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Crafting strategic responses to ecosystem dynamics in manufacturing

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ABSTRACT

This research goes beyond the dyadic view of co-opetition in supply chains and seeks to explore how firms that act as suppliers in a dynamic manufacturing ecosystem establish and sustain their strategic position. We interviewed 31 senior managers in seven firms that were identified by a committee representing government and academia as occupying various advanced manufacturing ecosystems. We argue that as actors within a manufacturing ecosystem interact overt time to co-create the overall product-service offerings, new relationships may be formed, and existing connections may be dissolved, giving rise to three co-opetition dynamics at the ecosystem level - capability configuration, value appropriation, and network governance. Our analysis unveiled eighteen operational tactics that suppliers deploy which combine to produce nine strategic responses that allow them to sustain their position within manufacturing ecosystems. Specifically, we discuss the role of suppliers in manufacturing ecosystems and capture the relationship between ecosystem dynamics and the strategic responses as they accommodate co-opetition. This research indicates that ecosystem performance is essentially a dynamic effort, which is simultaneously collective and distributed. Thus, policymakers should avoid carrying out analysis based on overly linear and single industry conceptualisations of manufacturing value networks.

1. Introduction

Management practitioners and scholars alike use a range of terms such as sector, industry, and market to describe and characterise a firm's environment. More recently, the ecosystem metaphor, a term borrowed from the field of biology, has entered the lexicon. The term ecosystem was first used in the management literature in the mid-1990s by Moore (1993) who was seeking to understand how firms could attain sustainable advantage by 'out-innovating' competitors. Since then, the concept of ecosystem has become associated with much more than just innovation, generating a broad appeal among management scholars.

According to Moore (1993, 1996) a business ecosystem is an economic community supported by several interacting actors that cooperate to create value that none of them would be able to generate on their own (Iansiti and Levien, 2004; Adner, 2006). Such multi-firm arrangements cooperate by performing complementary activities, integrating resources, and contributing heterogeneous capabilities while simultaneously competing to appropriate their share of the resulting value (West and Wood, 2013; Adner and Kapoor, 2016; Baldwin, 2018). While in some ways, the ecosystem metaphor resembles concepts such as the value network, it is different regarding a few key aspects (Dedehayir et al., 2018; Gomes et al., 2018). Most importantly, an ecosystem is inherently dynamic because it recognises the ongoing changes that occur due to the simultaneous occurrence of competition and cooperation, often referred to as co-opetition (Brandenburger and Nalebuff, 1996; Bengtsson and Kock, 2000). Furthermore, by conceptualising the environment as an ecosystem many organisations, for instance universities and financial institutions, that would normally not be considered relevant when viewed from the perspective of the traditional value network conceptualisation can now be incorporated (Sloane and O'Reilly, 2013).

Crucially, it is suggested that the ecosystem offers "new possibilities to operationalise the environment" (Gomes et al., 2018: p. 42). However, the key to understanding and unlocking these new possibilities is in characterising the dynamics that exist between different ecosystem actors (Granstrand and Holgersson, 2020). More specifically, there have been recent calls for more research into the cooperative and competitive interactions and underpinning activities, which generate the dynamics in the ecosystem (Overholm, 2015; Valkokari, 2015; Ritala and Almpanopoulou, 2017). How firms navigate the contradictory demands

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posed by having to simultaneously compete and cooperate (MacCarthy et al., 2016; Jacobides et al., 2018) is crucial to our broader understanding of how complex, interorganisational relationships function. Therefore, the concept of co-opetition, which involves both cooperation and competition in value chains literature has traditionally been studied as a linear and dyadic relationship, while focusing on the strategies of upstream and downstream actors (Pathak et al., 2014). However, this research moves beyond this limited conceptualisation and offers an ecological view to better understand how to manage co-opetition.

Davis (2016) and Bogers et al. (2019) studied the characteristics of the various roles in an ecosystem, distinguishing between competitors, suppliers, complementors, and lead firms. Until now most attention has focused on lead (also named focal and keystone) firms with an implicit assumption that becoming the lead firm in an ecosystem is the position all actors should strive for (Iansiti and Levien, 2004; Williamson and De Meyer, 2012; Teece, 2016; Liu et al., 2019). Therefore, ecosystem research is mostly informed from this perspective. There is less research on the supplier role in ecosystems, this is a significant omission as most firms will occupy this role in some way and at some point, in time.

Given the perceived criticality of the supplier role, the purpose of this paper is to broaden our understanding of how suppliers navigate the dynamics of ecosystems. It will do this by identifying and characterising how the dynamics unfold within a manufacturing ecosystem before focusing on firms that occupy the supplier role and investigating how they can maintain and develop their strategic position. Therefore, this study will answer the following research question: *How do firms in the supplier role in a manufacturing ecosystem strategically manage co-opetition to remain relevant and viable?*

As it is our intention to gain a supplier's view of what is needed to remain viable in an ecosystem, we focus on the firm's managerial agency rather than taking, as is more usual in ecosystems research, a dyadic, triadic, or multi-agency perspective that looks at the ecosystem as a whole (Dattée et al., 2018).

We proceed by first exploring the relevant literature to develop a dynamic understanding of a manufacturing ecosystem within which we expect suppliers to operate. We then provide an overview of our qualitative methods before presenting our empirical findings structured as a conceptual model that illustrates the strategic responses suppliers use. We then discuss how suppliers use these responses to remain relevant and viable within ecosystems. Finally, we establish what this means for ecosystems theory and develop a set of research propositions.

2. Literature review

2.1. The nature of ecosystems

Moore (1993) and Iansiti and Levien (2004) explicitly refer to biology to explain the usefulness of the ecosystem as a metaphor to describe how organisations are positioned in, and dependent on, the environment they operate in. In biology, an ecosystem is a community of living organisms that work together as a system. This system is facilitated by nutrient cycles and energy flows while it simultaneously copes with outside disturbances to stay resilient (Odum, 1971). Replace 'living organisms' with 'organisations'; find an organisational equivalent for the cycles and flows, and a useful metaphor is created.

Although useful, this metaphor is easily criticised (Ritala and Almpanopoulou, 2017) as it overlaps with adjacent concepts such as the supply chain which itself has increasingly come under scrutiny because of certain limitations regarding its conceptualisation including its static, linear nature and (presumed) hierarchical structure (Pathak et al., 2014; Fransman, 2018). To address these limitations the concept of the value network has gained popularity as it introduces horizontal coordination as an addition to vertical control structures (Peppard and Rylander, 2006; Sloane and O'Reilly, 2013; Johnson et al., 2021). Although an improvement on previous conceptualisations as it is of some use in characterising the sophistication of contemporary relationships between firms, its usefulness is somewhat limited as it still represents a rather static model and as such remains relatively silent on the dynamics of the connections between participating organisations (Dedehayir et al., 2018; Tsujimoto et al., 2018).

The recent theorisation captured in the concept of the ecosystem moves beyond the concept of the value network, allowing multi-organisation arrangements to be considered more dynamically, including a myriad of vertical, horizontal, and diagonal relations among actors (Sloane and O'Reilly, 2013). It, therefore, opens several new avenues for researching inter-organisational relationships and interdependencies (Sloane and O'Reilly, 2013; Ritala and Almpanopoulou, 2017). The ecosystem differs from previous conceptualisations in several ways.

First, ecosystems emphasise dynamic rather than static arrangements. The concept of the ecosystem questions the static nature of earlier multi-organisation arrangements (Pathak et al., 2014). Gawer (2009) and Rong et al. (2013) argue that previous conceptualisations, suppose a pre-defined and relatively stable relationship between organisations where the structure of the relationship generally follows the flow of material, with inter-organisational governance usually designed around this and arranged by contracts. In these arrangements value creation is based on each organisation occupying a particular role and delivering a well-defined contribution to an end-product where value appropriation is settled by negotiation and enforced by a formal contract. These earlier conceptualisations typically find it difficult to accommodate change and innovation other than as part of a purposeful redesign usually initiated by the focal firm. In contrast, an ecosystem is dynamic with the nature of the linkages not limited to contractual agreements but based more on recognising the interdependence created by a network of formal and informal relations (Brusoni and Prencipe, 2013; Leten et al., 2013; Jacobides et al., 2018). Therefore, an ecosystem's governance arrangement is seen as continuously adjusting as actors and contributions change as the ecosystem evolves (Adner and Kapoor, 2010).

Second, ecosystems have the scope to accommodate more complex value propositions. The concept of the ecosystem has the potential to accommodate an alternative view of the type of value propositions that might emerge from a multi-organisation arrangement. The blurring of the distinction between products and services means that the value proposition, in other words, the complex functionality embodied within a system of use, that a manufacturing ecosystem creates often takes the form of a product-service bundle (Johnson et al., 2021), provided by a collection of legally independent firms (Jacobides, 2019). Therefore, membership in an ecosystem is gained through the ability of an organisation to contribute to the product-service bundle (Johnson et al., 2021). This characteristic further differentiates the ecosystem from the value network and from other forms of arrangement like the cluster (Porter, 1990), as the boundary of the ecosystem is defined not by geography but rather by a collective capability that denotes membership (Dedehayir et al., 2018).

Third, and somewhat related to the previous point, ecosystems have the scope to include organisations that are not core to the value proposition. The concept of ecosystems revises the composition of multi-organisation arrangements. A limitation of previous conceptualisations such as the supply chain and the value network are that they tend to include only upstream and downstream organisations whose offerings are directly assembled into the final product, parts that are on the critical path for value creation (Adner, 2017). Consequently, they exclude organisations that are not directly involved in the conversion process but that may add intangible value, for example, regulatory bodies, finance providers, user communities, governments, and universities (Iansiti and Levien, 2004; Carayannis and Campbell, 2009; Tsujimoto et al., 2018). In contrast, ecosystems can accommodate all organisations with something to offer and this recognises that the value proposition is more extensive than if it would just be based on a combination of organisations in a value network (Adner and Kapoor, 2010; Pathak et al., 2014;

Dedehayir et al., 2018).

Fourth, ecosystems move beyond the concept of the industry by questioning the scope of other multi-organisation arrangements. Early work by Iansiti and Levien (2004) suggested that the concept of the industry was too strict with most value propositions requiring contributions from beyond the boundary of the industry that they were traditionally associated with. Alternatively, an ecosystem spans multiple industries (Teece, 2016; Jacobides, 2019). Hence, the inherent dynamics within the ecosystem require actors to conceptualise their operational models differently and embrace new strategic frameworks.

Finally, ecosystems recognise there are multiple roles an organisation can adopt including that of competitor, complementor (Gomes et al., 2018), supplier, or lead organisation (Adner and Kapoor, 2010; Gawer, 2014). In other words, ecosystems establish a structure within which complementarities in either production and/or consumption can be contained without the need for vertical integration (Adner and Kapoor, 2010), but also horizontal and diagonal relationships among actors (Sloane and O'Reilly, 2013; Brozović and Tregua, 2022).

Therefore, in summary, research has shown that the concept of the ecosystem differs substantially from other conceptualisations of multi-organisation arrangements. Ecosystems are dynamic, accommodate a greater variety of participants, facilitate the creation of more complex value propositions, move beyond the boundary of a single industry, and recognise that participants can adopt multiple roles. However, the concept of ecosystems is itself not homogenous, it appears in different guises, having emerged from different strands of the initial thinking that inserted the term into the academic vocabulary of management (Gawer, 2014). One strand developed the concept of the business ecosystem. The other strand developed the concept of the innovation ecosystem. Both strands eventually found some common ground in the concept of the platform ecosystem. To capture the dynamics in a manufacturing ecosystem, we will investigate these strands in more detail.

2.2. Business ecosystems

Business ecosystems evolved from earlier work that was mainly associated with Porter (1980) who posited that firms compete in industries, describing an industry as all the firms that are in the business of producing the same product or service. A firm's capability can be captured as a value chain, with specific value activities appreciated in terms of the value that is added by each activity and the costs incurred to add this value (Porter, 1985). Value is understood as what customers are prepared to pay for the end-product or end-service that defines the industry. Adopting Porter's terminology, competition, therefore, is about value appropriation, in other words, how much of what a customer pays is apportioned to each firm in the value system.

However, there is increasing recognition that competition must be supplemented with complementarity, leading to the realisation that cooperation is equally important. Complementarity refers to the effect that the value propositions of two or more firms, when combined, represent more value than each of the value propositions when offered separately (Brandenburger and Nalebuff, 1996).

Although recognised in other arenas, complementarity in value propositions and the cooperation required to achieve this complementarity became increasingly important because of developments in manufacturing where firms began to offer product-service bundles that combined a product with financing, maintenance, and other service offerings. This became known as servitization (Vandermerwe and Rada, 1988; Baines and Lightfoot, 2014; Johnson et al., 2021). In addition, previously dominant dyadic buy-supply relationships developed into multilateral connections that comprised more enduring, cooperative arrangements increasingly supported by inter-organisational IT infrastructures. This type of arrangement is gaining increasing prominence due to what is now commonly referred to as Industry 4.0 (Koh et al., 2019).

Consequently, the concept of industry became outmoded (Teece, 2016) for two reasons. First, the product-service bundle that increasingly characterised what manufacturing and other firms have on offer does not fit the industry definition (which tends to imply a single product or service) as product-service bundles often incorporate contributions from firms from many different industries (Livesey, 2006; Johnson et al., 2021; Paton et al., 2021). And second, competition as the main dynamic that firms must deal with is supplemented with cooperation because delivering these product-service bundles requires firms to coordinate their activities (Sminia et al., 2019b).

Furthermore, in addition to concerns about value appropriation, firms also must consider the network governance (Sminia et al., 2019a) of all the activities that the collection of firms engage in while delivering a product-service bundle. Within ecosystems, the mechanisms of network governance differ from those of, for example, value networks where network governance tends to be done by the firm that is the systems integrator. This is usually the firm closest to the end-user market.

To capture this interplay between competition and cooperation the term co-opetition was introduced (Brandenburger and Nalebuff, 1996; Bengtsson and Kock, 2000). As can be easily appreciated, competition and cooperation do not sit well together. That is the reason why the value appropriation dynamic, in other words, who gets what from the ecosystem, is often in conflict with the network governance dynamic, in other words, who controls the ecosystem.

2.3. Innovation ecosystems

Innovation ecosystems researchers recognised that many product-service bundles display a technological architecture (Gawer, 2014; Kapoor, 2018) and associated modularity (Baldwin, 2018; Johnson et al., 2021). The technological architecture refers to the configuration of a product-service bundle that is composed of various component parts, sub-assemblies, and associated services. Each of these component parts tends to have firms specialising in their manufacture and supply so each of these firms bring their own, sometimes unique, capabilities (Barney, 1991) to the ecosystem. Although they are in many ways like a business ecosystem, the emphasis in innovation ecosystems is on the creation of new value propositions as opposed to delivering an existing value proposition (Granstrand and Holgersson, 2020).

In addition to firms, an innovation ecosystem might also include “the material resources (funds, equipment, facilities, etc.) and the human capital (students, university staff, industry researchers, industry representatives, etc.) that make up the institutional entities participating in the ecosystem” (Jackson, 2011: 2). Therefore, from an ecosystem perspective, innovation is a distributed activity as it takes place across a large collection of organisations (Bessant and Moslein, 2011) and this is recognised with the concept of open innovation (Chesbrough et al., 2014).

This distributed and open activity adds a third dynamic, besides network governance and value appropriation, to how ecosystems operate. This is the capability configuration dynamic that appears due to the constant ‘jostling for position’ that takes place as actors seek to contribute something to the ecosystem based on their capabilities (Sminia et al., 2019a). This capability-based competition helps stimulate capability development and innovation as organisations attempt to improve their position (Teece et al., 1997). However, it further complicates the issue of network governance in that all this innovation requires additional coordination because improvements regarding one aspect of the combined value proposition have consequences for other aspects (Adner and Kapoor, 2010). Such coordination can be achieved by setting certain standards for firms to comply with (Miller and Toh, 2020) and by creating associated modularity which is recognised to coordinate the various contributions (Jacobides et al., 2018). The offering, therefore, consists of recognised contributions that different firms can concentrate on individually while being confident that they will all fit together into the final product-service bundle (Jacobides

et al., 2018).

2.4. Platform ecosystems – a combined view

The competition regarding value appropriation that is emphasised within business ecosystems combined with the capability-based competition present within innovation ecosystems has led researchers to start analysing what is going on with firms like Apple, Amazon, IBM, and Google (Moore, 1993). Those firms set themselves up as a technological hub in which other firms had to commit to being able to participate. These arrangements were categorised as platform ecosystems.

A platform ecosystem is defined as "… a technical system comprising a core set of essential functional elements (the platform) plus a set of optional complements" (Baldwin, 2018: p. 2). The platform and each complement are separate modules bound together by commonly recognised design rules. Some platform ecosystems, such as Apple, Amazon, and Google, centre around a platform leader, often termed an orchestrator, who is in control of the platform (Adner, 2017; Kapoor and Agarwal, 2017). While others such as Wikipedia and Android feature some form of collective governance (West and Wood, 2013).

However, these two forms of governance each deal with competition differently. In ecosystems with a platform leader, this leader acts as a gatekeeper and coordinator deciding who is allowed to contribute what capability and what value they will appropriate in return for it. In ecosystems that exhibit collective governance, coordination and appropriation are arranged and developed mainly by consensus as the ecosystem takes shape. Like business ecosystems, platform ecosystems display the value appropriation dynamic in that the success of each actor within the ecosystem is determined by how much value each gets out of the ecosystem.

In summary, how an organisation is going to build and defend its position within an ecosystem as it develops is informed by the role it takes. All roles are affected by value appropriation (Moore, 1993; Clarysse et al., 2014; Adner, 2017;), capability configuration (Moore, 1993; Adner and Kapoor, 2016; Helfat and Raubitschek, 2018), and network governance dynamics (Gawer and Cusumano, 2014; Wareham et al., 2014; Jacobides, 2019; Sminia et al., 2019a;) that must be dealt with simultaneously by each actor.

In turn, the activity of all actors will affect the institutional arrangements within the ecosystem, as firms actively develop and defend their position the ecosystem will remain volatile (Pierce, 2009). Co-opetition will assume a form by which many possible different strategies will be pursued involving different coalitions of interested parties. However, strategies used to navigate these dynamics will vary according to the roles that an organisation might occupy at a specific time.

So far, the role of platform leader has attracted the most attention as it has been proposed as the most desirable (West and Wood, 2013; Wareham et al., 2014; Adner, 2017; Kapoor and Agarwal, 2017; Hannah and Eisenhardt, 2018; Jacobides, 2019) and the complementor, as the most newly identified role, has also been investigated (Kapoor and Lee, 2013). However, more crucially, little work has been done to investigate the activity of organisations occupying the role of suppliers in ecosystems. This is a significant omission as it is arguably the most ubiquitous, long-standing, and fundamental role in inter-organisational relationships. Therefore, in this research, we focus on firms that take on the supplier role in manufacturing ecosystems.

3. Methods

Like Ritala and Almpanopoulou (2017), we recognise the value of qualitative process research for the study of dynamic phenomena like ecosystems, as it can offer a richer understanding (Langley, 1999). To implement this research strategy, we undertook a multiple-case design based on literal replication (Yin, 2014).

3.1. Case study selection

There are many organisations, institutions, and individuals present as actors in any given ecosystem (Autio and Thomas, 2014). An actor is a legally independent, but economically interdependent unit involved in performing separate productive activities within the ecosystem (Baldwin, 2018; Jacobides et al., 2018). We considered the whole organisation or business unit (as an actor within the manufacturing ecosystem) as the unit of analysis.

Our research design principally relies on qualitative analysis of seven purposefully selected case firms in the UK, each acting as a supplier within high-value manufacturing ecosystems (Paton et al., 2021). We identified these cases in cooperation with Scottish Enterprise (SE), a national manufacturing development agency, which is working together with various stakeholders, including universities, to improve performance in the manufacturing sector. Their ambition is to encourage high-value, advanced manufacturing in Scotland (Scottish Government, 2016).

Using purposive sampling method (Creswell, 2002), our sample selection criteria included four elements. Firstly, the authors had long-term relationship with SE that aims to support and develop high value manufacturing companies. Through discussion with the SE representatives, we were offered a list of innovative, high value manufacturing companies that were account managed by SE for continuous improvement and growth.

Second, the list included firms that were supplying complex product and service bundles in B2B manufacturing ecosystems covering various industries. Also, the suppliers were established and for-profit companies, which allowed us to investigate the dynamics exposed by co-opetition over a period. Following initial introductions by SE, seven manufacturing suppliers accepted to participate our research study.

Three of the firms (Case A, F and G) are business units of larger parent companies with headquarters outside Scotland; the remaining four firms are Scottish SMEs. Table 1 presents primary data sources and the volume of our qualitative data (31 semi-structured interviews) in detail. Additionally, we have conducted desk research on seven case study organisation and used that secondary data (e.g., company websites and news items) for familiarisation and triangulation purposes as suggested by Braun and Clarke (2006). Table I describes each firm, its ecosystem actors, and the data sources.

3.2. Data analysis

We intentionally did not follow a dyadic or triadic design, which would have included primary data gathered from other ecosystem actors (Dattée et al., 2018). Rather than concentrating on the level of the ecosystem, we focus on the supplier firms within it to ensure the findings captured their managerial agency and therefore provided uncontaminated clarity on the activities and strategies that this type of firm is engaged in to stay adaptive and viable.

We commenced our initial engagement with the sample firms by conducting desk research. This included examining company websites and news items. Apart from providing us with secondary data for triangulation purposes, this preliminary understanding informed our preparations for the interviews and the subsequent data analysis.

The primary sources of data were a series of semi-structured, face-to-face interviews, each ranging from 60 to 90 min (see Table I). Data triangulation is also achieved by interviewing a minimum of three managers in each case study firm. In total, we conducted 31 interviews on-site with senior managers. We asked questions about the firm's strategic, innovation, operational, and technology development activities. All interviews were digitally recorded and transcribed, and this amounted to 25.4 h of recordings and 583 pages of transcribed audio.

Data analysis consisted of an open coding process using thematic analysis (Braun and Clarke, 2006) which allowed us to identify patterns in a large and complex dataset, as well as links within analytical themes.

Table I
Case study overview.

Case	Case overview	Examples of ecosystem actors	Primary data sources (interviews)
Case A	Founded: 1966 in Scotland and is now a subsidiary of a larger company End-user: Consumers of alcoholic beverages System of use: Recreational alcohol consumption Use case: Whisky Supplier contribution to the ecosystem: Product - capping system; service - engineering system that designs and supports this custom product. The manufacturing capability that produces it efficiently. The value is a reliable, secure, fit-for-purpose capping system that contributes to the quality feel of the whisky bottle and therefore supports the brand image.	• suppliers (raw materials, glass, etc.) • customers (Diageo, Chivas) • business assistance organisations (Scottish Enterprise) • design agencies • universities • tooling manufacturers	(IA1) Design and R&D Manager, 40 min, 12 pages of transcriptions (IA2) Supply Chain interview, 50 min, 16 pages of transcriptions (IA3) Financial Controller, 45 min, 13 pages of transcriptions (IA4) Quality Manager, 45 min, 15 pages of transcriptions (IA5) Sales Manager, 30 min, 11 pages of transcriptions (IA6) Business Engineering Manager, 30 min, 9 pages of transcriptions (IA7) Technology Manager, 45 min, 13 pages of transcriptions
Case B	Founded: 2009 in Scotland and remains privately owned End-user: Merchant navy System of use: Seaborne transport Use case: Ship propulsion Supplier contribution to the ecosystem: Product - cooling pump for diesel ship engines; service - engineering system that designs and supports this bespoke product. The manufacturing capability that produces it efficiently. The value is therefore a reliable fit for purpose electro-mechanical assembly fully supported throughout its lifecycle.	• suppliers (bearings, seals, etc.) • customers (Caterpillar, MAN Diesel & Turbo) • business assistance organisations (Scottish Enterprise, Scottish Development International) • local colleges • design agencies • classification society (Bureau Veritas/Lloyds Register)	(IB1) CEO/Owner, 120 min, 42 pages of transcriptions (IB2) Finance Director, 60 min, 24 pages of transcriptions (IB3) Design and Engineering Manager, 60 min, 25 pages of transcriptions
Case C	Founded: 1997 in Scotland and remains privately owned. End-user: Medics or scientists System of use: Mass spectrometry Use case: Measurement of gas compounds Supplier contribution to the ecosystem: product - compressor that is part of a mass spectrometer; service - engineering system that designs and supports this bespoke product. The manufacturing capability that produces it efficiently. The value is therefore a reliable fit for purpose electro-mechanical assembly fully supported throughout its lifecycle.	• suppliers (lab equipment, gas, instruments, pneumatic fittings, etc.) • customers (Scientific industry – Agilent, AB Cyex and Walters, hospitals, universities, Industrial clients from wine and airlines industry) • global distributors • certification bodies	(IC1) Managing Director/Owner, 60 min, 24 pages of transcription (IC2) Recruitment Manager, 50 min, 21 pages of transcription (IC3) Sales and Marketing Director, 60 min, 21 pages of transcription (IC4) Service Director, 70 min, 31 pages of transcription (IC5) Engineering Director, 65 min, 25 pages of transcription (IC6) Operations Manager, 60 min, 26 pages of transcription (IC7) HR Manager, 55 min, 24 pages of transcription
Case D	Founded: 1833 in Scotland and remains privately owned End-user: Oil companies System of use: Refinery Use case: Control of the flow of chemical compounds Supplier contribution to the ecosystem: product – complex large-scale valves; service - engineering system that designs and supports this custom product. The manufacturing capability that produces it efficiently. The value is therefore a reliable fit for purpose mechanical assembly fully supported throughout its lifecycle.	• suppliers (machining subcontractors, components, etc.) • customers (food factories, car plants, tyre plants, power stations, shipyards, energy companies) • business assistance organisations (Scottish Manufacturing Advisory Service) • distributors • testing facilities • certification bodies • universities	(ID1) Owner/ Managing Director, 75 min, 32 pages of transcription (ID2) Foundry, 12 min, 6 pages of transcription (ID3) Technical and IT Manager, 45 min, 14 pages of transcription
Case E	Founded: 1986 (as a university spin-out) in Scotland and is now a subsidiary of a larger company End-user: Female patients System of use: Female maternal health care Use case: Reproductive medicine Supplier contribution to the ecosystem: Reliable and cost-efficient drug delivery by way of a controlled release insert The value is therefore a reliable fit for purpose multi-use device produced efficiently.	• suppliers (components, raw materials, etc.) • customers (health care, pharmaceuticals firms, NHS) • universities • regulatory bodies (European Medicines Agency) • industry advisors (Scottish Medical Consortium)	(IE1) Director of Operations, 45 min, 18 pages of transcription (IE2) R&D Director, 60 min, 27 pages of transcription (IE3) Production, 55 min, 22 pages of transcription (IE4) Finance and HR Manager, 45 min, 20 pages of transcription
Case F	Founded: 1966 and is now a subsidiary of a larger company. End-user: Manufacturing companies that require material to be cut to specific forms and sizes System of use:	• suppliers (components, raw materials, etc.) • customers (precision engineering companies) • business assistance organisations (Scottish Enterprise) • universities • regulatory bodies	(IF1) Vice President and General Manager, 20 min, 8 pages of transcription (IF2) Director of Product, 35 min, 15 pages of transcription (IF3) Engineering

(*continued on next page*)

Table I (*continued*)

Case	Case overview	Examples of ecosystem actors	Primary data sources (interviews)
	Production line Use case: Precision cutting Supplier contribution to the ecosystem: Product – laser cutter; service - engineering system that designs and supports this custom product. The manufacturing capability that produces it efficiently. The value is therefore a reliable fit for purpose electro-mechanical assembly fully supported throughout its lifecycle.		Director, 35 min, 18 pages of transcription
Case G	Founded: 1921 in Scotland and is now a subsidiary of a larger company End-user: Manufacturing companies that require precision gear solutions as part of their manufacturing process System of use: production line Use case: Industrial automation Ecosystem value proposition: machine Supplier contribution to the ecosystem: product – gearing systems; service - engineering system that designs and supports this custom product. The manufacturing capability that produces it efficiently. The value is therefore a reliable fit for purpose mechanical assembly fully supported throughout its lifecycle	• suppliers (components, raw materials, etc.) • customers (oil & gas, tool manufacturers, machine manufacturers) • business assistance organisations (Scottish Enterprise), • universities • certification bodies	(IG1) Operations Manager, 35 min, 12 pages of transcription (IG2) Managing Director, 40 min, 13 pages of transcription (IG3) Sales & Marketing Director, 40 min, 15 pages of transcription (IG4) Technical Director, 35 min, 11 pages of transcription

We started by importing the transcribed interviews into NVivo 12. Coding initially focused on the ecosystem dynamics of value appropriation, network governance, and capability configuration, which emerged from our literature review. However, as presented in Table II, more detailed codes emerged inductively and were categorised as first-order concepts to capture specific activities of the supplier firms, for example, participating in joint initiatives.

We subsequently found that these first-order concepts could be grouped within the three ecosystem dynamics, resulting in 102 supporting 'references' for the capability configuration dynamic, 50 'references' for the network governance dynamic, and 108 'references' for the value appropriation dynamic. A reference in NVivo is a count of the number of selections within a source that are attached to a node. Furthermore, all these 'references' provide evidence for the first-order concepts that emerged from our literature review. In total, we have 260 'references' from which we inductively derived our first-order concepts.

Table II
Data structure.

Operational Tactics (First Order Concepts)	Strategic Responses (Second Order Themes)	Ecosystem Dynamics (Aggregate Dimensions)
A1. Participating in joint initiatives A2. Balancing co-opetition	A. Building Collaborative Resonance	Capability Configuration Dynamic
B1. Specialising in complementarity B2. Supplying critical offerings	B. Pursuing Indispensability	
C1. Engaging in product/ technology development C2. Conducting speculative work	C. Participating in Anticipatory Innovation	
D1. Lowering excessive dependency on customer D2. Partnering with the customer	D. Mitigating Dependency Risk	Network Governance Dynamic
E1. Monitoring performance indicators F2. Complying with directives	E. Delivering on Standards	
F1. Establishing formal agreements F2. Gaining endorsements	F. Formalising Relationships	
G1. Focusing on servitization G2. Creating premium offerings	G. (Re)defining Contribution	Value AppropriationDynamic
H1. Agreeing payment terms H2. Settling power struggles	H. Finding Compromises	
I1. Utilising non-monetary exchange I2. Investing in relationships	I. Accepting Non-pecuniary Returns	

While grouping in accordance with the three ecosystem dynamics, we were able to gather the first-order concepts into broader second-order themes. The development of each second-order theme also involved a continuous consultation with relevant literature, so that empirically driven themes could be connected to theoretical concepts, especially the three ecosystem dynamics. As consistent analytical themes emerged from our analysis, data saturation had been achieved (Constantinou et al., 2017), with the observed relationships serving as a foundation for our theoretical categories. We provide an overview of the links between our raw data and the theoretical categories in Table II.

4. Findings

From a supplier's perspective, the three ecosystem dynamics are absorbed and dealt with by nine strategic responses and the associated operational tactics that support these responses. The strategic responses appear as second-order themes in our analysis while the associated tactics appear as first-order concepts (Table II).

4.1. Capability configuration dynamic

The capability configuration dynamic is generated as actors position themselves in relation to what capability they contribute to generating the overall complex functionality (value proposition) that an ecosystem provides. Our findings indicate that suppliers strategically position themselves as collaborative, indispensable, and innovative members of

the manufacturing ecosystem while constantly reframing their capability.

4.1.1. Building collaborative resonance

Building collaborative resonance is the strategic response suppliers use to constructively find a balance between the often-opposing priorities and modes of operation that exist between actors within an ecosystem. To do this, we found that suppliers deploy two tactics: participating in joint initiatives and balancing co-opetition.

All the suppliers in our study collaborate with other ecosystem actors (both on and off the critical path for value creation) including the government, other suppliers, customers/OEMs, regulatory bodies, knowledge providers, and certification organisations to be able to continue to participate in the ecosystem. The following statement illustrates this general point:

> The equipment and machines we use are custom-built, robotic, bespoke, and unique for us. We specify our requirements and collaborate with [machine suppliers] in the UK, Italy, and Germany… We also co-develop and innovate with specialist manufacturers and other small molecule suppliers. Then, we collaborate with the NHS [customer] and the regulatory body [complementors] in the UK and insurance companies in the US to justify our costs and prices. (Case E)

Furthermore, suppliers that participate in joint initiatives cleverly make use of other ecosystem actors' specialised and complementary capabilities. For example, Company G, which manufactures gearboxes, collaborates with other ecosystem actors who have more expertise in certification processes. Company G then focuses on manufacturing the gearbox. Another example from Case C describes the collaborative process of designing a compressor where ecosystem actors work jointly in designing for improved reliability and maintainability of their compressor product and then continue to work jointly to manufacture and support it. However, within ecosystems, cooperation coexists with competition as illustrated by the following statement from a manager within Case G:

> We've all got our own wee [little] niche areas and we do compete with certain of these guys in certain areas, but quite often there's enough work for everybody and we help each other out. There's a [competitor]…, and we swap work back and forward with them quite a lot. Quite a lot of gear-cutting companies are our customers and suppliers as well.

Here companies demonstrate the ability to exist in a state of co-opetition by balancing competitive and cooperative activity and finding ways to gain from both.

In summary, the ability of suppliers to cooperate and compete simultaneously with other actors is critical in building collaborative resonance within the ecosystem. This collaborative resonance helps actors to work together (despite having to compete) to shape the capability configuration within the ecosystem.

4.1.2. Pursuing indispensability

Pursuing indispensability is the strategic response suppliers use to ensure that their offering is necessary to the ecosystem. To do this, we found suppliers deploy two tactics: specialising in complementarity and supplying critical offerings.

Given that the success of manufacturing ecosystems is dependent on its actors' complementary capabilities, the strategic positioning of suppliers in manufacturing ecosystems is found to be dependent on tailoring their capabilities around critical and bespoke offerings to make themselves indispensable for delivering the overall complex functionality that forms the value proposition. This means that suppliers strategically position themselves in the manufacturing ecosystem so that the other ecosystem actors cannot operate without them. For example, the Design Manager in Case A highlighted that what they do is bespoke, and their customers always involve them in any new product development. He explained:

> …because we're central to the market…they [ecosystem focal firm] almost view us as a kind of extension to their design department.

Similarly, Case C provides another example, where they claim that their bespoke offering is integral to the customer's product service combination, proving them with indispensability. The Managing Director said:

> We are offering a gas generator in comparison to a cylinder of gas which is significantly different. What we're manufacturing and selling is a complementary solution, producing the gas on-site and on demand. That is an offering that makes us unique in what we do. If our product is broken, then the whole system is broken so, our product is an integral part of the whole lot.

Other interviewees explained how they attempted to become indispensable in their ecosystems by offering complementary critical services for the overall value proposition. Another example, Case F, offers a critical service that contributes to the ecosystem value proposition in the biotech sector. The focal firms require their laser equipment to be reliable as a broken laser may result in delays to their process and wastage of their biological samples. To ensure the correct service level is achieved Case F holds inventory at strategic locations around the world so if a laser cannot be repaired then a new laser can be installed. In doing this, Case F has recognised that the operational service capability that complements the product is critical to being an indispensable actor in the ecosystem.

In summary, the ability of suppliers to develop and deliver offerings that are both essential to the value proposition and that complement the offerings of other actors is crucial to maintaining their position in the ecosystem. This indispensability helps actors to stabilise the capability configuration within the manufacturing ecosystem.

4.1.3. Participating in anticipatory innovation

Participating in anticipatory innovation is the strategic response suppliers use to ensure they meet the anticipated future needs of their ecosystems to secure their long-term position as these ecosystems constantly evolve. To do this, we found suppliers deploy two tactics: engaging in product/technology development and conducting speculative work. For example, Case F pioneered a particular type of laser technology because they anticipated where the market was heading and proactively developed a dedicated product for that market. Anticipatory innovation activity involves noticing rhythms and regularities in how technological change occurs:

> "…the lifecycle for a platform is typically ten years but for a particular variant of that platform is only going to be a year, two. So, you have to constantly innovate to stay cutting edge because not only is the market growing quickly but the capabilities of the products are also evolving very quickly. There's quite a lot of innovation…"

Anticipatory innovation also develops additional capability so that the actor's position becomes more prominent in the ecosystem. The following statement from a senior manager in Case A illustrates this point:

> The company's strategy is to be very innovative, to try and differentiate ourselves from our competitors and, I guess, to innovate a way up the value-added chain so to try and move ourselves into a space [better position] where we can make the most money.

In doing so, innovation means doing speculative work to offer new and complementary capabilities to the changing ecosystem. One senior manager in Case A indicated that anticipatory innovation is speculative but also critical to their positioning and explained how this was one of the order-winning qualities:

> We're now looking at augmented reality, which basically you can put it on an iPad, you can show the bottle with a closure on it, sat on a supermarket shelf. How it would look against the other ranges. That's the kind of thing that's keeping us ahead.

In summary, the ability of suppliers to build and reframe capabilities and anticipate which new offerings are needed is critical to the ongoing development of the capability configuration within the evolving manufacturing ecosystem.

4.2. Network governance dynamic

The network governance dynamic is generated as actors strive to create some form of coordination to govern the many interdependencies between actors in an ecosystem. Here, we found that ecosystems comprise complex and fluid inter-organisational relations which are not always led by focal firms. We identified three strategic responses that appear with this dynamic: mitigating dependency risk, delivering on standards, and formalising relationships.

4.2.1. Mitigating dependency risk

Mitigating dependency risk is a strategic response suppliers use to ensure that their business maintains multiple options. To achieve this, we found suppliers deploy two tactics: lowering their dependency on any single ecosystem actor and partnering with other ecosystem actors.

In an ecosystem, becoming overly dependent on another actor is recognised as posing risk. Interestingly, some respondents felt the notion of collaborative work was overplayed and that some larger customers were adept at playing suppliers off against each other or recognised their own exposure to one type of customer. For example, an interviewee from Case G identified the biggest business risk as doing too much business with specific ecosystem actors.

> We need to be in a position where we're not dependent on the big guys [ecosystem focal companies] all the time.

A way to mitigate this risk is to establish long-term partnerships by which some form of coordination is achieved by the suppliers themselves. This strategic response is not always motivated by making money in the short-term but instead is seen as an investment in the future. For example, Case C collaborated with their customer (the largest international mass spectrometer seller) in expanding their business in Thailand by using their distributors. Although creating this dependency was seen as a risk, they also saw it as an opportunity to develop their capability and establish a long-term partnership with their customer, who are themselves members of the ecosystem. Thus, establishing a long-term relationship by which (parts of) both organisations can coordinate activities decreases the risk of being suddenly passed over. Other risk-mitigating activities include diversifying the customer or supplier base by becoming members of multiple ecosystems. An interviewee from Case G explained:

> In the last few years, we've worked increasingly in the Oil & Gas sector, but of course, recent events have emphasised the fact that we can't be entirely reliant on that sector for growth and for future business, so we've got to continue to explore other markets as well, other sectors that might need our products.

Similarly, an Operations Manager in Case C highlighted the need to expand their own supply base to manage their interdependencies in the manufacturing ecosystem. This brings the need to consider shifts in partner alignment, reconfigure activities and relationships and craft new strategies for network governance. He explained:

> Because we've got a unique product, one of the challenges is you maybe only get that part from one supplier and it's such a vital part to what we do. We need to make sure we have a second source and that helps us manage price, it helps us encourage them to deliver on time or we go to somebody else.

Such expansion could mean that a supplier must learn to manage a portfolio of loose and tight cooperative relationships as they are not part of well-established and static value networks. In summary, suppliers mitigate dependency risk by building more numerous and stronger relationships with other actors and that activity helps shape the network governance arrangement within the ecosystem.

4.2.2. Delivering on standards

Delivering on standards is the strategic response suppliers use to ensure that they are perceived by other ecosystem actors as legitimate and suitable collaborators. To do this, suppliers deploy two tactics: monitoring performance indicators and complying with directives set by ecosystem actors such as customers and complementors (e.g., regulatory bodies).

Informants mentioned standard-setting to bring some consistency and stability to their ecosystems. All our case companies spend time on audits conducted by their customers. On occasion, these standards and checking on compliance against them have also been organised by way of establishing regulatory bodies. These audits serve to shape and stabilise relationships between ecosystem actors. For example, an interviewee from Case B explained:

> I would say with our core customers it's continuity in supply in our relationship…we spent a lot of time getting certified and audits… Our customers have done audits on us, and they've made recommendations and suggestions. They've followed up on it and that's kind of free advice for us to close our gaps and improve.

As these suppliers are rated and audited by customers and regulators, they increasingly monitor their own performance using KPIs as this is critical in ensuring compliance and viability. Suppliers review their performance against, for example, monthly scorecards supplied by customers. Case G has an A+ rating in product performance, on-time delivery, and responsiveness to technical queries and claims from one of its customers.

Obtaining certification from regulators also provides viability to suppliers. To illustrate, a senior manager in Case E emphasised the important role of the Scottish Medicines Consortium (SMC), which is highly regarded in the pharmaceutical sector. Their customers are, for instance, the National Health Service in the UK and US health insurance companies. Firm E found that they not only must convince ecosystem actors about the efficacy of their polymer drug delivery systems, but they also need to be regulated by the SMC, which is a major ecosystem actor that occupies the complementor role.

Complying with directives and gaining certification as a strategic response demonstrates the usefulness of the ecosystem concept as it allows for governance structure to be influenced by complementors, in other words, actors who are not part of the direct path for value creation (Adner, 2017).

In summary, the ability of suppliers to deliver on standards brings them the credibility they need to ensure they are perceived by others as legitimate ecosystem actors. Delivering on standards helps to ensure each actor occupies the correct position within the network governance structure.

4.2.3. Formalising relationships

Formalising relationships is the strategic response suppliers use to ensure they remain embedded within the ecosystem through managing loose and tight relationships in the manufacturing ecosystem. This is essential to crafting ecosystem strategies to manage dependence and independence from other actors. To do this, suppliers deploy two tactics: establishing formal agreements and gaining endorsements.

An important strategic response within the network governance dynamic involves contracting among ecosystem actors. Formal mechanisms such as intellectual property rights arrangements, confidentiality agreements, as well as other contractual agreements, are utilised to discipline and motivate ecosystem actors. For example, in Case B, the

ecosystem leader sets terms and conditions at the beginning of a new collaborative project. They are asked to sign a non-disclosure agreement before sharing any information about the diesel engine for which a cooling pump is to be designed. However, Case B usually insists on bilateral agreements to protect its position in the ecosystem. Formalising and forcing compliance are part of this too. A director at Case G sheds further light on this activity:

> One of our customers is very demanding in the documentation that they require. We've established a way of doing that that's acceptable to them and that makes it more difficult for them to go and immediately find alternative suppliers, because that documentation is vital to their product, so it's locking us into them and them into us in a way that isn't quite the case if you're just doing a more run-of-the-mill-type work.

Furthermore, suppliers try to gain endorsement from influential and respected bodies to increase their standing, which then adds formal recognition to their reputation and helps them to organise and sustain their relationships with other actors in the ecosystem because they are recognised as reliable and trustworthy actors. For example, a senior manager in Case A told us that they often get involved with organisations [ecosystem complementors] such as Scottish Environmental Protection Agency (SEPA), Health and Safety Executive (HSE), and various other official bodies. They seek endorsement by submitting regular written reports and developing strategies to keep these organisations satisfied with what they do. As a result, they are recognised by these complementors in the ecosystem, and this enhances their viability.

In summary, the ability of suppliers to formalise relationships with other actors is critical to the stability and longevity of their position in the ecosystem. Formalising relationships ensures there is a formal representation of the structure of network governance.

4.3. Value appropriation dynamic

The tension between having to cooperate to generate value collectively at the ecosystem level and compete to capture value at the firm level is at the heart of the value appropriation dynamic. We confirmed that ecosystem actors engage in value appropriation to sustain their livelihood. Who gets what within an ecosystem is a key dynamic that determines a firm's survival and success. Based on our observations, we identify three types of strategic response: (re)defining contribution, finding compromises, and accepting non-pecuniary returns.

4.3.1. (Re)defining contribution

(Re)defining contribution is the strategic response that suppliers use to ensure their contribution evolves and stays relevant so they can continue to benefit from their membership in an ecosystem. To do this, suppliers deploy two tactics: focusing on servitization and creating premium offerings.

Importantly, we found that a key to appropriating value is a supplier's ability to define and refine their contribution as the actors and the ecosystem itself evolve. In terms of strategic positioning, a notable feature of supplier strategies was attempting to contribute higher value offerings to the overall value proposition. Many firms indicated they were moving into servitization (Case A, B, C, E, F). This means, for example, that a customer no longer pays for a product but buys into a subscription model where ownership remains with the supplier. For example, in Case C, such a change means that their gas generators are rented to the customer within a service level agreement as opposed to being sold with a service plan. In this sector, this, in practice, means a move from a capital expenditure (Capex) model to an operations expenditure (Opex) model. Thus, the value proposition changes from offering a product with added services to offering an agreed level of performance. This brings benefits for customers and suppliers both in relation to performance and cash flow. A senior manager at Case C illustrates this point:

> If the customer takes a seven-year contract, then we'll give them the generator. Because, over the seven years we'll make a lot more money and the customer has a lot less hassles…it's an Opex model, not a Capex model, where they haven't got to try and get a bunch of funding up the front to buy the product, it's just each year's subscription fee.

Other suppliers stressed the need to focus on premiumisation. For example, Case B was approached to sell their pumps for use within ships in the Chinese Navy because their pumps were perceived to be of a higher standard than those available in China.

In summary, the ability of suppliers to alter their offerings is critical to ensuring that they continue making useful contributions to the evolving ecosystem.

4.3.2. Finding compromises

Finding compromises is the strategic response suppliers use to ensure the returns are divided equitably between the actors within the ecosystem. To do this, suppliers deploy two tactics: agreeing payment terms and settling power struggles.

The actual appropriation of value tends to manifest by money flowing between various actors in the ecosystem. This means ecosystem actors need to agree on payment terms. However, the eventual deal struck must be acceptable to all parties. The need to negotiate and find compromises was highlighted by the Design and Engineering Manager in Case B:

> You can have a pump which has the best parts inside, or you can have a pump which has got parts inside which are not quite as good and will only last you so long… some companies actually want something that's only going to last five years instead of paying a premium [for longer life]. It depends on how they're driven really.

This demonstrates that compromises are made in relation to the composition of the offering. Other cases demonstrated that more direct financial compromises are possible. In addition to the standard price-to-volume trade-off, some actors indicated that higher absolute prices could be traded-off against a more beneficially phased payment plan either in frequency or cash phasing or in a longer contract term.

However, many of our case companies highlighted their small size and suggested that negotiations could be difficult because of the asymmetry in power. To illustrate this, one of our interviewees from Case A offered this example:

> I used to be in charge of customer service at [a Food & Drinks Co], I had to go and visit all the multiples, and I used to really not like going to [a large Supermarket chain] because they treated you abysmally… they're just too big and strong.

In summary, common across all cases is the need for negotiation and compromise among ecosystem actors as the ability of suppliers to compete and cooperate with other actors helps all actors to work together to ensure that value is appropriated equitably within the ecosystem.

4.3.3. Accepting non-pecuniary returns

Accepting non-pecuniary returns is the strategic response suppliers use to increase the variety of ways that they might benefit from the ecosystem and maximise value appropriation in the longer term. To do this, suppliers deploy two tactics: utilising non-monetary exchange and investing in relationships.

Our findings show that in an ecosystem, value is not always appropriated as a monetary exchange in an economic sense; value appropriation may take the form of anything that is desirable for the involved parties. Consequently, the suppliers we studied indicated that they have various non-pecuniary motives for participating in an ecosystem. For example, the Managing Director in Case C explained:

> A more intimate relationship with a customer would allow us to have the sale, the revenue from the service, the relationship for any other equipment going forward and then the replacement business. We're in business, it is about the money but the way to get the money is to do the right thing with the customer. And not just the customer, everyone that's around you [ecosystem actors].

Similarly, Case E fostered a collaborative relationship with the World Health Organisation (WHO). They participated in a project to develop and manufacture a product for postpartum haemorrhage. They did not make money on it in the short-term but believed it was the right thing to do as it added to their reputation as an ecosystem actor. Case A also demonstrated a willingness to trade-off immediate financial gain for the opportunity to build a longer-term relationship. The following statement by the Financial Controller at Case A provides another illustration:

> I think finance doesn't have the final say because probably there are some products that we wouldn't manufacture on a purely financial basis. So, there is an element of strategy, there is an element of capturing the customer. So, we don't make money on it (immediately), but we make money on that customer in the long term.

It appears, that the value that is being appropriated is not necessarily a matter of immediate money flows. Non-pecuniary mechanisms also incorporate value exchange of a sort, as these are investments in relationships or goodwill in the expectation that this will pay off in the long term.

In summary, the willingness of suppliers to accept non-pecuniary returns is critical in building goodwill within the ecosystem in the expectation that this will pay-off in the longer term while nurturing symbiotic relations in the manufacturing ecosystem. Accepting non-pecuniary returns builds the social capital required to safeguard the long-term value appropriated by a supplier in the ecosystem.

5. Discussion - conceptualising supplier activity within ecosystems

The linear view using dyadic analysis fails to address the realities of contemporary manufacturing (Pathak et al., 2014). The concept of the value network, although still useful in some contexts, has been criticised for lack of clarity on the dynamics that exist between participating organisations and the inherent interdependences (Dedehayir et al., 2018; Tsujimoto et al., 2018). Recent theorisation based on the concept of the ecosystem moves beyond these limitations, allowing the dynamic nature of these multi-organisation arrangements to be co-evolving and facilitated by a myriad of vertical, horizontal, and diagonal relationships, for example with governments, universities, regulatory bodies, support organisations, and financial institutions (Sloane and O'Reilly, 2013). Hence, the concept of the ecosystem is gaining attraction in adjacent literature (e.g., service ecosystems (Brozović and Tregua, 2022), innovation ecosystems (Adner, 2006), business ecosystems (Teece, 2016), platform ecosystems (Baldwin, 2018), and entrepreneurial ecosystems (Rocha, 2004)) as it accounts for the interdependencies between various heterogeneous organisations whether they are on the critical path for value creation or not (Adner, 2017). However, this theorisation is lacking definition in relation to how actors, act and react within manufacturing ecosystems.

Hence, this research set out to characterise manufacturing ecosystem dynamics and investigate how firms occupying the supplier role navigate these dynamics posed by co-opetition (Brandenburger and Nalebuff, 1996). While it remains clear that suppliers will perform activities that can be understood based on the conceptualisation of the value network (Sloane and O'Reilly, 2013), it is also apparent that additional forms of activity exist that come into focus because of understanding the relevant environment as an inherently dynamic ecosystem.

We found that there are nine strategic responses, crafted among suppliers in a manufacturing ecosystem. Each of these responses contributes to one of the three ecosystem dynamics as illustrated in Fig. 1. The key point to note is that the complex and interdependent interactions within the ecosystem appear due to mutual causality (Feldman and Orlikowski, 2011). In other words, the strategic responses of the suppliers, shape ecosystem dynamics while simultaneously the ecosystem dynamics prompt suppliers to employ a particular strategic response. In doing so, suppliers absorb the complexities in the evolving ecosystem and become viable in the context of constant change.

5.1. Capability configuration dynamic

The capability configuration dynamic appears as suppliers share and combine capabilities within the ecosystem to ensure it produces the required complex functionality (overall value proposition). The concept of ecosystem allows us to appreciate a wider set of contributions than would be the case based on the standard value network concept because it recognises a more heterogeneous and complementary resource base (Iansiti and Levien, 2004; Dattée et al., 2018; Jacobides et al., 2018). The resultant capability configuration shaped by these integrated resources is a key feature of ecosystems as members must align their activities to create a mutually beneficial outcome (Jacobides et al., 2018). Ecosystems are dynamic entities, they are inherently volatile and unstable (Adner and Kapoor, 2010) and this dynamism forces suppliers to innovate to upgrade their capability in anticipation of an emerging future state that they themselves are instrumental in creating.

Our research indicates that while innovativeness in technological prowess and R&D capability is still important, it must also include the ability and legitimacy to cooperate with other ecosystem actors in ways that will lead to stable collaborative institutional arrangements despite the inherent dynamism of ecosystems. This combination of the ability to innovate in anticipation of a changing state and the ability and legitimacy needed to achieve collaborative resonance despite the inherent volatility of the ecosystem leads to a supplier becoming indispensable within the ecosystem. This state of indispensability will result in creating the impetus and continuing willingness to change, innovate and strive for ongoing collaborative resonance.

Unlike more traditional value networks, in ecosystems suppliers work more proactively with other ecosystem actors beyond their direct customer in attempts to build collaborative resonance that will benefit both themselves and other actors in terms of greater indispensability as the ecosystem evolves dynamically.

This leads to Proposition 1: A supplier remains viable in a manufacturing ecosystem if it can conduct anticipatory innovation that enhances the ecosystem value proposition while building collaborative resonance with other actors and this leads to indispensability in the long term.

5.2. Network governance

The network governance dynamic is generated as suppliers work to build the optimal control and coordination system to ensure the ecosystem is equipped to provide the required complex functionality through mutual value creation. Governance within an ecosystem is positioned broadly on the continuum between coordination by the hierarchical organisation and coordination by market forces (Gawer and Cusumano, 2014). Along this governance continuum (Bogers et al., 2019), various coordinating mechanisms, standards, norms, regulations, and rules come into being (Teece, 2016). Ecosystem governance may comprise a mixture of mechanisms that enable a balance of control and cooperation (Parker et al., 2017; Bogers et al., 2019).

Institutional arrangements are widely studied in service ecosystems literature (Tuominen et al., 2020; Vink et al., 2021), which highlights the importance of norms and regulations that the actors create for network governance and for mutual value creation (Brozović and Tregua, 2022). Our research in the context of manufacturing indicates that to position themselves on this governance continuum with each

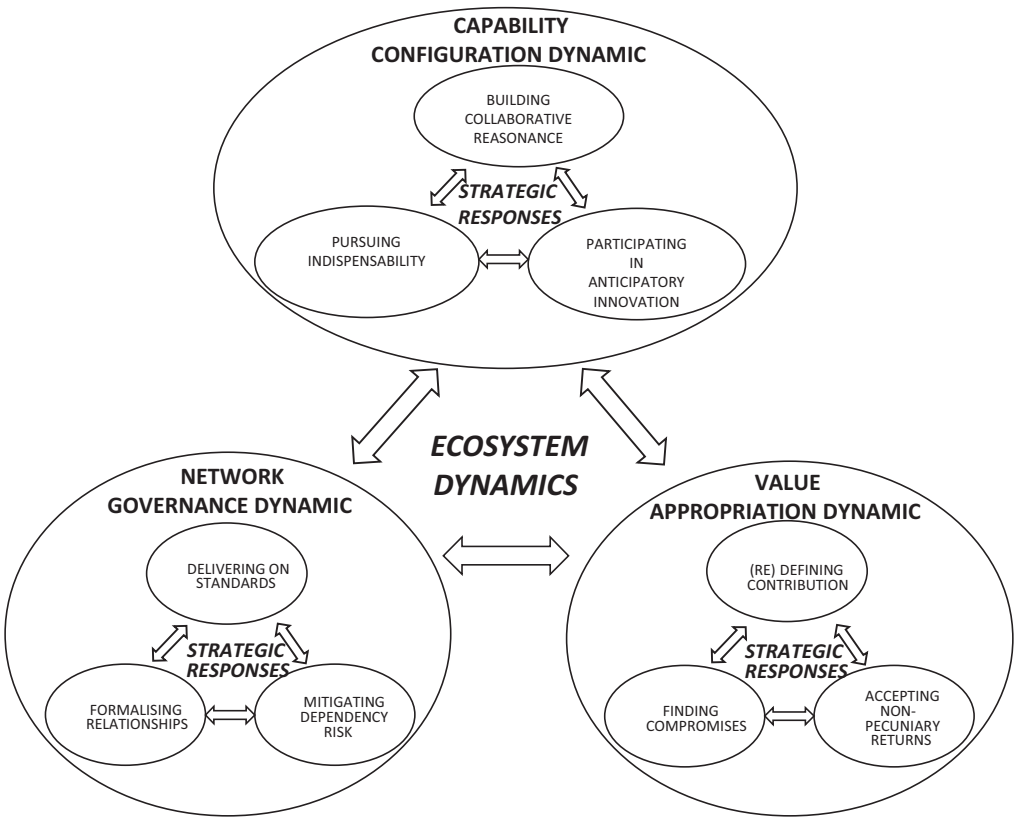

Fig. 1. Conceptual framework for manufacturing ecosystem dynamics from a supplier's perspective.

relationship they are involved in, suppliers must deliver on standards, norms, and regulations to ensure they are viewed as credible actors within the ecosystem. They must do this while creating formal but flexible institutional arrangements with other actors. Most crucially though, they must ensure that they mitigate any over-reliance on any other actor in the ecosystem, particularly those that occupy the customer role, as this asymmetry in power will serve to disrupt the governance arrangement of the ecosystem. This requires crafting strategies to determine where the boundaries of dependence and independence are present in the ecosystem (Adner, 2017). Managing the changes in interdependence highlighted by the shifts in network governance arrangements gives rise to the need for an ecosystem perspective.

Unlike the traditional value network concept, based on the ecosystem notion, we find suppliers undertaking a mix of traditional value network behaviour such as delivering to standards and setting formal contracts. But more crucially they also engage in more sophisticated activities, such as dependency risk mitigation, that ensure that there is no single point of failure in the ecosystem, and this increases the likelihood of the ecosystem's long-term success.

This leads to Proposition 2: A supplier remains viable in a manufacturing ecosystem if it strategically manages dependencies and interdependencies by consistently delivering on standards and formalising relationships while reducing its dependency on other actors.

5.3. Value appropriation dynamic

The value appropriation dynamic is generated as suppliers work to gain the best return for the contribution they make to the ecosystem. To commit to an ecosystem, firms should perceive their return as fair (Iansiti and Levien, 2004; Williamson and De Meyer, 2012). Without an equitable return on the investment made, actors will not commit. Our research indicates that within ecosystems value appropriation can extend beyond the standard monetary exchange. Particularly, a non-pecuniary exchange enables suppliers to safeguard their value appropriation in the long-term rather than prioritising immediate monetary returns.

Actors may appropriate value by leveraging the ecosystem for growth, reputation, greater efficiency, or added resources. In extreme cases, a firm appropriating mostly non-monetary value may still be interested in participating in an ecosystem (Talmar et al., 2018) if it is receiving value in other forms. To accept non-pecuniary returns suppliers must exhibit flexibility by demonstrating the willingness to find compromises with other actors and to regularly redefine the contributions that they are willing to make to gain the returns that they require.

Unlike the traditional value network concept, utilising the ecosystem concept (Adner, 2017), suppliers are seen to focus less on short-term competitive value appropriation where their gain comes with an associated loss to another actor. They operate more symbiotically by adopting strategies that prioritise long-term benefits to the entire ecosystem. Hence, a productive ecosystem will ensure the alignment of actors and create conditions to close the gaps between actor expectations and contributions (Adner, 2017).

This leads to Proposition 3: A supplier remains viable in a manufacturing ecosystem if, while redefining its contribution, it seeks mutually beneficial compromises and is willing to accept both monetary and non-pecuniary returns for long-term performance.

5.4. Implications for theory

Theoretically, a value network is conceptualised as a combination of a Value System (Porter, 1985) and the Agency Theory derived nexus of contracts (Fayezi et al., 2012). Value networks are organised primarily based on the outcome of competition between suppliers with each trying to capture as much value as they can (Pathak et al., 2014). They are governed, in Agency Theory terms, by efficient contracting where each

dyadic relationship is controlled by a contract that specifies what, how, and when a supplier is expected to deliver. The value network sees every supplier adding specific value directly to the overall value proposition.

An ecosystem is conceptualised differently. While value network behaviour is still present, the ecosystem concept recognises that there is more going on (Brozović and Tregua, 2022). We have shown in this study that ecosystems are dynamic, accommodate a greater variety of participants, facilitate the creation of more complex value propositions, move beyond the boundary of a single industry, and recognise that participants can adopt multiple roles.

In addition, the value proposition produced by an ecosystem differs from that produced by a value network. In ecosystems, the value proposition is built on complementarity, i.e., the product/service bundle delivers more value than each product and/or service would deliver on its own, and the relationships between the ecosystem actors that produce that product service bundle are governed not only by competition but by cooperation, as capabilities combine. Consequently, the coordination activity required to produce a product/service bundle goes beyond pure competition and exceeds what can be captured by a contract. An ecosystem is about co-opetition sustaining a dynamic arrangement of value appropriation, network governance and capability configuration (Sminia et al., 2019b). Therefore, the concept of ecosystem compels a supplier to think and act beyond their traditional value network roles, where relationships are treated as predetermined, bidirectional, and dyadic (Sloane and O'Reilly, 2013; Brozović and Tregua, 2022). It urges the firm to consider its role and activities as part of an ever-evolving ecosystem, and the contribution it can make to further develop the overall complex value proposition of the ecosystem's product/service bundle. This requires a more dynamic conceptualisation of the supplier's role.

5.5. Implications for policy and practice

This more dynamic conceptualisation of supplier activity within ecosystems has noteworthy implications for practice and policy (Jacobides, 2019). Ecosystem performance in manufacturing is attained by a dynamic effort among various actors. As we have demonstrated here, this dynamism is recognised by firms occupying the supplier role and this recognition is exhibited in the strategies and tactics that they deploy in an effort to maintain and improve their position. This effort is simultaneously collective and distributed with all actors involved in delivering complex functionality within a product/service bundle for a system of use. Thus, policy makers and support organisations should consider avoiding the trap of seeing static, overly linear, or single industry conceptualisations of manufacturing value networks. Where this happens, the resilience and competitiveness of the value base is reduced because it encourages perpetuation of an existing situation.

The three research propositions offered in this study shows that ever-increasing complexity and evolving nature of ecosystems bring different ecosystem dynamics to deal with by actors. We contribute by clarifying organisational responses from a manufacturing supplier perspective to the problem of complexity. We found that suppliers enact on several co-opetition (Brandenburger and Nalebuff, 1996) and co-creation absorbing activities (Table 2) rather than trying to reduce this complexity.

As Moore (1993) suggested firms should be acknowledged not as members of a single industry but instead as contributors to (possibly) several ecosystems, each consisting of organisations from a diverse array of what might previously have been thought of as discrete industries. This is particularly true for firms who take on the role of supplier. The dynamic and diverse nature of the concept of the ecosystem tells us that policy should focus on ensuring firms' continued participation in an ongoing process of developing their capability both as an ongoing viable contribution to multiple ecosystems rather than committing them to a linear path predetermined to fit within a single industry classification.

6. Conclusion

We specifically set out to answer the question: *How do firms in the supplier role in a manufacturing ecosystem manage co-opetition to remain relevant and viable?* To answer this question, we investigated the dynamics of the supplier role by conducting a bottom-up analysis consisting of seven purposefully selected case firms, each operating within evolving, high-value manufacturing ecosystems.

The ecosystems lens is particularly relevant to understand contexts where innovations require a change in multilateral relationships among actors (Adner, 2017), and therefore, ecosystem dynamics become crucial for understanding strategic responses. Our analysis reveals that each ecosystem dynamic has associated strategic responses that help suppliers to maintain and develop their position in shifting and evolving environments. These strategic responses contribute to the ecosystem dynamics while the ecosystem dynamics themselves stimulate these strategic responses in a mutually causal way (Fig. 1).

Of course, some of these strategies can be seen as being based on the standard value network concept (Pathak et al., 2014). For example, to be successful suppliers must always deliver on standards that are set within the dyadic contracts that govern the value network. However, some strategies, such as building collaborative resonance across the entire value network including actors on and off the critical path for value creation (Brandenburger and Nalebuff, 1996), will be less apparent as the focus on the dyadic nature of contracts will, to a great extent, prevent this.

Our contention is that it is not the presence or absence of any single strategy but the combination of these carefully crafted strategies that differentiate the ecosystem from other conceptualisations of inter-organisational arrangements such as the value network. To capture how this combination occurs, we have created three propositions that capture the specific operational tactics that deliver these strategic responses and their salience for suppliers to remain viable as they manage co-opetition in the manufacturing ecosystem.

Interestingly, in contrast to the previous understanding, it seems that firm activities are not always motivated by gaining a bigger slice of the pie in the short term, where a focus on costs and efficiency is the instinctive reaction. Finally, we argue that the ecosystem concept provides a fertile area for firm strategy beyond how it is characterised in the purely economic sense. Continued study of ecosystem dynamics will serve to eliminate myopia created by static and linear conceptualisations of the environment while firms must contend with the ever-changing circumstances they face.

CRediT authorship contribution statement

Aylin Ates: Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Visualization, Validation, Software, Project administration, Investigation, Formal analysis, Data curation. **Steve Paton:** Conceptualization, Writing – original draft, Writing – review & editing, Visualization, Project administration, Investigation. **Harry Sminia:** Conceptualization, Writing – original draft, Writing – review & editing, Investigation. **Marisa Smith:** Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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