few people, then you just need another strong core that you can offer to other people.*

Besides scaling the offer, most ecosystems were improving internal efficiency by building-up supermodularity in production. In the cases focusing on supermodularity in consumption (e.g. Moving, Home, Sharing, Mobile Payment, Car), extending the offers on the consumption side let to the involvement of an increasing number not just of customers but also of complementors over time. And this allowed the orchestrators to gather data and improve the offerings on that ground. An executive from the insurance firm being a complementor in the Car case explains that nicely:

> *'And of course you need data. We do not need data specifically about how . . . [says the name of the interviewer] is driving. But I want to know: Are you driving in a city? On the countryside? Motorway? Daytime? At night? Short distance? Long distance? How old are you? That's necessary to optimise the insurance solution'.*

Same in the Moving case, as the CEO states:

> *I believe if anyone would try to copy us it would not take much longer than 9 months. But that's pointless since what sets us apart are our user-insights. [. . .]. And yes, I believe that is increasingly becoming our strength, the user-insights, the data, the knowledge about what customers are doing.*

Thus, supermodularity in production in these cases emerged out of an increasing number of customers and partners over time, which led to an increasing amount of data, and, thus, the chance to optimise the offerings. The situation in the cases with uniqueness in consumption and production and no supermodularity in consumption (Factoring, 3D-Printed Sole, Insurance), building-up of supermodularity in production appeared to be more difficult. Due to the strong co-specialisation, those cases were characterised by only a few modules and partners to keep complexity and coordination efforts as low as possible. Arguably, this decreases the potentials for strong overall supermodularity. However, the Factoring case shows that some levels of supermodularity in production are possible even in those cases: By integrating more partners providing the same complement (in this case: insurance solution), the offer can be scaled to more customers, which helps to spread the costs of the other complements across more customers. These findings are summarised and presented case-by-case in the following table:

4.5. Synthesis of findings into an overarching model of how to define and utilise different types of complementarities in emerging ecosystems

Our findings, summarised in Tables 2–3, are integrated into one overarching model. It does not only yield an overview on our findings and links sections 4.1 - 4.4 and Tables 2–3. It also yields direct implications for practitioners on possible development trajectories of their ecosystem and adaptions of the architecture of complementarity given certain boundary conditions. From the left, it shows the (ecosystem-) external factors that influence the desired outcome on ecosystem level. For instance, competition for the ecosystem's value proposition makes it desirable to increase the value proposition's competitiveness. These outcomes are getting stronger towards the bottom (vertical axis). The middle section shows the different configurations of complementarity and the patterns of how that complementarity was being changed or adapted over time to achieve those stronger or weaker outcomes. On the right, the figure shows the challenges these configurations have for ecosystem orchestrators (stronger towards the bottom, vertical axis). Accordingly, moving from the top to the bottom of the figure, the competitive strength of value proposition, its innovativeness, and lock-in effects are increasing (desired outcomes on ecosystem level, on the left). But the same is true for the challenges for the orchestrator, namely the difficulty to convince and integrate partners, the dependency from the partners, and the investments needed for implementing the value proposition. Consequently, orchestrators need to purposefully choose the configuration of complementarities that is most suitable given the situation at hand and balance the desired outcomes with the challenges.

It is important to note that the figure shows the developments over time as seen in our cases, which does not imply that the very same order or development must be present in any given setting. As with any innovative initiative, the built-up of a de novo ecosystem is likely to start with a minimum viable solution as an initial configuration (shown on the left). On the other hand, when emerging ecosystems reach the phase of maturity and scaling, it is also likely that they will extend the existing offering towards the customer and partners to make more revenues and try to fix issues that will have arisen during their development. Thus, the starting point and the endpoint of the ecosystem configurations as shown in our figure are likely to be present in other ecosystems initiatives as well. However, one can expect that ecosystems will not optimise their configurations of complementarities to increase lock-in of partners/customers or strengthen the USP of the value proposition if there is no external competition on ecosystem or value proposition level (as demonstrated by the Move case, for instance). Thus, arguably, we might not find the changes, or at least not all of them, being shown in the middle of the model (related to section 4.2 and 4.3) in such situations.

Neither the patterns nor the specific architectures of complementarity are directly explained in the figure. Instead, we use the same names for the patterns in the figure and in Tables 2–3 and show (please, see the dashed frames), which patterns or configurations of complementarity are being explained in which section of the findings. Thus, the figure serves as an overview on our findings, linking the observed patterns in our findings, and summarised the detailed explanations on both patterns and configurations of complementarity as shown in the findings and Tables 2–3.

5. Discussion and implications for theory and practice

5.1. Discussion and implications on how to define and utilise different types of complementarities in emerging ecosystems

As explained in the introduction and literature review, there is a major gap in literature on the effects and how to define and utilise different types of complementarities in emerging ecosystems (Hou and Shi 2021; Jacobides, Cennamo, and Gawer 2018; Nambisan, Zahra, and Luo 2019; Rietveld and Schilling 2021). The model introduced in the previous section is directly adressing that gap by depicting different configurations of complementarities given the situation at hand and the resulting outcomes and challenges. And it allows to derive further implications for theory and practice along these lines:

Even at first glance, one can see that the ecosystems/configurations of complementarity shown below in Figure 1 appear to be more stable over time. They do not seem to require much adaption to create lock-in effects or to increase the value propositions' USP as a response to external factors such as rising competition on ecosystem or value proposition level. These configurations are only being changed at a later point in time, when entering the phase of maturity and scaling. On the other hand, the ecosystems/configurations of complementarity displayed above in Figure 1 appear to be less stable and require constant adaptions to external drivers over time, for instance when competition is rising, or further lock-in effects are needed to avoid losing partners to competing ecosystems. Based on our findings, we can explain that:

First, we can observe that unique complementarity in production typically leads to higher levels of co-specialisation and less fungibility compared to generic complementarity. This is positive, since it leads to a lock-in effect of partners, which might increase the ecosystem's stability over time, especially when confronted with competing ecosystems that try to lure partners away from the current one. But it also makes it more difficult to convince partners to commit to the ecosystem. Thus, we can observe two trajectories: The ones shown above in Figure 1 start with generic complementarity in production but, over time, they intend to lock-in partners and customers by trying to switch to unique complementarity in production. Ecosystems that start with unique complementarity in production, however, do not need to create further lock-ins over time, making them more stable in this regard. Arguably, such stability of the partner structure is beneficial in situations of strong competition by other ecosystems, which might try to attack the ecosystem by pulling its members away and into their network. Second, on the consumption side, we found that supermodularity is likely to create a lesser USP of the ecosystem's value proposition compared to uniqueness. Thus, ecosystems with unique complementarity in consumption (configurations below in Figure 1) are more likely to perform well in competitive environments and do not require adaptions in case of rising competition on value proposition level. On the other hand, ecosystems with supermodularity in consumption are likely to struggle in more competitive conditions. Such ecosystems can start with supermodularity in consumption in case competition is low and, if competition increases over time, react to those conditions by creating further value propositions based on unique complementarity on production and consumption. These value propositions should be supermodular to the existing value proposition in order to increase its competitiveness (As demonstrated by the Home case

and displayed, for instance, by pattern b in Figure 1 and explained in section 4.3). Taken together, partner and customer lock-ins are driven by unique complementarity in production whilst competitive strength stems from unique complementarity on the consumption side. Thus, ecosystems starting with uniqueness on both sides (trajectories shown below) do not need much adaption over time when lock-in effects are needed or an increase of the value proposition's USP is required. Those starting with supermodular/generic complementarities on either side, however, (the ones shown above in Figure 1), need to adapt whenever the conditions are changing.

This is an important finding for practitioners since it clearly shows the configuration of complementarity being most favourable given the situation at hand. And it shows that the more ecosystems rely on unique complementarities, the more stable they are over time: Ecosystems based upon generic modules or supermodularity can more easily adapt to changing conditions over time. In case of uniqueness on one or even both sides, however, the ecosystem is very much set to the path of bringing the value proposition to the market and scaling it. This is nicely shown by the apparent stability of the configurations shown below in Figure 1 (and explained in section 4.1). Thus, such ecosystems need to start with a very strong value proposition from the beginning onwards and are likely to be less dynamic and stick to the existing path of development having been set early-on. This also leads to the implication that ecosystems with uniqueness on one or even both sides take longer to bring their value propositions to the market but once they achieve that, they are likely to perform strongly and with excellent USP and stable configurations of complementarity. As explained in the findings, however, this only works if customers are willing to pay a price high enough to compensate for the higher risk and effort of orchestration caused by such configurations. Those with supermodularity in consumption (regardless of type of complementarity in production), however, might be faster on the market and achieve quicker returns. But they might need constant adaptions and changes over time when external conditions are changing (as shown above in Figure 1). On the downside, the more generic or supermodular complementarities are in place, the more adaptable they are.

This leads to implications for theory as well: Lingens, Miehé, and Gassmann (2020) showed that ecosystems being confronted with stronger environmental uncertainty should remain small with few partners and maintain loose connections to those to be more flexible and adaptable. Based on our findings, we can argue that, in such uncertain regimes, ecosystems with supermodular or generic complementarities are more favourable compared to unique complementarities, since they allow for more flexibility as well. This is an important aspect to keep in mind in the case of start-up-led ecosystems (please, see Lingens, Böger, and Gassmann 2021), because funding needs as well as the speed of scaling might differ significantly in the two types of ecosystems: The ones shown below in Figure 1 are likely to scale slowly at the beginning, with more resources needed to implement the value proposition compared to those shown above in Figure 1. But, once they are set on their path, they might deliver more stable revenues and be more resilient over time against competition on ecosystem and value proposition level (and need, therefore, less resources at a later point in time due to less adaptions).

In the same vein, we found that ecosystems scale differently depending on the type of complementarities: Those with supermodularity in consumption are growing based on scaling the initial value proposition and/or by adding further value propositions being

supermodular to the initial ones (for instance, pattern Á). Ecosystems with uniqueness on both sides, however, are growing by scaling the initial value proposition (trajectory shown below in Figure 1). In case further value propositions are created, this is done to utilise the existing technologies and, as a side effect, to build-up supermodularity in production (pattern ý). The further value proposition(s) do not necessarily need to be supermodular in consumption to the existing ones. Compared to that, supermodularity in production typically emerges in ecosystems with supermodularity on the consumption side, when utilising the large sets of customer and market data that are typically being collected by such ecosystems. In case of uniqueness on both sides, supermodularity in production seems to be more difficult to achieve given the low number of partners in such ecosystems.

5.2. Discussion and implications for ecosystem management in general

Given the central importance of complementarity for the ecosystem concept, our findings on that very topic and the model displayed by Figure 1 yield more general implications on ecosystem management as well. First, we are addressing the calls by Jacobides, Cennamo, and Gawer (2018) and Dattée, Alexy, and Autio (2018) for research on the influence of competition on ecosystem development. As stated above, the stronger the competition, the more orchestrators will try to build up value propositions based on uniqueness on the consumption and even production side. Sole uniqueness in production, however, does not seem to increase the ecosystem's USP significantly. This also offers an extension of the findings of Shipilov and Gawer (2020, p. 117), who stated that 'one can predict that ecosystems with stronger average complementarities are likely to perform better than ecosystems with weaker average complementarities because the former will have created a higher value for either producers or customers'. Our findings offer a more fine-grained view on that aspect: Besides the question of 'weak' vs. 'strong' complementarities, the key aspect for ecosystem performance is the type of complementarities and whether they appear on the production or consumption side.

All of this offers an important contribution to previous conceptual findings on ecosystems. Adner (2017) defined ecosystems very much based on 'the' value proposition of the ecosystem. Jacobides, Cennamo, and Gawer (2018) opened-up that strict and narrow view by focusing more on the concept of complementarity, which created the understanding of an ecosystem having more than one value proposition. Accordingly, Hou and Shi (2021) called for research on the question of how and why several value propositions in one ecosystem would emerge. Our findings are amongst the first to shed light on that crucial aspect: ecosystems being built upon a value proposition with uniqueness on production and consumption tend to focus on that very value proposition. If anything, they might use the same partners and technologies to develop several value propositions when entering the maturity phase, which might not necessarily need to be in relation to each other (please, see the trajectories displayed below in Figure 1). According to Adner (2017), this could even be viewed as the emergence of several ecosystems out of the same or overlapping group of partners. However, ecosystems based on supermodularity on the consumption side tend to develop several value propositions very early-on: Either to scale and cover more customer demands or because they are creating further

value propositions based on uniqueness on both sides to strengthen the ecosystem's USP (please, see the trajectories displayed above in Figure 1).

This aspect is also connected to another one: Cusumano, Yoffie, and Gawer (2020) make the claim that future ecosystems will be 'hybrid', combining innovation and transaction platforms. Our cases clearly confirm that and offer very detailled insights into that matter by showing that ecosystems focusing on innovative value propositions typically develop transaction elements when entering the scaling and maturing phase, whilst mere transaction ecosystems built-up innovative elements when competition is rising.

Since we are focusing on newly emerging ecosystems, we can also contribute to the related literature focusing on building-up ecosystems. In this sense, Dattée, Alexy, and Autio (2018) suggest that orchestrators can choose amongst different settings of complementarities and interdependency from partners and are calling for a better understanding of how and why orchestrators prefer one setting to another. Our findings are clearly offering some insights on that question by showing the different aims (USP vs scaling vs lock-in) orchestrators are pursuing by utilising different types of complementarities.

6. Limitations and conclusion

We started with the research question of ' How do orchestrators leverage different configurations of complementarities in emerging ecosystems?'. Whilst we create several implications for theory and practice, our findings are not without limitations and open-up some new questions for future research as well. Besides the usual ones of any qualitative work, we would like to mention the more specific ones in particular.

First, we studied ecosystems from very different industries and driven by very different types of orchestrators (e.g. start-up vs. established firm). This was done with the idea of theoretical sampling (Eisenhardt, 1991) in mind and in order to create initial findings on a still under-researched yet highly relevant topic (Hou and Shi 2021; Jacobides, Cennamo, and Gawer 2018). This strategy yielded recurring patterns that occurred regardless of the type of ecosystem. However, whilst we can present an over-arching model of how different types of complementarities are being used and how ecosystems develop very differently depending on that aspect, we would like to encourage future research that provides more in-depth findings along these lines and look specifically on ecosystem development depending on one particular type of complementarity. In the same vein, future research might study whether these development paths also occur in situations when the external factors studied in this paper, such as rising competition, do not occur: Do ecosystems show the same development paths even in such situations? And when and why do they re-configure complementarities?

Second, whilst our case sample covers very different types of ecosystems, none of our cases showed supermodularity on production from the very beginning onwards. Our findings suggest that firms are focusing on the offering of the ecosystem towards the customer and strive to scale the ecosystem and improve its USP. Supermodularity in production was built-up later in an attempt to increase efficiency and might, thus, point towards entering the stage when the ecosystems become more mature. Also, in order for supermodularity in production to have a significant impact, ecosystems can be expected

to be build around a larger number of partners. Such situation is less likely to happen from the beginning onwards. These reasons suggest that the firms in our sample seem to represent a common pattern of firms. But larger-scale samplings might confirm or extend that suggestion.

Third, we are focusing on newly emerging ecosystems. This raises the question whether the patterns shown by our findings are also present in later stages. Fourth, we are looking at ecosystems being driven by their respective orchestrators, who are shaping the ecosystems and purposefully developing different types of complementarity. Ecosystems might also emerge self-propelled or, at least, in settings in which orchestrators have less control over their development (Dattée, Alexy, and Autio 2018; Jacobides, Cennamo, and Gawer 2018). Can we observe the same patterns in those ecosystems as well? Finally, our model displayed in Figure 1 indicates that different configurations of complementarity lead to more or less benefits and challenges. However, given the qualitative nature of our work, we did not meassure or quantify the exact differences. Quantitative works might yield insights on that issue and allow for even more specific recommendations for practitioners. Taken together, our paper is amongst the first studying different types of complementarities in emerging ecosystems. Since the concept of complementarity is at the very heart of the ecosystem concept, we would like to encourage future work building-upon or complementing our initial findings.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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