Technological Forecasting & Social Change 173 (2021) 121147

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

journal homepage: www.elsevier.com/locate/techfore

Ecological determinants of smart home ecosystems: A coopetition framework

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ARTICLE INFO

Keywords:
Smart home
Ecosystems
Population ecology
Coopetition

ABSTRACT

Nearly every industry classification is experiencing slow growth and increasing concentration. Seldom do researchers have an opportunity to observe an emerging industry segment with as much promise as the smart home ecosystem, an exponentially growing industry. The study presents a novel approach using industry life cycle model and a coopetition framework to understand the process of the ecosystem development. Building on recent literature suggesting companies that purposefully match strategy to life cycle stage, the paper describes the strategic motivations and critical factors involved in the competition-based evolution of smart home ecosystems from early to growth phases, leading to a decision among the largest competitors to engage in coopetition. Following life cycle theory, in a mature phase, we forecast companies will attempt to differentiate by leveraging their brands, services, and bundles to drive differentiation. The standardization discussed in industry life cycle research is complemented by using the collaboration model required for complex and highly integrated systems. We provide four propositions and discussion of implications for future research and practice.

1. Introduction

At the heart of strategic management literature is the quest for firm survival and competitive advantage (Porter, 1980). Literature regarding organizational change suggests that firms must continually adapt their strategies to respond to changes in their environment (Barton et al., 2017; Cyert and March 1963; Luecke, 2003). Industry life cycle (ILC) is a lens through which to view the strategic positioning process – through industry evolution and firm adaptation (Agarwal et al., 2002; Jovanovic and MacDonald, 1994; Karniouchina et al., 2010). Viability over the long term (across multiple stages in the life cycle) requires firms operating in the industry to adjust strategy to create and capture value (Dyer et al., 2018; Karniouchina et al., 2010; Ritala and Tidström, 2014). Firms that are purposeful and proactive in matching their strategies to life cycle stages may create and capture more value and increase likelihood of survival versus those who do not (Coley, 2009; G.K. Deans, Kroeger, and Zeisel, 2002; Sabol et al., 2013). Growth is becoming more and more challenging for most firms, as nearly every industry classification has seen marked concentration representing industry maturity (Grullon et al., 2019).

It has been said that “yesterday’s business challenges are the subject of today’s research in strategic management” (Rumelt et al., 1991, p. 21). It is not often that researchers can observe an industry in the making; most studies of industries are ex facto. In a time of challenged growth opportunities, even in the technology sector, this study capitalizes on a promising emerging industry growth segment – smart home systems. Recently, IoT presented a generation of novel innovation opportunities and a promise of accelerated growth (Birkinshaw et al., 2007). The digital revolution and IoT has inspired the development of more integrated product/service systems (Coreynen et al., 2017; Lazzari, 2019; Porter and Heppelmann, 2014). However, when offering fully integrated solutions, firms must increasingly rely on partners and ecosystem participants (Porter and Heppelmann, 2015).

We attempt to answer three research questions. First, how do ecosystem industries like smart home systems evolve? Second, why would leading companies in the industry shift strategy from proprietary design and standards to an industry-wide standard? Finally, how do leading companies and their relationships with each other evolve after

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https://doi.org/10.1016/j.techfore.2021.121147
Received 18 January 2021; Received in revised form 24 June 2021; Accepted 18 August 2021
Available online 8 September 2021

achieving standardized commercial solution? Our conceptual development focuses on an emerging ecosystem of smart home devices. We define smart home systems as a combination of "smart devices and sensors that are integrated into an intelligent system, offering management, monitoring, support and responsive services and embracing a range of economic, social, health-related, emotional, sustainability and security benefits" (Marikyan et al., 2019, p. 144). Potential benefits of smart home systems include health therapy and support, energy management and sustainability, convenience and comfort, and pleasure and consultancy (Baudier et al., 2020; Marikyan et al., 2019; Rasch, 2013; Shin et al., 2018). By 2020 there were more than 500 smart home devices launched (Nelson, 2020), and the global market for smart home devices and appliances is projected to reach $141 billion by 2023. This new industry segment is projected to be over fifty percent of the size of smart phone revenues by 2023 (Shin et al., 2018). Yet, the early adopter market for smart home devices is saturated, mass appeal is declining (Marikyan et al., 2019), and, despite expectations of exponential growth in the future, the industry is experiencing a stall with penetration less than 4% (Baudier et al., 2020; Shin et al., 2018). While not uncommon during early life cycle development, technical issues, including installation complexity, lack of interoperability between devices, and threat of obsolescence given rapid industry advancement are some factors impeding ecosystem development.

Recent research has provided user insights into issues impeding mass market penetration (Baudier et al., 2020; Marikyan et al., 2019; Shin et al., 2018) as well as challenges facing device developers. Existing firms must make strategic bets not only on the device innovation but also on the ecosystem and the partners for development, as Amazon, Google, and Apple have each introduced proprietary systems. These issues highlight the multidimensional challenges facing this emerging industry (Reisinger, 2020).

The paper presents a novel approach to understanding the strategic motivations and critical factors involved in the competition-based life cycle evolution of the emerging smart home ecosystem industry. We introduce a coopetition framework to explain the cooperation among competitors required to coalesce around an industry standard[1] as the catalyst needed to break through current challenges. The coopetition framework is increasingly important given global interdependencies, blurring of industry definitions, and rapid advancement of technology toward more integrated and autonomous solutions that are unlikely to happen without a concomitant ecosystem of players. We uniquely apply the strategic approach of coopetition to explain competing industry leader motivations to temporarily collaborate toward the development of an industry standard required to propel the emerging industry forward. Our theoretical premise is rooted in the industry life cycle literature and coopetition literature. We propose that for cooperation among competitors to manifest, size and importance of opportunity must be substantial, and collaboration efforts and resource sharing must bring about a much larger and superior solution, creating a larger pie to share. The industry life cycle literature provides the necessary scaffolding to develop insights into the strategic shifts in firm positioning in the smart home ecosystem (Agarwal, Sarkar & Echambadi, 2002; Davis and Marquis, 2005; Karniouchina et al., 2010). We briefly explain how the nuances of ILC in a technology-based system versus product-driven industry evolution (Ranganathan et al., 2018; Utterback and Abernathy, 1975), geared toward awareness and proactive strategic management of position in the smart home devices ecosystem (Sabol et al., 2013; Coley, 2009), should increase the speed of value creation and subsequent value capture.

We aim to make the following contributions. First, industry lifecycle research helps to explain the behavior of companies as they evolve within an emerging growth segment (i.e., smart home ecosystem) from the early to the growth phase with a defining characteristic – standardized solution. We introduce a coopetition framework to explain the cooperation among competitors required to coalesce around a single standard using a clearly defined alliance as the catalyst needed to develop an emerging industry ecosystem. Coopetition literature provides for conditions when competing companies make strategic decisions to collaborate to bring the resources necessary to bear on a solution (Bengtsson & Kock, 2000; Gnyawali and Madhavan, 2001). In system-based industries, multi-firm collaboration across the entire ecosystem reduces uncertainty (resource) and propels industry growth and trajectory (Ranganathan et al., 2018). We build upon the work of Dahl (2014) and Hoffman et al. (2018) with an example that explains antecedents, process, timing and consequences of coopetition. The study answers the call for more research to understand the process of standard setting and studies with more commercial meaning leading to value capture and market growth (Ranganathan et al., 2018). To our knowledge, the standardization discussed in industry life cycle rarely includes the collaboration model required for complex and highly integrated systems like the smart home systems that can be explained by a coopetition framework.

Second, we contribute to strategic management literature by building a deeper understanding of competitive dynamics related to networks (Gynawali and Madhavan, 2001; Ritala and Tidstrom, 2014) and ecosystems (Shin et al., 2018; Ranganathan, 2018). We build on the work of Agarwal and colleagues (2002), adding insights to the discussion concerning the impact of speed of development and timing on strategic choice and intentionality of industry life cycle progress. We also address the need for research related to service as a means for firm differentiation during mature phases of life cycle (Cusumano et al., 2006).

Our article proceeds as follows. First, we review the three streams of research—smart home device literature, industry life cycle, and coopetition literature. Not surprisingly, smart home research is comprised of conceptual studies (like this one) and empirical studies focusing on early adopter populations (Marikyan et al., 2019). We review relevant life cycle research to help understand the current progress and expected path of the smart home system industry. Finally, we review relevant coopetition literature to bring a novel perspective on motivations for industry leaders who are competitors to collaborate on a standard. We then introduce a conceptual model of the smart home autonomous life cycle presenting our four propositions. We conclude with a discussion of the implications of our study for future research and practical application.

2. Literature review

Smart home devices are embedded in a connected ecosystem in the home that leverages internal and external networks to interactively control the home from inside or outside and learns from user-generated data in the home to anticipate user needs (Rasch, 2013). We consider the complex of interdependent parts of a network of businesses to resemble the community of organisms functioning together in an ecological ecosystem. Three streams of literature are reviewed for relevance to the study. First, smart home system literature helps to define the focus of study. The study uses the model of industry life cycle to explain and predict the unfolding of an emerging and promising industry opportunity, motivating a review of relevant ILC research. Thereafter, we review relevant works in coopetition, the strategic framework the study uses to explain the observed and predicted interplay between competition and cooperation among industry competitors at different stages of the smart home system industry life cycle.

2.1. Smart home review of literature and industry status

The concept of a smart home has been around in fiction since the Jetsons cartoon first aired in 1962 (Hollander, 2018; see literature

[1] A standard is defined as "the technical specifications that define the rules of interaction between the different complementary technologies that comprise a system (Ranganathan et al., 2018, p. 3197)."

review of Smart Homes in Table 1). Smart home ecosystem (SHE) has been well defined in literature as "smart devices and sensors that are integrated into an intelligent system, offering management, monitoring, support and responsive services and embracing a range of economic, social, health-related, emotional, sustainability and security benefits" (Marikyan et al., 2019, p. 144). Key words that are common across smart home system definitions found in literature include: "intelligent" – the ability to acquire data from the environment on behavior and usage and to adapt or apply that knowledge to deliver tailored user benefits; "integrated" or "networked" – individual components providing multi-functionality (i.e., linked and coordinated sensors, devices, controls, and appliances) and interoperability to allow in-home or remote access, monitoring, and control; and "central communication" – a user-accessible central interface, such as voice-generated smart assistance (Baudier et al., 2020; Kim et al., 2019; Marikyan et al., 2019; Shin et al., 2018). Sales of smart home devices and appliances are projected to reach $141B by 2023 (Statista.com, 2020), making it over half the size of the now saturated smart phone market (Shin et al., 2018; Macrotrends, 2020). Industry participants have currently launched approximately 500 individual smart home device offerings such as app-managed security systems, robotic vacuums, thermostats, or smart home speakers with voice assistants (Nelson, 2020). The smart offerings have been enabled by smaller sensors and microprocessors that can be integrated into everyday devices in order to utilize wireless technology to communicate and by the ability to collect and analyze data to predict user needs and behavior (Knote et al., 2019). Industry revenues of such connected devices were estimated to be over $15 billion as of 2017 with household adoption rates forecasted to be as high as 75% by 2025 (Statista.com, 2020). As such, smart home systems represent one of the most promising new global industry segments.

However, smart home systems are lagging behind expectations (Mennicken and Huang, 2012; Shin et al., 2018). Adoption has slowed, with penetration below 4% (Baudier et al., 2020). Over the past several years, major technology giants including Amazon, Google, and Apple have gobbled up promising smart device entrants and have introduced their own smart offerings in an attempt to unify or connect some of the smart products into proprietary systems. For example, Nest is owned by Google, and Ring is owned by Amazon. Amazon, Google, and Apple compete with each other for consumers to buy their smart speaker assistants and with device providers to build solutions that work with their proprietary systems (Haselton, T. 2019).

Recently, the three tech giants realized that to catapult forward the development of smart home service systems associated sales of their smart speaker assistant (SSA) products, they would need to move from proprietary interfaces to a standardized system to connect devices. This alliance among competitors, known as Zigbee, aims to create a common language as the new smart home standard to enable secure, reliable, and seamless use across smart home service devices, addressing the lack of compatibility and communication between different smart devices, which has been a significant barrier to the development of the smart home service system (Joseph, 2020). Historically, technology systems have required a significant time horizon to reach a standardized solution to similar impediments; the progression through all four phases can be as long as 25 years (G.K. Deans, Kroeger, and Zeisel, 2002). Literature provides ample examples of such alliances plagued by delays in progress or outright failure (Ranganathan et al., 2018). Yet, on May 11, 2021, in less than two years of focused collaborative development, a common open source standard for smart home products and systems was announced as complete and ready for testing, the first products expected to be on the market in the fall 2021 (Higgenbotham, 2021).

The economic importance of the SHE, specifically its size, rapid growth, and potential benefits is generating increasing research interest. According to a review article by Marikyan et al. (2019), given the early stage of development, the majority of studies are conceptual or theoretical in nature (like this one). A few studies have gathered data through surveys and or actual usage data from early adopters to gain an empirical understanding of user perspective and usage. The literature review points out the perceived versus actual benefit deficit to explain the low adoption rate. Barriers to penetration are discussed as technology, usability, privacy, and implementation barriers.

The slower than anticipated adoption of a proliferation of smart home products and services is explained in a study using the technology acceptance model (TAM) to surface interoperability and compatibility as driving factors (Shin et al., 2018). Specifically, usefulness is driven by function and ease, which requires the establishment of cooperation among products and service providers – a functioning smart home ecosystem which does not yet exist. The authors recommend more research as the industry evolves using a systems perspective. Development of smart home appliances have been studied through in-depth interviews with manufacturers using a product-service system approach (Kim et al., 2019). Two development areas were identified to respond to users demand for seamless experience. The first area of opportunity recognized is to increase the "smartness" of appliances – the ability to learn (gather more data) and apply the learning to tailor user experience. The second area is to increase the connectivity among the smart appliances to create a more collaborative ecosystem.

"Digital natives" were surveyed concerning their intentions to live in a smart home (Baudier et al., 2020). Comfort and convenience were found to be primary drivers for smart home intention. The study points out the challenge that companies face in developing new products and services and refining existing products and services in the absence of a fully operational smart home system. Several studies focus on the lack of industry standard and the challenge that creates for future development (Knote et al., 2018). A typology is introduced based upon the 31 design characteristics, 10 dimensions, and five clusters identified among current smart personal assistants (Knote et al., 2019). Bentley et al. (2018) studied actual user data from Google Home to identify daily and day-of-week usage patterns and frequency of types of commands. While overall frequency of use was higher than expected, the study found that use quickly plateaued and command types were limited and repetitive. The authors summarize findings as users quickly adopting habitual usage patterns given limited usefulness.

Potential benefits of smart home systems have been studied in literature and have been characterized using a variety of categories (Baudier et al., 2020; Marikyan et al., 2019; Mennicken and Huang, 2012; Rasch, 2013; Shin et al., 2018). Most include some combination of the four categories summarized by Baudier et al. (2020): healthcare, energy/sustainability, safety/security, and convenience and comfort. More recently, researchers have been able to survey and analyze usage data from early adopters of smart home devices (summarized below) that may be impeding mass market attraction (Baudier et al., 2020; Marikyan et al., 2019; Shin et al., 2018).

The most significant issues surfaced in literature are technical, privacy/security, and overall cost/usefulness. While not uncommon during early life cycle development, smart home system technical issues are abundant. These include installation complexity, lack of interoperability between devices, and threat of obsolescence given rapid industry advancement (Marikyan et al., 2019). Users have little tolerance for technology that is not reliable, trustworthy, and easy to use (Baudier et al., 2020). Users complain of complicated interfaces and pre-programmed options not personalized to users (Rasch, 2013). Many individual devices require separate applications to access and control individual elements (security system, door locks, thermostat, smart mattress) that are not integrated into a holistic smart home system (Kindström, 2010; Knote et al., 2019). Perhaps the greatest overall issue is cost/benefit. Price Waterhouse Coopers (2017) identified the most significant dissatisfaction (80%) was not meeting consumer expectations for usefulness or helpfulness, leading to limited use. Most consumers see smart home system devices and appliances as too expensive, given low perceived benefits and potential risk of obsolescence, and thus are considered a "non-essential luxury" or novelty (Baudier et al., 2020, p. 3).

Table 1
Smart home systems literature.

Citation	Main focus	Approach	Key contributions to literature/findings	Gaps / future research direction	Linkages for study
Baudier et al., 2020	Digital Natives intention to live in a Smart Home (SH). The study seeks to address a gap in user-oriented research.	Empirical /surveys. New scale extended from TAM2 and UTAT2 models	New scale introduced and tested. Points out challenge that companies will face in both refining existing SH services and devices at the same time they are developing newer ones. Reflects on absence of fully operational SH system. Both PE and H were found to explain intention to use. Comfort & convenience overwhelming driver of SH intention.	Broaden demographic groups, and dimensions beyond PE and H, using new scale.	Importance of PE and H support need for standardization / life cycle and requirement to move beyond early adopters to mainstream and toward connected system given user dissatisfaction.
Bentley et al., 2018	Smart Speaker Assistant actual usage (via command types) studied over extended timeframe, including command types, time of day/ week variation, demographic differences	Empirical / Google Home data	Frequency of use higher than expected per day, command types identified (i.e., automation, small talk, alarm, time, video, weather, information, lists). Use doesn't change over time suggesting habit and lack of exploration. Most frequent command is music.	Limitations – single device data vs smart home system. Need research means to collect and study multi-functional device and service automation (actual vs self-report surveys)	Limited holistic empirical support - why conceptual work still necessary to the field. Limited breadth of usage over time - user interface and utility still an issue
Kim et al., 2019	Product-service systems perspective to identify opportunities for developing smart home appliances (SHA)	Empirical / Qualitative In-depth Interviews	SHA attribute definition (i.e., context awareness, user friendly interaction, proactivity) and 3 categories identified- within the appliance, related to user and related to others SHAs and external stakeholders.	Two SH areas for development identified (1) increasing the ability of the devices or appliances to recognize and adapt to changes to provide more personalized user experience. (2) SH ecosystem approach - multiple collaborating partners from large enterprises to develop systems platforms to smaller players that develop appliances and components.	Recognition of user requirements for broader usage - seamless and consistent experiences requiring components to be designed as part of bigger system. Collaboration can be cross industry (i.e., food retailer and kitchen appliance mfg.) as well as with competitors. Discusses industry Lifecycle - early phase is technology driven, then moves to user driven - not sustainability yet.
Knote et al., 2018	Review of research on Smart Assistants from 2000 –2017 across disciplines.	Review and assessment of SPA literature.	Provide summary of five principles of SPAs and three future research domains	Taxonomy opportunity.	Point out the current situation of unstandardized SPA systems offered by leading tech companies (i.e., Alexa vs Siri) links to need for standardization in paper.
Knote et al., 2019	Provide a taxonomy of SPAs based on review above to eliminate fragmentation of terms	Empirical - cluster analysis based on systematic literature review (above)	Provide classification of SPAs (5 clusters) to aid future research based on degree of intelligence and degree of interaction of the system.	Leverage taxonomy in future research	Size and potential of market is noted. Need for interface for SH and smart living/standard. SPAs recognized as key interface in broader smart service system. Lack of standardization in SPAs and SH systems today - 31 design characteristics, 10 dimensions, 5 clusters.
Marikyan et al., 2019	Review SH literature from user perspective to understand smart home user adoption and implementation.	Review - SH literature	2002 –2017 review. Identified gaps in literature.	Research gaps identified: (1) Need for user-centric research - SH acceptance and adoption (barriers), (2) Technology-centric (services and characteristics, integration of devices/ecosystem perspective (3) Regulations (policies and ethics), (4) Research methods -limited quantitative/empirical research.	Four phases of evolution noted now in phase 3 interoperability phase. Research gaps support-ecosystems, continued conceptual and theoretical work. No reference of similar study including industry life cycle / pop ecology and or coopetition.
Mennicken and Huang, 2012	How smart technologies are being developed and incorporated into homes. Motivations, benefits and challenges are surfaced and discussed.	Empirical - Qualitative study based on interviews of SH technology providers, SH planners/builders, SH users	Develop a process for smart home creation from planning to preparing technical infrastructure, to iteration to some level of stability the latter two steps being software oriented the former more hardware and infrastructure oriented.	Future research paths should focus on deeper understanding of the planning involved and assistance for non-technical users.	Points to challenges of penetration beyond early adopters. ILC support.
Shin et al., 2018	Provide an understanding of slow SH adoption and demand	Empirical - surveys of adoption and	Demographic variances to intention to purchase (older	Need for additional study on smart home market as it	Need for system perspective - interconnectivity and

(continued on next page)

Table 1 (*continued*)

Citation	Main focus	Approach	Key contributions to literature/findings	Gaps / future research direction	Linkages for study
	using technology acceptance model (TAM)	diffusion of SH services using TAM	more likely to purchase in near-term), smaller purchases more likely than holistic systems. Suggesting need for targeted marketing efforts toward early adopters to build demand while SH systems are becoming more mainstream / popular.	continues to evolve and data is more available.	collaboration among players even competitors. Importance of SH to growth to large ICT players in maturing smart phone industry. Support for standardized solution to provide user usefulness. Note of phase of market development between early adoption and mass market - alignment to life cycle in study.

Uncertainty and obsolescence concerns, common at this phase in technology development, are deterring not only users but also developers of devices and appliances (M. E. Porter and Heppelmann, 2015; Reisinger, 2020). Currently developers must place a bet on one of three proprietary ecosystems marketed by Amazon, Google, or Apple. What if they pick the wrong one? Many are not only having to pick a partner but also recognize they are competing with the platform owners on devices as well, fragmenting and holding back the potential of the industry segment (Haselton, T. 2019).

Without resolution of these issues, the smart home system industry will not realize its potential (Reisinger, 2020). The need, or in some cases requirement, for a common ecosystem is a common theme in continuing discussions of smart home systems (Baudier et al., 2020; Kim et al., 2019; Knote et al., 2019; Marikyan et al., 2019; Shin et al., 2018)

2.2. Product life cycle model provides the underpinning for the study

A business is to industry as a species is to biology. The analogy well portrays individual firms as member parts of a "collective identity" (M. T. Hannan and Freeman, 1977; Mathias et al., 2018). Studies of industry populations focus on the stage of lifecycle development and the circumstances that motivate members to do things and factors that limit them. Davis and Marquis (2005) study organizational theory in firms prior to 1980 and note that the industry life cycle model may have lost utility with the changing environment of alliances, international expansion, and network orientations and recommend a more problem- or mechanism-driven approach to studying organization. Utterback and Abernathy (1975) presented findings of an empirical investigation of the product and process interaction through industry life cycles in an innovation context. Agarwal and colleagues (2002) integrate research on technology management, organization ecology, and evolutionary economics to study the impact of time on survival rates and relationships in life cycle progression. Common themes found across the streams include variation at entry leading to competition resulting in density changes between phases.

Several research studies focus on the benefits of profits and competitive advantage through purposeful strategy developed to match industry life cycle stages (G.K. Deans, Kroeger, and Zeisel, 2002; Karniouchina et al., 2010; Sabol et al., 2013). G.K. Deans et al. (2002) suggest industry life cycles are shortening; ~~meaning~~ the speed at which companies are moving through the stages is accelerating. In the past it has been said industry life span cycles were about 25 years. Long-term success (firm survival) depends on how purposeful a company is in creating and implementing strategy that changes to align with the specific stages of life cycle.

Table 2 provides a summary of literature reviewed. We adopt the industry life cycle phases and characteristics set forth in prior literature as described below.

During the introductory phase, a large and diverse set of competing firms are in pursuit of product innovation, generating a high degree of variety in product, approaches, and experimentation, often without clearly defined customer needs (Karniouchina et al., 2010; Sabol et al., 2013; Utterback and Abernathy, 1975). Competitors are presenting product and service offerings (innovation) in an attempt to see what the customer wants (Cusumano et al., 2006; Sabol et al., 2013). A consequence is that customers are often presented with options that they do not need or fully understand ahead of customer demand (Anderson and Wladawsky-berger, 2016; Margalit, 2019). The "industry" or ecosystem is flooded with new entrants, often encouraged by the introduction of new technology. The phase is characterized by uncertainty, with rules lacking and users limited to early adopters (low penetration). Because of the speed of development and experimentation, products are often undergoing ongoing revisions and may frustrate users due to poor quality and stability (Sabol et al., 2013). This set of conditions requires flexible production processes (Utterback and Abernathy, 1975). Companies should be working to establish barriers to entry by protecting proprietary technology and innovation to gain market share (G.K. Deans, Kroeger, and Zeisel, 2002).

During the growth phase, market leaders emerge and offerings decrease (Miles and Snow, 1978). Customer value propositions become clear, generating rapid user penetration. Market leaders define standards for the industry, resulting in a coalescence around a dominant design and or standard. In the second phase, major players emerge and should be focused on building scale and consolidating the industry (G.K. Deans, Kroeger, and Zeisel, 2002). Penetration forces leaders to focus on process efficiencies for scale and mass production – the process becomes more important than the product (Agarwal et al., 2002; Utterback and Abernathy, 1975). Leaders compete for customer attention through key distribution channels. During this phase, market entrants that cannot follow the new standards will fall out. This is the survival-of-the-fittest stage (Agarwal, R.Sarkar & Echambadi, 2002; Singh and Lumsden, 2015). Innovation becomes more incremental than radical as the focus shifts to efficient delivery of the product (Agarwal et al., 2002). While standardization may force a shakeout, it also opens the door for new entries that can leverage the more clearly defined standards to find niche opportunities (Agarwal, R.Sarkar & Echambadi, 2002; Singh and Lumsden, 2015).

During the maturity phase, the industry becomes concentrated and products become commoditized (G.K. Deans, Kroeger, and Zeisel, 2002; Miles and Snow, 1978). Consolidated leaders look for ways to differentiate based not on product, but on branding, quality, bundling, or other services. Cusumano et al. (2006) support this concept as a catalyst for the development of service offerings, a progression from product to process to service in software industries. Services become the means to differentiate by providing flexibility and customization offerings to de-commoditize mature products. Fewer bigger players defend their positions in declining growth and look for ways to form alliances with peers to fend off outside disruption and capitalize on new growth opportunities (G.K. Deans, Kroeger, and Zeisel, 2002). Purposeful crafting of company strategies that consider life cycle stages should result in shorter life cycles and greater share of industry spoils.

The evolution of an ecosystem is different from other product-based industry evolution. Technological and information system advances are generating promising emerging growth segments. The digital revolution

Table 2
Relevant industry life cycle/population ecology literature.

Citation	Main focus	Approach	Key contributions to literature/findings	Gaps / future research direction	Linkages for study
Agarwal et al., 2002	Provide an integration of technology management, organization ecology and evolutionary economics research to study the impact of time on survival rates and relationships.	Empirical - test lifecycle approach using 33 product innovations over the 20th century	Shows changes in entry barriers and resulting density shifts between growth and mature phases. Firm size discussed (i.e., small firms can occupy strategic niches while large firms control direction of standardization and ability to drive efficiency creating barrier for new entrants.	Future research – Gain deeper understanding of dominant design motivation, speed of development through phases and impact on density. Future research needs to explore impact of time on strategic choice as well as intentionality.	Speed to dominant design a focus for study. Large players control the selection of dominant design by allow smaller players due to ecosystem development requiring device and service extensions.
Cusumano et al., 2006	Add service view to existing models of industry lifecycle evolution (beyond product and process). Authors attempt to explain the role of service in firm and industry evolution.	Empirical - Analyzing revenue mix and contribution of services at publicly listed firms in software products industry.	Findings show a crisscross effect between product vs service - gradual transition to services as the dominant source of revenues over time as firms age and increase	Firms need to increase service capabilities during maturity - different from product to process shift. IoT and service offering flexibility may make this finding more significant.	The service addition phase is relevant to the study and may also be expanded or further defined by other complementary products that the competitors can offer consumers. Context of computer software is somewhat analogous to SH.
Davis and Marquis, 2005	Shifts in org boundaries, use of alliances and networks, expansion of markets (international) shape organization decision make making away from traditional paradigms used in research. Explore a more problem driven approach to study organizations as unit of analysis	Conceptual/theoretical Field vs individual firm level or organization level focus.	Advocate a shift from paradigm driven OT research to problem drive and mechanism driven research.	Relatively few studies focus at the field level of analysis. The rebirth of new industries provides rich context for studying fields.	Study supports changes in industry make-up and need for research to match yet current industry environment has changed once again – maturity of most industry classifications.
G.K. Deans et al., 2002	New industries are fragmented and consolidate as they mature - they progress through a predictable path or a consolidation life cycle.	Empirical, secondary research - Study of ~1400 mergers across 13-year time horizon.	Suggest that companies can plot with precision where they fall in the cycle and plan accordingly. Speed through stages is key to advantage. Slower companies become acquisition targets or fail. Merger competence is critically important to success and speed. Need awareness of the curve or likely to fall out.	NA	The consolidation curve and life cycle approach are analogous and supportive of prediction of progress especially given speed of the alliance to standardize the technology platform.
Jovanovic and MacDonald, 1994	Present a model to explain why firm density shifts in industry life stages based on competitive model of innovation opportunities which fuel entry and then failure to innovate prompts exit.	Empirical - secondary data from 1906 to 1973 for the US automobile tire industry.	Industry specific innovation for costs is significant over improvement in quality. Note that cutting edge technology remains cutting edge for less than a decade and it is challenging to stay current requiring investment.	NA	Another example of industry life cycle phases
Karniouchina et al., 2010	ILC systems approach used to explain variances in firm performance	Empirical – longitudinal secondary data from ~2000 firms across ~50 industries. Business unit, corporate parent and industry effects at each stage.	Industry competition changes across life cycle. Growth has higher business unit effect. BU effect high across all phases but corporate and industry effect increases markedly over phases.	Highlights need for theorizing about interplay between competitive imitation and reduction of business level opportunities for new value creation over time.	ILC and Systems theory perspective. Can predict how change will unfold for the industry or the system (ecosystem).
Sabol et al., 2013	Success of companies depends on their ability to craft the appropriate strategies for each industry life cycle phase. Each stage requires a different strategy and firms that can match strategy to life cycle phase will create more value.	Conceptual/theoretical	Industries progress through distinct phases and each requires different strategies. Firms that are aware can maximize position at each phase but with an understanding of all phases.	Suggests ability to predict and plan through decline and that the industry change is predictable and therefore strategy must be geared to each phase but also understand all phases for maximum profits based on competitive strategy	Provides format for discussion of SH phases and strategy for study. Growth phase is where study contributes - more than leader or challenger - multiple leaders.
Singh and Lumsden, 2015	Provides a review of theory and research in organization ecology with emphasis on organization at population levels of analysis and key processes.	Review and conceptual study	Encourage the study of organizational change by better understanding the population ecology model which is parallel but not fully applicable from living organisms to organizations.	Need more studies of organizational change. Reasons for maturity and slowed growth is inertia - Rates of org change reaches peak during adolescent phase then declines. More work on community level interdependencies between	Discussion of life cycle approach and phases and competitive dynamics and characteristics driving shifts in stages to apply to study. Large organizations are important as change agents central to communities.

(*continued on next page*)

Table 2 (*continued*)

Citation	Main focus	Approach	Key contributions to literature/findings	Gaps / future research direction	Linkages for study
				populations. Continue to study process which brings change in populations of organizations. More critical examination of nature of organizational evolution.	
Utterback and Abernathy, 1975	Present an integrative theory to predict differences in innovation – product v process	Empirical - synthesis of prior empirical research including Myers & Marquis study of 567 innovations crossing industries and including 120 firms.	Shifts from a product life cycle approach with the product characteristics as the unit analysis to process characteristics as product progresses through PLC. Locus of innovation shifts from product to process with the stages of development	NA	Provide PLC model for product and process innovation that can inform the ILC model that is being used in the study.

and IoT have inspired the development of more integrated product/service systems (Coreynen et al., 2017; Lazzari, 2019; Porter and Heppelmann, 2014). New emerging high promise segments are few and far between; when they present there is a rush to get a piece of the action. However, there is a limit to how far an individual company can go in offering a fully integrated solution. Rather, the products from one company may be part of a broader interdependent bundle of products and services (Porter and Heppelmann, 2015).

In the study, we characterize the ecosystem of smart home service systems as analogous to an industry described in the literature and identifiable as a population/community and or species, as discussed in population ecology. Smart home systems go beyond an organizational level domain to a macro level ecosystem study of organization behavior, which makes industry life cycle with its genesis in population ecology an appropriate lens for the study (Mckinley and Mone, 2003).

2.3. A brief review of relevant coopetition literature

Coopetition describes a relationship between parties (two or more) within a given domain wherein the parties simultaneously compete and cooperate (Brandenburger and Nalebuff, 1996; Dowling et al., 1996). The literature on coopetition is provided in Table 3. Several theories have been used to study coopetition, including resource dependency and transaction cost theory (Giovanni Dagnino and Padula, 2002). Coopetition is not a static condition – it evolves from a prior state of either competition or cooperation (Bengtsson & Kock, 2000), and the sequence can have a bearing on the relationship during the state of coopetition. In other words, parties can begin a relationship in an alliance (cooperation) and progress to competition to reach a coopetive relationship (Tidström and Hagberg-Andersson, 2012) or begin a relationship as competing companies that advance to cooperation to reach a coopetition relationship (Cui et al., 2018; Ranganathan et al., 2018). The duration of the coopetive relationship may not be long term, as it has been recognized that managing both a competitive and cooperative relationship with a partner can be confusing, involves risks, and creates tensions (Raza-Ullah et al., 2014). Relevant to our study is the fundamental premise that the motivation of one party to compete or cooperate with another within their given domain is purposeful and strategic (Hannah and Eisenhardt, 2018; Orudzheva and Struckell, 2020; Ritala and Tidström, 2014).

Ranganathan et al. (2018) found that competing firms are often required to collaborate in order to develop the technical standards that enable interoperability between their products and that the more directly competitive the products are, the greater the need for collaborative standardization. Direct competitors, especially the largest with the most power, have a sense of urgency to increase the size of the market. In product-based industries, standards can emerge from competition and consumer demand of a certain offerings. In system-based industries, multi-firm collaboration across the entire ecosystem reduces uncertainty (resource) and propels industry growth and trajectory. The authors explain that standard setting can take place through voluntary standard-setting committees, which bring together representation from a variety of firms to create the rules of compatibility between various system components. Wi-Fi, 3 G, and HDMI are provided as examples of collaboration among competitors to align on standards in ICT. In an earlier study, authors note the proliferation of alliances that represent cooperative links among firms that continue to aggressively compete with each other (Gnyawali and Madhavan, 2001). The authors note that alliance studies are skewed toward managing alliance risks rather than focused on motivations to unleash industry growth potential. The study reinforces that alliances are formed based on strategic need and can be motivated by access to resource, to manage risks and ultimately to unleash market potential.

The motivation for collaboration among competitors to collectively create value they could not otherwise capture alone is further explained in a study published by Ritala and Tidström (2014). The study explains that the recognition that collaboration among competitors can increase the "size of the pie" through resource sharing for efficiency. Collaboration provides the ability to significantly expand the size of the market through shared versus fragmented platforms, especially when technology is involved and in a network or ecosystem that involves a broad set of players. Bengtsson et al. (2010) align the two conditions of coopetition (cooperation and collaboration) to value creation and value appropriation. Value creation for individual firms as well as the industry at large is defined as the motivation for competitors to collaborate. Collaboration is the process that enables resource sharing (including knowledge). Once the value is created, competitors can capitalize on the outcomes (value capture), a process which occurs over time. The authors call for more study of the dimensions of coopetition which each represent distinct firm strategies and occur over time.

Answering the call (above), Hoffmann et al. (2018) define each of the conditions (dimensions) of coopetition. Cooperation is linked to value creation as firms share and exchange resources in pursuit of a common goal. Competition is the pursuit of market position by firms offering comparable products to a targeted set of customers and is linked to value appropriation. The authors discuss environment and motivations and the interplay between competition and cooperation. They call for more guidance in research on how firms and markets can experience the greatest positive consequence of coopetition.

The process of coopetition is illustrated in a study of craft brewers where direct competitors benefitting from collaboration (resource and knowledge sharing) must continuously assess the value of continued collaboration. In this example, the collaboration enabled the segment more power against outside coalitions (i.e., the large beer corporations) (Mathias et al., 2018). Analogous to industry life cycle, the study (Dyer et al., 2018) discusses alliance life cycle. The dimension of cooperation

Table 3
Coopetition literature.

Citation	Main focus	Approach	Key contributions to literature/findings	Gaps / future research direction	Linkages for study
Arslan, 2018	Understanding the relationship between competition and cooperation among firms based on common and private benefit potential.	Empirical – secondary data from JV partners.	Differential benefits arise when partners extract private benefits as common benefit potential decrease over time. Differential benefits increase when a partner holds a dominant control. When common benefits are high private benefits may be less opportunistic	Better understanding of small firm vs large firm benefits. Levels of tolerance for private benefit extraction.	Reinforces joint value creation of cooperation and value appropriation of competition consistent with coopetition used in study. Common benefit of alliance weakens over time (Zigbee)
Bengtsson et al., 2010	Clarify definition of coopetition and increase understanding of coopetition dynamics.	Conceptual multilevel model	Model introduced parsing the cooperative and competitive strategies each on a continuum from weak to strong. The study suggests the best outcome may be moderate levels of both competitive and cooperative activities.	More research focused on answering questions: How do coopetition dynamics vary depending on time limit of activities involved? How do structural conditions influence coopetition?	Study is project focused and time bounded to some extent and adds to the further understanding of coopetition.
Chin et al., 2008	Characterizes coopetition as revolutionary mindset. Identifies and prioritizes success factors to coopetition strategy	Empirical – Qualitative using expert interviews	Provide three categories of success factors for coopetition (management commitment, relationship development and communication management) with management commitment found to be most critical	NA	Coopetition as strategy. Definition of coopetition and dimensions.
Dahl, 2014	Why cooperative relationships change over time? Framework introduced with three scenarios as change catalysts.	Conceptual/ theoretical	Suggests change is intentional. Can come from reformulation of goals or purpose and or external environmental drivers or success or lack of success of outcomes.	Answers calls for research on cooperation from process perspective.	…
Dyer et al., 2018	Alliance life cycle explanation of value creation and capture - how the dimensions evolve (are dynamic) over time in alliance relationships based on level of complementary resource and resource interdependence.	Conceptual / theoretical	The level of resource dependence informs the speed at which alliances reach potential in VC and how quickly they dissolve. Factors leading to higher C are highlighted - trust, ties, customized assets. Factors triggering competition among alliance partners are discussed (internal and external)	Researchers should take a dynamic view of coopetition and alliances to explain VC and VA	Alliance life cycle perspective of value creation and capture. Low resource interdependence means fast in/out from value creation to appropriation. The resource in this case is knowledge and consensus for standard setting for industry. Clarity of strategic direction and outcome going into the alliance.
Gawer & Henderson, 2007	Intel case study allows examination of motivations to compete in complementary markets as the platform owner vs stay out to encourage other company innovation in those markets.	Qualitative Case study Intel and PC industry - 14-year span of market entry data.	First to explore platform owners' decisions to enter complementary markets and impact on ecosystem. Findings - they first use internal org. structure (separate divisions) to clarify and signal intentions to compete in complementary markets, second subsidize entry into complementary markets indirectly to lower cost of entry for all and third attempts to commit to stability and security of subsidies rules of the game. Key is assessment of ability to match or beat other entrants. These are decisions related to vertical integration.	NA	Systems perspective /ecosystem vs product/service specific as industry. Market entry is life cycle perspective. And evolution of markets developed on platforms.
Gnyawali and Madhavan, 2001	Understanding competitive dynamics in cooperative relationships [technology] among competitors based on networks as key resource to firms especially those with stronger positions in the network	Conceptual - model of structural embeddedness of competitive dynamics	New conceptual model an embeddedness approach to competitive dynamics - importance of networks as loci of firm resources	5 areas noted - not relevant to study.	Strategic management approach - competitive dynamics related to networks of competitors in cooperative relationships [coopetition] technology context. Resource motivation.
Hoffmann et al., 2018	Authors address limited research looking at nature and		Framework for coopetition including antecedents,	Opportunities in each of the areas noted - antecedents,	Motivations (antecedents) are tied to environmental

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Table 3 (*continued*)

Citation	Main focus	Approach	Key contributions to literature/findings	Gaps / future research direction	Linkages for study
	interplay between competition and cooperation vs well developed research streams on each dimension of coopetition.	Special edition overview- conceptual framework	processes and consequences of cooperating with competitors. Value creation and appropriation. Temporal dimension relating to the interplay. How do they coevolve? Capabilities and organization to support coopetition. Methods to study relationships and networks.	process, consequences, temporal dimension, managing tensions, etc.	conditions - i.e., life cycle framework and alignment with life cycle. Temporal and process aligns with Life cycle model. Management of tensions can be noted as temporal and organizational.
Mathias et al., 2018	How smaller players can band together as competitors and continue coopetition relationships to ward of the Goliaths. Uses identify perspective - important to emerging industry and segment growth.	Empirical - Interviews of craft brewers in the US (21 founders) and archival information (secondary sources)	The study found that early in the emergence of craft brewers, small players were struggling until a coalition was formed to help and share and after the industry segment was more mature, they continued to cooperate and help other, newer players (pay it forward) - coopetition persisted - to help others and protect the category.	Paper attempts to address the lack of study of how this relationship progresses beyond the nascent stage - over time. Addresses call (Park et al. 2014) to provide insight into interplay between cooperation and competition over time. Future questions - will it persist when growth stops?	Takes an industry view. Predictive of Zigbee alliance future. They must continually weigh the benefits and costs of coopetition and cooperation usually diminishes as less economic incentives are available – ZigBee…. occurs as market categories mature – product life cycle.
Ranganathan et al., 2018	How competitive tensions and cooperative motivations shape firm interactions during technology coordination activities requiring multi-firm interaction.	Empirical – longitudinal secondary data d services.	Builds on strategy literature on survival and innovation and combines research on both competition and collaboration. Importance of considering complete ecosystem.	Study of ICT at ecosystem level including motivations for cooperation among competitors to set standards. Discussion of standard forums to inform direction of technological change.	Supports use of coopetition for explanation of motivations to collaborate on standard. Study meets call for research in context where goals are more commercial meaning leading to more immediate value capture and market growth.
Ritala & Tidstrom, 2014	Address gap - How is value created and appropriated in a coopetitive network, and how does this differ in the firm and relational level strategies of the participating actors	Qualitative: Exploratory longitudinal case study	To address gap in literature focused on coopetition and examining both the firm level and relational level motives involved in value-creation and appropriation strategies.	More study of how coopetition strategy works in networks and can be managed to create and appropriate value. Other industries or context to study VC and VA in networks	VC and VA relevant to study as motivators. This study and its linkage to evolution of coopetitive over time links to ILC. Provide support for two motivations in study - strategic importance of value creation and resource sharing (cost reduction) and value appropriation. We address future research need highlighted.

and competition are dynamic and evolve over time and are aligned to value creation and value capture. The level of resource dependence informs the speed at which alliances reach full potential in value creation and how quickly they dissolve. High interdependence drives the need to develop alliances to create value. The authors suggest researchers should take a dynamic view of coopetition and alliances to explain value creation and value appropriation.

In the paper, we focus on the sequence of competitors in pursuit of the development of smart home autonomous systems making a strategic decision to cooperate – to form a temporary alliance among competitors – and enter a coopetive relationship. Research has cited examples of competitors setting technology standards (Ranganathan et al., 2018). Likewise, hostile competitors have banded together to fight legislation that would negatively impact all parties (Butler, 2016). Orudzheva and Struckell (2020) describe the adoption of standardized ATM technology in banking in the 1990s as an analogous scenario. Banks looking to expand their brands through consumer access independently began the development of ATM technology. They soon realized that the resource constraint (i.e., the individual cost of the ATM per location) would limit the ability for single bank breadth. Standardizing the technology and, in this case, allowing third parties to install and manage the ATMs yielded more locations than ever imagined, and all large banks realized the benefit of customer access to cash and other banking services. The banks were then back to a state of competition for customer attention through brand, services, and other feature differentiation.

2.4. Theoretical model and propositions

Our proposed framework suggests that companies that have a strong strategic intention to develop all or part of a system may begin through proprietary development but find an end to the value they can deliver without collaborating with competitors to unlock the larger value a more complete system solution would offer. Ecosystems like the smart home ecosystem may be out of the reach of an individual company, requiring a broader external network to converge on a standardized solution or dominant design and to bring the necessary resources to the solution (i.e., knowledge, data, technology, and capital). Three stakeholders will benefit from standardization: consumers hesitant to purchase something that may become obsolete or waiting for a more seamless and convenient endgame, device makers or suppliers currently trying to figure out who to partner with or whether to enter at all, and big players who realize that a fragmented approach is holding back the revenue potential.

The paper presents a novel ILC and coopetition-based approach (Fig. 1) to understanding some of the strategic motivations and critical factors involved in the evolution of ecosystem solutions through one example: smart home ecosystem development. One aspect critical for industry growth, especially when technology is involved, takes place in the growth phase, in which an industry moves to standardization that allows it to advance through coalescence (Coreynen et al., 2017; Henderson, 1999; Sabol et al., 2013; Utterback and Abernathy, 1975). While standardization is necessary to accelerate "industry," once a penetration

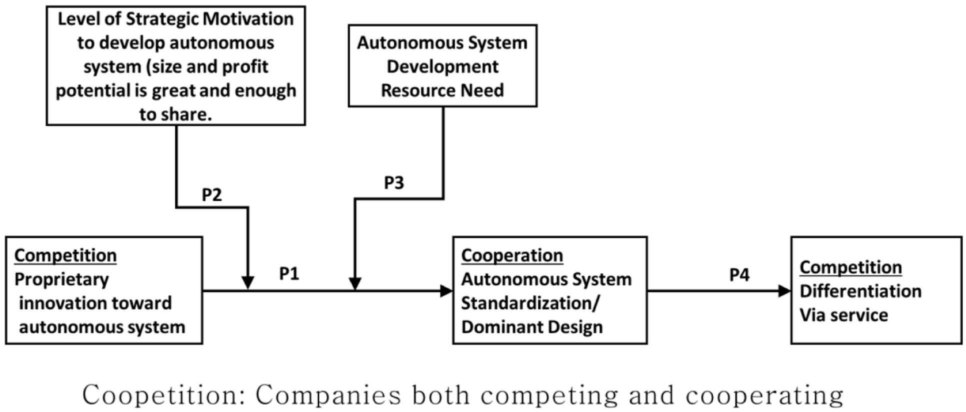

Fig. 1. Theoretical model: Ecological determinants of autonomous systems: A coopetition framework.

peak has been reached consumers are generally left with standardized or commoditized products (Miles and Snow, 1978).

The study suggests that, in the case of ecosystem solutions, the standardization process can happen only through the collaboration of strong players across the ecosystem, a phenomenon that can be explained by a coopetition framework. To our knowledge, the standardization discussed in ILC and innovation rarely includes the collaboration model required for complex and highly integrated systems like smart home systems, which can be explained by a coopetition framework.

2.5. Competition to cooperation yields coopetition

In the study, we characterize the ecosystem of smart homes as analogous to an emerging industry described in the ILC literature (Mathias et al., 2018). The literature describes key elements that characterize the growth phase of industry development as distinct from the earliest phase.

At the earliest stages of development, smart home ecosystem members have generated a flurry of one-off individual smart offerings (an estimated 500 different devices or appliances by 2022) using proprietary systems and software with value propositions that are not clearly defined or understood by consumers (Nelson, 2020; PwC, 2017). Smart home development efforts have been more motivated by technology interest than by consumer desire (Bentley et al., 2018). This was confirmed by Toni Reid, VP of Alexa Experience & Echo Devices at Amazon: “We had a vision but did not know if the customer would go for it” (Reisinger, 2020). The breadth of offerings is significant enough for the ecosystem to establish a legitimate identity which also gives rise to specific competitive dynamics (M. Hannan and Freeman, 1977; McKinley and Mone, 2003).

The nature of the industry life cycle proposed by population ecology suggests that industry standardization is an important element and distinguishing characteristic of the growth phase of industry evolution (Monfardini et al., 2012). Per ILC, industries begin to evolve from a position in which they offer a flurry of new product entries designed with a limited knowledge of consumer requirements (Karniouchina et al., 2010; Sabol et al., 2013; Utterback and Abernathy, 1975) to one in which customer value propositions are more clearly defined and market leaders drive industry standards (Miles and Snow, 1978). For some players, standardization provides clarity that provides access to dominant design blueprints (Agarwal, R.Sarkar & Echambadi, 2002; Singh and Lumsden, 2015). In ecosystems characterized by significant levels of interdependence among firms, competing firms are often required to collaborate to develop shared technical standards to enable interface between products (Ranganathan et al., 2018). In fact, failure to coalesce around a standard can delay value creation (lower overall industry growth) for all members of the ecosystem and flatten the growth trajectory for the industry (Henderson, 1999; Ranganathan et al., 2018). In their theory of the innovation and product life cycle, Utterback & Abernathy (1975) suggest a similar evolution for product life cycles that shifts from product experimentation and unstandardized production to a more refined product selection and systematic process (standardization) during the growth phase, when the scale of production becomes critical. The framework builds on prior research suggesting that individual companies that have a strong strategic intention to develop all or part of a system begin through proprietary development, often without attempting to address an identified customer need (Utterback and Abernathy, 1975). Failing to collaborate with competitors to unlock the larger value through a more complete system solution, these individual competitors find themselves at an end to the value they can deliver.

Examples illustrate competitors within an industry that cooperated for a time (coopted) to develop a shared technology. Major competitive banks (i.e., Citigroup, Bank of America, and Wells Fargo) ultimately rejected original proprietary models for ATM introduction, intended as a means to differentiate, for competitive advantage, recognizing that ATM functionality and access would be broader and established more rapidly by working together on a standardized solution that all banks would share (Bátiz-Lazo, 2015). Today, there are more than 400,000 ATMs in the United States handling more than 30 transactions a day with an average fee of $2 for non-banking customers; ATMs are generating more than $5T in fees for the competitive banks (ATMDepot.com, n.d.). Other examples of major competitors choosing to collaborate on a standardized technology system to propel industry trajectory are noted in literature, including those in DVD (Chin et al., 2008), Wi-Fi, 3 G, and HDMI development (Ranganathan et al., 2018).

Prior research has provided guidance to the ecosystem study. In ecosystems characterized by significant levels of interdependence among firms, competing firms are often required to collaborate to develop shared technical standards to enable interface between products (Ranganathan et al., 2018). In fact, failure to coalesce around a standard can delay value creation for all members of the ecosystem and flatten the growth trajectory for the industry (Ranganathan et al., 2018).

In considering smart home ecosystem development, consumers using smart devices have expressed frustration with the limitations imposed by separate applications, clunky user interfaces, and standardized rather than tailored services offerings (Rasch, 2013). The inability of different smart devices to connect to each other limits adoption and market potential (Reisinger, 2020). Device manufacturers are also being impeded by the lack of industry standards. By contrast, a proposed standard for internet-connected smart home devices, which has been touted as a solution to the confusion and a gateway to smart home service systems, should drive accelerated growth (Reisinger, 2020).

Recently, Amazon, Google, and Apple, the three tech giants controlling smart speaker share, and who are introducing devices across smart home system categories, realized that, to catapult forward the development of smart home service systems and the associated sales of their own products, they would need to move from proprietary interfaces to a standardized system for connecting devices (Higgenbotham, 2021). Before the alliance, smart device companies were forced to choose one of the three major players for connectivity. The three competed with each other for consumers to buy their smart speakers and with device providers to build solutions that worked with their proprietary systems, holding back the potential of the emerging industry segment (T. Haselton, 2019a). This rare alliance among competitors, known as Zigbee, aims to create a common language as the new smart home standard to enable secure, reliable, and seamless use across smart home service devices, addressing the lack of compatibility between smart devices and smart speakers and the lack of communication among different smart devices, barriers to the development of the smart home service system (Joseph, 2020).

Players seeking a major share of growth in an emerging industry segment involving technological complexity are forced to make a trade-off decision at some point in development – they must choose to pursue either an open or closed system. Proprietary systems provide the allure of competitive advantage. A good example involves the decision of some of the same companies discussed above to pursue proprietary operating systems for mobile phones and PCs (i.e., Android/Google, Windows/Microsoft, and IOS/Apple) (Bohn, 2017). However, closed systems have generally been found to be more limiting over time. Certainly, when considering smart home ecosystems, it seems impractical for any one player to control all the necessary elements (i.e., smart speaker assistant and all connected devices and appliances) for a complete and integrated smart home ecosystem (Porter and Heppelmann, 2015). Without resolution of these issues, the smart home system industry will not realize its potential (Reisinger, 2020). The need or, in some cases requirement, for a common ecosystem has been presented as a common theme in discussions of smart home systems (Baudier et al., 2020; Kim et al., 2019; Knote et al., 2019; Marikyan et al., 2019; Shin et al., 2018).

Some coopetition scholars describe the evolution of the coopetive relationship from a process perspective as dynamic (Bengtsson et al., 2010b; Dahl, 2014). The process perspective aligns with the evolution of growth phases introduced through population ecology. The need to cooperate – specifically, the need to standardize technology to improve utility for users – is a natural part of the life cycle of the ecosystem and a clear path for smart devices. The duration of the coopetition relationship may be defined as short in nature, in this case less than 24 months (Higgenbotham, 2021; Dosi and Nelson, 1994; Raza-Ullah et al., 2014).

Thus, we propose:

P1: Individual competitors within an industry pursuing smart home ecosystem solutions will evolve from proprietary solutions toward collaboration toward a standard, thereby entering a phase of coopetition – simultaneously competing and cooperating to launch the ILC from early to growth phase where significant value is created.

2.6. Strength of strategic motivations and competition -> cooperation relationship -> coopetition

Strategic alliances are "cooperative agreements aimed at achieving competitive advantage for the partners" (Elmuti et al., 2005, p. 1). The motivation of one party to compete or cooperate with another within their given domain is purposeful and strategic (Hannah and Eisenhardt, 2018; Orudzheva and Struckell, 2020; Ritala and Tidström, 2014). Recent literature suggests that firms that are purposeful and proactive about matching their strategies to life cycle stages may create and capture more value and increase likelihood of survival versus those that do not (Coley, 2009; G.K. Deans, Kroeger, and Zeisel, 2002; Sabol et al., 2013). Coopetition can accelerate the development of important growth segments (Hoffmann et al., 2018).

The framework suggests that companies that have a strong strategic intention to develop all or part of an ecosystem begin through proprietary development; yet, individual players find an end to the value they can deliver without collaborating with competitors to unlock the larger value through a more complete system solution. If the size of the opportunity is great enough (revenue growth and profit potential) and important enough, collaboration among competitors becomes an attractive or necessary means to an end. The strategic motivation for companies to move from competition to cooperation or coopetition in SHE is to develop and gain a fair share of what is expected to be a market of 1.5B devices in the next four years (Haselton, T. 2019). Only through cooperation will this new market develop so that alliance partners, also competitors, can reap their fair share of the benefits from a new and growing market and invest in longer term growth. Exploration is critical, even for the three major technology members as they aspire for their growth to continue to outpace GDP and to replace growth in core product categories now slowing in maturity. The relational risk in the cooperative relationship, expected to be higher given the strength of the competition of the parties and their degree of symmetry, must be perceived as less than the performance risk if no action is taken (Bengtsson & Kock, 2000; Das and Teng, 2001). The decision for competitors to become allies involves a deliberate strategic consideration on the part of each member of the cooperative relationship directed toward the achievement of specific goals that are at least partially convergent with the goals of other members to create certain value (Dagnino and Rocco, 2009; Dagnino and Padula, 2002). The greater the need to achieve the goal for each party, the greater the motivation to cooperate to create value. The strategic intent of Amazon, Google, and Apple is to sell more smart speakers and devices, which includes broadening the use of their assistants, allowing the collection of more data, and continual improvement in voice recognition (Bentley et al., 2018; Mennicken and Huang, 2012).

Thus, we propose,

*P2: The greater the strategic motivation among individual competitors for commercialization of an ecosystem solution (*i.e.*, smart home ecosystem), the greater the cooperation among competitors to work toward a standardized solution.*

2.7. Influence of resource requirement on competition -> cooperation relationship-> coopetition

Research has examined the trade-off between cooperation and competition and found that the greater the resource need, the greater the motivation for competitors to shuck their more opportunistic development path for a higher and faster success model with lower risk (Bengtsson and Kock, 2000b). The preponderance of alliance literature is supported by resource-based view theory (Lavie, 2006). Alliance literature has established the basis of beneficial relationships between parties, even competing parties, as a means to combine resources and capabilities, to minimize risk in uncertain ventures, to reduce individual party capital investment, and to share complementary knowledge toward the co-development of a shared initiative (Bengtsson & Kock, 2000; Das and Teng, 1999). The downside of having to share the spoils with competitors must be offset by the benefits: "the collaborative advantage" (Das and Teng, 2001, p. 2) or the "reward outcome" (Balliet and Van Lange, 2013, p. 1092).

Examples of collaboration among competitors are increasingly evident in the press. For example, collaboration among major banks during the development of complex and expensive ATM technology (Bátiz-Lazo, 2015; Brandenburger and Nalebuff, 1996). Major companies in the highly competitive automobile manufacturing industry, seeking means to reduce costs in a mature market for new cars, have turned to a series of cooperative alliances among competitors to accelerate returns and reduce development expenses (Ewing and Boudette, 2019; Holmes, 2018; Shiraki et al., 2019; Taylor et al., 2019). Likewise, cooperating parties in a pharmaceutical alliance recognized the expenses, knowledge requirements, and risk of development required a unique partnership – a relationship of "frenemies" (Eisenstein, 2018).

Coopetition can reduce risks and capital investment and allow greater simultaneous development activity for competing parties (Hoffmann et al., 2018). The outcomes of coopetition through access to resources should yield longer term sustainability for the firms involved through value creation (Bengtsson & Kock, 2000). Uncertainty and obsolescence concerns, common at this phase in technology development, deter both users and developers of devices and appliances (Porter and Heppelmann, 2015; Reisinger, 2020). Currently, developers must place a bet on one of three proprietary smart home systems marketed by Amazon, Google, or Apple or choose not to enter at all, given uncertainty and resource risk (Haselton, T. 2019).

Each of these examples illustrates a resource requirement necessary to achieve an initiative that requires collaboration among competitors. Thus we propose,

P3: The complexity, risk, and cost of resources required to develop and commercialize smart home ecosystems increase the motivation and level of cooperation among competitors to work toward a standardized solution.

2.8. Competition -> co-operation-> competition

As noted, coopetive relationships are motivated by strategic intentions and access to external resources to achieve a goal or solve a problem that involves cooperation with competitors. In the study, the parties are direct competitors first and evolve into a coopetive relationship required to develop a standardized platform and motivated by the desire to unleash the potential of SHE. But there is an end to the usefulness of the collaboration and, once a standard is introduced, the benefits of continuing to collaborate decline (Mathias et al., 2018). Firms in growth phase, once standards have been introduced, focus on clarifying their consumer value propositions, building scale, efficiency to lower prices, driving penetration, and taking share of a much bigger market (Agarwal, R.Sarkar & Echambadi, 2002; Utterback and Abernathy, 1975). A shakeout will occur – those companies that cannot follow the new standard will fall out (Singh and Lumsden, 2015). Firms shift from value creation requiring standardization to value capture, which places the firms back in a primarily competitive relationship (Dyer et al., 2018), and coopetition comes to an end.

Later, as the SHE matures, growth will slow and competitors will be fewer and bigger. During the maturity phase, the industry becomes concentrated and products become commoditized (G.K. Deans, Kroeger, and Zeisel, 2002; Miles and Snow, 1978). Consolidated leaders look for ways to differentiate based on branding, quality, bundling, or other services not based on product. Cusumano et al. (2006) support this concept as a catalyst for the development of service offerings, a progression from product to process to service in software industries. Services become the means by which to differentiate by providing flexibility and customization offerings to de-commoditize mature products. Fewer bigger players defend their positions in declining growth and look for ways to form alliances with peers to fend off outside disruption and to capitalize on new growth opportunities (G.K. Deans, Kroeger, and Zeisel, 2002).

As noted earlier in the study, software and services have become a common response to physical product maturity, a means to offer customer customization and differentiation using existing capital investment and infrastructure (Coreynen et al., 2017; Porter and Heppelmann, 2014; Stephenson, 2017). We follow the research on servitization, innovation, and technology to predict that the products – in this case, the smart home ecosystem products – will become commodities, and the competitors (i.e., Amazon, Google, and Apple) will begin to differentiate, competing for customers by leveraging their other services and capitalizing on the rich data assets accumulated through the autonomous smart home service system (Coreynen et al., 2017). For example, Google has a broad portfolio of services that can leverage the smart home through their SSA, including an internet search engine, email, a news aggregator, calendar software, a web browser, a thermostat, life-extending technologies, computerized contact lenses, robot assistants, a social network, a language translation service, video conferencing software, and autonomous vehicles, to name a few (Carlson, 2014).

Once the standard has been introduced, technology giants that have collaborated to develop the standard will revert to competing, convincing consumers to purchase their brand of smart speaker and smart devices. Following the life cycle theory, these companies will likely leverage their brands, bundles, and services to drive differentiation (Cusumano, 2015; Miles and Snow, 1978). Thus, we propose that,

P4: Following the commercialization of the smart home ecosystem standardized solution developed through collaboration among competitors, competitors will revert to a primarily competitive relationship to drive market share of a bigger pie. They will look for ways to differentiate based on service, brand and other features.

3. Discussion

In the study we sought to answer three research questions. First, how do ecosystems industries like smart home ecosystem evolve? Second, why would leading companies in the industry shift strategy from proprietary design and standards to an industry-wide standard? Finally, how do leading companies and their relationships with each other evolve after achieving standardized commercial solution? During early phases, a proliferation of new product innovation, often not matched to consumer needs, creates a legitimate identity for the industry. The smart home example reflects behaviors common during the early development phase. Many competitors introduce offerings to get into the game, often with little understanding of customer preferences. Early adopters are disappointed by the difficulty of use and lack of integration, which becomes an impediment to further penetration.

3.1. Contributions

We contribute to strategic management literature by building a deeper understanding of competitive dynamics related to networks (Gynawali and Madhavan, 2001; Ritala and Tidstrom, 2014) and ecosystems (Shin et al., 2018; Ranganathan, 2018) with an offensive (value creation) rather than defensive (risk management) approach. Purposeful strategy matched to ILC should result in greater reward for members and longevity for the industry. We also build on the work of Agarwal and colleagues (2002), adding insights to the discussion concerning the impact of speed of development and timing on strategic choice and intentionality of industry life cycle progress. The faster the recognition of the need to standardize and the development of the standardized solution, the greater the access to value for the members.

We note the evolution of ecosystems like smart homes are different from other product-based industry evolution. There is a limit to how far an individual company can go in offering a fully integrated solution. With ecosystem development, the products from one company are part of a broader interdependent bundle of products and services (Porter and Heppelmann, 2015). Open development and standardization can yield a faster and superior solution if the right players are contributing (Porter and Heppelmann, 2014). Collaboration toward a standardized solution can unleash the growth potential and trajectory for the industry (Ranganathan et al., 2018).

We broaden the application of coopetition to industry life cycle study which has not appeared in prior literature. While the motivation for competitors to compete is well documented in research, the application of coopetition to ILC to explain the required progression in smart home systems from early to growth phase (standardization) and later to maturity (defining future competition) has not been presented. To our knowledge, the standardization discussed in industry life cycle rarely includes the collaboration model required for complex and highly integrated systems like the smart home systems that can be explained by a coopetition framework.

We build upon the work of Dahl (2014) and Hoffman et al., (2018) with a smart home system example that allows explanation of antecedents, process, timing, and consequences of coopetition. Overall, the study answers the call for more research to understand the process of standard setting and studies with more commercial meaning leading to value capture and market growth (Ranganathan et al., 2018).

3.2. Research and practitioner implications

Literature provides guidance for companies moving from early to growth phase in smart home systems. To attract the mass market, focus needs to shift to product value proposition rather than novelty which may have appealed to early adopters (Mennicken and Huang, 2012). Our study aligns with others to recommend proactive strategy at the onset of entry to match life cycle stages through a dynamic planning process from early development through maturity. Literature suggests greater longevity, value creation, and value capture for those that purposefully develop and implement dynamic ILC strategy. For example, in system-based industries, early planning toward a standardized solution could save capital and provide flexibility in approaches chosen for entry and development at the firm level. Understanding the inevitable requirement of standardization could also allow artful development of alliance partners early in the industry life cycle. Likewise, forward thinking around mature life cycle differentiation at the onset could allow greater value capture.

3.3. Future research and study limitations

The study provides a conceptual framework for smart home systems based on literature from three relevant research streams: smart home systems, ILC, and coopetition. Smart home systems are a new and rapidly developing growth segment providing researchers a phenomenon of interest as the system continues to evolve. Specifically, the timeline for the industry development could be investigated. The average industry life cycle is about 25 years. Given the rapid development of the smart home system industry, it is likely that the industry will reach maturity much faster or very quickly spawn new industries for growth as their own emerging segments. Other examples of technology and systems-based coopetition and ILC studies have provided insights and support to the study. Future research can continue to follow the evolution of the system development and attempt to empirically support the model. The model could be expanded to formally include environmental conditions as antecedents and to propose additional moderators and outcomes.

4. Conclusion

We introduce a coopetition framework to explain the cooperation among competitors required to coalesce around a single standard using a clearly defined alliance as the catalyst needed to propel the development and trajectory of the smart home system industry potential. The coopetition framework is important, given the global interdependencies, blurring of industry definitions, and rapid advancement of technology toward more integrated and autonomous solutions that are unlikely to happen without a tangled ecosystem of players. The environment of development toward system solutions makes it unlikely that a single company or a single industry has the resources to invest in the most beneficial solution.

CRediT authorship contribution statement

Elisabeth Struckell: Conceptualization, Writing – original draft, Writing – review & editing. **Divesh Ojha:** Conceptualization, Writing – review & editing. **Pankaj C. Patel:** Writing – review & editing. **Amandeep Dhir:** Writing – review & editing.

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